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2002

Edited by
D.S. Emond and L.L. Lewis

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Front cover photo
This artwork, comically depicting many real geology stories, was commissioned by the Yukon Geology Program to celebrate ten years of service. Original painting by Chris Caldwell.

Back cover photo
Photo of Tombstone Mountain, located in the Tombstone Park, Yukon. Archer, Cathro & Associates (1981) Limited, 2002 inductee to the "Prospector's Honour Roll" has been a leading explorer in Yukon for more than 37 years. Partners and key employees of the firm have included Al Archer, Bob Cathro, Rob Carne, Doug Eaton, Sandy Main, Bill Wengzynowski, Mike Phillips and Joan Mariacher. The company, along with Jim Stephen, donated its mineral claims in the Tombstone Mountain area to facilitate creation of Tombstone Park. Photo by Government of Yukon.

PREFACE

Yukon Exploration and Geology (YEG) is the main publication of the Yukon Geology Program (Indian and Northern Affairs Canada and Yukon Government). This is the 25th volume of the YEG series, and marks a special year, since this is the tenth anniversary of the Yukon Geology Program. The volume contains up-to-date information on mining and mineral exploration activity, studies by industry, and results of recent geological field studies. Information in this volume comes from prospectors, exploration and government geologists, mining companies and students who are willing to collectively benefit the Yukon's mineral industry. Their assistance and patience is sincerely appreciated.

A special mention goes again to Maurice Colpron of the Yukon Geology Program for his able assistance in the translation, review and composition of French abstracts, as well as the review of several manuscripts. Some of the others that were involved in critical reviews included Don Murphy, Lee Pigage, Steve Traynor, Bill LeBarge and Grant Lowey. Sincere appreciation is extended to co-editor Lara Lewis for her careful eye, clear head, keen sense of grammar and perseverance, and especially for facilitating a short holiday for me at Christmas. Wynne Krangle and Peter Long of K-L Services also continue to provide excellent service in putting this production together, including editing suggestions, design of diagrams, volume layout, and working under the pressure of a tight deadline. Sherry Aldridge and Dan Coventry of the Queen's Printer ensured that the printing process went smoothly.

The 2002 volume has four parts. The first — **Mineral Industry** — includes overviews of mining and exploration in the Territory, as well as prospecting activity documented as part of the Yukon Mining Incentives Program. The second part — **Government** — outlines the activities and organization of the Yukon Geology Program, and includes announcements of the fourth Mining Land Use Reclamation Awards, the Robert E. Leckie Awards. The third part — **Geological Fieldwork** — contains reports describing regional mapping, and more detailed geoscience studies. The last part — **Property Descriptions** — is a collection of geological reports of mineral occurrences with recent exploration advances or detailed studies, and is authored by industry and government geologists, as well as university students.

We welcome any input or suggestions that you may have to improve future YEG publications. Please contact me at (867) 667-3203 or by email at emondd@inac.gc.ca.

Diane Emond

PRÉFACE

Yukon Exploration and Geology (YEG) est la publication principale du Service de géologie du Yukon (ministère des Affaires indiennes et du Nord canadien et gouvernement du Yukon). Il s'agit du 25e volume de la série YEG; il marque une année spéciale, puisque le Service de géologie du Yukon fête cette année son dixième anniversaire. Ce volume contient une mise-à-jour des activités d'exploitation minière et d'exploration minérale ainsi que des études fournies par le secteur privé, et les résultats d'études géologiques de terrain récentes. Les informations qu'il renferme ont été recueillies par des prospecteurs, des géologues du secteur privé et des services gouvernementaux, des sociétés minières et des étudiants disposés à faire profiter de ces connaissances l'ensemble de l'industrie minière du Yukon. Nous leur sommes sincèrement reconnaissants de leur aide et de leur patience.

Nous tenons à remercier de nouveau Maurice Colpron, du Service de géologie du Yukon, pour l'aide compétente qu'il a fournie à la traduction, la révision et la rédaction des résumés en français, ainsi que pour la révision de nombreux manuscrits. Parmi ceux qui ont participé aux lecteurs critiques figurent notamment Don Murphy, Lee Pigage, Steve Traynor, Bill LeBarge et Grant Lowey. Nous tenons à exprimer notre sincère reconnaissance à la rédactrice adjointe Lara Lewis pour son regard vigilant, sa lucidité, son sens grammatical aigu et sa persévérance ainsi que, tout particulièrement, pour m'avoir permis de profiter de courtes vacances à Noël. Wynne Krangle et Peter Long, de la société K-L Services, continuent d'offrir une prestation d'excellence pour la réalisation du présent ouvrage, notamment à titre de conseillers en édition, tout en assurant la conception des schémas et la mise en page du volume, cela sous la contrainte de délais serrés. Enfin, Sherry Aldridge et Dan Coventry, de l'Imprimeur de la Reine, ont veillé à ce que le processus d'impression se déroule sans problêmes.

Le volume de 2002 renferme quatre parties. La première — **Mineral Industry** — présente des aperçus de l'exploitation et de l'exploration minérales au Yukon ainsi que des travaux de prospection tels que documentés dans le cadre du Yukon Mining Incentives Program d'encouragement des activités minières au Yukon. La deuxième partie — **Government** — esquisse les activités et l'organisation du Service de géologie du Yukon; on y trouvera également l'annonce des quatrièmes prix pour la restauration des sites miniers — les Prix Robert E. Leckie. La troisième partie — **Geological Fieldwork** — comprend des rapports décrivant les résultats de cartographie régionale et des études géoscientifiques détaillées. La dernière partie — **Property Descriptions** — est un recueil de rapports géologiques portant sur des indices minéraux ainsi que des textes sur les progrès récents en matière d'exploration et des études détaillées; elle a été rédigée par des géologues du secteur privé et des services gouvernementaux ainsi que par des étudiants universitaires.

Nous accueillons avec plaisir les commentaires et suggestions visant à améliorer les volumes futures du YEG. Prière de me contacter au (867) 667-3203 ou, par courriel, à emondd@inac.gc.ca.

Diane Emond

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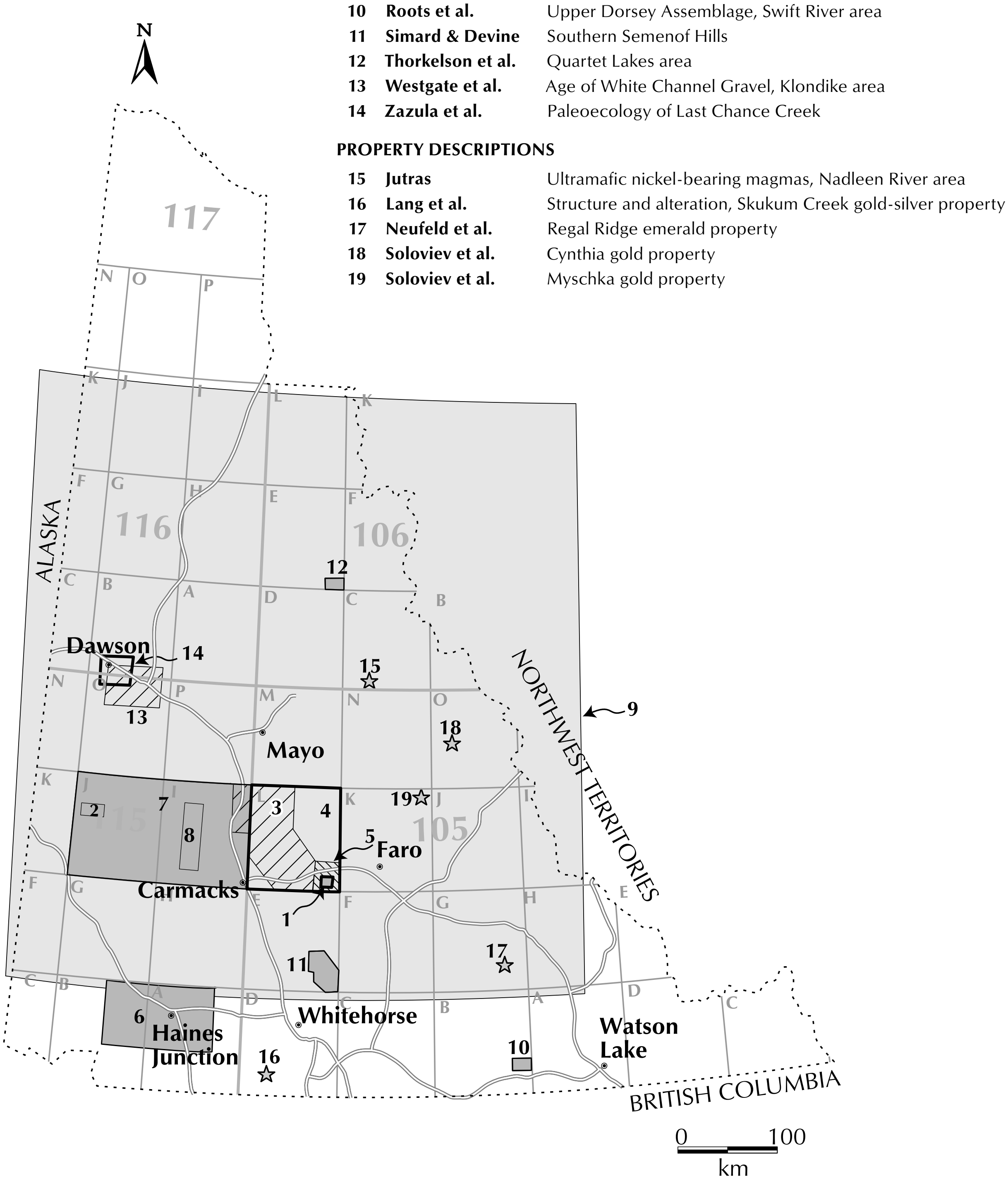

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Yukon Geology Program

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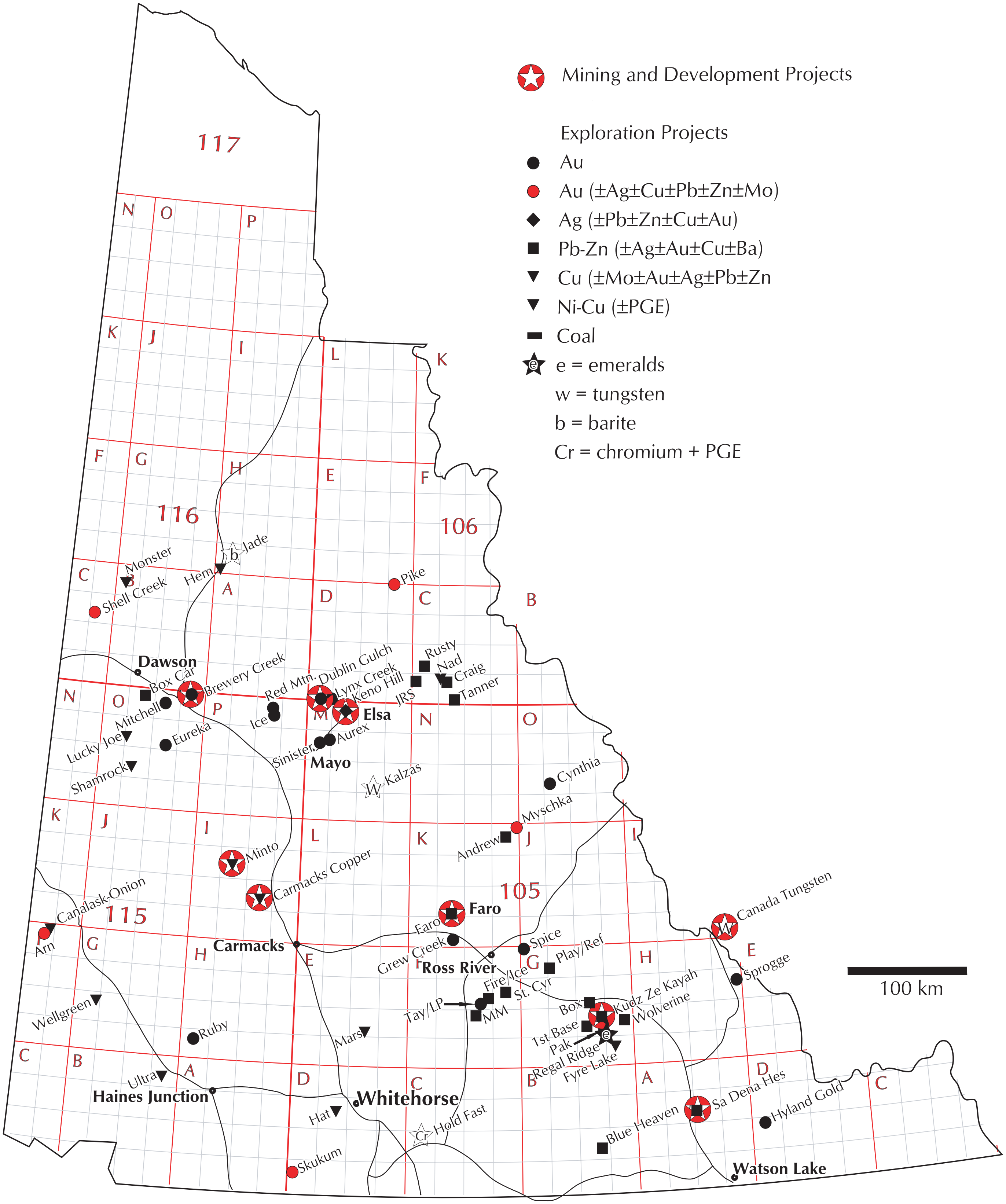

Figure 1. *Location of Yukon mines, development projects (permitted or undergoing permitting), and exploration projects in 2002. Not all projects are shown on the map. Background of the map shows the National Topographic System (NTS) grid.*

Yukon Mining, Development and Exploration Overview, 2002

Mike Burke[1]
Yukon Geology Program

Burke, M., 2003. Yukon Mining, Development and Exploration Overview, 2002. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 2-30.

ABSTRACT

Mineral exploration continues to suffer from the effects of low commodity prices and the extreme difficulty of companies to raise venture capital on the stock markets. Despite these adverse conditions many companies continued to explore Yukon for a wide range of deposit types and commodities. Several new discoveries of significant gold and base metal occurrences were made in 2002. The number and size of drilling programs decreased slightly from 2001. This is reflected in the $6.9 million estimate of exploration expenditures for 2002, a small decrease from the $7.2 million spent in 2001. Claim staking has been robust in 2002 with 4080 claims staked to the end of December, a significant increase over the 1702 claims staked in 2001. The number of claims was bolstered by the late season staking of prospective emerald targets in the Finlayson Lake area near the Regal Ridge emerald discovery, and geophysical targets similar to the Lucky Joe copper-gold occurrence near Dawson City.

Yukon, unfortunately, had no operating hard rock mines in 2002. The Brewery Creek mine did recover some gold during rinsing of the heap leach pad, however, Viceroy Resources' efforts were directed at the reclamation of the mine site. The company received the 2002 Robert E. Leckie Award for their outstanding reclamation practices. Mine development at the Minto copper-gold-silver project is currently on hold due to low copper prices while A.M.T. Canada continues to maintain the Keno Hill and Elsa silver mines, with a goal of resuming production in 2003.

RÉSUMÉ

L'exploration minière continue de subir les contrecoups de la faiblesse des prix des minéraux et la très grande difficulté des sociétés de réunir des capitaux de risque sur les marchés boursiers. Malgré les conditions défavorables, de nombreuses sociétés ont poursuivi leurs activités d'exploration au Yukon à la recherche de gisements et de minéraux très variés. En 2002 on a découvert plusieurs occurrences importantes d'or et de métaux communs. Par rapport à 2001, les programmes de forage ont légèrement fléchi en nombre et en importance. Les dépenses d'exploration ont en effet diminué, passant de 7,2 millions de dollars en 2001 à 6,9 millions de dollars en 2002. Les jalonnements ont été nombreux en 2002, atteignant 4080 à la fin de décembre, une hausse marquée par rapport à 2001 alors que le nombre de claims n'a pas dépassé 1702. Le nombre de jalonnement de claims a été augmenté par les jalonnements de fin de saison effectués sur des cibles susceptibles de receler des émeraudes aux environs du gîte d'émeraudes de Regal Ridge dans la région de Finlayson Lake et sur des cibles offrant des caractéristiques géophysiques semblables à celles de l'occurrence de cuivre-or de Lucky Joe près de Dawson City.

En 2002, il n'y avait malheureusement aucune mine en production au Yukon. Même si on a récupéré de l'or par rinçage de la base de lixiviation en tas, la Viceroy Resources a axé ses efforts sur la restauration du site minier à Brewery Creek. Elle a d'ailleurs reçu en 2002 le prix Robert E. Leckie pour la qualité de ses méthodes de restauration. Les travaux de mise en valeur de la mine de cuivre-or-argent Minto ont été interrompus à cause de la faiblesse des prix du cuivre. La société A.M.T Canada, pour sa part, prévoit reprendre la production en 2003 à ses mines d'argent de Keno Hill et Elsa.

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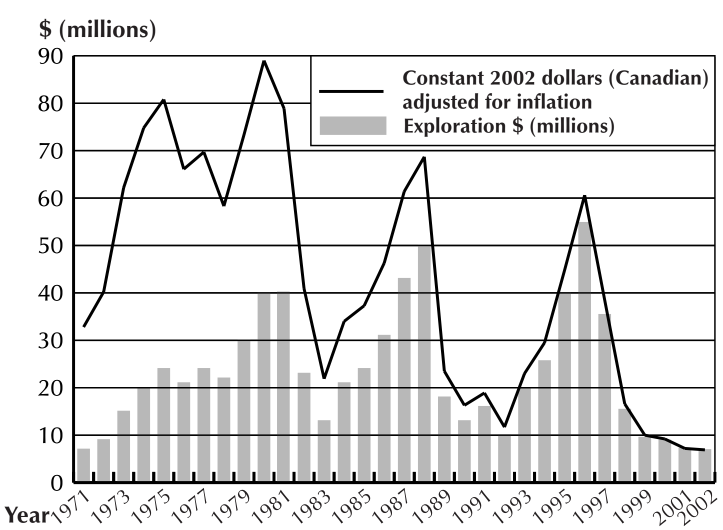
INTRODUCTION

Exploration continued in 2002 for many different commodities and deposit types within the Yukon (Fig. 1). Gold was the main target of explorationists in Yukon, with 60% of exploration dollars directed towards the precious yellow metal. Although preliminary estimates indicate a drop in exploration spending to $6.9 million (Fig. 2), the increase in claim staking and the high number of significant new discoveries made in 2002 bode well for the coming exploration season. New gold discoveries include an intrusive-hosted gold system intersected by drilling at ASC Industries' Ice property; sediment-hosted intrusive-related gold mineralization in drill core not previously analysed for gold at Expatriate Resources' Lynx Creek project; Klad Enterprises' extensive new intrusive-related gold systems on the Cynthia and Myschka claims (Soloviev et al., this volume); Atac Resources' high-grade gold-copper skarn intersected in drilling on their Arn property; and an extensive gold- and copper-mineralized quartz-carbonate vein associated with an Algoma-type iron formation on Shawn Ryans' Shell Creek property. Base metal discoveries include a regionally extensive copper-gold-mineralized horizon on the Lucky Joe property of Copper Ridge Exploration; high-grade zinc-lead in a carbonate-quartz breccia drilled by Noranda on the Andrew property of Ron Berdahl; a new sedimentary-exhalative system intersected in drilling on Manson Creek Resources' Tanner project and volcanogenic massive sulphide (VMS) mineralization on their JRS claims; and a new VMS occurrence on the Box claims of Expatriate Resources in the Finlayson Lake district. True North Gems announced the discovery of additional areas of emerald mineralization on their Regal Ridge property.

The Yukon government continued to support and encourage the mining industry in Yukon by increasing funding of the Yukon Mining Incentive Program to $850 000. The function of the program is to provide a portion of the risk capital required to locate and explore for mineral deposits in Yukon. The Yukon government also supports the industry through the Yukon Mineral Exploration Tax Credit, which provides a 25% tax refund on eligible exploration expenditures until March 31, 2003. Eight of fourteen Yukon First Nations have settled their land claims; four of the remaining six First Nations have a Memorandum of Understanding with the Government of Canada and Yukon that negotiations are complete. After a legal and technical review these First Nations are anticipated to ratify their claims by April 1, 2003.

Mine development expenditures were incurred at both the Minto copper deposit and the Keno Hill silver mine. Minto Explorations conducted only a minor amount of work at the Minto site, as the project is currently on hold due to low copper prices. A.M.T. Canada Inc. purchased the historic Keno Hill silver mine in central Yukon in October of 2001. The company is currently maintaining the site and, pending permitting of the project, plans to begin reprocessing tailings in 2003.

Figure 2. *Yukon exploration expenditures: 1971-2002.*



MINING AND DEVELOPMENT

Production from the **Brewery Creek** gold mine (Yukon MINFILE 2002, 116B 160) declined significantly, triggering the company to begin their detoxification and heap stabilization program in the second quarter of 2002. The company also continued with significant reclamation and revegetation of pits, dumps and mine site roads (Fig. 3). In recognition of their work, they received the 2002 Robert E. Leckie Award for outstanding reclamation practices. Approximately 2 million tonnes of capacity remain on the heap leach pad, and Viceroy has been actively evaluating areas near the mine for additional reserves. Remaining resources at the mine site could also be placed on the pad, with a sufficient rise in the price of gold.

Mine development expenditures were incurred at the **Minto** copper-gold-silver deposit (Yukon MINFILE 2002, 115I 021, 022) of Minto Exploration and by A.M.T. Canada at the **Keno Hill** silver mine (Yukon MINFILE, 2002, 105M 001).

The Minto project is currently on hold due to low copper prices. The project, located 240 km northwest of Whitehorse, is being developed as a conventional open pit mine and milling operation. The in-situ geological reserve for the deposit, above a cut-off grade of 0.50% Cu, is 8.818 million tonnes with grades of 1.73% Cu, 0.48 g/t Au (0.014 oz/ton) and 7.5 g/t Ag (0.22 oz/ton). This reserve contains 179 million kg (336 million lbs) of copper, 4.37 million grams (140,500 ounces) of gold and 67.68 million grams (2.176 million ounces) of silver. The ore that will be mined as per the current mine design is 6.51 million tonnes with grades of 2.13% Cu, 0.62 g/t Au (0.018 oz/ton) and 9.3 g/t Ag (0.27 oz/ton) with an overall stripping ratio of 4.9:1.0. Minto Exploration incurred minor expenditures in road and site maintenance at the project in 2002 and conducted geological mapping and sampling outside the deposit area.

A.M.T. Canada Inc. continued to maintain the historic **Elsa** properties (Yukon MINFILE 2002, 105M 001) at the Keno Hill silver mine in central Yukon. The company is planning on using proprietary technology to reprocess tailings at the mine site. The mine has produced over 200 million ounces of silver at a historic camp grade of 1370 g/t Ag (40 oz/ton Ag) from vein deposits within the Mississippian Keno Hill Quartzite. A.M.T. Canada also proposes to restart underground mining. Proven and probable underground reserves at the property are 415 000 tonnes grading 1145 g/t Ag, 7.5% Pb and 5.6% Zn.

The **Cantung** mine of North American Tungsten Corporation entered into commercial production in 2002. Yukon companies supply the bulk of the supplies and services to the mine, which is accessed through Yukon but is located in the Northwest Territories. The mine also provides high-quality employment for many Yukoners.

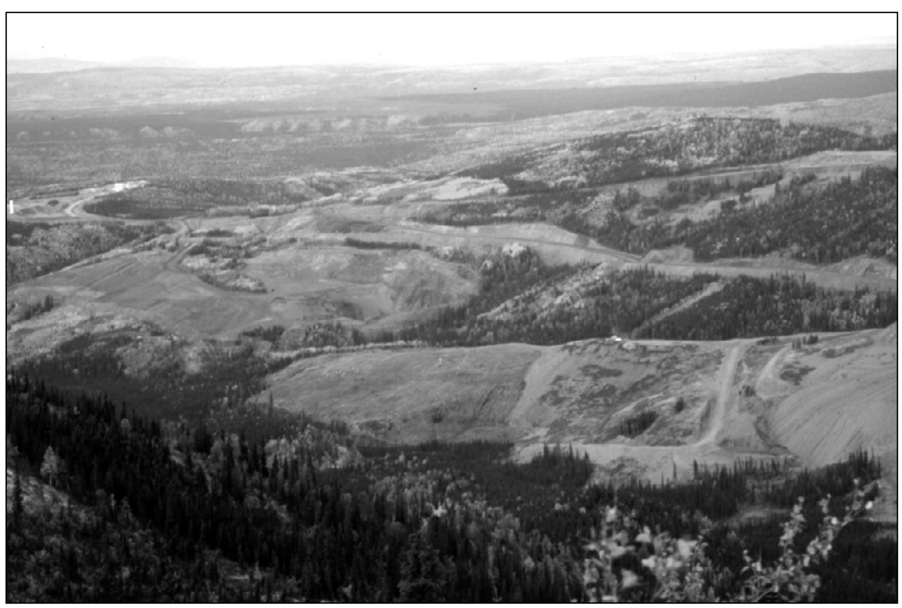


Figure 3. *Recontoured open pits at the Brewery Creek minesite. Photo from Karen Pelletier.*

EXPLORATION

Exploration in Yukon is typically divided equally between the search for base and precious metals, with slight variations from year to year. Approximately 60% of the $6.9 million spent on exploration in 2002 was directed towards the search for precious metals, mainly gold (Appendix 1). The bulk of exploration was conducted by junior mining companies and prospectors, which accounted for 90% of total Yukon exploration expenditures. Companies continued to be faced with the inability to quickly raise funds to achieve exploration success. A return to healthy exploration levels in Yukon will continue to be hampered by the lack of investment in the junior mining sector. Despite this, several significant discoveries were made in 2002, mainly by prospecting, but more significantly in drill holes. A change may be in the air, as True North Gems had no difficulty in raising funds for continued exploration on the Regal Ridge emerald property in the Finlayson Lake area. The company successfully completed their Initial Public Offering in late November to raise $1.23 million and captured the attention of the market and other junior mining companies.

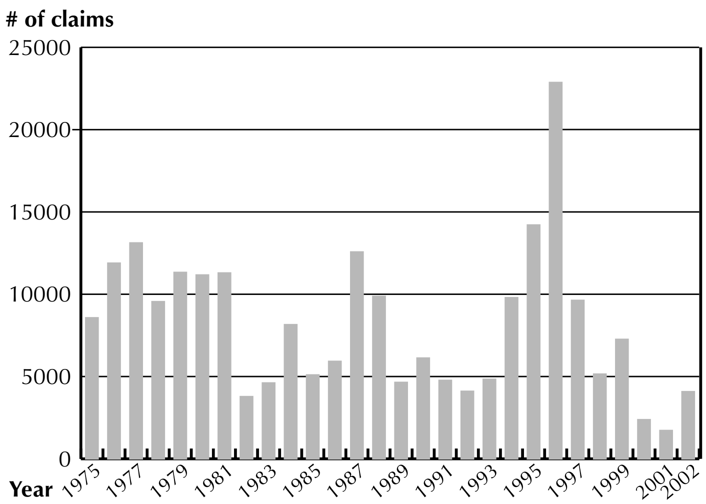


Figure 4. *Quartz claims staked: 1975-2002.*

Claim staking has mounted a significant comeback with a total of 4080 (Fig. 4,5) claims recorded in 2002, more than doubling the 1702 claims staked the previous year. Although the number of drilling programs remained the same as in 2001, the total footage drilled decreased to 11 205 (3415.3 m), a decrease of 13% from 2001 (Appendix 2). The total number of exploration projects has increased over 2001, buffering the decrease in exploration expenditures despite the decline in drilling.

This overview highlights a number of exploration projects conducted in Yukon during the 2002 field season and is by no means a comprehensive review of all exploration conducted. Several projects have not been included because of restrictions on disclosure for publicly traded companies, and for competitive reasons, when companies and individuals choose to not openly share exploration results.

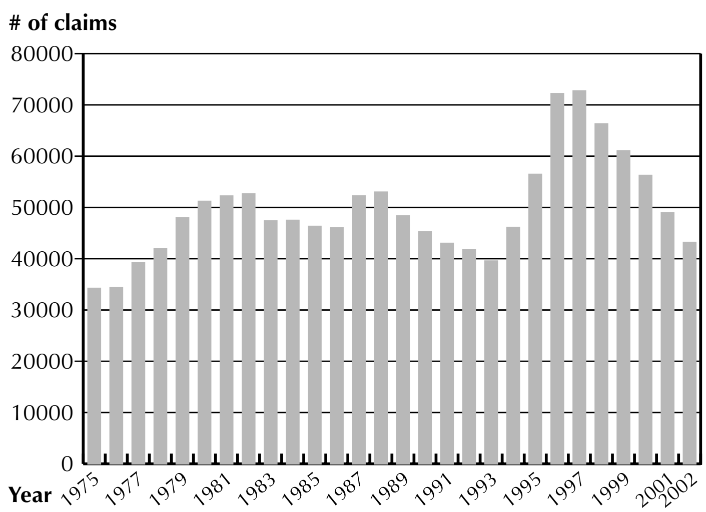


Figure 5. *Quartz claims in good standing: 1975-2002.*

PRECIOUS METALS

Regent Ventures performed a program of induced polarization geophysics, geochemistry and detailed geological mapping followed by 949 m of diamond drilling in six holes on their **Red Mountain** property (Yukon MINFILE 2002, 115P 006). In conjunction with the geological work, a compilation of all available exploration data since 1993 was performed (Fig. 6). Gold mineralization in the Saddle zone, where most of the work has concentrated, is hosted within a swarm of Cretaceous Tombstone Suite biotite-quartz monzonite dykes cutting adjacent sandstones of the Neoproterozoic to Lower Cambrian Hyland Group, and in flat-lying quartz-tourmaline and quartz-tourmaline-sulphide mineral breccias. The dykes are truncated by a shallowly dipping structure, but the drilling (i.e., DD02-35) demonstrated that gold mineralization continues into the sedimentary rocks and breccia zones below the structure. Diamond drill hole DD02-35 intersected 13.24 g/t Au over 2.0 m in a quartz-tourmaline breccia. The compilation work demonstrated that the Saddle zone is a large low-grade mineralized system with many drilling intervals in the 500- to 1000-ppm-Au range over tens of metres. Higher grade intersections of up to 46.1 g/t Au over 1.0 m (DD01-28) occur within the low-grade zones. Further work, including down-hole surveying of historical drilling, will be done to refine the geological model of the zone and direct future drilling. Several other targets have also been identified on the property, including the 50/50 zone, which is a prominent fault zone visible on surface. The zone exhibits the highest multi-element geochemical response on the claims. Historical drilling has targeted the 50/50 zone, but all holes were abandoned before successfully penetrating the structure.

Figure 6. *Anna Fonseca, geologist, examining drill core at Regent Ventures' Red Mountain project.*

ASC Industries Ltd. explored the **Ice** property, which adjoins Regent Ventures' claims to the north. They conducted a program of geophysics (induced polarization and magnetic surveys), geochemical sampling and geological mapping, followed by diamond (Fig. 7) and reverse circulation drilling. Reverse circulation drilling successfully intersected the Red Mountain stock, which was shown to be a sill-like body with the following selected assays: RC02-04 returned 4.6 m grading 0.85 g/t Au and 4.6 m grading 0.84 g/t Au; RC02-05 intersected 5.1 m of 1.07 g/t Au and 1.53 m of 4.35 g/t Au at the bottom of the hole; RC02-06 intersected 12.19 m grading 1.47 g/t Au, including 2.35 g/t Au over 6.1 m; RC02-09 assayed 0.91 g/t Au over 15.24 m, including 3.83 and 3.12 g/t Au over 1.53 m, respectively. All holes intersected zones of anomalous gold within the intrusive rock. Diamond drilling targeted the higher

Figure 7. *Diamond drilling on the Ice property of ASC Industries.*

grade Treadwell vein where surface samples assayed up to 14.2 g/t Au. Drilling intersected anomalous gold values associated with quartz-sulphide mineral veins.

Expatriate acquired the **Len** claims (Yukon MINFILE 2002, 106D 020) located 8 km east of the Dublin Gulch deposit and expanded the property, now renamed Lynx Creek. The claims were previously explored for gold mineralization hosted in a quartz-sulphide mineral vein system within a small Cretaceous Tombstone Plutonic Suite granodiorite intrusion. Drilling in 1997 outlined a quartz-sulphide mineral vein over a 300-m strike length with intersections including hole 97-1 in a narrow high-grade zone grading 15.5 g/t Au over 1.83 m, and a wider zone of 4.23 g/t Au over 6.1 m in hole 97-3. Hole 97-6 was drilled 100 m along strike of the vein system and intersected pyrite-arsenopyrite veinlets in quartzite proximal to the intrusion. Unsplit core in hole 97-6 was sampled by Expatriate and assayed 0.79 g/t Au over its entire 59.1-m length, including 1.23 g/t Au over 27.1 m. Soil sampling, using a power auger, was completed to better define soil anomalies located proximal to the granodiorite.

Klad Enterprises Ltd. conducted detailed geological and structural mapping, and rock and soil sampling on a number of properties north of Ross River in the eastern portion of the Cretaceous Tombstone Plutonic Suite. The **Myschka** property (Yukon MINFILE 2002, 105K 090) is underlain by a quartz diorite stock that intrudes Road River cherts and minor shale. Extensional faulting has resulted in at least four east-trending breccia and alteration zones that crosscut and surround the quartz diorite stock (Soloviev et al., this volume). The breccia zones are extensively leached and altered. Leached material returned anomalous gold values in the 100 to 200 ppb range; sulphide samples returned values up to 550 ppb Au, 57.2 g/t Ag and 6.9% Pb. A detailed description of the property is contained in Soloviev et al. (2003a, this volume).

The **Cynthia** property (Yukon MINFILE 2002, 105O 007) of Klad Enterprises Ltd. is characterized by two large Cretaceous Tombstone Suite quartz-monzonite stocks that cut Cambro-Ordivician Road River Group chert, shale and minor limestone. Three structurally controlled zones — Ted, Garry and Intersection — were explored in the 2002 program. The gold grades within the mineralized structures are commonly in the range of 200 ppb to 2.0-3.0 g/t, with higher (up to 16 g/t Au) values attributed to the fault intersection area (Fig. 8). A detailed description of the property geology and exploration results is presented in Soloviev et al. (2003b, this volume).

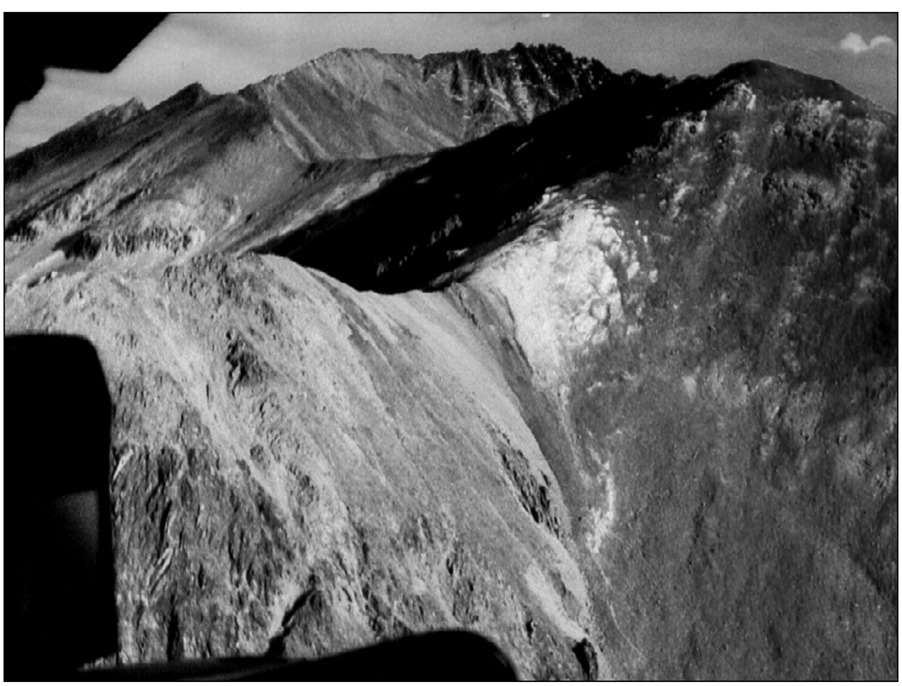


Figure 8. *Aerial view of the Intersection zone on Klad Enterprises' Cynthia property. The zone is the area of white alteration in the foreground. Photo by Klad Enterprises.*

Southeastern Yukon contains a number of intrusive-related gold occurrences associated with the mid-Cretaceous Selwyn Plutonic Suite. Properties include the **Hit** claims (Yukon MINFILE 2002, 105H 036) of Hudson Bay Exploration and Development Ltd.; the **Fer** claims (Yukon MINFILE 2002, 105H 102) of Rimfire Minerals Corporation/Boliden Ltd.; the **Hy** claims (Yukon MINFILE 2002, 105H 102) optioned by Athlone Minerals Ltd. from Phelps Dodge; the **Justin** claims (Yukon MINFILE 2002, 105H 035) of Eagle Plains Resources; and NovaGold Resources' **Sprogge** claims (Yukon MINFILE 2002, 105H 035). The various properties occupy a northwest-trending structural corridor, which hosts various styles of distal and proximal intrusive-related gold mineralization in Neoproterozoic to Lower Cambrian Hyland Group sedimentary rocks of the Selwyn Basin. The belt has been subjected to mostly reconnaissance-type exploration with only minor drilling conducted on the Hit property in 1999 and on the Sprogge claims in 2000. Eagle Plains was the only company to conduct any activity on their claims in 2002. They conducted a small program of geological mapping, geochemistry and detailed sampling in the area of the Confluence zone (Fig. 9), which hosts chalcedonic veining within coarse clastic rocks. Previous continuous chip-sampling in Confluence zone trenches returned 4.24 g/t Au over 4.5 metres; individual veins within this interval returned geochemical analyses of up to 59 250 ppb (approximately 59 g/t) Au. At the Discovery zone, gold-bearing pyritic mineralization occurs within a quartz monzonite dyke and adjacent calcareous siltstone. Chip sampling across this zone has returned 2.38 g/t Au over 22.5 m. Results of the 2002 program have not been released.

Ross River Minerals Inc. conducted a program of geologic mapping, prospecting, excavator trenching and diamond drilling on their **Tay-LP** property (Yukon MINFILE 2002, 105F 121) in south-central Yukon. The claims cover the western portion of the Ketza-Seagull Arch, a domal uplift created by the intrusion of one or more buried Cretaceous intrusions (Abbott, 1986). Small plugs of biotite-quartz monzonite have been mapped on the property and are interpreted from geophysics to form larger bodies at depth. The quartz monzonites intrude folded and faulted Lower Cambrian to Devonian metamorphosed calcareous sedimentary rocks. Semi-massive to massive sulphide mineralization consists of replacement-type pyrrhotite ± pyrite, arsenopyrite and chalcopyrite in calcareous metasedimentary rocks; and similarly mineralized quartz-sulphide mineral vein float is found over much of the 20-km length of the

Figure 9. *Bernie Kreft, prospector, on the Justin claims optioned by Eagle Plains Resources. Photo by Eagle Plains Resources.*

Figure 10. *Robin Tolbert (right) examining drill core with Lee Pigage of the Yukon Geology Program on the Tay-LP property of Ross River Minerals.*

claims. Outcrop on the property is sparse due to widespread glacially deposited material. Ross River Minerals completed seven diamond drill holes totalling 568 m on the Tay-LP claims (Fig. 10) and an additional four holes totalling 343 m on the adjacent Ram claims optioned from Almaden Minerals. Drilling intersected significant mineralization in four of the holes drilled on the Tay-LP claims. Hole TLP02-03 intersected 3.00 m grading 2.24 g/t Au, TLP02-04 intersected 1.57 m grading 2.73 g/t Au, TLP02-06 intersected 1.45 m grading 1.45 g/t Au, and TLP02-07 intersected 31.81 m grading 1.35 g/t Au, including 14.06 m of 2.58 g/t Au and 3.56 m of 8.99 g/t Au. The higher grade intersection in hole TLP02-07 consisted of a massive quartz-pyrrhotite vein crosscutting a thick zone of pyrrhotite replacement in calcareous metasedimentary rocks. Drilling by previous operators intersected mineralization with >1 g/t Au in drill holes over a 7.5 km length of the property, outlining a mineralized system of significant size. Ross River Minerals' program in 2002 continued to define the controls on the gold-bearing phase of mineralization within the extensive sulphide mineralized system.

Tagish Lake Gold Corp. continued to advance the **Skukum** gold-silver property towards their goal of resuming production. The property consists of a land package of greater than 1000 claims which encompasses three known gold-silver mineral deposits: **Skukum Creek** (Yukon MINFILE 2002, 105D 022), **Mt. Skukum** mine (Yukon MINFILE 2002, 105D 158) and **Goddell gully** (Yukon MINFILE 2002, 105D 025), as well as numerous exploration targets. The Skukum Creek deposit is a polymetallic, shear-hosted gold-silver vein within mid-Cretaceous granodiorite of the Coast Plutonic Complex and is the main exploration target of Tagish Lake Gold. Mt. Skukum mine consists of epithermal gold-silver veins and breccias hosted in the Eocene Mt. Skukum Volcanic Complex. The Mt. Skukum mine was in production from 1986 to 1988 and produced 2419 kg (77 790 troy ounces) of gold from 233 400 tonnes of ore. Goddell gully consists of gold-bearing polymetallic veins hosted in the Goddell shear zone within mid-Cretaceous granite of the Coast Plutonic Complex. Prior to the 2002 drilling, the three gold-silver mineral deposits on the Skukum property had estimated geological resources of 1 072 000 tonnes grading 9.63 g/t Au and 175.21 g/t Ag, or 10 323 kg (332 000 ounces) of gold and 187 834 kg (6 039 000 ounces) of silver. Tagish Lake Gold acquired the properties by amalgamating Omni Resources and Trumpeter Yukon Gold, resulting in the consolidation of all three deposits under a single company.

Figure 11. *Underground drill at the Skukum Creek deposit.*

In 2002, Tagish Lake Gold rehabilitated the underground workings at Skukum Creek and conducted a 15-hole underground diamond-drilling program (Fig. 11), totalling 2502 m, to test the deposit at depth. The program proved that the deposit continues at depth, with similar grades to that encountered in previous drilling (Table 1).

A detailed field and petrographic examination of structure and alteration at Skukum Creek was also conducted and is summarized in Lang et al. (this volume). The company has announced its intentions to begin the next phase of exploration early in the new year, which will consist of deepening the underground workings to allow continued drilling of the Rainbow zone extension. Drilling of the Ridge zone, which was intersected by surface drilling in 2001, will also be feasible from the underground extension.

Viceroy Resources Corporation optioned the **Eureka** claims (Yukon MINFILE 2002, 115O 057) from Expatriate Resources and Strategic Metals. The Eureka claims are located in the southern portion of the Klondike goldfields at the headwaters of Eureka Creek. Intensely oxidized, altered and silicified quartzite of the Devonian

Table 1. *Skukum Creek drill results.*

Hole #	From (m)	To (m)	Interval (m)	Au (g/t)	Ag (g/t)
Rainbow Zone					
SC02-05	143.06	143.75	0.69	4.65	125.1
SC02-06	185.01	187.82	2.81	4.68	167.3
including	186.92	187.36	0.44	10.08	423.9
SC02-07	81.35	88.45	7.10	10.04	504.7
including	81.35	84.16	2.81	19.57	778.0
SC02-08	65.80	66.40	0.60	4.80	125.1
SC02-09	102.50	103.80	1.30	4.96	173.9
SC02-10	161.40	162.59	1.19	8.78	267.6
and	166.03	175.77	9.74	3.61	246.4
including	166.03	167.67	1.64	14.72	1226.6
SC02-11	98.35	104.03	5.68	7.76	129.7
including	102.37	103.52	1.15	30.84	550.7
and	113.29	116.43	3.14	3.02	53.2
including	115.21	116.43	1.22	6.07	90.9
and	119.62	123.20	3.58	4.72	579.7
including	119.62	120.82	1.20	10.61	1626.5
SC02-12	179.30	191.34	12.04	6.52	164.6
including	180.32	185.44	5.12	10.46	260.7
SC02-13	104.24	104.84	0.60	3.92	260.8
and	182.87	183.02	0.15	5.55	307.4
and	191.67	191.85	0.18	10.94	163.3
and	195.05	196.96	1.91	3.11	65.9
SC02-14	141.39	155.02	13.63	6.85	78.5
including	146.86	149.14	2.28	19.82	112.7
and	159.81	162.21	2.40	33.48	265.0
SC02-15	116.75	121.20	4.45	3.95	62.3
including	116.75	118.35	1.60	7.54	86.9
and	124.48	125.50	1.02	4.56	54.8
and	127.30	128.56	1.26	16.23	240.8
SC02-17	122.91	125.15	2.73	8.79	109.1
SC02-18	118.50	121.49	2.99	13.45	144.2
Sterling Zone					
SC02-16	131.43	132.74	1.31	1.53	11.4
Kuhn Zone					
SC02-16	204.05	206.96	2.91	8.32	69.2
SC02-19	168.35	168.70	0.35	1.78	38.5

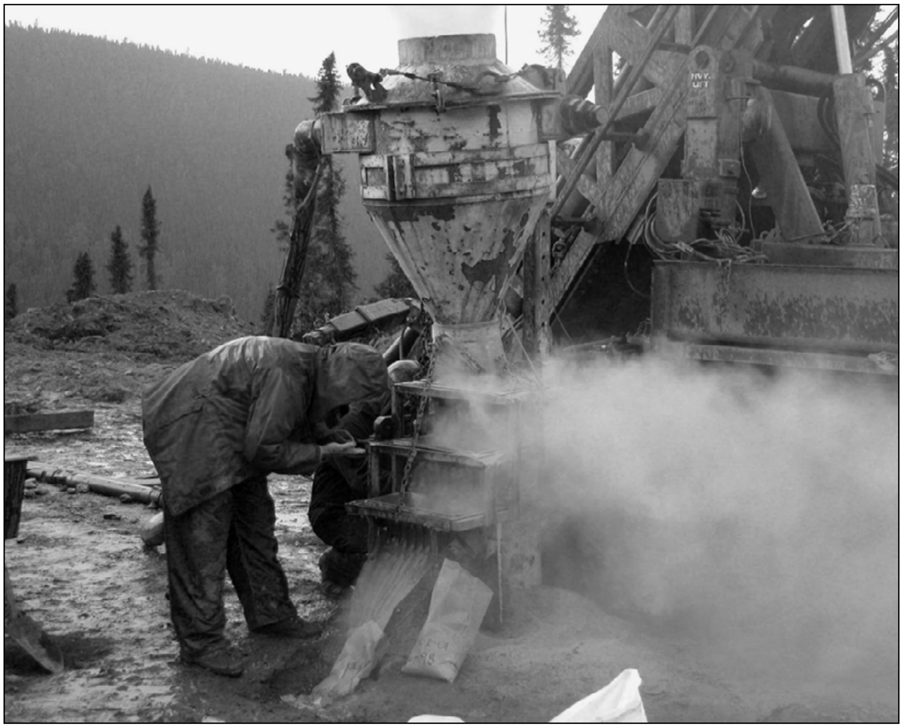


Figure 12. Rick Diment with Viceroy Resources examining a rock chip from reverse circulation drilling on the Eureka property.

to Mississippian Nasina Assemblage of the Yukon-Tanana Terrane have returned values up to 15 g/t Au from surface trenching. Viceroy conducted additional surface excavator trenching, and drilled four reverse circulation holes for a total of 390 m (Fig. 12). No results have been released from the program.

In the southwestern Yukon, Atac Resources explored the **Arn** property (Yukon MINFILE 2002, 115F 048) with geological mapping, prospecting and drilling (Fig. 13) of the first four diamond drill holes ever drilled on the claims. The property is located within 6 km of the Alaska Highway. Garnet-epidote skarn and magnetite skarn with pyrrhotite, pyrite and chalcopyrite formed in the Triassic Nikolai Greenstone, which consists of mainly volcanic rocks with minor limestone beds that have been intruded by Cretaceous diorite dykes. Bedrock exposure on the claims is very poor. Previous work identified three skarn horizons with high-grade gold and copper mineralization in hand trenches and float boulders. Drilling was conducted to gain a better understanding of the poorly exposed geology and test the high-grade gold mineralization. The drilling successfully intersected high-grade gold skarn mineralization associated with a steeply dipping structural zone containing three faults. Hole Arn-3 intersected 1.01 m of 11.29 g/t Au and 0.02% Cu; hole Arn-4 intersected 12.67 m grading 11.92 g/t Au and 0.22% Cu, which includes 1.98 m averaging 64.42 g/t Au with 1.16% Cu and 5.95 m grading 1.05 g/t Au and 0.43% Cu. Additional prospecting conducted along the trend of the structural zone identified a new zone 3 km from the discovery drill holes. Assays up to 14.7 g/t Au were collected from skarn and vein mineralization, mainly in float boulders in a recessive weathering zone over a 1400 by 300 m area along the fault trace. The drill remains on site to continue testing this exciting new discovery in 2003.

Al Carlos of Whitehorse drilled six holes totalling 415 m on his **Grew Creek** (Yukon MINFILE 2002,

Figure 13. A helicopter gently moving the drill into place on the Arn claims. Note the small area affected by this method of drilling. Photo by Atac Resources.

105K 009) property, an Eocene epithermal gold-silver deposit near Faro. The deposit hosts a drill-indicated geological resource of 773 012 tonnes grading 8.9 g/t Au and 33.6 g/t Ag (Christie, 1992). Al has been conducting extensive compilation work on the property, and in 2000 conducted a geochemical survey utilizing the Enzyme Leach process on targets outside of the main Grew Creek deposit. Several anomalies were outlined with the survey and supported by historical airborne and ground geophysical data, conventional geochemistry and prospecting. Carlos drilled 191 m in four holes in 2001, and conducted this year's exploration program on one of these anomalies. Results for the 2002 drilling have not been released.

The **Spice** claims (NTS 105G/13), optioned by Atac Resources from Tanana Exploration Inc., were subjected to a small geological mapping and auger sampling program. The claims were initially staked as a follow-up to a highly anomalous till geochemical sample released by Jeff Bond (Bond, 2001) of the Yukon Geology Program. The analyses of the till show a well developed, down-ice dispersion train with anomalous values for gold (50 to 4460 ppb), arsenic (100 to 546 ppm) and mercury (5 to 52 ppm). The anomalous sample sites are commonly associated with cherty rhyolite or porphyritic rhyolite rock fragments. The anomalous area has only been partially outlined but appears to truncate up-ice along a prominent, northerly trending lineament. The geochemical response of the occurrence is similar to that of the Grew Creek epithermal gold-silver deposit located approximately 50 km to the west.

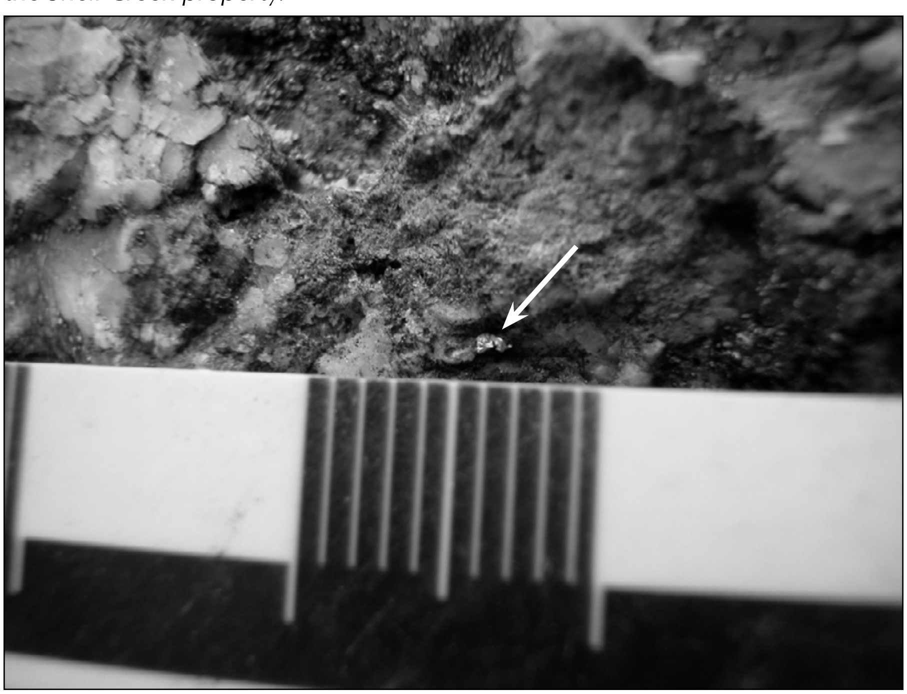
Exploration on the **Ruby Range** property (Yukon MINFILE 2002, 115H 047; Fig. 14) by Cash Minerals examined several areas of greater than 30 g/t Au related to an extensive system of mesothermal gold-bearing quartz-carbonate veins occurring in biotite and muscovite schist of the Kluane Metamorphic Assemblage, which is intruded by the Eocene Ruby Range Plutonic Suite. A program of prospecting and hand trenching traced one of the main vein systems (Rikus) over a total distance of 800 m. Earlier work on this target included surface chip sampling of two parallel veins and adjacent wall rock over a strike length of 60 m that yielded weighted average grades of 4.30 and 3.94 g/t Au across 3.20 and 3.65 m, respectively. Float occurrences elsewhere on the property have returned numerous high gold assays including 193, 122 and 102 g/t from three areas located approximately 1500 m apart along linear structures similar to the Rikus vein. Work in 2002 defined a number of promising targets at or near the junctions of veins, or where the veins are cut by cross-faults.

Figure 14. *Hot coffee on a wet day at Cash Minerals' Ruby project.*

The **Pike** claims (Yukon MINFILE 2002, 106E 040) optioned by War Eagle Mining from Strategic Metals Ltd. cover a Proterozoic Wernecke Breccia body containing iron oxide, copper, gold and uranium mineralization. Exploration targets include (a) an area in the breccia body with a 960 by 300 m gold-in-soil anomaly ranging from 25 ppb to 950 ppb with a partially coincident 700 by 300 m copper-in-soil anomaly ranging from 200 ppm to 7800 ppm, and (b) two parallel float trains of gold mineralization on a steep talus-covered slope downhill from the breccia body. The gold float trains are 65 m apart, 5- to 20-m-wide and each about 100 m long. Gold in the float trains consists of scattered fist- to fingertip-size fragments containing native gold in flakes, wires and rosettes in brecciated, hematite-stained, quartz-bearing rock, commonly within or adjacent to pitchblende or brannerite. Assays have ranged from less than 30 g/t Au (1 oz/ton) up to 64 652 g/t Au (2078.6 oz/ton).

Shawn Ryan staked the **Simba** claims to cover a known Algoma-type banded iron formation (Yukon MINFILE 2002, 116C 029) located on Shell Creek approximately 70 km northwest of Dawson City. The iron-formation is composed of two principal types of material, a black magnetite-grey chert facies and a thin-banded grey chert containing pyrite and pyrrhotite. The iron formation is intimately associated with epidote-altered volcanic tuffs and breccias, reportedly of the Cambrian to Silurian Marmot Formation. It forms part of a tightly folded group of rocks composed of various schists, argillite, slate, buff-brown gritty quartzite, and black maroon and green shales, all of Precambrian and/or Cambrian age. Ryan was investigating the possibility of gold associated with the iron formation based on anomalous regional geochemical surveys, geological modeling and anecdotal reports of placer gold in Shell Creek. Prospecting discovered a sporadically exposed quartz-carbonate vein(s) hosted within the volcanic rocks approximately 30 m stratigraphically above the magnetite iron formation. The vein(s) has(have) been traced intermittently by outcrop and float boulders over a 7-km strike length. The width of the vein is undetermined but some of the float boulders examined were approximately 2 m wide. The quartz-carbonate veins are weakly mineralized with malachite and chalcocite (?), and rarely with galena; and visible gold (Fig. 15) has been found in three locations over approximately 2 km. Ryan completed reconnaissance and grid soil and rock sampling, and geophysical surveys (magnetics) on the claims this season.

***Figure 15.** A flake of visible gold approximately 1 mm across associated with malachite from the Shell Creek property.*



Uravan Minerals Inc. drilled two holes totaling 495 m (Fig. 16) on the **Canalask/Onion** property (Yukon MINFILE 2002, 115K 077). The property covers the Triassic White River Intrusive Complex, the second largest mafic-ultramafic body located in the Kluane Mafic-Ultramafic Belt (Hulbert, 1997). Uravan targeted Ni-Cu-platinum group element (PGE) mineralization in marginal gabbros in the basal section of the Discovery-Onion and Sax-Cessna areas. Geophysics identified two strong horizontal-loop electromagnetic (HLEM) anomalies with coincident induced polarization (IP) chargeability-resistivity anomalies that were the targets of this year's drilling. Very broad areas of highly anomalous Ni-PGE mineralization were found hosted in the White River ultramafic sill, and broad areas of anomalous gold and copper mineralization were discovered in the footwall quartz-carbonate alteration zone and underlying sedimentary and volcanic rocks. Preliminary assay results indicate no economic mineralization was intersected in either hole. The broad areas of Ni-PGE mineralization hosted in ultramafic rocks (clinopyroxenite) occurred in zones of net-textured and disseminated magnetite plus ferro-chromite and sulphide minerals. Intersections ranged in grade from about 1100 ppm to 3100 ppm Ni, and 90 ppb to 634 ppb Pt, plus Pd over intervals greater than 20 m wide in both drill holes.

Figure 16. *Larry Lahusen of Uravan Minerals examining core from the Canalask/Onion property.*

Prospector Gord McLeod of Whitehorse restaked a chromite occurrence located approximately 50 km south of Whitehorse as the **HFA claims** (Yukon MINFILE 2002, 105C 012). The chromite (Fig. 17) has a layered appearance, but exhibits textures that indicate it was formed during a late mineralizing event. The host dunite is part of a larger layered ultramafic sequence. The showing is poorly exposed and the relationship of the dunite with the layered ultramafic rock is unclear. Additional mapping is required to determine if it is part of the layered sequence or a later dyke. McLeod conducted sulphide fusion assays on the chromite, which returned values of up to 159 ppb Pt, 5 ppb Pd, 417 ppb Ir, 406 ppb Os, 70 ppb Rh and 683 ppb Ru.

Figure 17. *Chromite (dark) in dunite at the Hold Fast property of Gordon McLeod.*

BASE METALS

Iron-oxide-associated copper-gold occurrences in Proterozoic 'Wernecke Breccia' continue to be an attractive exploration target in Yukon. Copper Ridge Exploration optioned the **Hem** claims (Yukon MINFILE 2002, 116G 082) from Shawn Ryan and explored the breccia occurrence with ground-based magnetometer and gravity surveys. The Hem claims cover a hematitic Wernecke Breccia cut by intermediate (Fig. 18) dykes exposed in a small window of Proterozoic clastic rocks. The Hem claims and the breccia body are bisected by the Dempster Highway where the road-cut provides a nice exposure of the breccia, mineralized with disseminated chalcopyrite. The property has since been renamed the Yukon Olympic. The hematitic breccia can be found in a continuous exposure along a creek on the east side of the Blackstone River for over 1.5 km. The geophysical surveys outlined a +4.5 mGal gravity anomaly 8 km long and 1 km wide with three distinct peaks that lie below the Paleozoic sedimentary rocks, which unconformably overlie the Proterozoic clastic rocks. The magnetometer survey outlined a magnetic anomaly, which is slightly offset from two of the gravity anomaly peaks. Late in the season, Copper Ridge optioned the property to Canadian Empire Exploration who conducted a two-hole diamond drilling program in November. The first hole was collared on the westernmost gravity anomaly, which was the lowest priority target but offered easy access from the Dempster Highway. The hole YO-1 was drilled to 563 m depth before being abandoned, however, the casing was left in the hole. The hole is reported to have intersected some breccia and minor sulphide mineralization, and results are pending. The second hole was drilled alongside the Dempster Highway on the road-cut showing, and results from that hole are also pending. Drill testing of the higher priority gravity targets are scheduled for 2003.

Figure 18. *Chalcopyrite and bornite mineralization in an intermediate dyke on the Yukon Olympic (Hem) property.*

Monster Copper Resources optioned the **Monster** property (Yukon MINFILE 2002, 116B 103) to Orezone Resources Inc. The Monster property covers a number of occurrences of 'Wernecke Breccia' with copper and gold mineralization within the Coal Creek Inlier, an oval-shaped east-trending window of Middle and Late Proterozoic clastic rocks. Drilling has not adequately tested any of the occurrences in the Inlier. A program of ground geophysics, geological mapping and prospecting was conducted in 2002.

Commander Resources also has significant claim holdings in the Coal Creek Inlier covering the **Rob** and **Lala** breccia occurrences (Yukon MINFILE 2002, 116B 099,113). The claims were last explored during the 1996 and 1997 field seasons with helicopter-borne magnetic and radiometric, ground-based magnetic and gradient induced polarization surveys, and geological mapping and sampling, followed by diamond drilling of 2672 m in 11 holes.

The **Lucky Joe** copper-gold occurrence (Yukon MINFILE 2002, 115 051) is located 50 km south of Dawson City in west-central Yukon. The property was staked by prospector Shawn Ryan in 2001 after the release of the Stewart River Multisensor Airborne Geophysical Survey flown by the Yukon Geology Program and Geological Survey of Canada as part of the Targeted Geoscience Initiative. Geological mapping based on the airborne geophysics is ongoing as part of the Stewart River component of the Ancient Pacific Margin NATMAP project. Shawn recognized a distinct, regionally significant geophysical signature in the airborne magnetic survey that was associated with the Lucky Joe occurrence. Reconnaissance soil surveying by Ryan demonstrated the Cu-Au-Mo metal signature associated with the Lucky Joe was also associated with the geophysical target. Copper Ridge Exploration optioned the property in 2002 and conducted additional claim staking, ground magnetic surveys, grid and reconnaissance soil sampling, and hand trenching. The claims are underlain by metamorphic rocks of the Paleozoic Yukon-Tanana Terrane. Magnetite-bearing amphibolite is underlain by quartz-muscovite and biotite-muscovite schist, quartzite and orthogneiss. Copper-gold-molybdenum mineralization is found in the upper 50 m of a blanket-like pyritic layer up to 300 m thick in schist and orthogneiss immediately below the amphibolite unit. Drilling on the Lucky Joe occurrence (Fig. 19) in the mid-1970s intersected broad zones of mineralization with values up to 0.95% Cu over 5.2 m. The work in 2002 outlined two areas of anomalous soil response approximately 7.5 km apart. The Bear Cub anomaly is an area 1500 m by 1000 m that returned greater than 250 ppm Cu and 10 ppm Mo, with peak values to 4300 ppm Cu, 76 ppm Mo and 573 ppb Au. The Ryan's Creek anomaly is over 3500 m long, up to 500 m wide and returned greater than 60 ppm Cu. The work clearly demonstrated the regional extent and significance of the mineralization in this area. Copper Ridge acquired the Shamrock

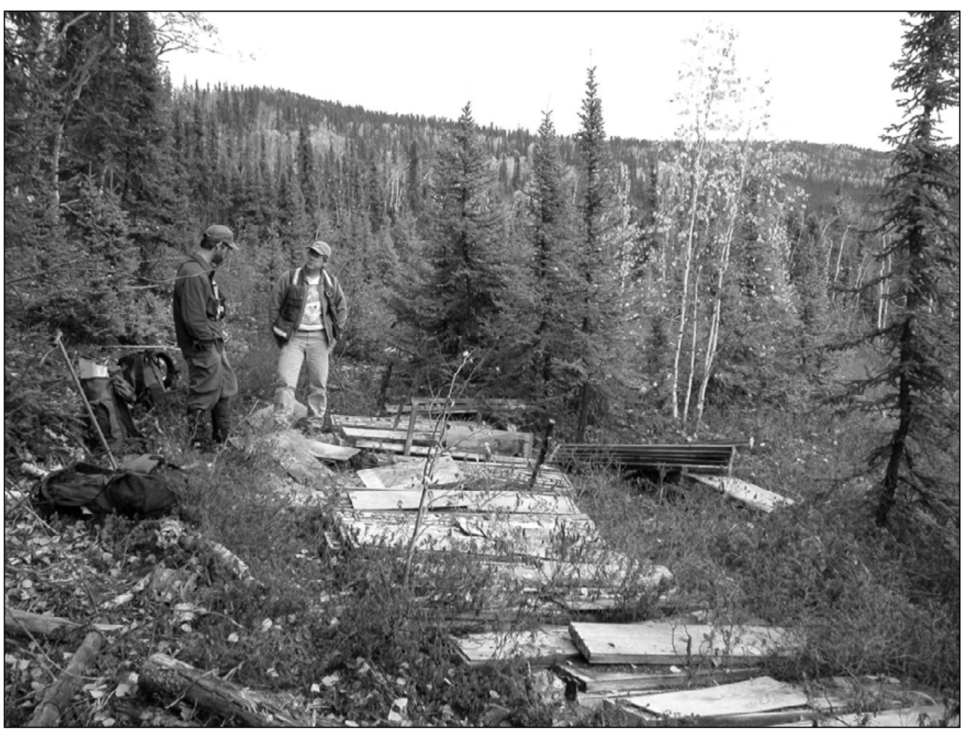


Figure 19. *Prospector Shawn Ryan (left) and Ken Galambos, Mineral Development geologist with the Yukon Geology Program, examine old drill core on the Lucky Joe property.*

Figure 20. Leached and gossanous kill zone on the newly staked Box claims of Expatriate Resources. Photo by Expatriate Resources.

property, consisting of 338 claims immediately south of Lucky Joe, based on a similar geophysical and geochemical signature.

Shawn Ryan conducted grid geochemistry, magnetic and very low frequency (VLF) geophysical surveys on his **Box Car** property (Yukon MINFILE 2002, 115O 071) in the Dawson area. The property is underlain by pale green- to tan-weathering quartz-muscovite-chlorite schist of the Permian Klondike Schist of the Yukon-Tanana Terrane. Soil sampling returned anomalous values up to 9 ppm Mo, 3000 ppm Pb, 700 ppm Zn, 250 ppm Cu and 65 ppb Au. The property is host to a known copper-lead-zinc-silver-gold vein, but Shawn is evaluating the claims for their volcanogenic massive sulphide (VMS) potential.

In the Finlayson Lake district, Expatriate Resources conducted regional reconnaissance work on some of their many properties in the area. Expatriate also staked additional claims based on recent mapping as part of the Finlayson Lake Targeted Geoscience Initiative, which identified a new belt of Kudz Ze Kayah-equivalent felsic volcanic rocks. The **Box** claims (NTS 105G/10; Fig. 20) cover a prominent leached and gossanous zone, where previous sampling in 1996 by Expatriate had identified anomalous multi-element soil geochemistry. Expatriate's field work, based on the geologic framework provided by recent government mapping, has identified new target areas in favourable Kudz Ze Kayah stratigraphy on the Pak (Yukon MINFILE 2002, 105G 032), Play and Ref (Yukon MINFILE 2002, 105G 051) claims.

Figure 21. Eagle Plains Resources staking the MM occurrence in the Pelly Mountain volcanic belt. Photo by Eagle Plains Resources.

Eagle Plains Resources performed regional reconnaissance in the vicinity of their large claim holdings in the Pelly Mountain volcanic belt (Hunt, 2002). Eagle Plains staked additional claims based on their program of detailed regional stream sediment sampling, prospecting and geological mapping. They also acquired, by staking (Fig. 21), the **MM** deposit (Yukon MINFILE 2002, 105F 012). Mineralization on the MM consists of stratiform lenses of barite-pyrite with associated silver, copper, lead and zinc sulphides that appear to be restricted to approximately the same stratigraphic horizon, and occur over a strike length of at least 3750 m. Modally, the lenses range from nearly pure barite to nearly pure pyrite.

Figure 22. Bedded pyrite in black shales from the Tanner property of Manson Creek Resources.

Mineralized drill intersections range from 0.9 m to 15.7 m in width, with grades of up to 5.9% Zn, 3.0% Pb and 55 g/t Ag (1.6 oz/t) over 7.2 m reported from hole 76-MM-02; and 13.5% Zn, 7.8% Pb, 1.3% Cu and 110 g/t Ag (3.5 oz/t) over 2.7 m reported from hole 77-MM-03.

Manson Creek Resources conducted three small helicopter-supported diamond drilling programs on the **Tanner**, **JRS** and **Rusty** (NTS 106C/3; 106C/4; 106C/5) properties, in 2002, exploring for sedimentary-exhalative (SEDEX) and VMS deposits. On the Tanner property, recent mapping by Manson Creek has identified prospective Devono-Mississippian Earn Group stratigraphy. Two holes totalling 306 m were drilled to test a 750-m portion of a 4.4-km airborne conductivity anomaly. Bedded barite and pyrite (Fig. 22), and pyritic synsedimentary breccias were intersected. Drilling returned values up to 1370 ppm Zn, 3.8 g/t Ag and 0.15 g/t Au over 1 m, and 20 m of 26.9% BaO. Manson Creek expanded the property to encompass the Tell occurrence (Yukon MINFILE 2002, 106C 091) where previous work returned up to 10% Zn.

Three holes drilled on the JRS property intersected narrow syngenetic pyritic massive sulphide horizons in Devono-Mississipian Earn Group stratigraphy similar to that hosting the **Marg** deposit (Yukon MINFILE 2002, 106D 009) located 50 km to the east. Mafic volcanic rocks, bedded barite, and chert of possible exhalative origin were intersected by drilling. Assays up to 2600 ppm Zn, 2760 ppm Cu, 27.6 g/t Ag and 0.38 g/t Au were obtained from bedded pyrite. A quartz-barite vein with pyrite and arsenopyrite in black shale was intersected in hole JRS01-02, and returned 0.30 g/t Au over 0.45 m. The mineralization is similar to a showing in another area of the claims discovered last season, which has assayed up to 4.27 g/t Au in grab samples.

On the **Nad** Claims (NTS 106C/3) Manson Creek Resources continued to explore for ultramafic-associated Ni-Cu mineralization in heavily serpentinized ultramafic flows and high-grade gold in associated listwaenites (Jutras, this volume). Grab

Figure 23. *Sphalerite-galena mineralization in calcite-quartz breccia on Noranda's Andrew property.*

samples from a pyrite-chalcopyrite lens in listwaenite assayed up to 20.37 g/t Au, 6.8 g/t Ag, 6.85% Cu, 0.56% Ni and 0.16% Co.

Noranda Exploration drilled eight holes totaling 1800 m on the **Andrew** property (Yukon MINFILE 2002, 105K 089) in central Yukon. Noranda optioned the claims from prospector Ron Berdahl in 2000, and conducted an airborne electromagnetic and magnetic survey in early 2001. This was followed by geologic mapping, prospecting, geochemistry, ground-based magnetic and gravity surveys over selected targets, and a 15-hole 2789-m helicopter-supported diamond drilling program. Drilling on the Andrew showing in 2001 and 2002 targeted an east-striking extensional fault zone within interbedded quartzites, shales and limestones of the Neoproterozoic to Lower Cambrian Hyland Group. Sphalerite-galena mineralization is hosted in a calcite-quartz breccia (Fig. 23). Significant intersections from the 2001 drilling are presented in Table 2.

Table 2. *Significant results from 2001 Andrew property drilling.*

Drill hole	From (m)	To (m)	Interval (m)	% Pb	% Zn	g/t Ag
AN-01-04	96.6	103.4	6.8	0.01	10.78	0.6
	110.10	137.60	27.50	0.12	12.84	1.8
AN-01-11	89.00	107.50	18.50	3.12	14.89	12.6
AN-01-12	151.15	163.15	12.00	0.01	5.25	0.8
	167.00	173.20	6.2	0.01	6.13	0.7
	214.7	255.60	40.9	.090	1.13	2.2
includes	214.70	221.50	6.80	0.01	2.61	0.5
and	251.15	255.60	4.45	6.32	2.40	12.5
AN-01-14	123.35	127.90	4.55	24.52	6.59	64.3
AN-01-15	141.20	143.75	2.55	22.63	3.59	60.9
	153.60	162.00	8.40	18.84	9.52	67.9
	185.85	196.10	10.25	20.16	10.98	45.7

The drill holes intersected mineralization over a 200-m strike length and approximately 150 m down-dip. Results from the 2002 drilling are not yet available and the property has since been returned to the vendor. Mr. Berdahl, the vendor, is awaiting a complete set of exploration data from Noranda, which can be made available for companies interested in optioning this significant new discovery.

GEMSTONES

True North Gems explored their **Regal Ridge** property (Yukon MINFILE 2002, 105G 147) for emeralds with prospecting, geological mapping, excavator trenching, bulk sampling and diamond drilling in 2002. They were very successful in recovering a large bulk sample of emerald-bearing material, discovering new emerald occurrences, and acquiring a much better understanding of the geological setting of the emerald deposit. Neufeld et al. present a preliminary paper on emerald mineralization at Regal Ridge in this volume. True North conducted a bulk-sampling program that recovered 120.34 tonnes of emerald-bearing material from seven different zones that was processed on site to yield 65 kg of emerald concentrate. The concentrate was transported to the True North laboratory facility in Vancouver, B.C., where the material was further processed. Emerald-bearing material was first sorted into three categories: gem quality, near-gem quality and non-gem quality. In general, the gem quality material is transparent and considered usable for faceting; the near-gem material is translucent and considered usable for cabachons; the non-gem material is opaque and could potentially be used for beads or other products. The various gem classification categories were defined by a consulting gemologist, William Rohtert, G.G. and an experienced facetor, Bernard Gaboury, MSc, PEng, President of True North. Microscopic examination of gem quality material showed it to be medium green with good saturation and transparency with some fractures, and no foreign inclusions. The near-gem quality material is also medium green with good saturation, but contains light to moderate fractures, some pits, and a few inclusions.

Detailed tables showing the gem, near-gem and non-gem yields (in grams) from each zone, plus the yield (in grams) and number of stones based on four size categories obtained using diamond sieves (+4.5, 3.9-4.5, 2.9-3.9, 1.9-2.9 mm), were presented in a December 12, 2002 news release available on the True North website at *www.truenorthgems.com*. The most impressive yield was obtained from Southwest zone (Fig. 24) where a 6.36 t bulk sample yielded 11.59 kg of emerald concentrate. From this, 121.42 g of gem quality and 587.33 g of near-gem quality stones were recovered for a yield of 19.09 g/t gem quality and 92.35 g/t near-gem quality emeralds. The sample produced 1092 gem quality stones with 284 in the +4.5mm size category, and 1903 near-gem quality stones with 714 in the +4.5mm range. The stones are currently being stabilized, cut and polished after which they will be evaluated by an independent qualified gemologist.

Recent mapping by the Yukon Geology Program and Geological Survey of Canada as part of the Targeted Geoscience Initiative in the Finlayson Lake area (Murphy, 2001) has provided

Figure 24. *Emerald concentrate from the Southwest #1 vein at Regal Ridge. Photo by True North Gems.*

an excellent geologic framework in the emerald discovery area. This, combined with details of the geologic setting of the emeralds provided by True North Gems, has demonstrated that the Finlayson Lake area has many unique geological characteristics required for emerald formation (W.R. Rohtert and J.H. Montgomery, 2002 field activity report, on website at *www.sedar.com*). This has resulted in the staking of many new properties that have the potential for emerald mineralization, and the re-evaluation of many existing claims for their emerald potential. Expatriate Resources Ltd. has entered into an agreement with YK Group to explore its extensive claim holdings in the Finlayson Lake district for emeralds. Pacific Ridge Exploration has re-examined their exploration database of geological information in the Fyre Lake area immediately south of Regal Ridge and has identified several emerald targets. Firestone Ventures Inc. is earning an interest in a 118-claim property from True North Gems. Hinterland Metals has optioned the **Gleam** property and International Arimex Resources, the **Glitter** property, both from True North Gems. Claim staking in the area is continuing.

Additionally, the coloured gemstone potential of the Yukon and the northern Cordillera is now being recognized, and exploration for gemstones is expected to increase in the coming years. A one-day seminar on northern gems at the annual Yukon Geoscience Forum attracted over 100 participants. The “Yukon Diamond Rumour Map” that was released at the seminar is available online at *www.emr.gov.yk.ca*.

ACKNOWLEDGEMENTS

This report is based on public information gathered from a variety of sources. It also includes information provided by companies through press releases and information from property summaries provided to the department by companies and from property visits conducted in the 2002 field season. The cooperation of companies in providing information as well as their hospitality and access to properties during field tours is gratefully acknowledged. Editing by Lara Lewis and Diane Emond is greatly appreciated.

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APPENDIX 1: 2002 EXPLORATION PROJECTS

PROPERTY	COMPANY/OWNER	MINING DISTRICT	MINFILE # or (1:50 000 NTS)	WORK TYPE	COMMODITY
1st Base	Arcturus Ventures	Watson Lake	105G-031	G,GC	Cu-Pb-Zn-Ag-Au
Andrew	Noranda Exploration	Whitehorse	105K-089	G,GC, DD	Zn-Pb-Ag
Arn	Atac Resources	Whitehorse	115F-048	G,GC,P,DD	Au-Cu
Brewery Creek	Viceroy Resources	Dawson	116B-160	Reclamation	Au
Blue Heaven	Strategic Metals	Watson Lake	105B-020	G	Ag-Pb-Zn-Cu
Box	Expatriate Resources	Watson Lake	(105G/10)	G,GC	Cu-Pb-Zn-Ag-Au
Box Car	Shawn Ryan	Dawson	115N-071	GC,GP,T	Cu-Pb-Ag-Au
Canalask	Uravan Minerals/ Expatriate Resources	Whitehorse	115K-077	DD	Ni-Cu-PGE
Cynthia	Klad Resources	Mayo	105O-007	G,GC,T	Au
Eureka	Viceroy Resources/ Expatriate Resources	Dawson	115O-057	G,T,RC	Au
Fyre Lake	Rock Resources/ Pacific Ridge Exploration	Watson Lake	105G-034	G	Cu-Co-Au
Grew Creek	Al Carlos	Whitehorse	105K-009	DD	Au-Ag
Hat	Kluane Drilling/ Norwest	Whitehorse	105D-053	G,DD	Cu-Au-Ag
Hem (Canadian Olympic)	Copper Ridge Exploration/ Canadian Empire	Dawson	116G-082	G,GC,GP,DD	Cu-Au
Hold Fast	Gordon McLeod	Whitehorse	105C-012	G,GC	Cr-PGE
Hyland Gold	Expatriate Resources/ Cash Minerals	Watson Lake	95D-011	G,GC	Au
Ice	ASC Industries Ltd.	Mayo	115P-006	G,GC,GP,DD,RC	Au
Kalzas	Copper Ridge Exploration	Mayo	105M-066	G,GC	WO_3
Keno Hill	A.M.T. Canada	Mayo	105M-001	D	Ag-Pb-Zn
Lucky Joe	Copper Ridge Exploration	Dawson	115O-051	G,GC,T	
Lynx Creek	Expatriate Resources	Mayo	106D-020	G,GC	Au
Mars	Saturn Ventures Inc.	Whitehorse	105E-002	G,GC	Cu-Au
Minto	Minto Resources	Whitehorse	115I-021,022	D	Cu-Ag-Au
Mitchell	JAE Resources	Dawson	115O-068	T	Au
MM	Eagle Plains Resources	Watson Lake	105F-012	G,GC	Cu-Pb-Zn-Ag
Monster	Monster Copper Resources/ Orezone Resources	Dawson	116B-103	G,GC,P,GP	Cu-Au
Myschka	Klad Resources	Mayo	105K-090	G,GC,T	Au
Pak	Expatriate Resources	Watson Lake	105G-032	G,GC	Cu-Pb-Zn-Ag-Au

continued...

APPENDIX 1 (continued): 2002 EXPLORATION PROJECTS

PROPERTY	COMPANY/OWNER	MINING DISTRICT	MINFILE # or (1:50 000 NTS)	WORK TYPE	COMMODITY
Pelly Mtn Project (Fire/Ice/St. Cyr)	Eagle Plains Resources	Watson Lake	105F-071,073	G,GC	Pb-Zn-Ag
Pike	Strategic Metals War Eagle Mining	Mayo	106E-040	G,GC,T	Au
Play/Ref	Expatriate Resources	Watson Lake	105G-051	G,GC	Cu-Pb-Zn-Ag-Au
Red Mountain	Regent Ventures	Mayo	115P-006	G,GC,GP,DD	Au
Regal Ridge	True North Gems/ Expatriate Resources	Watson Lake	105G-147	G,GC,T,DD,BS	Emeralds
Ruby Range	Cash Minerals Ltd.	Whitehorse	115H-047	G,GC,T	Au
Rusty/JRS/Tanner	Manson Creek Resources	Mayo	(106C/5,C/4,D/3)	G,GC,DD	Zn-Pb-Ag
Shamrock	Copper Ridge Exploration	Dawson	(115O/6)	GC	Cu-Au
Simba (Shell Creek)	Shawn Ryan	Dawson	116C-029	GC,GP	Au, Cu
Skukum	Tagish Lake Gold	Whitehorse	105D-22,25,158	G,GC,DD	Au-Ag
Spice	Atac/Tanana Exploration	Watson Lake	(105G/13)	G,GC,T	Au
Sprogge	Eagle Plains Resources	Watson Lake	105H-035	G,GC	Au
Tay/LP	Ross River Minerals	Whitehorse	105F-121	G,GC,T,DD	Au
Ultra	Tom Morgan	Whitehorse	115B-008	G,GC	Ni-Cu-PGE; Zn-Cu-Au-Ag
Wellgreen	Northern Platinum	Whitehorse	115G-024	G,GC	Ni-Cu-PGE

BS – bulk sample
D – development
DD – diamond drilling
ES – environmental studies
F – feasibility
G – geology
GC – geochemistry
GP – geophysics
M – mining
PD – percussion drilling
PF – prefeasibility
R – reconnaissance
T – trenching
U/GD – underground development

APPENDIX 2: 2002 DRILLING STATISTICS

		DIAMOND DRILL		RC/PERCUSSION DRILL	
PROPERTY	**COMPANY**	**metres**	**# holes**	**metres**	**# holes**
Andrew	Noranda Exploration/ Ron Berdahl	1800	8		
Arn	Atac Resources	182	4		
Canalask/Onion	Uravan Minerals/ Expatriate Resources	495	2		
Eureka	Viceroy Resources/ Expatriate Resources			390	4
Grew Creek	Al Carlos	414	6		
Ice	ASC Industries	422	2	604	10
Ram	Ross River Minerals/Almaden	343	4		
Red Mountain	Regent Ventures	949	6		
Regal Ridge	True North Gems	400	6		
Skukum Creek	Tagish Lake Gold	2502	15		
Tanner/JRS	Manson Creek Resources	791	6		
Tay-LP	Ross River Minerals	568	7		
Whse Cu (Hat)	Coyne and Sons	567	4		
Yukon Olympic	Canadian Empire/Copper Ridge Exploration	773	2		
TOTAL		10 209		994	

YUKON PLACER MINING OVERVIEW, 2002

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LeBarge, W., 2003. Yukon Placer Mining Overview, 2002. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 27-29.

Placer mining in the Yukon continued to be an important industry in 2002. A total of 115 mines were operating, with approximately 400 people directly employed in the industry. This represents a 7% decrease in the number of operating mines from the 2001 mining season, and an 18% decrease over the last two years. However, there were an estimated 600 additional jobs generated in 2002 in related service and hospitality industries. The effects of these economic benefits are especially felt in the small communities of Dawson and Mayo. As usual, the majority of active mining operations were in the Dawson Mining District (73) followed by the Whitehorse Mining District (30) and the Mayo Mining District (12).

For 2002, over 90% of the Yukon's placer gold was produced in the Dawson Mining District, which includes the unglaciated drainages of Klondike River, Indian River, west Yukon (Fortymile and Sixtymile rivers, and the Moosehorn Range) and lower Stewart River. The remaining gold came from glaciated regions, including Mayo, the Dawson Range, Kluane and Livingstone Creek.

Relative to 2001, placer gold production from Indian River drainages remained relatively unchanged. Klondike area drainages were higher overall, with less gold produced from Last Chance Creek and more gold produced on Gold Bottom Creek. West Yukon (Sixtymile, Fortymile, and Moosehorn) drainages produced more gold overall due to increases in the Moosehorn Range, but the Sixtymile area saw a decrease. Lower Stewart drainages produced less gold overall, but more was produced on Thistle Creek. No gold was reported from Clear Creek area this year. In the Dawson Range, placer gold production was much lower, due to cessation of mining operations on both Nansen and Canadian creeks. Mayo area drainages had increased gold production with the largest amount coming from Lightning Creek. In the Kluane area, much less gold was produced due to an absence of mining on Burwash Creek and

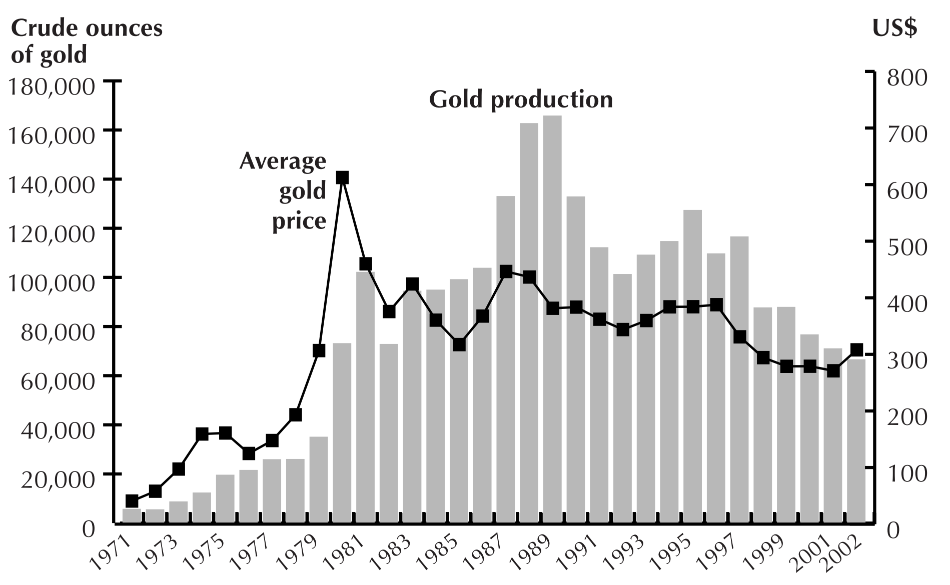

Figure 1. *Yearly gold production figures and average US gold price for the Yukon, 1971-2002.*

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decreased production from both Fourth of July and Gladstone creeks. In the Livingstone area, reported gold production was higher due to gold royalties reported from Little Violet Creek. In Whitehorse South drainages, no placer gold production has occurred since 1993, but interest in several creeks has continued with small-scale testing occurring on Evelyn, Iron and several other creeks.

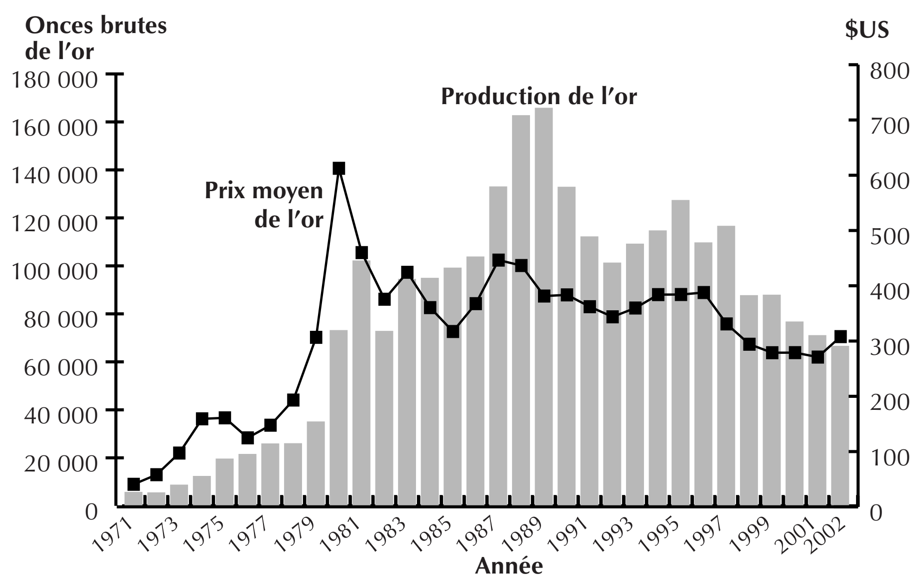
Total placer gold production for 2002 was 66,353 crude ounces (2 063 800 g) worth $25.8 million (Canadian funds) compared to 70,819 crude ounces (2 202 719 g) in 2001, which represents a 6.1% decrease. Since 1999, placer gold production has dropped 25% to its lowest level since 1979. However, due to a steady rise in the world market price of gold throughout 2002, the drop in gold production was offset considerably by an increase in value. The total dollar value of Yukon placer gold produced in 2002 was approximately $26 million, up slightly from the $23 million generated in 2001. This, combined with an overall decrease in fuel prices from 2001, resulted in a somewhat more profitable year for many Yukon placer miners.

SURVOL DE L'EXPLOITATION DE PLACERS AU YUKON EN 2002

L'exploitation de placers a continué d'être une importante industrie au Yukon en 2002. Au total, on a exploité 115 mines qui ont donné un emploi direct à environ 400 personnes. Ce chiffre représente une diminution de 7 % pour le nombre de mines exploitées par rapport à l'an 2001 et une régression de 18 % au cours des deux dernières années. Toutefois, on estime à 600 le nombre d'emplois additionnels créés en 2002 dans les industries des services et du tourisme d'accueil. Ce sont les petites agglomérations de Dawson et Mayo qui ont le plus profité de ces avantages. Comme dans le passé, la majorité des exploitations minières étaient situées dans le district minier de Dawson (73), suivi des districts de Whitehorse (30) et de Mayo (12).

En 2002, plus de 90 % de l'or placérien a été extrait dans le district de Dawson, soit dans les réseaux de drainage non englacées de la rivière Klondike, dans l'ouest du

Figure 1. *Production annuelle d'or et prix moyen américain de l'or au Yukon pour la période de 1971 à 2002.*



Yukon (les rivières Fortymile et Sixtymile et le chaînon Moosehorn) et dans le cours inférieur de la rivière Stewart. Le reste de l'or provenait de régions englacées, incluant Mayo, le chaînon Dawson, Kluane et le ruisseau Livingstone.

Par rapport à 2001, la production d'or placérien dans le réseau de drainage de la rivière Indian est demeurée relativement au même niveau. Les gîtes du réseau de drainage de Klondike ont été plus productifs dans l'ensemble; la production a été moins élevée au ruisseau Last Chance et plus élevée au ruisseau Gold Bottom. Dans l'ouest du Yukon (Sixtymile, Fortymile et Moosehorn), la production d'or a été plus élevée dans l'ensemble grâce aux augmentations enregistrées dans le chaînon Moosehorn même si la région de Sixtymile a connu un recul. La partie aval du réseau de drainage de la rivière Stewart a, pour sa part, produit moins d'or dans l'ensemble bien que le ruisseau Thistle en a produit plus. Le ruisseau Clear n'a pas produit cette année. Dans le chaînon Dawson, la production d'or placérien a beaucoup fléchi, et ce, à cause de l'interruption de l'exploitation sur les ruisseaux Nansen et Canadian. La région de Mayo a enregistré un accroissement de la production d'or, la grande partie provenant du ruisseau Lightning. Dans la région de Kluane, la baisse de la production est principalement due à une interruption de l'exploitation dans le ruisseau Burwash et à une diminution de la production dans les ruisseaux Fourth of July et Gladstone. Dans la région de Livingstone, la production d'or a été plus élevée si l'on base sur les redevances enregistrées au ruisseau Little Violet. Dans le réseau de drainage de Whitehorse Sud, il n'y a pas eu de production d'or placérien depuis 1993, mais plusieurs ruisseaux ont continué de susciter de l'intérêt si l'on se fonde sur les essais à petite échelle réalisés sur plusieurs d'entre eux, dont les ruisseaux Evelyn et Iron.

La production d'or placérien pour l'année 2002 a totalisé 66 353 d'onces brutes (2 063 800 g) qui vaut $25,8 million (en argent canadien), comparativement à 70 819 onces brutes (2 202 719 g) en 2001, une chute de 6,1 %. Depuis 1999, la production d'or placérien a dégringolé de 26 %, pour s'établir à son plus bas niveau depuis 1979. Cependant, la hausse constante des prix mondiaux de l'or tout au long de 2002 a contrebalancé le fléchissement de la production. En 2002, la valeur monétaire totale de l'or placérien produit au Yukon a atteint quelque 26 millions de dollars, comparativement à 23 millions de dollars en 2001. Si l'on combine ces résultats à la baisse globale des prix des carburants en 2001, l'année a été un peu plus profitable pour de nombreux exploitants de placers au Yukon.

Yukon Mining Incentives Program, 2002

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Galambos, K., 2003. Yukon Mining Incentives Program, 2002. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 31-38.

The Yukon Mining Incentives Program (YMIP) received 99 applications by this year's deadline of March 1, 2002. A total of $982,000 was offered to 62 successful applicants. From these programs, 9 were approved under the Grassroots Prospecting and Grubstake modules, 36 proposals were part of the Target Evaluation module and 17 applicants were approved under the newly added Focused Regional module. Precious metal exploration under the program was down from last year with approximately 41% of applicants searching for gold and platinum group elements. Base metal exploration accounted for 45% of approved programs; the remaining 14% of programs involved exploration for gem stones and other commodities. Exploration programs were proposed for all four mining districts and were fairly evenly dispersed over the entire Territory. Although total exploration spending is down from last year, the number of property options by prospectors is up significantly. To date there have been nine options signed for properties that have been explored under YMIP.

Highlights for the year, for both placer and hard rock exploration programs, include the discovery of significant gold and pathfinder anomalies in both soils and rock, and the extension of known

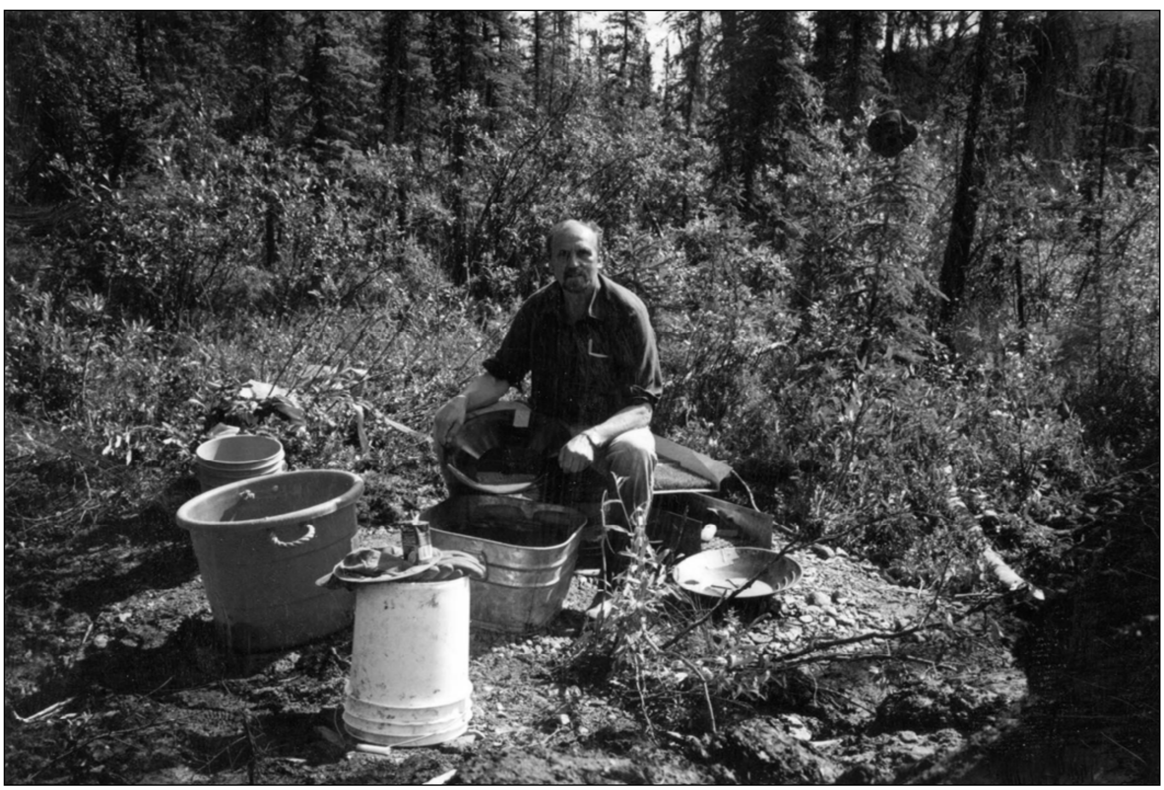

Figure 1. *Erwin Kreft is seen here processing some of the pay gravels excavated on Little Blanche Creek located in the Klondike goldfields. Photo by Exilda Driscoll.*

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showings through prospecting and geophysics. A number of significant exploration targets were found with the new Focused Regional module.

The following sections detail exploration highlights for selected YMIP projects.

LITTLE BLANCHE CREEK (TARGET MODULE)

Erwin Kreft (Fig. 1) had a successful season following up on previous auger drilling results on placer claims located on Little Blanche Creek, south of Dawson City. Previous drill programs outlined a pay streak averaging 6 ft (1.8 m) thick and 30 to 36 ft (9 to 11 m) wide. The best result from drilling was 5 ft (1.5 m) averaging 0.081 oz (2.5 g) of gold per bank yard from Auger Hole 2000-6. Test pitting of anomalous drill holes confirmed and enhanced results where target depths were reached. Hole #1, dug at the collar of drill hole 2000-6, returned 0.097 oz (3 g) of gold per bank yard or C$47/yd^3 at $308/oz. Hole #2 encountered abundant ground water and failed to reach bedrock. Hole #3, excavated at the collar of Auger Hole 2001-2 (0.06 oz/yd^3 over a 6-foot (1.8 m) interval), returned 0.109 oz (3.39 g) of gold per bank yard or C$52.80/yd^3. Little Blanche Creek placer gold has a purity of approximately 65%, so the number of crude ounces per bank yard is substantially more than reported.

IRON-OXIDE-COPPER-GOLD (FOCUSED-REGIONAL MODULE)

Prospector Bernie Kreft (Fig. 2) conducted a regional exploration project for Olympic Dam-type, iron-oxide-copper-gold (IOCG) targets north of Mayo this season. Three new areas of mineralization were discovered with values up to 2.65 g/t Au, 2% Cu and 0.25% Co. These values were returned from brecciated intrusive and sedimentary rocks as well as quartz-siderite and ankerite veins (Fig. 3). Brick red alteration and specular hematite are common to all brecciated occurrences. Exploration indicates large anomalous areas coincident with the new showings.

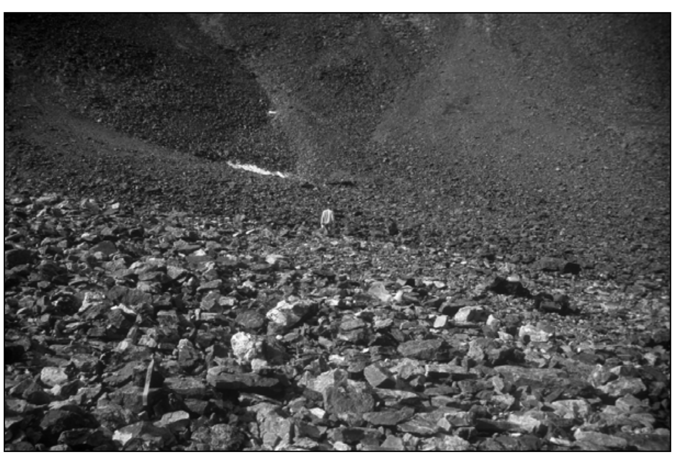

***Figure. 2.** Bernie Kreft is seen in the background of a large talus field that is 60-80% mineralized with pyrite, chalcopyrite and malachite. This is one of the new showings discovered this year during his program looking for IOCG targets.*

SEVERANCE PROPERTY (TARGET EVALUATION MODULE)

The Severance property was explored by 4763 NWT Ltd. and is located north of the Klotassin River, 260 km northwest of Carmacks on NTS sheet 115J/7. The property is underlain by granodiorite of the Cretaceous Dawson Range Batholith, which is intruded by Tertiary quartz-

***Figure 3.** This sample of weakly brecciated pink to beige chert with disseminated and fracture-controlled chalcopyrite assayed 1.92% Cu.*

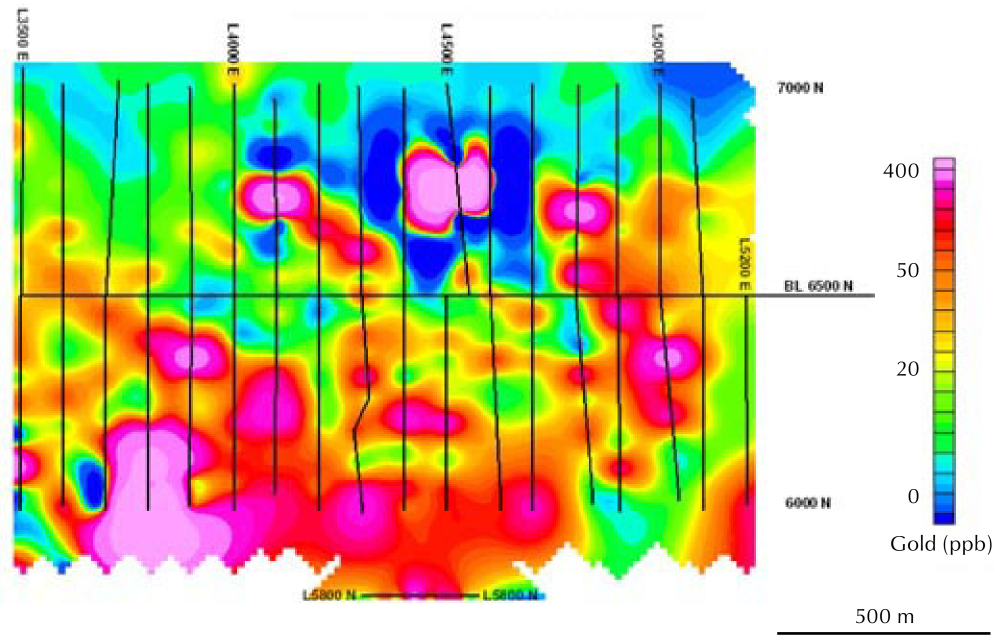

Figure 4. *Gold-in-soil plot showing what appears to be a number of mineralized structures on the Severance property. Geochemical plot by Aurora Geosciences Ltd.*

feldspar porphyry dykes. The area had been previously explored by Kennecott Canada Ltd. with reconnaissance stream sediment and soil sampling as a follow-up of an NGR (National Geochemical Reconaissance) stream sediment anomaly of 280 ppb Au on a tributary of Somme Creek. Kennecott's program returned a number of samples anomalous in gold, bismuth and arsenic. In January 2002, 4763 NWT Ltd. staked the Severance property, covering the area of anomalous soils. This summer the company conducted an exploration program consisting of geological mapping, prospecting and soil sampling. A grid was established to cover an area measuring 1.7 by 1 km, and soil samples were collected at 50-m stations on lines spaced 100 m apart. The soil program returned some significantly anomalous values (Fig. 4) with 31 of 344 samples being greater than 100 ppb Au, including four samples with 600, 738, 1965 and 2680 ppb Au. Coincident with the gold are copper, molybdenum and arsenic anomalies. Rock sample results included a grab sample of silicified and quartz-veined granodiorite with 7% disseminated pyrite which assayed 1.2 g/t Au and 0.35% Cu.

YUKON OLYMPIC PROPERTY (TARGET EVALUATION/FOCUSED REGIONAL MODULES)

Shawn Ryan had a very successful year of exploration in the Dawson district. While prospecting by snow machine in early April, he discovered a new showing off of his Hem property, located near Windy Pass on the Dempster Highway. The showing consists of a mineralized diorite dyke intruding an outcrop of hematite breccia immediately below a major unconformity (Fig. 5). Copper mineralization occurs as disseminated mineralization in the intrusive rock, as fracture fillings, with quartz-carbonate vein material, and as chalcopyrite-filled vesicles. In May, he was successful in optioning the Hem claims to Copper Ridge Explorations Inc. With assistance from the company, Shawn completed a large geophysical survey, including magnetics and gravity, over the claim block and

Figure 5. *Shawn Ryan at his new copper showing on the Yukon Olympic property.*

surrounding area. The survey revealed a very large and intense gravity anomaly to the north of the claims (Fig. 6). The gravity has a maximum amplitude of 6 milligals above background, a strike length of 8.2 km and a half amplitude width of 2.4 km. As with the Olympic Dam property in Australia, the gravity anomaly is related to, but not coincident with, a regional-scale magnetic anomaly. Additional staking to cover these targets has expanded the Yukon Olympic property to 377 claims. Copper Ridge subsequently optioned the property to Canadian Empire Exploration Corp. in September, 2002. Canadian Empire conducted a two-hole diamond drilling program in October and November, 2002. Results of the drill program are pending.

LUCKY JOE PROPERTY (GRASSROOTS PROSPECTING MODULE)

With the release of the initial Stewart River Multisensor Airborne Geophysical Surveys in 2001 (Shives et al., 2001), Mr. Ryan recognized a possible geophysical signature for the historic Lucky Joe copper-molybdenum property. He also realized that the size of this signature was very large and that the known mineralization was situated on the very edge of this anomaly. During the 2001 field season Shawn set out to test his theory with reconnaissance magnetic and soil surveys. Continued exploration during 2002 included test-pitting on some of the better geochemical anomalies, claim staking and expanded soil surveys. The property was optioned to Copper Ridge Explorations Inc. in June of 2002 and further staking and soil sampling ensued. The expanded property now covers much of the 6-km-wide and 16-km-long copper-in-soils anomaly that has been identified. A

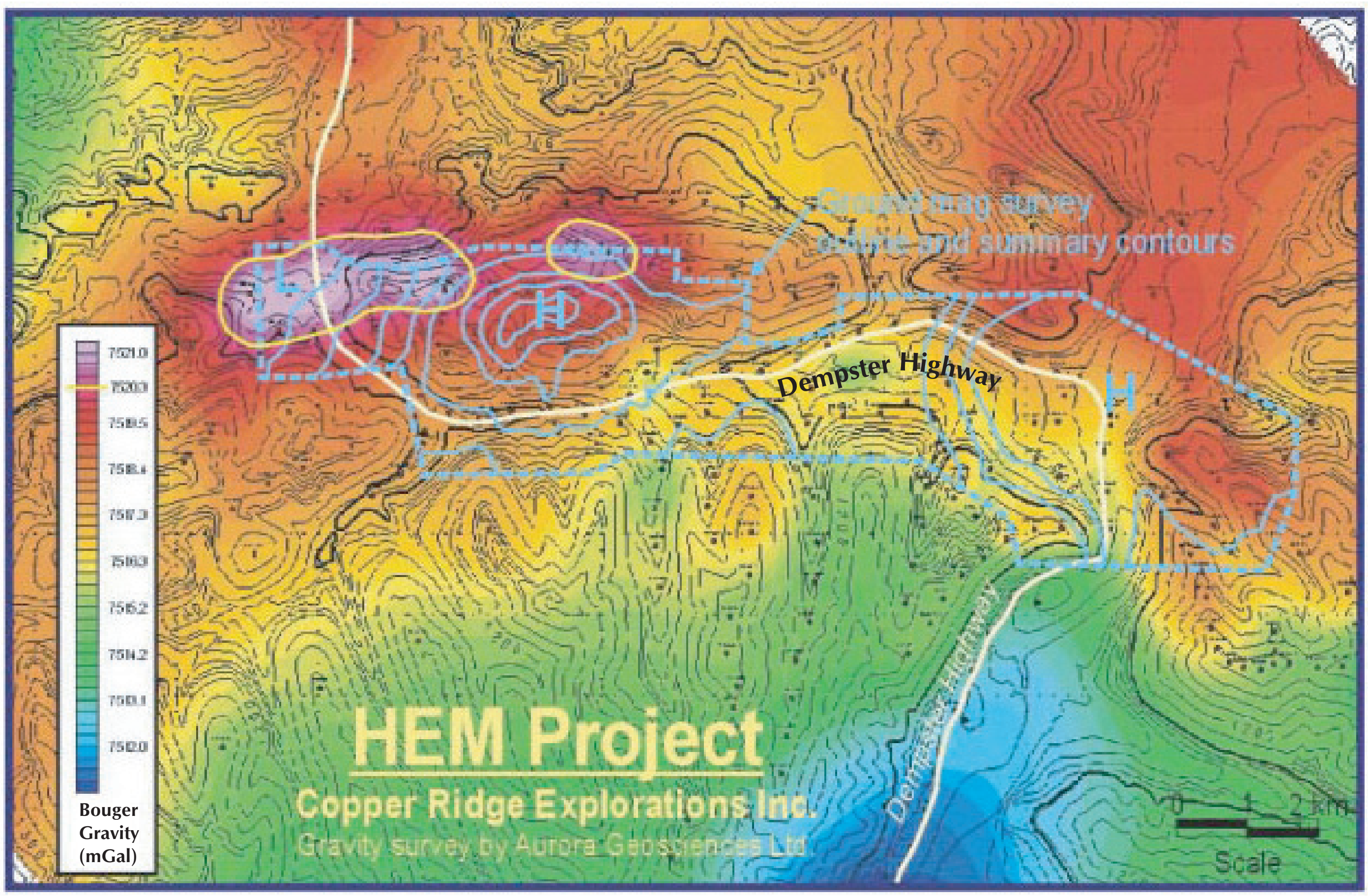

Figure 6. The large gravity anomaly found on the Yukon Olympic property is thought to comprise three discrete bodies, each with a density of 4. Modeling suggests that the two masses closest to the highway measure roughly 1 billion tonnes each; the eastern body is thought to be in the 5 to 6 billion tonne range, but situated slightly deeper. Geophysical plot by Aurora Geosciences Ltd. and taken from Copper Ridge's website at www.copper-ridge.com.

Figure 7. *Shawn Ryan is seen here in a pit located on the Ryan Creek anomaly where C horizon soils returned values of up to 1.19% Cu.*

Figure 8. *Folded iron formation located on Shawn Ryan's Simba claims, located at the headwaters of Shell Creek, approximately 70 km northwest of Dawson City.*

total of 1430 soil samples were collected from approximately 70 km of line and resulted in the discovery of two anomalous areas. The Bear Cub anomaly is 1750 m long, up to 1500 m wide and open in two directions. The core of the anomaly, 1500 m by 1000 m, averages greater than 225 ppm Cu and 10 ppm Mo, with many values in the 1000 to 4300 ppm Cu range. The Ryan Creek anomaly has a strike length of 3500 m, and an average width of 500 m using a threshold value of 60 ppm Cu, and is also open in two directions. Pits dug to date on the Ryan Creek grid revealed mineralization assaying up to 1.19% Cu in C-horizon soils (Fig. 7).

SHELL CREEK PROPERTY (TARGET EVALUATION/ FOCUSED REGIONAL MODULES)

The Simba claims were staked to cover the nose of a large banded iron formation unit situated just north of the Yukon River on Shell Creek, approximately 70 km northwest of Dawson City. The claims also cover a very small part of coincident regional-scale magnetic and gravity anomalies. Shawn Ryan conducted prospecting, and geophysical and geochemical surveys on the property this season looking for an Algoma-style banded iron formation gold target (Fig. 8). While prospecting an area to the northwest of the claims, a very large quartz-carbonate vein was found that parallels iron formation within what is believed to be Cambrian to Silurian Marmot Formation volcanic rocks. This vein was found to contain coarse visible gold for a strike length of over 2 km (Fig. 9). A number of copper showings have been found on the property, some of which are associated with visible gold.

CANYON GOLD GREW CREEK PROJECT (TARGET EVALUATION MODULE)

Al Carlos continued to explore his Canyon claims near the Eocene-aged Grew Creek deposit (geological resource of 773 012 tonnes grading 8.9 g/t Au and 33 g/t Ag). In 2000, Mr. Carlos conducted a 558-sample Enzyme Leach survey over the till-covered area approximately 1 km east of the deposit and over his Dozer claims to the west. Interpretation of the data was completed by Gregory T. Hill of Enzyme Laboratories, Inc. in Reno, Nevada. The Grew Creek survey revealed five anomalies. Anomalies A-D are oxidation anomalies aligned along what is thought to be a mineralized structure (Fig. 10). "Oxidation anomaly patterns tend to be characterized by oxidation halos where reduced material in the subsurface is undergoing very subtle oxidation. These halos flank the

Figure 9. *Visible gold is found in large quartz-carbonate veins at Shell Creek. This flake of gold measures almost 1 mm in length. Photo by Mike Burke.*

reduced body, and a "central low" is found over a "reduced chimney" located between the reduced body and the surface. The elements in these halos characteristically include at least part of the oxidation suite: Cl, Br, I, Mo, As, Sb, W, Re, V, Se, Te, U, Th" (G.T. Hill, pers. comm., 2000). Anomaly B is unique in that bismuth was detected in the oxidation halo suggesting a buried intrusion or rhyolite flow dome complex. Anomaly E is a combination anomaly with a high-contrast apical anomaly surrounded by a well developed nested halo set (Fig. 11). "Apical anomaly patterns tend to form highs directly over the source of the anomaly rather than forming a halo around the source. The source of the anomaly can be a mineral body or it can be a fault, unconformity or other feature that facilitates the movement of the trace elements to the surface. Combination anomalies contain an apical anomaly at the center which is surrounded by a halo or set of nested halos" (G.T. Hill, pers. comm., 2000). Anomaly E shares nearly the same geochemical signature as a nearby mineralized outcropping of conglomerate. Results from a 2001 drilling program on anomaly E – 191 m in four holes – were inconclusive, so Mr. Carlos completed a further 415 m in six holes this past season to further test this target. Hydrothermal breccias were intersected in a number of the holes and results are pending. Anomalies A-D and the classic oxidation anomaly located on the Dozer claims (Fig. 12) remain untested and are excellent drill targets.

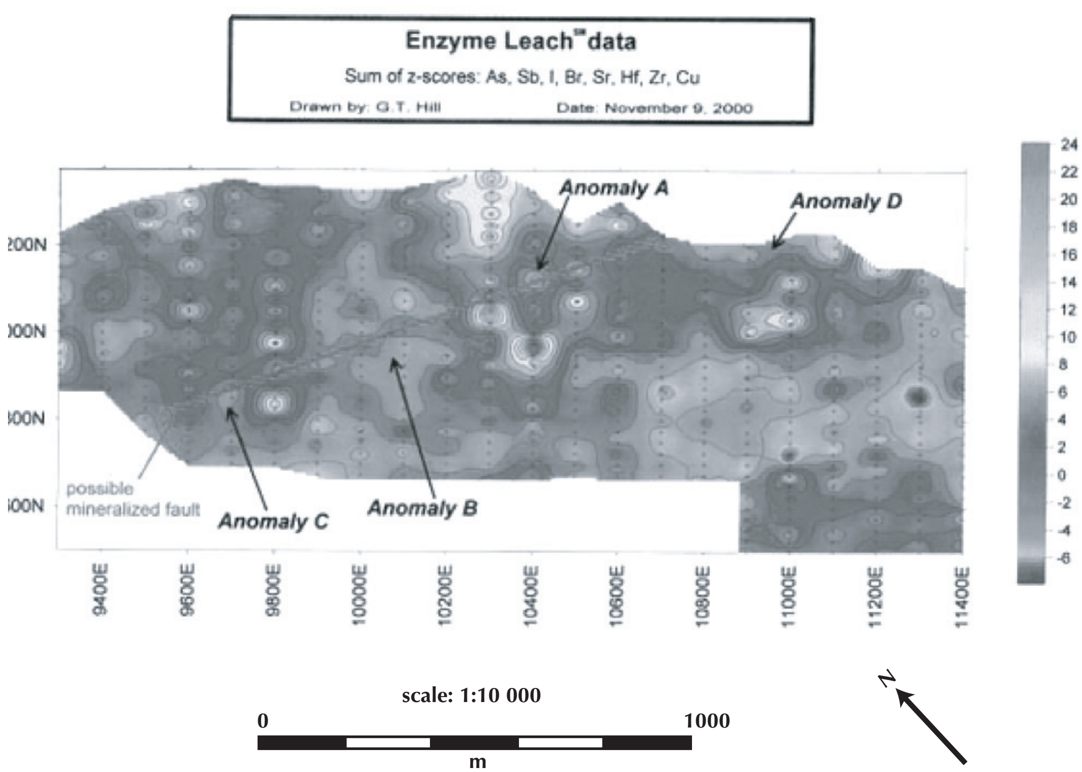

Figure 10. *Oxidation anomalies A-D aligned on a possible mineralized fault on the Canyon claims of Al Carlos. Geochemical plot by Enzyme Laboratories Ltd.*

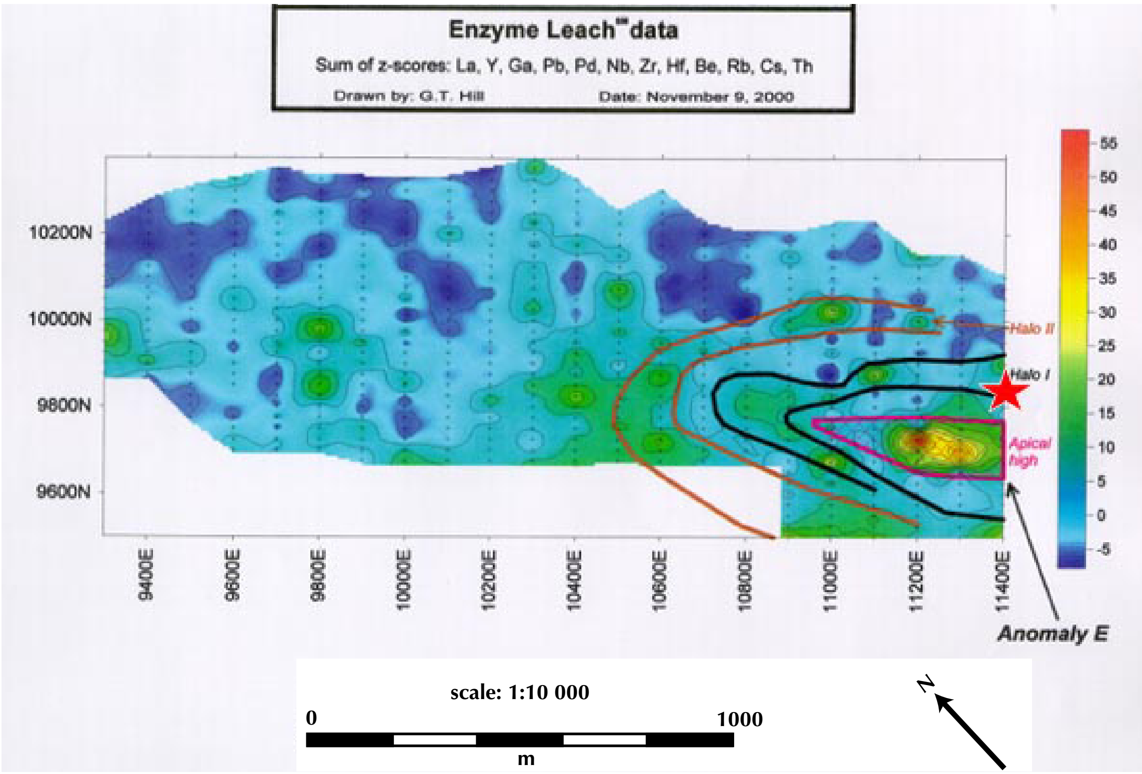

Figure 11. Apical anomaly E on the Canyon claims is shown in relation to the location of a mineralized outcrop of conglomerate. The outcrop assayed up to 2200 ppb Au in grab samples. Geochemical plot by Enzyme Laboratories Ltd.

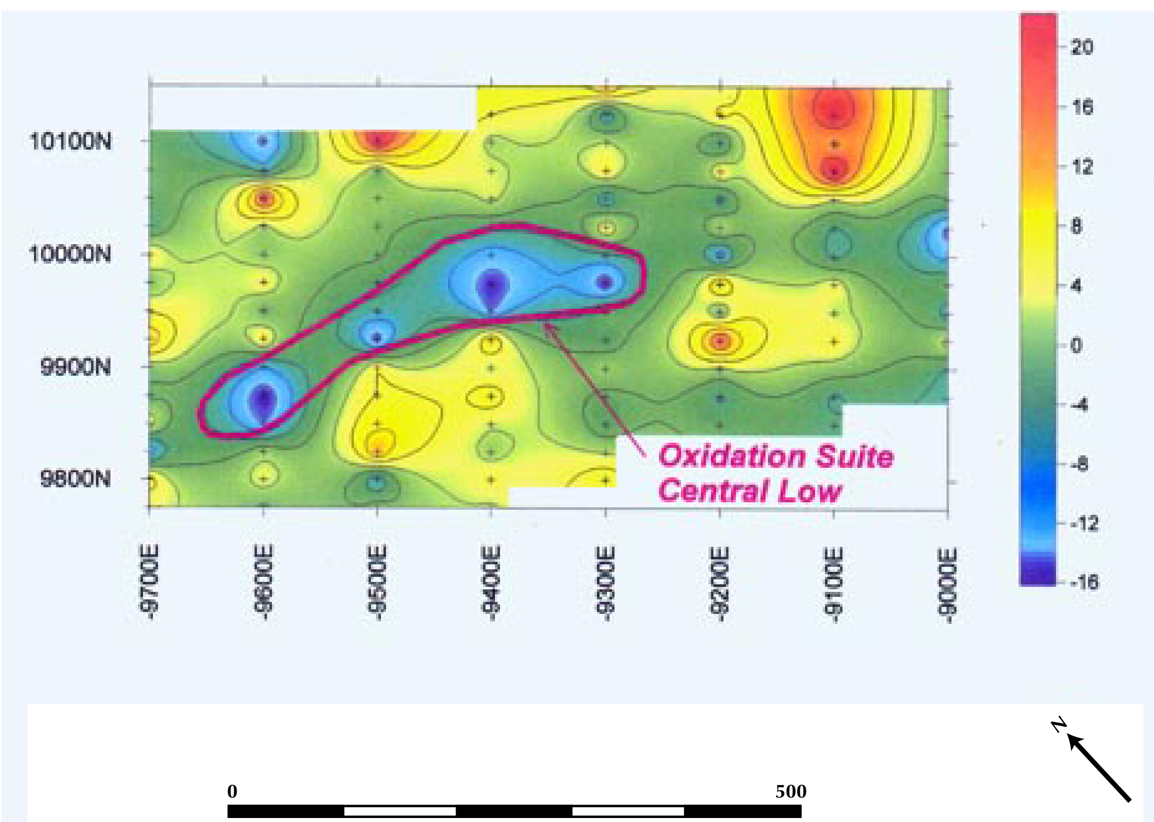

Figure 12. Data from the Dozer claims suggest that the most intense alteration and potential mineralization coincides with an inflection in the northwest-trending structure. Geochemical plot by Enzyme Laboratories Ltd.

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GOVERNMENT

Yukon Geology Program

Grant Abbott and staff
Yukon Geology Program

Le Service de géologie du Yukon

Maurice Colpron et Grant Abbott
Le Service de géologie du Yukon

Robert E. Leckie Awards for Outstanding Reclamation Practices

Andy Crowther
Mining Lands Division, DIAND

Yukon Geology Program

Grant Abbott[1] and staff
Yukon Geology Program

Abbott, J.G., 2003. Yukon Geology Program. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 41-54.

OVERVIEW

Ten years ago, the Canada-Yukon Geoscience Office opened its doors and marked the beginning of a *de facto* Yukon Geological Survey. Seven years ago, when the Canada-Yukon Mineral Development Agreements ended, the name changed to the Yukon Geology Program (YGP). The YGP (Fig. 1) includes two integrated and jointly managed offices with different administrative structures (Fig. 2). Federal funding is provided through the Exploration and Geological Services Division (EGSD), Yukon Region of the Department of Indian Affairs and Northern Development (DIAND), while Yukon Territorial Government (YTG) and cost-shared (YTG/DIAND) funding comes through the Mineral Planning and Development Branch of the Department of Energy, Mines and Resources (YTG). YTG independently manages and funds the Mineral Assessment Group and the Yukon Mining Incentives Program (YMIP). These are described separately. The Geological Survey of Canada (GSC) also maintains an office with the Program.

The past year has been a time of transition. In preparation for devolution of responsibility for administration of Yukon's land and resources from the Department of Indian Affairs and Northern Development, the Government of Yukon embarked upon a Renewal Process that examined how the government was organized and served the public. Out of that process, the Department of Energy,

Figure 1. *Yukon Geology Program staff from left to right: Jesse Duke, Don Murphy, Rod Hill, Grant Abbott, Jeff Bond, Bill LeBarge, Lee Pigage, Roger Hulstein, Ali Wagner, Karen Pelletier, Lara Lewis, Ken Galambos, Mike Burke, Amy Stuart, Maurice Colpron, Craig Hart, Derek Thorkelson, Jo-Anne vanRanden, Robert Deklerk, Julie Hunt, Charlie Roots, Diane Emond, Panya Lipovsky, Monique Raitchey, Grant Lowey and Steve Traynor. Missing: Robert Stroshein.*

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Mines and Resources was formed to assume responsibility for minerals, oil and gas, forestry, agriculture and lands. On April 1, 2003 the Geology Program will finally become one organization within the Mineral Development Branch (Fig. 2) of the Oil, Gas and Mineral Resources Division. The Geology Program will continue to be co-managed by Grant Abbott and Rod Hill. Jesse Duke will assume responsibility for the Geology Program as Director of the branch.

The Program has been fortunate to have had little staff turnover over the past year. We were sad to see Anna Fonseca leave the Mineral Assessment Group for the private sector, and Gary Stronghill leave the GIS Group for Ontario. Both positions have yet to be filled full-time.

This year being the tenth anniversary, staff have embarked on a number of commemorative activities. Local artist Chris Caldwell was commissioned to paint the poster shown on the cover. An open house was held for schools and the public to raise knowledge of the Program, Yukon geology and the mineral industry. Accomplishments of the Program were presented in a talk by Grant Abbott at the Geoscience Forum. Highlights include a quantum leap in the quality and quantity of the Yukon Geoscience database; significant measurable stimulation of mineral exploration; identification of significant, but under-explored mineral potential; and better information management. Some examples include doubling of detailed bedrock mapping coverage; generation of at least $50 million in exploration spending on YGP-defined

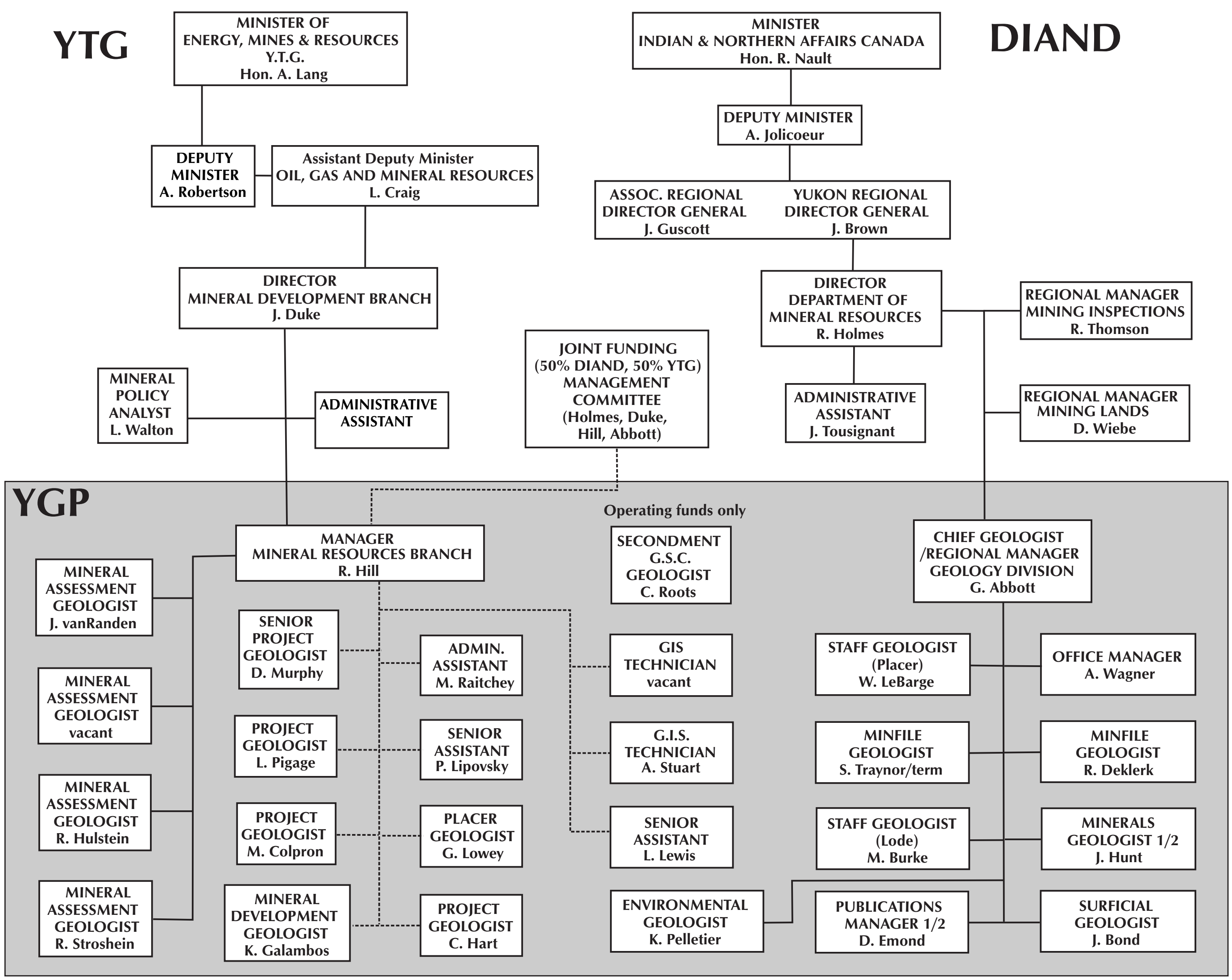

Figure 2. *Yukon Mineral Resources organization chart.*

geochemical, geophysical and geological targets; identification of untested geological, geochemical and geophysical targets in several parts of the Yukon-Tanana Terrane; and development of key databases and Internet distribution of all YGP Geoscience publications and data.

PROGRAM HIGHLIGHTS FOR 2002

FIELDWORK

The Yukon Geology Program is committed to providing a balanced complement of field projects, which not only quickly stimulate the mining and exploration industry, but also take the longer term view towards developing an understanding of the Yukon regional geological framework, and building the Yukon geoscience database. Field projects carried out in 2002 are shown in Figure 3, and the present state and location of geological, geochemical and geophysical surveys are shown in Figure 4.

The Yukon Geology Program continued to commit substantial resources to a joint Geological Survey of Canada-British Columbia Geological Survey Branch–Yukon Geology Program initiative, the Ancient Pacific Margin NATMAP (National Mapping Program) Project. This project is a multidisciplinary effort to better understand Yukon-Tanana and Kootenay terranes, arguably the least understood parts of the North American Cordillera. In Yukon, mapping projects include Finlayson Lake map area (Don Murphy), Glenlyon (Maurice Colpron), Stewart River (Steve Gordey, Jim Ryan/ GSC), and Wolf Lake (Charlie Roots/GSC). In southern B.C., the Project also includes regional mapping by Bob Thompson of the GSC, and in east-central Alaska, mapping by David Szumigala of the Alaska State Geological Survey, and mineral deposit studies by Cynthia Dusel-Bacon of the U.S. Geological Survey. Participation by numerous university researchers, graduate students and other specialists has greatly added to the depth and complexity of the Project. In Yukon, these include lithogeochemical studies in the Stewart River area by Steve Piercey of Laurentian University and mineral deposit studies by Jan Peter of the GSC. Regular workshops and field trips are one of the main benefits of such a large and diverse project. In November, 2002, the last NATMAP workshop was held in Sidney, B.C. and the project has now entered its synthesis phase, which is expected to be completed in 2004.

In 2002, the Yukon portion of the project has once again received a substantial boost from funds obtained through Natural Resources Canada's

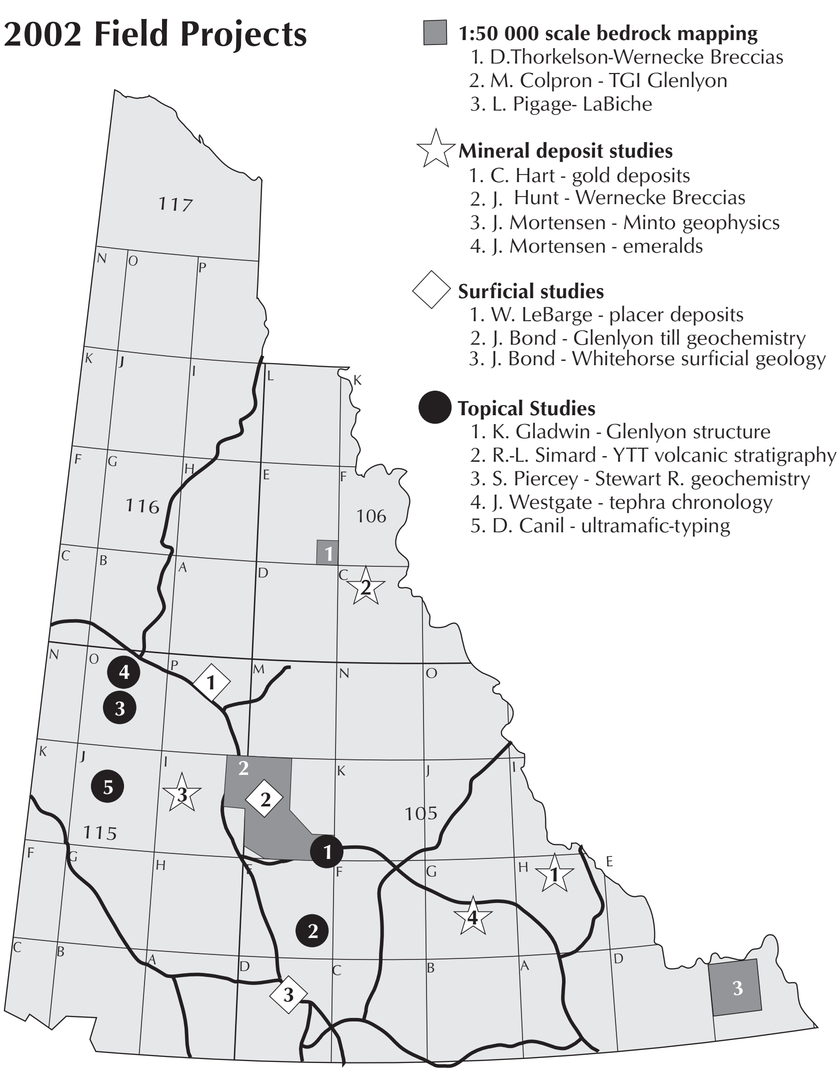

Figure 3. Field projects carried out or sponsored by the Yukon Geology Program in 2002.

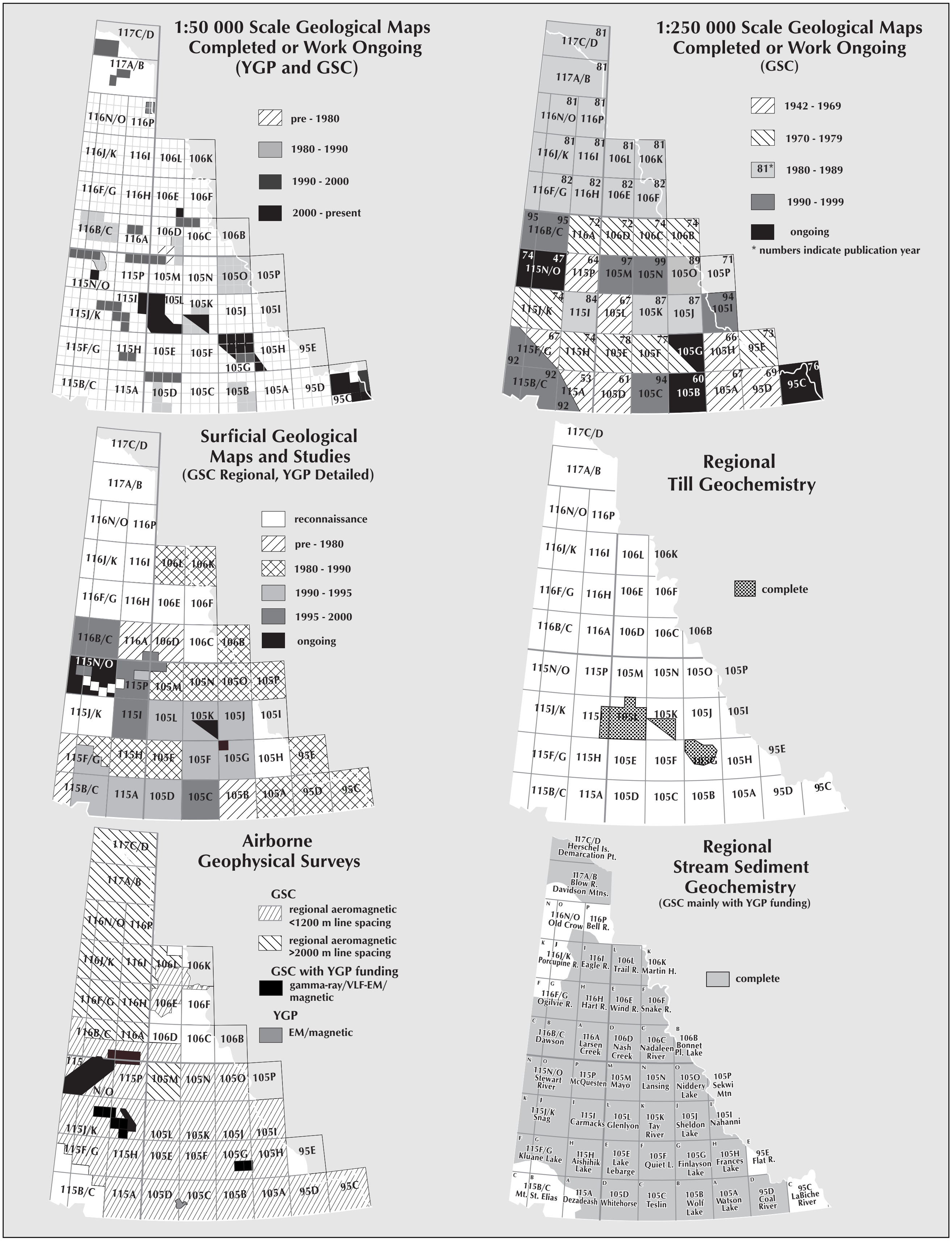

Figure 4. *Summary of available geological maps, and regional geochemical and geophysical surveys in the Yukon.*

Targeted Geoscience Initiative. In the Glenlyon map area, the extra funding enabled a program of accelerated regional bedrock mapping and till geochemistry. By using a contract helicopter for five weeks, five expert NATMAP participants (M. Colpron, D. Murphy, S. Gordey, J. Nelson and C. Roots) were able to map over half of the map sheet at 1:125 000 scale. As well, J. Bond, A. Plouffe and two assistants successfully carried out a regional till geochemical sampling program across the extensive overburden-covered parts of the area. Promising geological and geochemical targets were defined as a result.

Elsewhere, Don Murphy and Charlie Roots began the final compilation map and bulletin of Finlayson Lake and Wolf Lake – Jennings River map areas, respectively. In the Stewart River area, work included GSC bedrock mapping by Gordey and Ryan, and surficial mapping by Lionel Jackson for the GSC. Grant Lowey began the final compilation map and bulletin of his placer deposit studies.

Fieldwork was completed this year on the Central Forelands NATMAP Project, in which the Yukon Geology Program is a partner with GSC Calgary staff and university researchers. The Central Forelands Project is primarily focused on hydrocarbon-related geoscience, and includes regional mapping and topical studies in two separate areas: Trutch (94G) and Toad River (94N) in northern British Columbia, and Fort Liard (95B) and La Biche (95C) in Yukon and Northwest Territories. Tammy Allen and Lee Pigage joined the project in La Biche map area in southeast Yukon. The project has more clearly defined the geologic framework of the area with the highest hydrocarbon potential in all of Yukon. Mapping in the eastern part of the La Biche area has resulted in new structural interpretations that are key to hydrocarbon exploration. Work by Lee and Tammy in the western part of the map area has resulted in significant reinterpretation of both structure and stratigraphy.

Another major effort by the Yukon Geology Program has been to synthesize and enhance the geological database of the Anvil district. The Faro mine remains closed for the foreseeable future, but the possibility remains for renewed exploration and mining at some point. Lee Pigage has completed bedrock mapping, and has released a complete set of 11 geological maps of the district at 1:25 000 scale, and a compilation at 1:100 000 scale. A final report (bulletin) will be released in the spring of 2003. Jeff Bond completed surficial mapping and a till geochemical survey, and released 11 final maps and a bulletin in the spring of 2001.

Derek Thorkelson joined the YGP for six months while on sabbatical from Simon Fraser University. He has completed a 1:50 000-scale map sheet in the Wind River area (106E/1) of the Wernecke Mountains. The map area is an extension of Derek's previous project and includes extensive areas of Wernecke Breccia and many of the best-known Cu-U-Au occurrences associated with those rocks.

Craig Hart has completed a year's leave to undertake a PhD program at the University of Western Australia. Most of the requirements for the degree will entail writing papers on his previous field studies of the Tintina Gold Belt and other Yukon gold occurrences. Many of the students who received support from the YGP and assistance from Craig to study various aspects of Yukon gold deposits finished their studies this year. These included Mark Lindsay and Julian Stephens, under the supervision of Tim Baker at James Cook University; John Mair at University of Western Australia; and Erin Marsh and Seth Mueller under the supervision of Rich Goldfarb at the U.S. Geological Survey. This year, Craig carried out a preliminary investigation of intrusive-related mineral occurrences in northern Frances Lake map area with Lara Lewis.

Bill LeBarge and Mark Nowasad completed their studies of the relationship between sedimentology, grain size distribution and water quality of effluent from placer deposits. The technique will be evaluated for possible long-term applications and further research. Data gathered from this study was useful in the review of the Yukon Placer Authorization

Julie Hunt has returned to Australia to undertake a PhD program at James Cook University. YGP is funding her fieldwork. Julie partnered with Derek Thorkelson to complete fieldwork on the Wernecke Breccias, and is taking advantage of the Australian connection by comparing the Yukon breccias with similar Australian rocks that host giant ore deposits.

EXTERNAL SUPPORT

The YGP is providing financial and logistical support, or is a partner with graduate students and university researchers in the following projects:

John Laughton is completing an MSc thesis on the Slab volcanics in the Wernecke Breccias under the supervision of Derek Thorkelson at Simon Fraser University.

Kaesy Gladwin completed mapping and structural studies to characterize the boundary between the Yukon-Tanana and Cassiar terranes in southeast Glenlyon map area. This is an MSc project under the direction of Stephen Johnston at the University of Victoria.

Reza Tafti has begun a study of the Minto copper deposit for his MSc at the University of British Columbia under the supervision of Jim Mortensen. Through the project we will attempt to gain a better understanding of the nature, age and origin of the main host rocks to the Minto deposit and the Cu-Au mineralization contained within them. This information will be used as a basis for developing an exploration model for similar mineralization elsewhere in the Minto-Williams Creek belt.

Heather Douglas has begun a study of emerald and beryl occurrences in the Yukon and Northwest Territories for her MSc at the University of British Columbia under the supervision of Jim Mortensen and Lee Groat. The main focus of the study will be the Regal Ridge emerald deposit in the Finlayson Lake District. The purpose of the project is to understand the origin of the emerald occurrences and to develop exploration guidelines for the northern Canadian Cordillera.

Renée-Luce Simard is continuing a study of the volcanic stratigraphy, composition and tectonic evolution of Late Paleozoic successions in central Yukon for her PhD thesis at Dalhousie University under the direction of Dr. J. Dostal. The project will compare and contrast the depositional style, composition and tectonic setting of several volcanic successions within the belt of pericratonic terranes in the Northern Cordillera. These include the Klinkit succession in Wolf Lake map area, the Little Salmon succession in Glenlyon map area and the Boswell and Semenof formations in central Laberge map area.

Steve Piercey at Laurentian University, as part of the Ancient Pacific Margin NATMAP Project, began a study of the field, geochemical and isotopic attributes of volcanic and intrusive rocks in the Stewart River map area. The study will, in part, determine the similarities and differences of these rocks to volcanogenic massive sulphide (VMS)–bearing rocks in the Finlayson Lake district.

Dr. Dante Canil at the University of Victoria continued a study of the origin and emplacement of large ultramafic rock bodies in southwest Yukon, their potential for gold, nickel or platinum group element (PGE) mineralization, and their significance in Cordilleran tectonic evolution. This year, studies focussed on ultramafic rocks belonging to the Windy-McKinley Terrane in Snag map area of west-central Yukon.

John Westgate at the University of Toronto continued his studies of late Cenozoic tephrochronology of eastern Beringia. The objectives of this program are to establish a comprehensive tephrochonological framework to support studies in Quaternary geology, paleoenvironments and related fields. This year's studies focused on extension of the late Cenozoic tephra record of the Klondike Goldfields; determination of a precise and reliable glass fission track, magnetostratigraphic and Ar^{40}/Ar^{39} record for the widespread Dawson tephra bed; and establishment of the tephrochronological record preserved at Thistle Creek.

In addition to providing geochronological support to the GSC's Steward River project, Mike Villenueve has been using argon geochronology to 1) determine the cooling and uplift history of the Klondike region to aid in understanding mineralizing and tectonic processes in that region; 2) define the timing of recent volcanism in the Yukon, particularly the Fort Selkirk region; and 3) provide timing constraints on intrusion-related gold mineralization in the Tintina Gold Belt.

LIAISON AND SUPPORT TO INDUSTRY, FIRST NATIONS AND THE PUBLIC

Mike Burke and Bill LeBarge, our main links to the exploration industry, continued to monitor Yukon hard-rock and placer mining and mineral exploration activity, visit active properties, review reports for assessment credit, and maintain the assessment report library.

This year the YGP has focused more attention on increasing awareness among the public, schools and First Nations of geology and its importance to the mining industry, land use planning and environmental management. Karen Pelletier and Charlie Roots led the effort. The Geological Survey of Canada, with support from YGP, released its Geoscape Whitehorse Poster. The poster is one of a series that highlights geological features of interest in and around Canadian urban centres. The posters emphasize the impact of geology on everyday life. As a spin off to this project, a summer student gave presentations and led field trips through the Beringia Centre for school classes and the public. Karen Pelletier continued this initiative in the schools this fall. As part of the YGP 10th anniversary celebrations, an open house was held to again highlight Yukon geology and the activities of the YGP. Karen also organized field trips with

First Nations groups to visit the Brewery Creek mine site and other exploration properties to examine modern reclamation practices.

ENVIRONMENTAL STUDIES

Karen Pelletier continued to manage the Mining and Environmental Research Group (MERG) in partnership with Lori Walton at YTG. Projects funded this year included 1) Evaluation of In-pit Algal Detoxification of Metal-Contaminated Pit Lakes by Laberge Environmental Services & Microbial Technologies Inc.; 2) Mine Sludge Stability and Densification in Cold Climates by CANMET; 3) Examination of Revegetation Methodologies for Dry Stack Tailings in Northern Environments by Access Mining Consultants Ltd.; and, 4) Follow-up Monitoring: Shrub Trial Plots at Brewery Creek Mine and Bioengineering Trials at Noname Creek by Stu Withers. Other activities included review of Mining Land Use and water license applications, and monitoring of reclaimed sites to document the effectiveness of mitigation practices. Karen also represents YGP on several committees that sponsor environmental research involving geology.

INFORMATION MANAGEMENT AND DISTRIBUTION

With the increasing volume of information generated by YGP and others, and rapidly evolving digital technology, YGP has placed more effort and resources into making geological information more accessible. A large part of our effort has gone into developing and maintaining key databases. The other part of the effort has gone into making all of our information internet-accessible. Ongoing activities include support for the H.S. Bostock Core Library and the Elijah Smith Library.

Databases

Yukon MINFILE, the Yukon's mineral occurrence database, is maintained by Robert Deklerk. A new Microsoft Access 2000 version was released in November, 2002. The database now contains 2593 records, of which 500 have been revised, and is complete to the end of 2000. The database has been simplified and is easier to use. Modifications allow better data table interaction, faster searching and editing speeds, improved data table and editing features, and easier export of data to a GIS system. It is expected that the database will become current over the next year.

The Yukon Placer Database, compiled under the direction of Bill LeBarge, was released in the fall of 2002. The database is in Microsoft Access 2000 format and is a comprehensive record of the geology and history of Yukon placer mining. The database contains descriptions of 440 streams and rivers, and 1356 associated placer occurrences. It also includes location maps in Portable Document Format (PDF).

The Yukon GEOPROCESS File, under the direction of Diane Emond, is an inventory of information on geological process and terrain hazards, including 1:250 000-scale maps showing permafrost, landslides, recent volcanic rocks, structural geology, and seismic events. It also includes references and summaries of bedrock and surficial geology. The GEOPROCESS File is intended as a planning aid for development activities and is available for most areas south of 66° latitude. The maps are now standardized in colour, and available on a single compact disk. Maps with text are in AutoCAD 2000 format and as PDF.

Steve Gordey and Andrew Makepeace of the Geological Survey of Canada undertook the Yukon Digital Geology Project with funding from YGP. It included syntheses of bedrock geology and glacial limits, compilations of geochronology, paleontology, and mineral occurrences, and a compendium of aeromagnetic images. All are now available on CD-ROM. Bedrock geology and glacial limit paper maps are also available at 1:1 000 000 scale. An updated version is scheduled for release in early 2003.

The Yukon Regional Geochemical Database analysis was compiled this year by Daniele Héon and released in November. The database contains all of the available digital data for regional stream sediment surveys that have been gathered in the Yukon under the Geological Survey of Canada's National Geochemical Reconnaissance Program. It is available on CD-ROM in Microsoft Excel 2000 format (.xls) and in ESRI ArcView Shapefile format (.shp).

The YukonAge 2002 Database was compiled this year by Katrin Breitsprecher and Jim Mortensen at the University of British Columbia, and Mike Villeneuve with the Geological Survey of Canada with funding from YGP. The database contains over 1500 age determinations derived from over 1100 rock samples from the Yukon Territory and is available in both Microsoft Access 2000 format and as a flat file in Microsoft Excel 2000 format so that the data may be viewed without Microsoft Access.

H. S. Bostock Core Library

Mike Burke and Ken Galambos maintain the H.S. Bostock Core Library. The facility contains about 128 000 m of diamond drill core from about 200 Yukon mineral occurrences. Confidentiality of material is determined on the same basis as mineral assessment reports. Confidential core can be viewed with a letter of release from the owner. Rock saws and other rock preparation equipment are available to the public.

Elijah Smith Library

The library in the Elijah Smith Building is an invaluable resource that is available to the public, but often overlooked. The library also houses Yukon assessment reports and contains most geological journals and a good selection of references on general geology, Yukon geology, and economic geology. YGP has begun the process of converting all of the assessment reports into PDF Format. Conversion may be complete in 2003.

Information distribution

The Yukon Geology Program is now converted fully to digital publishing and has developed a threefold strategy for distribution of information. We sell and distribute paper maps and reports through our Geoscience Information and Sales Office. In addition, many of our recent publications and databases are available in digital formats at considerably lower prices than our paper copies. Our main effort over the last year has been to make all of our publications available through our website (www.geology.gov.yk.ca), free of charge. A directory of assessment reports is also available online. We are also pleased to make spatial data available through our interactive map server; the Map Gallery can be accessed through the YGP website. It currently allows viewing of regional geology, MINFILE locations, regional stream geochemistry, topography, roads and communities, and First Nations Land selections. Vector data can now be clipped and downloaded. Planned enhancements include addition of geophysics, geochronology and paleontology, and addition of more attribute data to existing coverages. Coverages from other agencies such as mineral claims will soon be available. Users are encouraged to provide feedback and suggest improvements.

Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada publishes Yukon Geology Program publications. Hard copies are available at the following address:

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EGSD Open File 2002-11/GSC Open File 4305: parts of 115N/9, 1:50 000 scale.

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EGSD Open File 2002-16/GSC Open File 4310: 115O&N and 116B, 1:250 000 scale.

EGSD Open File 2002-17D /GSC Open File 4311: Digital files of maps in pdf format on one.

CD-ROM including Phases 1 and 2, by R.B.K. Shives, J.M. Carson, K.L. Ford, P.B. Holman, J.A. Grant, S. Gordey, G. Abbott.

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EGSD Open File 2002-18/GSC Open File 4331: parts of 115I/10,11.

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Le Service de géologie du Yukon

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APERÇU

Il y a dix ans, le Bureau géoscientifique Canada-Yukon a ouvert ses portes, marquant en fait le début de la commission géologique du Yukon. Il y a sept ans, quand l'accord de développement minéral Canada-Yukon s'est terminé, le nom du bureau a changé pour celui de Service de géologie du Yukon (SGY). Le SGY (fig. 1) consiste en deux bureaux intégrés présentant des structures administratives différentes mais qui sont gérés conjointement (fig. 2). Le financement par le gouvernement fédéral est fourni par l'entremise de la Division des Services d'exploration et de géologie de la région du Yukon du ministère des Affaires indiennes et du Nord canadien (MAIN), alors que le financement par le gouvernement du territoire du Yukon (GTY) et à coûts partagés (GTY/MAIN) est obtenu par l'entremise de la Direction du développement minéral du ministère de l'Énergie, des mines et des ressources (GTY). Le GTY gère et finance indépendemment le Groupe d'évaluation du potentiel minéral et le Programme d'encouragement pour l'exploration minérale du Yukon; ce dernier est décrit brièvement ci-dessous. La Commission géologique du Canada (CGC) maintient également un bureau auprès du Service.

L'année qui se termine fut un temps de transition. En préparation pour le transfert entre le MAIN et le GTY des responsabilités d'administration des terres et des réssources, le GTY s'est engagé dans un processus de rénouvellement, qui portait sur l'évaluation de l'organisation du gouvernement et sur sa façon de servir le publique. C'est à la suite de ce processus que le nouveau ministère de l'Énérgie, des mines et des ressources (GTY) a été introduit. Sa fonction sera d'assumer la responsabilité pour les minéraux, le pétrole et le gaz, les forêts, l'agriculture et les terres. Au premier avril 2003, le Service de géologie deviendra finalement une seule organisation au sein de la Direction du développement minéral (fig. 2) de la Division des ressources pétrolières, gazières, et minérales. Le Service de géologie va continuer d'être géré conjointement par Grant Abbott et Rod Hill. Jesse Duke assumera la responsabilité pour le Service de géologie en tant que directeur de la Direction du développement minéral.

Au cours de 2002, le programme a eu la chance d'avoir une base d'employés stable, sauf qu'on a été triste de voir partir Anna Fonseca et Gary Stronghill.

Cette année étant le dixième anniversaire du Service de géologie du Yukon, les employés ont entrepris plusieures activités commemoratives. L'artiste locale Chris Caldwell a été commissionée pour peindre l'affiche qui apparait sur la couverture de ce volume. Nous avons aussi ouvert nos portes aux écoles et au publique afin d'augmenter la connaissance du publique de notre service, de la géologie du Yukon, et de l'industrie minière. Lors du Colloque géoscientifique annuel, Grant Abbott a présenté un exposé soulignant les accomplissements du Service au cours de sa première décennie. Il a entre autre mentionné l'amélioration de la qualité et de la quantité d'information géoscientifique maintenant disponible sur le Yukon; les effets positifs que le Service a apporté sur

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l'industrie d'exploration minérale; l'identification du potentiel minéral important, mais sous-exploré, du territoire; et une meilleure gérance de l'information géoscientifique. Les activités du Service de géologie ont entre autre contribuées à doubler la couverture de cartographie géologique de détail du territoire; ont genérées au moins $50 million en dépenses d'exploration sur des cibles identifiées à l'aide de nouvelles données géologiques, géochimiques et géophysiques produitent par le SGY; ont identifiées plusieurs nouvelles cibles géologiques, géochimiques et géophysiques qui doivent toujours être vérifiées dans le Terrane de Yukon-Tanana; et ont développées plusieurs nouvelles bases des données. De plus le Service de géologie distribue maintenant la plupart des ses publications et bases de données par l'entremise de l'internet.

Les travaux de terrain du Service de géologie du Yukon n'ont pas seulement pour objet de stimuler de façon immédiate l'industrie minière, mais aussi de développer une meilleure connaissance de la géologie régionale du Yukon et d'augmenter la base de données géoscientifiques pour les générations à venir. Les travaux de terrain executés au cours de l'année 2002 sont indiqués sur la figure 3 et l'état actuel des couvertures géologiques, géochimiques et géophysiques du territoire est illustré sur la figure 4.

Le Service de géologie du Yukon contribue toujours d'importantes ressources au projet CARTNAT (Programme national de cartographie géoscientifique du Canada) de l'ancienne marge du Pacifique, une initiative conjointe des commissions géologiques du Canada, de la Colombie-Britannique et du Service de géologie du Yukon. Ce projet est une étude multidisciplinaire visant à mieux comprendre les terranes de Yukon-Tanana et de Kootenay, soit les parties considérées comme les moins bien connues de la cordillère nord-américaine. Au Yukon, des travaux de cartographie géologique ont été exécutés dans les régions de Finlayson Lake, de Glenlyon, de Stewart River, et de Wolf Lake. Ce projet inclut aussi des travaux de cartographie géologique dans le sud de la Colombie-Britannique et dans le centre-est de l'Alaska, de même que des études de gîtes minéraux en Alaska. La participation de nombreux chercheurs universitaires, d'étudiants de deuxième et de troisième cycle, et d'autres spécialistes ont grandement contribué à la valeur scientifique du projet. En outre, en 2002 on a entamé une étude lithogéochimique dans la région de Stewart River et l'on poursuit des études de gîtes minéraux à plusieurs endroits au sein du terrane de Yukon-Tanana.

En 2002, la partie yukonnaise du projet CARTNAT a une fois de plus reçu du financement additionnel par l'entremise de l'Initiative géoscientifique ciblée du ministère de ressources naturelles du Canada. Ces fonds additionnels ont permis de compléter un levé géochimique du till et la cartographie géologique de plus de la moitié de la carte de Glenlyon. Des cibles géologiques et géochimiques d'interêt furent identifiées lors de ce programme.

Ailleurs, la cartographie géologique des régions de Finalyson Lake et de Wolf Lake est maintenant complétée et en est à la phase de compilation et de rédaction. Dans la région de Stewart River, outre les travaux de cartographie géologique, le programme de cartographie des dépôts superficiels par la CGC s'est complété en 2002 et l'étude des placers entreprise par le Service de géologie du Yukon est maintenant en phase de compilation et de redaction.

Les travaux de terrain du projet CARTNAT de l'avant-pays central, auquel le Service de géologie du Yukon participe, se sont aussi complétés au cours de l'année 2002. Ce projet, qui recouvre en partie le nord de la Colombie-Britannique, le sud-ouest des territoires du Nord-Ouest, et le sud-est du Yukon, a pour principal objectif d'augmenter les connaissances géoscientifiques des régions présentant un potentiel d'hydrocarbures. Les travaux de cartographie géologique menés par le Service de géologie du Yukon dans la région de La Biche River ont permis de reviser les interprétations stratigraphiques et structurales de cette région, qui contient le plus haut potentiel d'hydrocarbures au Yukon.

Au nombre des autres objectifs majeurs visés par le Service de géologie du Yukon, mentionnons celui consistant à synthétiser et à améliorer la base de données géologiques du district d'Anvil, initiative qui comprend la cartographie géologique du socle rocheux et des dépôts superficiels, et des levés géochimiques de till, en plus de l'étude des gîtes minéraux. Un rapport couvrant la cartographie des dépôts superficiels et la géochimie du till, de même qu'une carte de compilation géologique régionale à l'échelle de 1 : 100,000 sont maintenant disponibles. Le rapport géologique final devrait être disponible au printemps 2003.

Derek Thorkelson a joint le Service de géologie du Yukon pour une période de six mois lors de son congé sabbatique de l'université Simon Fraser. Il a complété une carte à l'échelle de 1 : 50,000 dans la région de Wind River, dans les monts Wernecke, où l'on retrouve de nombreux indices Cu-U-Au associés aux brèches de Wernecke. Les brèches de Wernecke continuent d'être l'objet d'une étude métallogénique, où les brèches yukonnaises seront comparées aux équivalent australiens qui renferment plusieurs gisements importants.

L'étude des indices aurifères du Yukon se poursuit. Une série d'articles portant sur la ceinture aurifère de Tintina et d'autres indices du Yukon est maintenant en préparation. De plus une étude préliminaire des indices minéraux associés aux intrusions dans la partie nord de la région de Frances Lake a été entamé au cours de 2002.

Un autre projet étudie la relation entre la sédimentologie, la répartition granulométrique et la qualité de l'eau des effluents provenant des gisements placériens. Les travaux de terrain sont maintenant complétés et la technique sera évaluée pour d'éventuelles applications à long termes.

Finallement, le Service de géologie du Yukon continue son assistance financière et logistique de nombreuses études thématiques conduites par des étudiants de deuxième et de troisième cycle, et par des chercheurs universitaires.

PROGRAMME D'ENCOURAGEMENT POUR L'EXPLOITATION MINÉRALE DU YUKON

Cette année, 99 demandes relatives au programme ont été reçues avant la date limite. Au total, 982 000 $ ont été accordés à 62 demandeurs. Neuf demandes ont été approuvées dans le cadre du volet 'Grassroots' et du volet 'Grubstake', 36 demandes ont obtenuent du financement dans le cadre du volet Évaluation de cibles, tandis que les 17 autres faisaient partie du nouveau volet de Cibles régionales. Un peu moins d'explorateurs commandités dans le cadre de ce programme ont recherché des métaux précieux : environ 41 % des candidats ont recherché de l'or et des éléments du groupe du platine, 45 % des métaux communs, et 14% des pierres précieuses et d'autres matières premières. Des programmes d'exploration ont été proposés dans les quatre districts miniers et presque partout sur le territoire du Yukon. Bien les dépenses totales d'exploration soient à la baisse par rapport à l'année précédente, le nombre de concessions minières qui ont fait l'objet d'options est à la hausse. Jusqu'à date, neuf ententes entre prospecteurs et entreprises minières ont été signées pour des concessions qui furent explorées dans le cadre de ce programme.

PRIX ROBERT E. LECKIE

Pour une quatrième année consécutive, on a décérné à l'industrie minière les prix Robert E. Leckie pour la restauration de sites miniers. Le prix pour les pratiques exceptionnelles de restauration de mines a été décerné à la société Viceroy Resource Corporation pour les travaux qu'elle a effectué sur la mine Brewery Creek. On a remis le prix pour les pratiques exceptionnelles de restauration de placers à David McBurney pour les travaux de restauration qui ont été exécutés à Indian River.

DIFFUSION DE L'INFORMATION

Le Service de géologie du Yukon produit maintenant une gamme complète de publications numériques. Toutes nouvelles cartes et rapports géologiques sont disponibles sur demande en format numérique, et toutes publications récentes sont aussi disponibles (sous format PDF) sans frais sur notre site internet (http://www.geology.gov.yk.ca). De plus, une gammes de rapports d'évaluation de propriété minières est maintenant disponible par l'entremise de notre site internet. Nous sommes aussi fier de notre service de carte interactive ('Map Gallery'). Ce service est disponible par l'entremise de notre site internet et permet la visualisation de la géologie régionale, des sites MINFILE, des levés régionaux de géochimie des sédiments de ruisseaux, de la topographie, des routes et des communautés du Yukon, et des sélections des terres des nations authochtones. Les données vectorielles peuvent maintenant être sélectionnées et téléchargées. Certaines des améliorations à venir incluent l'addition de données géophysiques, géochronologiques et paléontologiques. De plus, la couverture des concessions minières sera bientôt disponible.

Les publications du Service de géologie du Yukon sont diffusées par la Division des services géologiques et d'exploration (MAIN). Elles sont disponible à l'addresse suivante :

Bureau d'information et des ventes en géosciences

a/s Conservateur des registres miniers
Affaires indiennes et du Nord canadien
300 rue Main-bur. 102
Whitehorse (Yukon) Y1A 2B5
Téléphone : (867) 667-3266
Télécopieur : (867) 667-3267
Courriel : geosales@inac.gc.ca

Pour en savoir plus long sur le Service de géologie du Yukon, visitez notre page d'accueil à http://www.geology.gov.yk.ca ou communiquez directement avec :

Grant Abbott, Géologue principal intérimaire
Division de l'exploration et des services géologiques
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300 rue Main-bur. 345
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C.P. 2703
Whitehorse (Yukon) Y1A 2C6
Téléphone : (867) 667-5384

Robert E. Leckie Awards
for Outstanding Reclamation Practices

Andy Crowther[1]
Mining Lands Division, DIAND

Crowther, A., 2003. Robert E. Leckie Awards for Outstanding Reclamation Practices. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 59-62.

The fourth annual Robert E. Leckie Awards for outstanding reclamation practices were presented in Whitehorse, November, 2002. The awards for quartz and placer exploration and mining were first established in November, 1999. The two awards are given for reclamation and site restoration efforts that go well beyond what is required by law, either by reclaiming land for which there is no obligation to reclaim, adding features to the land that have enhanced the area and local community, or returning mined land to a condition that is not only sound but aesthetically pleasing. The award is named after the late Robert (Bob) Leckie who passed away in November, 1999 (see YEG, 1999).

QUARTZ MINING RECLAMATION

The 2002 Robert E. Leckie Award for Outstanding Reclamation Practices in Quartz Exploration and Mining was awarded to Viceroy Minerals Corporation (Fig. 1). During its years of operation the reclamation work carried out at the Brewery Creek mine has been methodical and extensive. Approximately 63.2 hectares were reclaimed in 2001 alone.

The landscape throughout the mined-out area has been left in a stable and aesthetically pleasing form that blends in well with the surrounding topography. Growth media has been spread wherever it was available and much of the disturbed areas have been seeded. The bulk of the reclamation work was accomplished in 2001 and 2002.

Figure 1. *Brewery Creek landscape from the air.*

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The Brewery Creek mine provides an excellent example of how modern mining techniques practiced by responsible companies have changed the face of the industry.

An honourable mention was given to Eagle Plains Resources for their clean-up efforts at the Rusty Springs property (Fig. 2). The removal of old fuel drums not only cleaned up this wilderness area, but helped prevent contamination of the surrounding environment.

PLACER MINING RECLAMATION

David McBurney is the recipient of the 2002 Award for Outstanding Placer Mining Reclamation Practices. David McBurney has been placer mining on the Indian River for the last 10 years. His water licence allows the leave strip on one bank of the Indian River to be mined and reclaimed, with requirements for special fish habitat features to be provided. Mr. McBurney has met all of the conditions in his water licence and has even sacrificed small portions of mineable ground in order to preserve some stands of large trees adjacent to the original river bank (Fig. 3). Mr. McBurney has moved his operation gradually upstream working in an organized and systematic manner. Wherever previous mining disturbances were encountered, Mr. McBurney has reclaimed the old workings along with his own.

Reclamation works completed include the bank and leave strip of the Indian River, according to unique conditions, as well as recontouring and revegetation of mined-out areas. This included mining pits being backfilled and levelled, tailing piles completely flattened and overburden spread evenly over the whole area. Reclamation works have been ongoing and progressive each year.

An honourable mention was given to Frank and Karen Hawker for ongoing mining reclamation in the Sixtymile River area (Fig. 4). The Hawkers' methods emphasize that reclamation can easily follow on the heels of mining and that good planning can lead to the improvement of a site as it is being mined.

Congratulations is extended to all noteworthy recipients of the 2002 Robert E. Leckie Reclamation Awards.

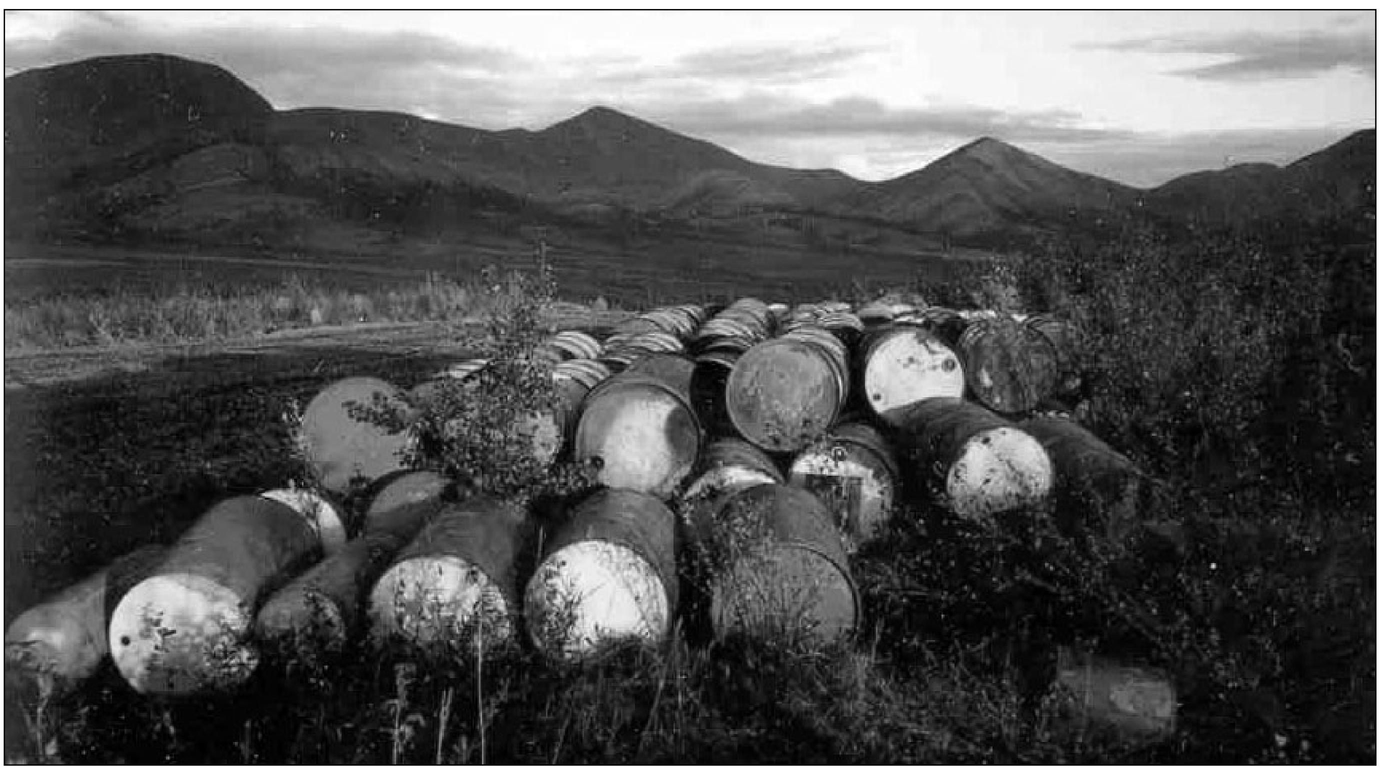

Figure 2. *Old fuel barrels collected via helicopter from the Rusty Springs property.*

Figure 3. *David McBurney's restored river bank, with large rock armouring along the bank and overburden spread up to the edge.*

Figure 4. *The Hawkers' reclaimed Sixtymile River stream channel and banks.*

GEOLOGICAL FIELDWORK

Geology and metamorphic conditions in rocks of the Cassiar Terrane, Glenlyon map area (105L/1), south-central Yukon

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Black, R., Gladwin, K. and Johnston, S.T., 2003. Geology and metamorphic conditions in rocks of the Cassiar Terrane, Glenlyon map area (105L/1), south-central Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 65-76.

ABSTRACT

Lower Paleozoic miogeoclinal calcareous rocks of the Cassiar Terrane are intruded by the Early Cretaceous Glenlyon Batholith. Garnet-biotite and garnet-muscovite-biotite-aluminum silicate-quartz geothermobarometry on the intrusive wall rocks indicate metamorphism to lower amphibolite facies at temperatures of approximately 700°C and pressures of approximately 3 kbar. Progressive deformation, indicated by porphyroblast-matrix relationships, are interpreted to be a result of minor displacements of the country rock associated with and facilitated by intrusion of the Glenlyon Batholith, followed by static heating. Isolated skarn units exist along contacts between the batholith and its wall rocks. A skarn unit is also present along a nearby north-northeast-trending dextral strike-slip fault that predates and is intruded by the batholith.

RÉSUMÉ

Les roches calcaireuses du Paléozoïque précoce du terrane de Cassiar sont recoupées par le batholite de Glenlyon du Crétacé précoce. La géothermobarométrie des roches encaissantes, utilisant les assemblages grenat - biotite et grenat - biotite - muscovite - aluminosilicate - quartz, indique un métamorphisme du faciès des amphibolites inférieures et des températures et pressions d'environ 700°C et 3 kbar, respectivements. La déformation progressive enregistrée dans les relations de fabriques entre les porphyroblastes et la matrice sont vraisemblablement le résultat d'un déplacement mineur le long de la marge du batholite suivi d'un réchauffement statique. Des indices de skarn forment des affleurement isolés le long du contact entre le batholite et les roches encaissantes, de même que le long d'une faille de décrochement dextre d'orientation nord-nord-est qui est recoupée par le batholite.

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INTRODUCTION

Miogeoclinal rocks of Cassiar Terrane, in southeastern Glenlyon map area (105L), occur in a narrow northwest-striking belt between the western margin of the Early Cretaceous Glenlyon Batholith and the Tummel fault zone, which separates Cassiar Terrane from allochthonous rocks of the Yukon-Tanana Terrane (Fig. 1; Colpron et al., 2002; Gladwin et al., 2002; Campbell, 1967).

During intrusion of the batholith, platformal to basinal rocks of Cassiar Terrane were extensively metamorphosed, developing pods of lead-zinc skarn mineralization in marble (Lokken occurrence, Yukon MINFILE, 2001, 105L 001). Some exploration work has been done on the Lokken occurrence (Doherty, 1991; Doherty 1996), but little documentation of its geology and the conditions during contact metamorphism has been recorded.

This paper presents the results of detailed (1:20 000 scale) geological mapping and geothermobarometric studies from a 25 km^2 area around the Lokken occurrence. This study was conducted as part of a larger regional mapping program (Yukon Targeted Geoscience Initiative (TGI), Fig. 1; Colpron et al., this volume) and in concert with more extensive detailed mapping of the Truitt Creek area (Gladwin et al., 2002; this volume).

GEOLOGY

CASSIAR TERRANE

Rocks west of the Glenlyon Batholith are calcareous pelite and carbonate, interbedded with calc-silicate rocks and minor amphibolite of the Cassiar Terrane (Gordey and Makepeace, 2001). Originally mapped by Campbell (1967), these rocks were assigned to the Middle Cambrian (and younger ?) Harvey Group. On a recent compilation, Gordey and Makepeace (2001) incorporated the Harvey Group within the Upper Proterozoic-Lower Cambrian Ingenika Group (Windermere Supergroup).

Regional mapping north of the study area has reinterpreted these rocks as higher grade equivalents of the Cambrian-Ordovician Kechika Group and Silurian-Devonian Askin Group (Gladwin et al., 2002; this volume; Colpron et al., 2002; this volume). In addition, this mapping indicates that much of the area Campbell (1967) thought was underlain by metasedimentary rocks is actually underlain by granitic rocks of the Glenlyon Batholith (Gladwin et al., 2002). In the study area (Fig. 2), metasedimentary rocks of the Cassiar Terrane have been contact-metamorphosed to amphibolite facies. Six mappable units are recognized in the area. They vary from coarse-grained, metaclastic rocks of the Kechika

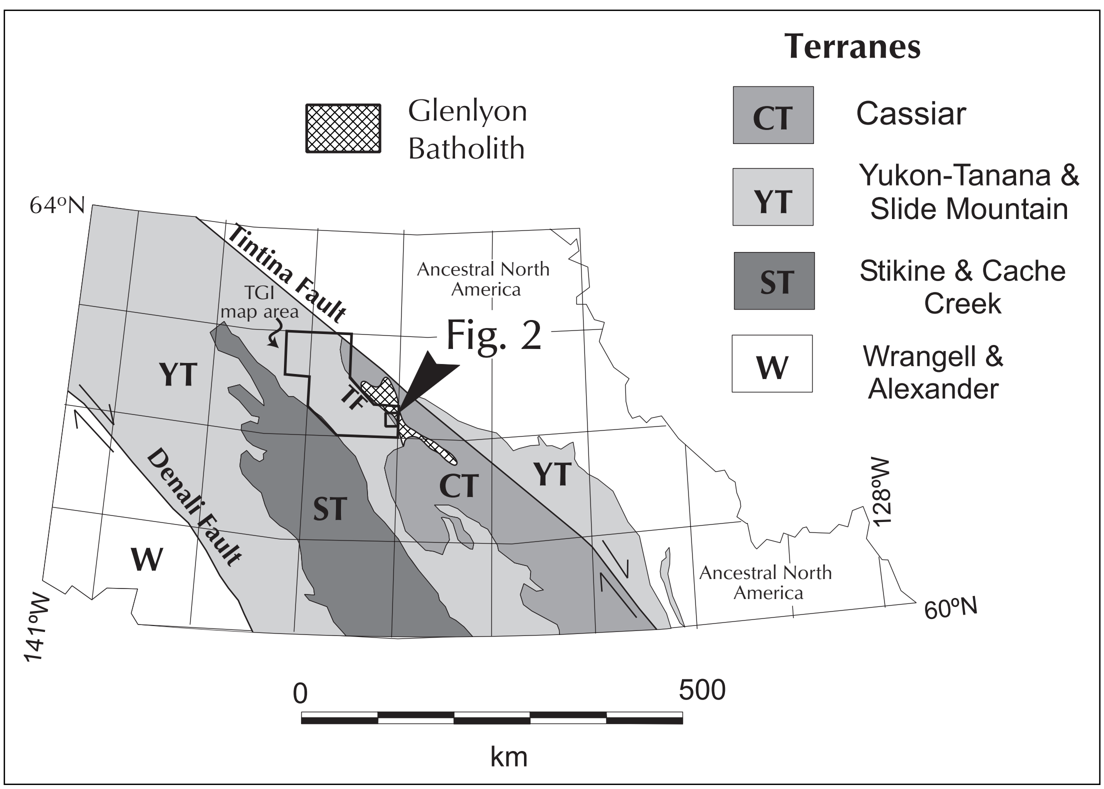

Figure 1. *Simplified regional geological map of the southern Yukon (modified after Wheeler and McFeely, 1991). The study area (indicated by the Figure 2 box) is located near the Tummel Fault (TF) at the western margin of the Cassiar Terrane.*

Group at the bottom of the section to fine-grained calcareous rocks of the Askin Group at the top. Compositional layering is parallel to the dominant schistosity, which strikes northwest and dips moderately to the southwest.

The Kechika Group in the area consists of five mappable units. The structurally lowest unit (MBa) consists of brown, rusty-weathering, quartz-muscovite-biotite schist, which forms layers up to 50 m thick. Near the margin of Glenlyon Batholith, the schist is deformed by irregular folds that have amplitudes of 30-50 cm. These folds are mimicked by a 5-cm-thick sill of muscovite pegmatite, and are interpreted to have been produced by intrusion of the batholith. Minor amounts of coarsely recrystallized marble contain < 5% evenly distributed biotite flecks that are aligned parallel to the dominant foliation. Foliated amphibolite sills occur locally. They are generally parallel to the schistosity, but locally cut across the schistosity and compositional layering at low angles. Green quartzite layers <2 m thick, rare, medium-grained garnet-wollastonite-diopside calc-silicate schist, and gneiss are also included within this unit. Unit Mba also occurs as pendants that occupy topographic high points within the Glenlyon Batholith. Rocks within these pendants exhibit an intense alteration, and layering is discordant with the regional structural trend outside of the batholith.

A unit (MBbm) of tan- to grey-weathering, coarsely crystalline, impure marble (± diopside) is repeated three times in the area (Fig. 2). It is up to 60 m thick and comprises calc-silicate layers (up to 30% of the unit) and minor amounts of quartz-biotite-muscovite schist. Marble layers commonly include amphibolite sills up to 2 m thick that are boudinaged and folded with the surrounding layers.

A unit (MBbs) of foliated, medium-grained, light grey to brown biotite-quartz schist (± cordierite ± andalusite) is repeated twice with the underlying marble unit (MBbm). It also includes significant amounts of quartz-mica schist, minor coarsely recrystallized pelitic marble (± diopside), minor amphibolite, and rare calcareous quartz-plagioclase pebble metaconglomerate. The biotite-quartz schist (unit MBbs) contains less than 10% feldspar, and is crenulated. Two horizons of pebble metaconglomerate occur above and below a 100-m-thick succession of quartz-mica schist and marble. The lower metaconglomerate horizon (at least 1 m thick) is well sorted, with oblate pebbles 3-6 cm in diameter. The upper horizon of metaconglomerate is well sorted and contains smaller pebbles (2-3 cm in diameter).

Unit MBc is dominated by green to white, medium-grained, plagioclase-diopside ± garnet ± wollastonite calc-silicate gneiss and schist, coarse crystalline pelitic marble and minor amphibolite. This unit overlies the westernmost occurrence of marble of unit MBbm (Fig. 2). Calc-silicate layers up to 80 m thick show cm-scale compositional layering defined by green and white banding of diopside-rich and quartz-plagioclase-wollastonite-dominated layers, respectively. A unit of rusty brown to gold, medium-grained garnet-biotite-muscovite schist, with minor plagioclase-diopside calc-silicate schist and coarsely crystalline marble (MBab) occurs above the calc-silicate unit (MBc; Fig. 2). This unit contains 1-4 mm poikiolitic garnet porphyroblasts with quartz inclusion trails.

A medium- to coarse-grained, medium grey marble, unit MBd, with numerous calcite veins is the westernmost unit, adjacent to the Tummel fault zone. This marble is compositionally homogeneous and lacks the significant siliciclastic component observed in the marble unit MBbm. It is assigned to the Askin Group (Gladwin et al., 2002; Colpron et al., 2002).

GLENLYON BATHOLITH

More than half (>12 km^2) of the study area is underlain by the Glenlyon Batholith (Fig. 2). It is characterized by three comagmatic felsic phases (Fig. 3): (a) muscovite pegmatite, (b) biotite-muscovite ± hornblende granite, and (c) ± hornblende-biotite granodiorite. All phases are characterized by a weak planar foliation that is interpreted as a magmatic fabric.

The muscovite-biotite + hornblende granite is grey, equigranular to porphyritic, medium- to coarse-grained, with 5-10% muscovite. Plagioclase megacrysts up to 4 cm long are locally present. This phase is common in the northern part of the study area and exists as rare apophyses in the country rock. The granite is interpreted to be the oldest phase of the intrusion as it is cut by both the granodiorite and the pegmatite. A single outcrop of moderately foliated muscovite-biotite granite occurs at the margin of the batholith. This foliated granite is metamorphosed to chlorite grade (lower greenschist facies) and has a foliation consisting of aligned chlorite grains <0.5 mm long, concordant with the regional structural trend. This foliated granite is interpreted as an early phase of the batholith that was partially cooled and subsequently deformed and metamorphosed during intrusion of the main phases of the batholith.

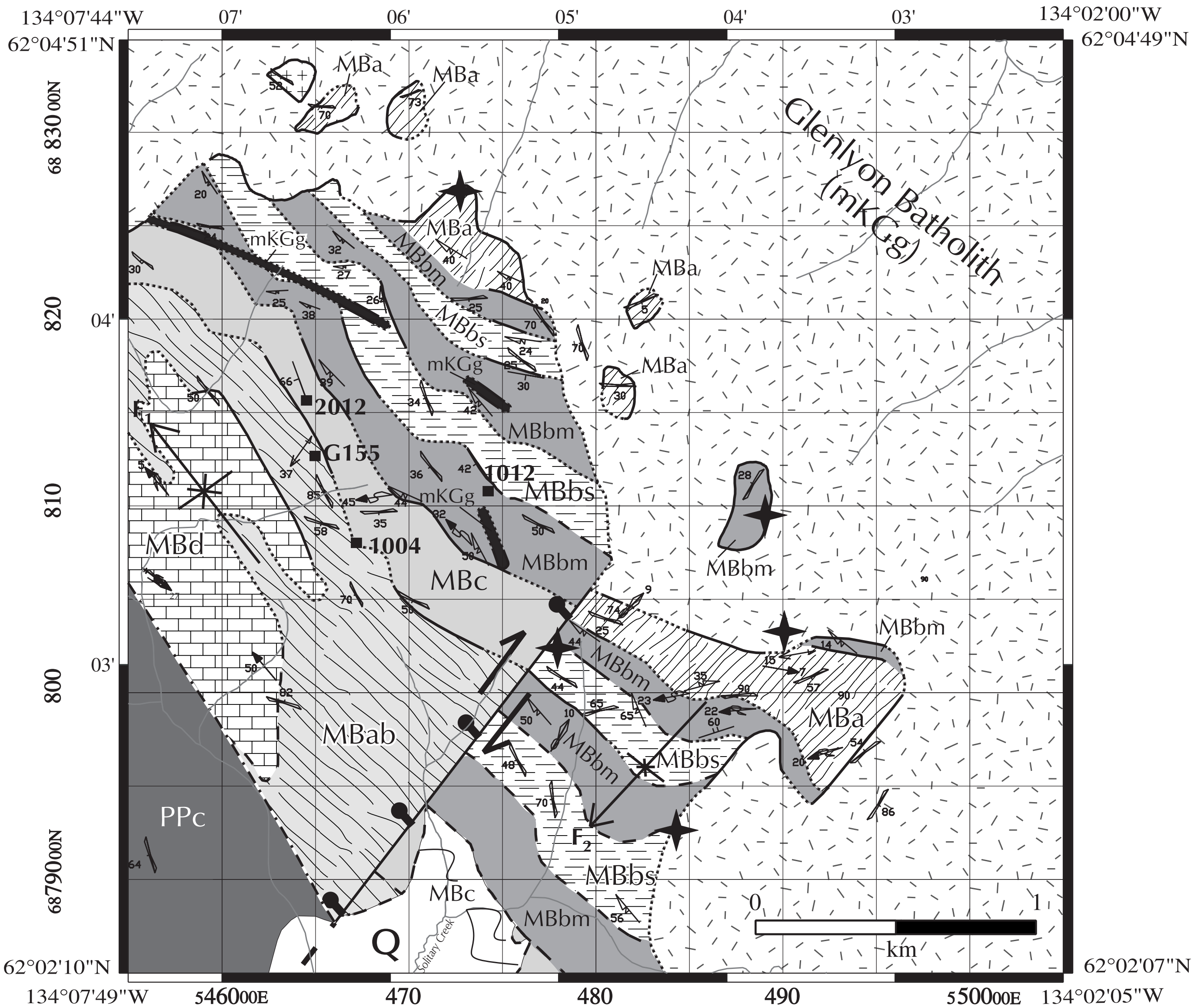

Figure 2. *Geological map of the study area. The locations of geothermobarometry samples are indicated by black squares. Labels correspond to the last 4 digits of the sample numbers. Legend on opposite page.*

The biotite granodiorite is pink-weathering, equigranular, medium- to coarse-grained and leucocratic with <5% biotite. This is the most voluminous phase of the batholith, and rarely occurs as dykes. Contacts between the granodiorite and granite phases are undulatory (Fig. 3) and gradational, indicating a comagmatic relationship.

The granite pegmatite occurs as apophyses in country rock and as dykes within the batholith. Pegmatite veins and dykes are characterized by 3-5 cm muscovite booklets. Pegmatite veins cut and are younger than the more equigranular granite and granodiorite phases of the batholith. Pegmatite, however, locally grades into more equigranular muscovite granite, indicating that the pegmatite veins are probably a late stage melt of the batholith and not the products of a younger magmatic event.

The batholith intrudes older Paleozoic continental margin rocks of Cassiar Terrane. A single K/Ar whole rock age determination of 105 ± 4 Ma (Hunt and Roddick, 1990) from north of Robert Campbell highway indicates an Early Cretaceous age for the Glenlyon Batholith.

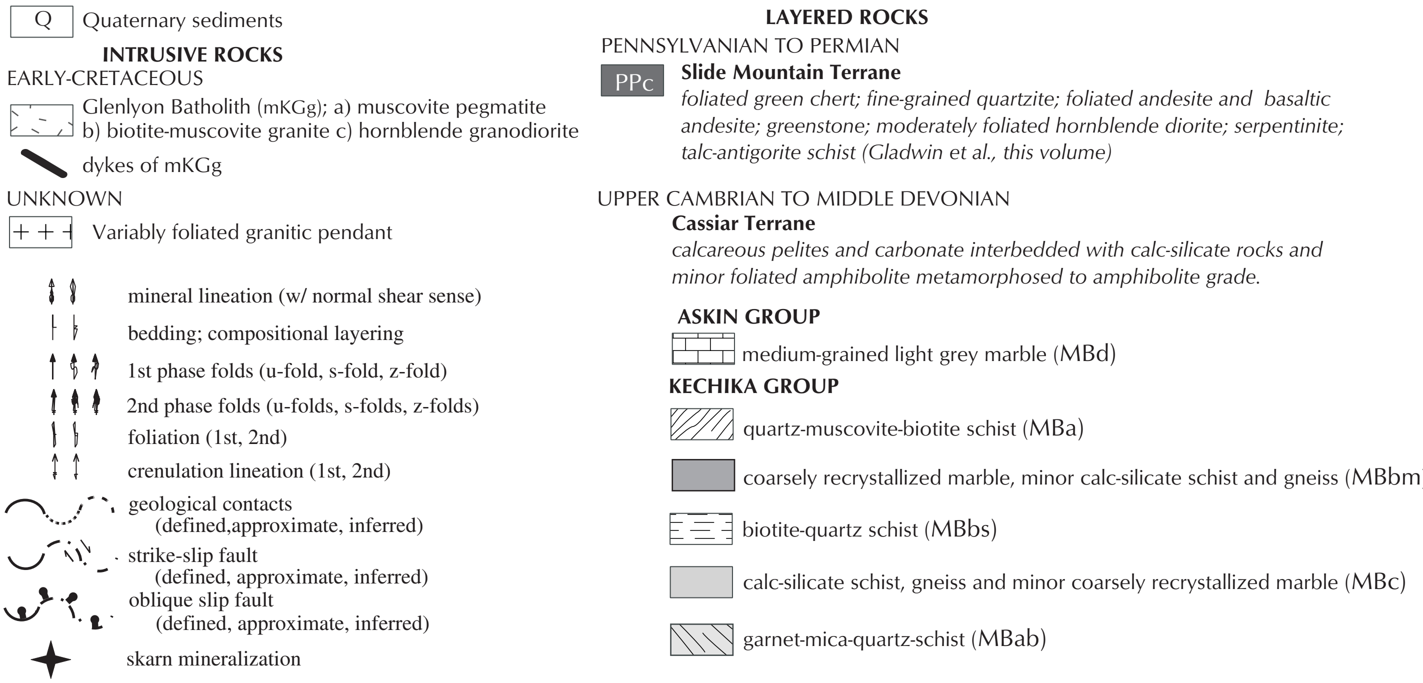

Figure 2. *Legend for map on preceeding page.*

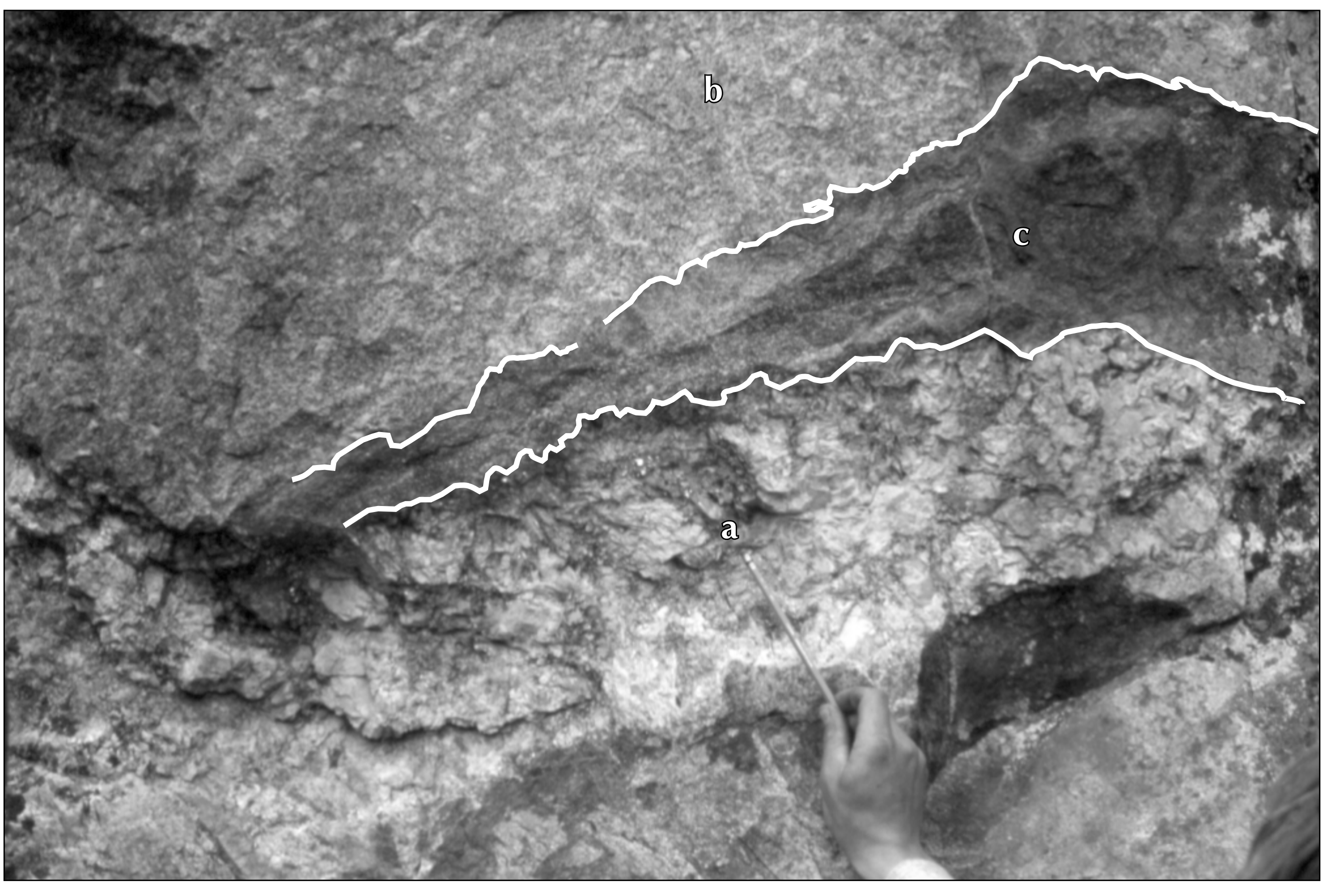

Figure 3. *The three phases of the Glenlyon Batholith:* ***(a)*** *muscovite pegmatite,* ***(b)*** *biotite-muscovite granite and* ***(c)*** *hornblende-biotite granodiorite. The upper two phases share an embayed contact suggesting comagmatism.*

STRUCTURAL GEOLOGY

Two phases of deformation are evident in rocks of the Cassiar Terrane. The first produced a north-northwest-striking, west-dipping, layer-parallel foliation defined by micas in the schists (S_1). The foliation is axial planar to tight folds (F_1) that plunge 23°-43° to the northwest (Fig. 4a,b). First phase structures are dominant and define the structural trend in the area. The second phase of deformation includes 1) the development of a northeast-striking oblique-slip fault, 2) the formation of broad open wrinkles in the phase one schistosity, and 3) the development of open, moderately west-plunging folds (Fig. 4c). The second phase open folds (F_2) deform the dominant foliation and locally modify the regional structural trend such that it is nearly parallel with second phase fold axes (Fig. 2). Compositional layering, defined by 1-2 cm thick siliciclastic layers in marble and 2-3 cm thick diopside-quartz layers in calc-silicate rock, converges at low angles to the S_1 foliation and is interpreted to represent transposed bedding. The foliation commonly parallels the intrusive margin near the batholith, locally creating push folds with amplitude of 30-50 cm. A northeast-striking fault in the study area has a net dextral strike separation of 1 km. The fault is truncated to the southwest by the Tummel fault zone (Gladwin et al., this volume) and to the northeast by the Glenlyon Batholith.

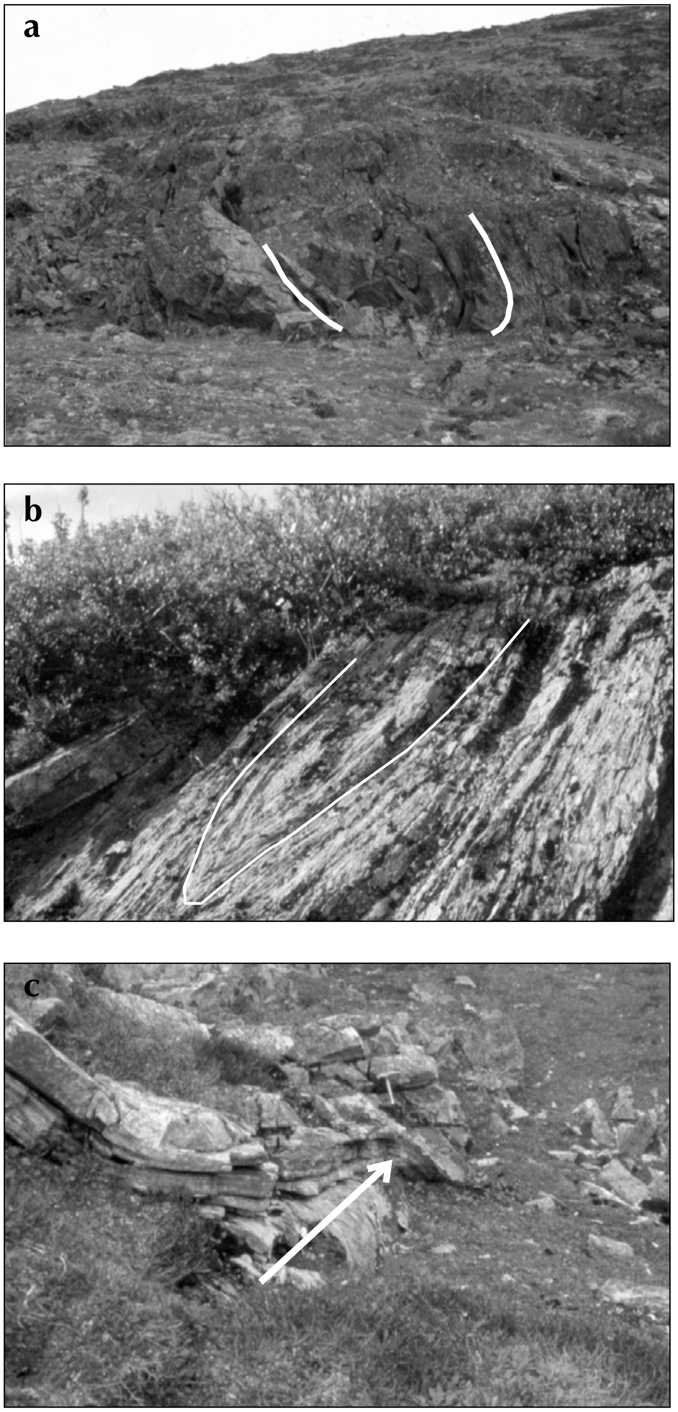

Figure 4. (a) *F_1 fold view looking up plunge. The fold is closing to the northeast and plunging slightly to the northwest in southern map area. Field of view is approximately 20 m.* ***(b)*** *View looking down plunge of F_1 fold in the northern part of the map area. Field of view is approximately 4 m.* ***(c)*** *West-plunging broad open F_2 fold; hammer for scale. The arrow points down plunge.*

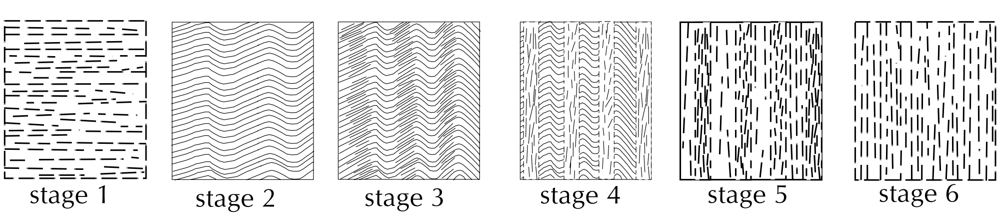

Figure 5. *The six stages of cleavage development (after Bell and Rubenach, 1983).*

METAMORPHISM

Contact aureole mineral assemblages overprint a regional greenschist facies fabric. Porphyroblast inclusion trails preserve earlier schistosities frozen during progressive deformation (Bell & Rubenach, 1983; Olesen, 1978; Vernon, 1978). Bell and Rubenach (1983) identified six stages defined by the geometry of the matrix fabric (S_e) during the development of a new schistosity (Fig. 5). Internal fabrics (S_i) may capture one or several stages of secondary schistosity development. The terminology of Bell and Rubenach (1983) is used here. Foliated rocks in this study area exhibit a stage 5 S_e observable in all lithologies. Locally, porphyroblasts have captured stages 2 to 4 of foliation development.

Brown to burgundy, 1-4 mm diameter, almandine-rich garnet porphyroblasts are abundant in unit MBab. The garnets are subhedral to anhedral, with quartz inclusions (S_i) preserving stages 2 to 4 of schistosity development (Figs. 6a,b). S_i fabric is continuous through the core of the

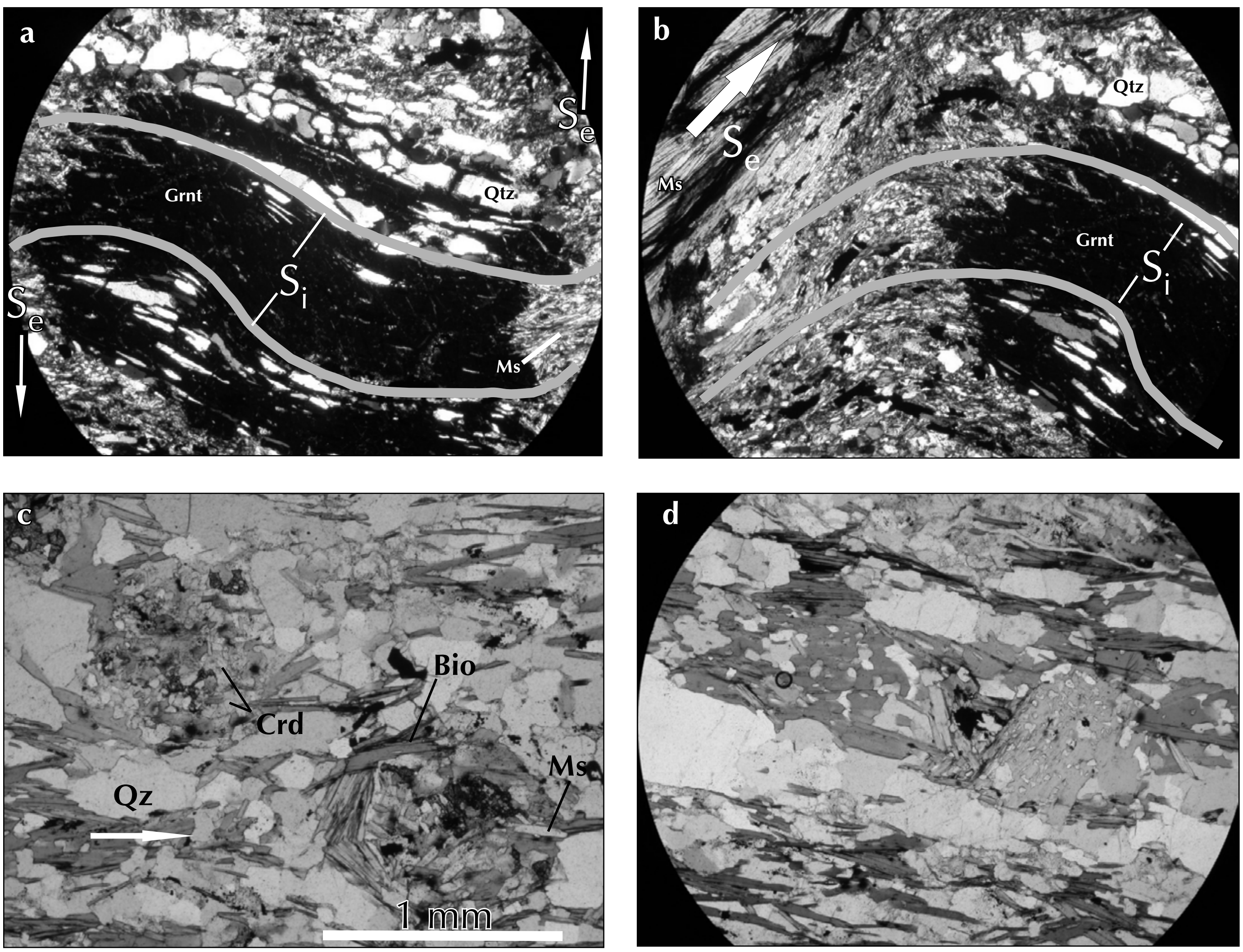

Figure 6. ***(a)*** *A garnet porphyroblast with inclusions of quartz preserving stage 3 foliation. Arrows indicate attitude of the dominant (stage 5) foliation outside of the porphyroblasts.* S_i *lines define internal fabric. Field of view is 2.5 mm.* ***(b)*** *The same garnet showing an inclusion trail emerging from garnet and bending into alignment with biotite-muscovite foliation. White arrow indicates dominant foliation; grey lines follow inclusion trails within garnet. Field of view is 2.5 mm.* ***(c)*** *Biotite-quartz-cordierite-tourmaline aggregates growing across the foliation.* ***(d)*** *Late growth biotite porphyroblast developed across the foliation. Field of view is 2.5 mm. Photomicrographs taken at 4x magnification.*
And – andalusite; Bio – biotite; Crd – cordierite; Grnt – garnet; Ms – muscovite; Qtz – quartz.

Table 1. *Electron microprobe mineral analysis results.*

Sample	Ox% (Na)	Ox% (Mg)	Ox% (Al)	Ox% (Si)	Ox% (K)	Ox% (Ca)	Ox% (Ti)	Ox% (Cr)	Ox% (Mn)	Ox% (Fe)	Ox% (Ba)	Wt% (F)	Wt% (Cl)	total
Garnet														
RB004-1	0.04	1.53	21.39	36.52	–	9.63	0.14	0.01	0.66	29.09	–	–	–	99.02
RB004-2	0.03	1.16	21.43	37.11	–	9.93	0.17	0.00	0.80	29.55	–	–	–	100.18
RB004-3	0.03	1.03	21.33	36.80	–	10.00	0.14	0.05	1.27	29.04	–	–	–	99.68
RB004-4	0.05	1.10	21.54	37.10	–	9.78	0.14	0.02	1.16	29.85	–	–	–	100.76
KG155-1	0.00	1.52	21.46	36.55	–	8.80	0.09	0.07	0.63	30.70	–	–	–	99.83
KG155-2	0.01	1.28	21.43	36.88	–	9.23	0.11	0.00	0.80	30.42	–	–	–	100.16
KG155-3	0.01	1.31	21.44	36.47	–	8.92	0.12	0.00	0.75	30.44	–	–	–	99.48
KG155-4	0.02	1.22	21.40	37.05	–	9.33	0.08	0.01	0.84	29.89	–	–	–	99.83
KG155-5	0.04	0.99	21.53	36.87	–	9.27	0.11	0.03	2.69	28.55	–	–	–	100.09
KG155-6	0.03	0.97	21.30	36.62	–	9.54	0.13	0.01	2.88	28.09	–	–	–	99.57
RB02012-1	0.03	2.37	21.58	37.04	–	7.12	0.09	0.04	0.30	31.64	–	–	–	100.22
RB02012-2	0.01	1.85	21.41	37.12	–	7.15	0.07	0.00	0.28	32.40	–	–	–	100.30
RB02012-3	0.04	1.19	21.07	36.89	–	8.30	0.09	0.01	1.93	30.68	–	–	–	100.21
RB02012-4	0.01	1.11	21.25	36.77	–	8.72	0.11	0.01	2.53	29.90	–	–	–	100.40
RB02012-7	0.00	2.12	21.66	36.98	–	6.44	0.08	0.02	0.25	32.90	–	–	–	100.46
RB02012-8	0.02	1.63	21.27	36.87	–	6.99	0.04	0.04	0.54	32.54	–	–	–	99.93
RB02012-9	0.04	1.12	21.24	37.05	–	8.77	0.11	0.00	2.39	29.96	–	–	–	100.67
RB02012-10	0.01	1.36	21.46	36.96	–	7.97	0.09	0.00	0.95	31.36	–	–	–	100.16
Pyroxene														
RB01004-1	0.08	8.61	0.37	51.20	–	23.57	0.00	0.02	0.22	14.99	–	–	–	99.06
RB01004-2	0.09	9.22	0.33	51.05	–	23.71	0.00	0.01	0.27	14.99	–	–	–	99.66
RB01004-3	0.08	9.43	0.25	51.52	–	23.40	0.04	0.02	0.30	14.42	–	–	–	99.46
RB01004-4	0.09	9.47	0.22	51.25	–	23.31	0.01	0.02	0.31	14.30	–	–	–	98.99
Biotite														
KG155-1	0.15	7.53	17.34	35.12	9.40	0.05	2.50	0.07	0.21	23.29	0.18	0.48	0.10	95.85
KG155-2	0.13	7.51	17.47	34.81	9.19	0.07	2.39	0.07	0.19	23.56	0.20	0.47	0.18	95.60
KG155-4	0.05	9.05	18.01	32.49	6.36	0.08	1.44	0.00	0.26	25.54	0.12	0.33	0.15	93.50
KG155-6	0.18	8.45	19.23	36.13	9.87	0.00	2.43	0.06	0.22	20.04	0.12	0.45	0.08	96.74
KG155-7	0.12	8.45	19.20	36.11	9.87	0.00	2.34	0.00	0.18	20.10	0.01	0.43	0.07	96.47
KG155-10	0.05	6.32	20.90	33.20	8.81	0.05	0.69	0.03	0.19	24.47	0.03	0.24	0.13	94.74
RB02012-1	0.23	7.67	19.21	35.84	9.63	0.03	2.79	0.00	0.07	20.46	0.04	0.25	0.00	95.99
RB02012-2	0.16	7.78	19.38	35.98	9.83	0.00	2.82	0.04	0.06	20.67	0.05	0.31	0.01	96.78
RB02012-5	0.24	8.56	18.61	35.76	9.65	0.00	2.98	0.03	0.08	20.24	0.11	0.34	0.05	96.26
RB02012-6	0.23	8.74	18.38	36.54	9.64	0.00	2.95	0.05	0.07	19.46	0.02	0.40	0.00	96.07
RB02012-9	0.14	5.76	18.87	34.82	9.48	0.00	3.22	0.07	0.12	23.75	0.11	0.11	0.00	96.34
RB02012-10	0.13	5.64	19.21	34.75	9.67	0.00	3.22	0.06	0.16	23.48	0.08	0.21	0.03	96.40
Feldspar														
KG155-1	5.52	0.00	28.47	55.79	0.01	10.52	–	–	–	0.32	–	–	–	100.72
KG155-2	6.17	0.00	27.20	57.33	0.14	9.06	–	–	–	0.08	–	–	–	99.98
KG155-3	5.77	0.00	27.63	56.20	0.14	9.93	–	–	–	0.01	–	–	–	99.77
RB02012-3	6.09	0.00	27.42	57.62	0.26	9.37	–	–	–	0.03	–	–	–	100.79
RB02012-4	5.81	0.01	27.86	56.36	0.24	9.96	–	–	–	0.05	–	–	–	100.28
White Mica														
KG155-8	0.40	0.04	18.45	65.47	16.27	0.00	0.02	0.02	0.00	0.25	0.27	0.00	0.01	101.20
KG155-9	0.40	0.03	18.50	65.77	16.43	0.02	0.00	0.00	0.04	0.41	0.16	0.00	0.00	101.75
RB02012-3	0.44	1.18	33.54	47.52	10.26	0.01	0.74	0.03	0.01	1.61	0.21	0.13	0.01	95.55
RB02012-4	0.41	1.00	33.41	46.52	9.78	0.02	0.56	0.01	0.00	1.24	0.26	0.14	0.04	93.22
RB02012-7	0.46	0.87	34.84	45.90	10.53	0.00	0.49	0.04	0.07	1.49	0.31	0.06	0.00	95.01
RB02012-8	0.50	1.21	33.54	46.71	10.57	0.01	0.52	0.04	0.00	1.52	0.22	0.15	0.01	94.84

Ox: oxide; Wt: weight

garnets to the rims where it emerges at the anhedral garnet boundary and is incorporated into a muscovite-biotite fabric that bends into alignment with S_e. Stage 3 is the most commonly observed relict schistosity and is interpreted to be synchronous with the peak of garnet growth.

Aggregates of biotite-quartz-cordierite ± tourmaline, <1 mm in diameter in biotite-quartz schist of unit MBbs are common (Fig. 6c). Locally, garnets occur within the aggregates as anhedral masses in disequilibrium with surrounding minerals and are interpreted to be retrograded garnet pseudomorphs. Biotite in these aggregates typically has metamict haloes around zircon inclusions. S_e is defined by biotite and is locally included within porphyroblasts, but more commonly displays a weak wrap-around texture that implies late development of the biotite-quartz-cordierite porphyroblasts (with respect to development of the main schistosity).

Post-kinematic contact metamorphism affects the entire study area. It is most commonly characterized by late-developing <1 mm biotite porphyroblasts that grow across a well defined biotite ± muscovite foliation in units MBa and MBbs (Fig. 6d). Further from the batholith, smaller <0.2 mm muscovite porphyroblasts in garnet-

Table 2. *Summary of mineral assemblages, thermometers and barometers used, and calculated P-T.*

Sample no.	Rock name	Mineralogy	Thermometer/ Barometer used	Calculated T (°C)	Calculated P (kPa)
KG01-155	garnet-biotite-muscovite-schist	quartz, muscovite, biotite, almandine, albite, andalusite, tourmaline	garnet-mica-aluminosilicate, garnet-biotite	738	3.1
RB01-004	garnet calc-silicate schist	almandine, diopside, calcite, sphene, epidote, plagioclase	garnet-diopside	577	–
RB01-012	knotted biotite schist	quartz, muscovite, biotite, almandine, albite, andalusite, cordierite, tourmaline, chlorite	garnet-mica-aluminosilicate, garnet-biotite	661	2.7
RB02-012	garnet-biotite-muscovite-schist	quartz, almandine, muscovite, biotite, albite, chlorite	garnet-biotite	721	–

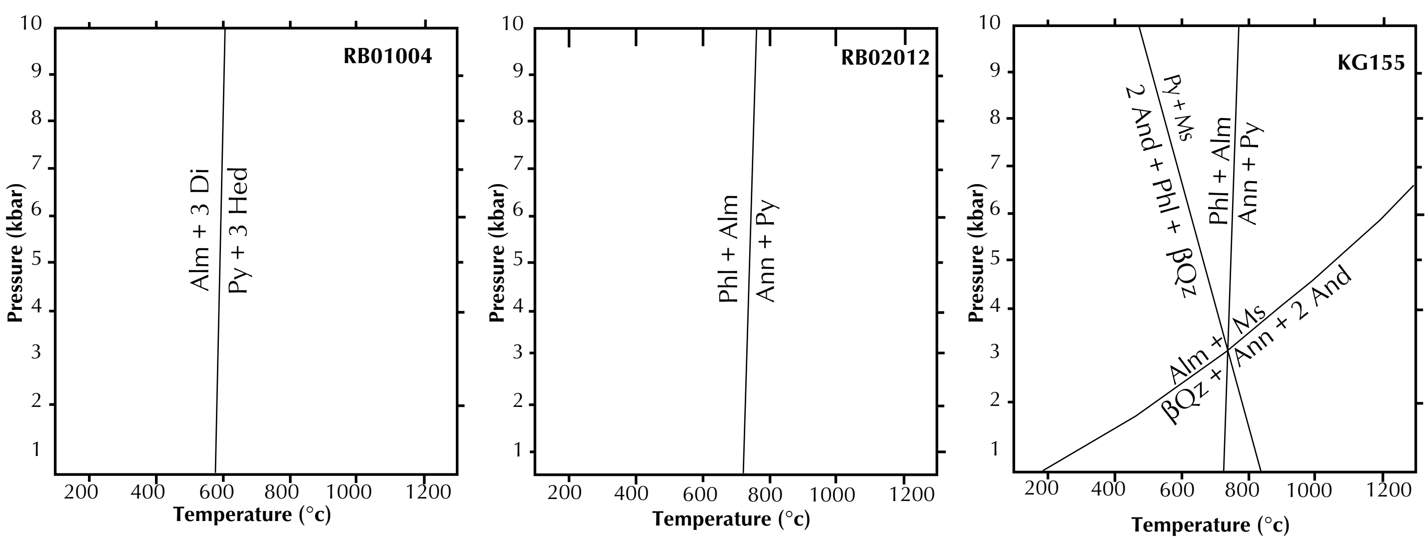

Figure 7. *Pressure-temperature plots constructed using TWEEQU software (Berman, 1991). Alm – almandine; Di – diopside; Py – pyrope; Hed – hedenbergite; βQz – beta-quartz; Ms – muscovite; Phl – phlogopite; Ann – annite; And – andalusite.* ***(a)*** *Univariant Fe-Mg exchange reaction from a calc-silicate schist 1300 m from the batholith, resulting in a temperature of 590°C.* ***(b)*** *Univariant garnet-biotite Fe-Mg exchange reaction from a garnet-mica schist taken 1100 m from the batholith's margin. A temperature of 730°C is extrapolated at 3 kbar.* ***(c)*** *Garnet-biotite-aluminosilicate-quartz and garnet-biotite exchange reactions from a garnet-mica schist 1380 m from the intrusive margin. Results indicate a pressure of 3.1 kbar and a temperature of 738°C. This sample is considered representative of the pressure and temperature conditions achieved during emplacement of the Glenlyon Batholith. Sample locations shown on Figure 2.*

muscovite-biotite-quartz schists of unit MBab grow across the dominant biotite-muscovite foliation. The biotite porphyroblasts commonly include zircon and quartz; the muscovite locally includes tourmaline. Both the muscovite and biotite porphyroblasts are oriented randomly, defining no coherent foliation and are interpreted to be post-kinematic thermal metamorphism.

Gladwin et al. (this volume) show that contact metamorphism associated with Glenlyon Batholith affect rocks up to 10 km west of the batholith.

GEOTHERMOBAROMETRY

Analyses were obtained using wavelength dispersive analysis on the Cameca SX-50 electron microprobe at the University of British Columbia. The data was collected as oxide percentages (Table 1), reduced, and P-T plots (Fig. 7) were constructed using the thermobarometric database and software of Berman (1991). Geothermobarometry results are shown in Fig. 7 and summarized in Table 2.

Samples of metapelite with garnet + biotite + quartz + muscovite + plagioclase + cordierite + andalusite, and calc-silicate rocks with garnet + clinopyroxene + quartz mineral paragenesis were selected for microprobe analysis (Table 2). The garnet-biotite thermometer of Berman (1991) and solid solution models of Berman and Aranovich (1996) for garnet and biotite were used. Pressure was determined using the net transfer equilibria reaction for biotite-garnet-muscovite-quartz-aluminosilicate (Ghent and Stout, 1981) and the solid solution models of Chatterjee and Froese (1975) for mica and Berman et al. (1995), and Berman and Aranovich (1996) for garnet and biotite.

Pressure and temperature estimates based on microprobe analysis suggest low pressure amphibolite facies metamorphic conditions in the aureole of the Glenlyon Batholith. Pressure estimates of 3.1 kbar and temperatures of 570° C and 720°C were derived from microprobe analyses. These results are consistent with the lower amphibolite facies metamorphism indicated by metamorphic mineral assemblages, and the presence of cordierite and andalusite in metapelites of the Cassiar Terrane adjacent to the Glenlyon Batholith.

MINERALIZATION AT THE LOKKEN OCCURRENCE

Pods of lead-zinc-silver skarn mineralization occur at the contact between the Glenlyon Batholith and marble horizons (Fig. 2; Yukon MINFILE, 2001, 105L 001). A single occurrence along the north-northeast striking oblique fault was also noted. Suphide minerals consist of disseminated to massive sphalerite, galena and pyrite with associated diopside, garnet, actinolite, calcite and quartz (Doherty, 1996). Layers of marble can be clearly followed into the margin of the batholith where the carbonate has been replaced by mineralization. This implies the mineralization is attributable to the intrusion of the Glenlyon Batholith. If mineralization is a product of the intrusion then the pressure and temperature constraints on metamorphism must also constrain the mineralization event. A single locality of mineralization in the north of the study area occurs in unit MBa on the intrusive contact. Chlorite, quartz and muscovite mineral paragenesis at this site indicate low temperature metamorphism (Winkler, 1979). This is interpreted to be a result of replacement of earlier minerals by infiltration of meteoric waters.

DISCUSSION

The Glenlyon Batholith was intruded syn- to post-kinematically, as indicated by inclusion trails within garnet porphyroblasts and chlorite metamorphism in the earliest phase of intrusion. Biotite-quartz-cordierite porphyroblasts display both syn-kinematic and post-kinematic growth features. Strain during intrusion of the batholith was accommodated by local push folds at the margin and development of a margin parallel schistosity. Displacement at the margin of the batholith is interpreted to be minimal due to lack of significant foliation within the batholith, and it likely occurred during emplacement of the earliest phases of the intrusion. Randomly oriented biotite and muscovite porphyroblasts growing across foliation show that metamorphism continued after the cessation of strain, further enhancing schistosity in the wall rocks. Rotated pendants of country rock that cap topographic high points are interpreted to have foundered into the magma during intrusion. A contact aureole imposed by the batholith extends up to 10 km away from the batholith (Gladwin et al., this volume).

Geothermobarometric results from calc-silicate schists and meta-pelites indicate that the country rocks to the Glenlyon Batholith were metamorphosed at 8 to 10 km depth and subject to temperatures between 570°C and 720°C. Higher than expected mineral formation temperatures are encountered in rocks over 1 km from the nearest surface expression of the batholith. This may indicate that the intrusion is present beneath these locations at relatively shallow depths, or may be due to circulation of abundant calcium-rich fluids. The results here are similar to those documented by Smith and Erdmer (1990) in country rock surrounding the Early Cretaceous Anvil Batholith near Faro, south-central Yukon. The Anvil Batholith is similar both in age and in composition, with three phases including muscovite-biotite granite, hornblende-biotite granodiorite, and minor granite intrusions. Rb-Sr whole rock ages of ~99 Ma for the hornblende-biotite granodiorite phase and ~100 Ma for the muscovite-biotite granite, and K/Ar crystallization ages of 81-102 Ma suggest an Early to mid-Cretaceous age for intrusion of the Anvil Batholith(Pigage and Anderson, 1985).

A mineral occurrence along a fault intruded by the Glenlyon Batholith indicates the fault may have acted as a conduit for migration of mineralizing fluids. Metamorphic conditions determined from wall rocks to the batholith suggest that mineralizing fluids were probably in excess of 600°C.

CONCLUSIONS

The Early Cretaceous Glenlyon Batholith consists of three coeval phases intruded syn- to post- kinematically into wall rocks of the Cassiar Terrane. Contact metamorphic mineral assemblages record pressures of ~3 kbar (8-10 km depth) and temperatures in excess of 600°C. Skarn mineralization developed near the intrusive margin during intrusion and development of the contact aureole. Similar results from other studies of Early Cretaceous batholiths and their aureoles may imply a unique intrusion style.

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Harzburgite Peak: A large mantle tectonite massif in ophiolite from southwest Yukon

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ABSTRACT

Detailed mapping of bedrock in the northern Wellesley basin adjacent to the Donjek River revealed a coherent sequence of cumulus-textured gabbros, sheeted dykes, and a large massif of spinel harzburgite. The coarse-textured harzburgite tectonite covers an area of ~75 km^2, and is generally well preserved, making it one of the largest and most exceptional mantle tectonite bodies yet recognized in Yukon. Together with regional aeromagnetic data the new field observations are interpreted as part of a large ophiolite complex with a strike length extending ~100 km throughout the Wellesley basin. No age data are available, but correlation with identical ultramafic bodies to the northwest in Alaska suggests that the ophiolite in Wellesley basin may represent a klippe of Slide Mountain Terrane overlying rocks of the Yukon-Tanana Terrane.

RÉSUMÉ

La cartographie détaillée du substratum rocheux dans le nord du bassin de Wellesley près de la rivière Donjek a révélé la présence de séquences cohérentes de gabbros à texture de cumulus, de dykes stratifiés, et un gros massif de harzburgite à spinelle. La tectonite de harzburgite à texture grossière couvre une superficie de ~75 km^2; elle est généralement bien conservée, ce qui en fait l'un des amas de tectonite mantellique les plus vastes et les plus exceptionnelles du Yukon. Conjuguées aux données aéromagnétiques régionales, les nouvelles observations de terrain en font un vaste complexe ophiolitique d'une longueur de ~100 km à travers le bassin de Wellesley. Malgré l'absence de datations, il est possible de le corréler avec des massifs ultramafiques identiques au nord-ouest en Alaska. Les ophiolites du bassin de Wellesley pourraient donc représenter une klippe du terrane de Slide Mountain reposant sur le terrane de Yukon-Tanana.

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INTRODUCTION

Ophiolites are integral parts of many mountain belts. Their study aids in understanding the assembly of orogens and the history of seafloor spreading in past ocean basins (Moores, 1982; Moores and Jackson, 1974). Ophiolites occur throughout the Cordillera, and have been the subject of many detailed studies in California and Oregon (see Coleman, 2000), but with fewer comprehensive studies to the north in Yukon and Alaska. This contribution describes detailed mapping of gabbros, sheeted dykes, and a large massif of harzburgite tectonite in the Wellesley basin of southwest Yukon, extending investigations from the previous year (Shellnutt et al., 2001).

STUDY AREA

The field area lies just north of Wellesley basin and straddles the Donjek River, 10 km east of its confluence with the White River in southwest Yukon (Fig. 1). The study area is accessed by helicopter from an abandoned airstrip near the village of Snag, the latter reached by a four wheel drive passable road north of the Alaska Highway. Wellesley basin is characterized by low-lying swampy areas giving way to largely vegetated peaks but with good bedrock exposure.

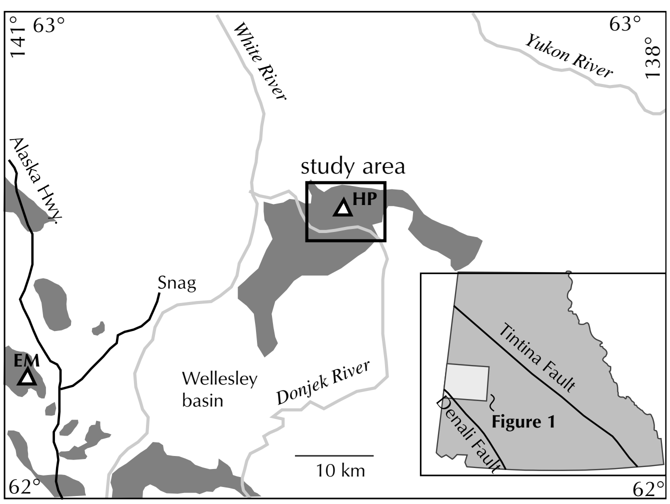

Figure 1. *Location of the study area in southwest Yukon, showing bedrock geology assigned to Windy-McKinley Terrane (shaded, Gordey and Makepeace, 1999). Also shown are the locations of Harzburgite Peak (HP) and Eikland Mountain (EM) referred to in the text.*

Rocks in the area were previously mapped at 1:250 000 scale by Tempelman-Kluit (1974) who recognized isolated bodies of gabbro, harzburgite and "massive and featureless greenstone." Tempelman-Kluit (1974) recognized a spatial association of mafic and ultramafic rocks in the area but his study, being reconnaissance in nature, did not recognize any distinct coherency or stratigraphic relationships between them. Tempelman-Kluit (1976) assigned these mafic and ultramafic rocks a probable Permian-Triassic age, on the basis of correlations to limestones bearing similar ages associated with similar rocks to the southeast near Atlin. This would place at least some of the mafic and ultramafic rocks in southwest Yukon as part of the Cache Creek Terrane (Monger, 1991). Limestones associated with similar mafic and ultramafic rocks, however, also occur to the northwest in Nabesna Quadrangle of Alaska, and contain coral and stromatoporoids of Devonian age (Richter, 1976). This correlation has served in part as the basis for assigning mafic and ultramafic rocks in Wellesley basin to the Windy-McKinley Terrane, an assemblage of early Paleozoic-Cretaceous mélange and gabbro with oceanic affinity (Monger, 1991).

GEOLOGY

In this study, detailed mapping revealed units of gabbronorite and gabbro, a small interval of sheeted dykes, and a large massif of harzburgite tectonite in a sequence southward from granitoids of the Dawson Range (Fig. 2).

GABBRO AND GABBRONORITE

Large and continuous exposures of gabbro and gabbronorite occur south of the contact with granitoids of the Dawson Range batholith. The rock is isotropic and medium- to coarse-grained. Grain size can be patchy and heterogeneous on a metre-scale. The rock contains euhedral plagioclase, with well developed cumulus textures in oikocrysts of ortho- and clinopyroxene. Clinopyroxene has two sets of exsolution lamellae forming a herringbone texture. Also notable are trellis-textured ilmenite and minor apatite. Plagioclase and clinopyroxene are fresh (Fig. 3a). Orthopyroxene has altered to serpentine and chlorite, with only relict cores preserved, that weather a conspicious rusty brown.

SHEETED DYKES

Dykes, 10 cm to 1 m wide, sporadically cross-cut gabbro, and increase in concentration southward to a point where they are difficult to distinguish from fine-grained gabbro or 'greenstone', except for having chilled margin contacts. The dykes are not well exposed or areally extensive. They are dark green on a fresh surface, aphanitic, rarely plagioclase-phyric, and commonly contain millimetre-sized veins and stringers of epidote, quartz and carbonate. In thin section the dykes show subophitic textures. Clinopyroxene is locally fresh, but is more commonly replaced by actinolite and chlorite. Plagioclase is only slightly altered to epidote and chlorite. Minor ilmenite shows skeletal textures and is replaced by leucoxene. Some of the dykes have a mesostasis of former glass, now replaced by chlorite (Fig. 3b). Conspicious blebs of pyrrhotite (<1 mm) are recognized in some dykes.

HARZBURGITE

A 75 km^2 mass of this rock forms Harzburgite Peak (Fig. 1). A second large mass occurs to the southeast, immediately across the Donjek River (Tempelman-Kluit, 1974). This rock is massive and weathers dun brown. Centimetre-scale layering defined by varying olivine/orthopyroxene ratio (Fig. 4a) is observed in places, but is not common throughout the area. Rare metre-long replacive dunite bodies (Kelemen and Dick, 1995) are concordant to layering but pinch out along strike. Olivine is recessive, whereas orthopyroxene (1–2 cm) and spinel (up to 5 mm) weather up to produce a knobby surface.

In thin section the rock is coarse-textured. Olivine (1 to 4 mm) is partially serpentinized, whereas orthopyroxene is fresh in most places, and shows exsolution lamellae of clinopyroxene and well developed kink-banding (Fig. 4b). Spinel occurs as either symplectitic intergrowths within orthopyroxene (Fig. 4c), or as holly-

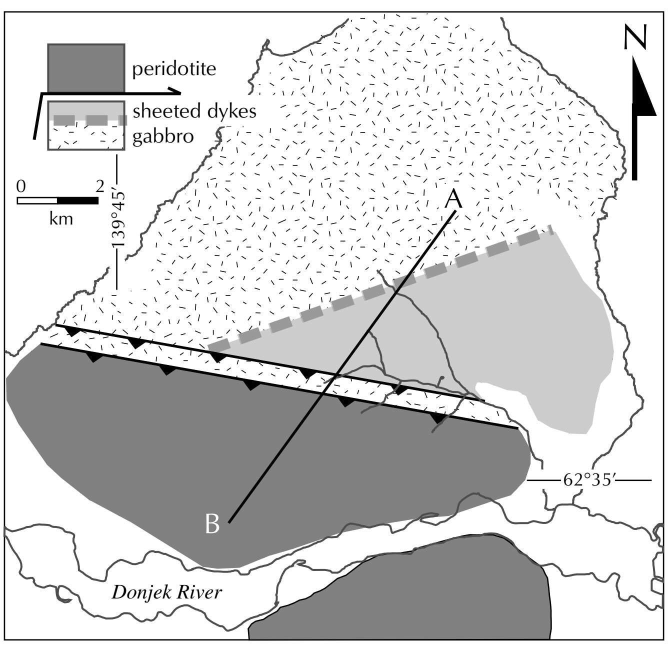

Figure 2. Simplified geological map of study area (location shown in Figure 1). Line A-B indicates the location of a cross-section shown in Figure 6. The gabbro-sheeted dykes contact, indicated by the dashed grey line, is gradational. Triangular teeth point into the hanging wall of thrust faults.

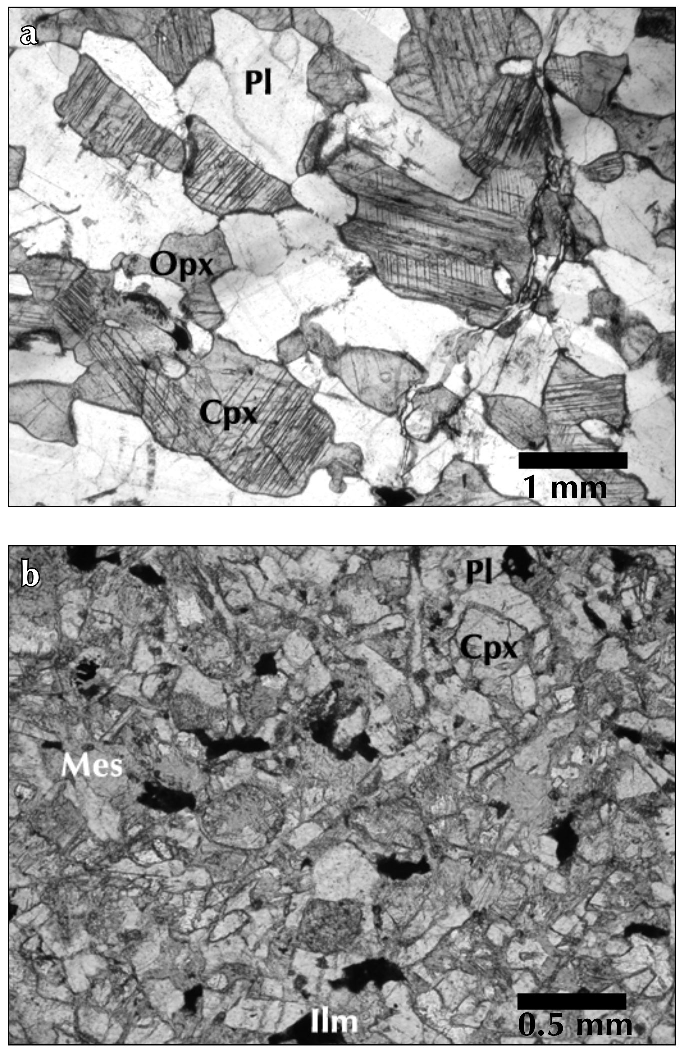

***Figure** 3. Petrographic observations of gabbro and sheeted dykes. **(a)** Photomicrograph in plane-polarized light of gabbro, showing plagioclase (Pl), clinopyroxene (Cpx) and orthopyroxene (Opx). **(b)** Photomicrograph in plane polarized light of sheeted dyke, showing plagioclase (Pl), clinopyroxene (Cpx), ilmenite (Ilm) and a mesostasis of chlorite after glass (Mes).*

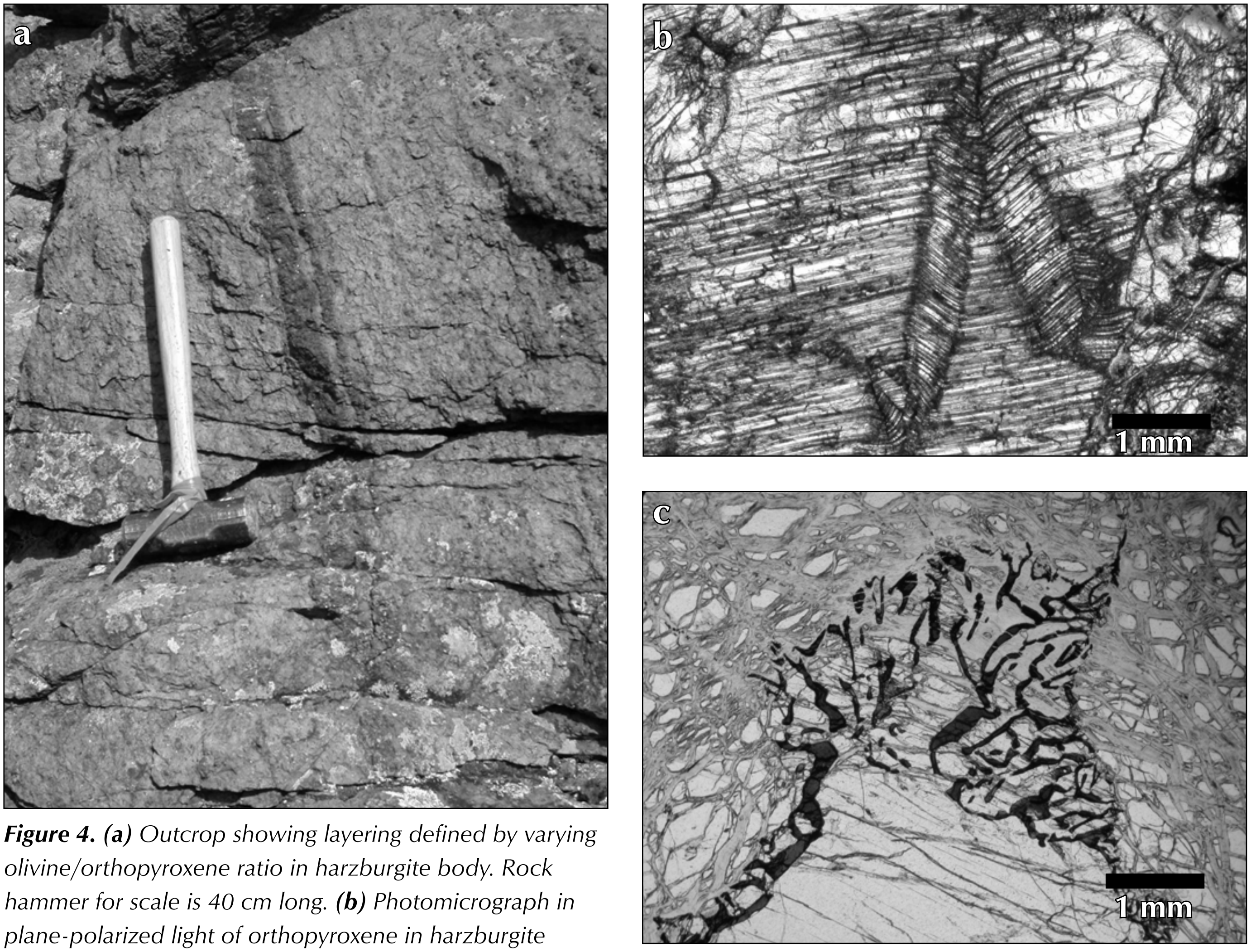

Figure 4. ***(a)*** *Outcrop showing layering defined by varying olivine/orthopyroxene ratio in harzburgite body. Rock hammer for scale is 40 cm long.* ***(b)*** *Photomicrograph in plane-polarized light of orthopyroxene in harzburgite showing well developed kink-banding.* ***(c)*** *Spinel symplectite (dark) intergrown with orthopyroxene in harzburgite. Plane-polarized light.*

leaf textures typical of many mantle tectonites (Mercier and Nicolas, 1975). Clinopyroxene is rare, but where present occurs mainly along grain boundaries with orthopyroxene and spinel. The clinopyroxene content increases to the southwest in the harzburgite body. The degree of serpentinization is patchy on the outcrop scale and mainly concentrated along joint planes.

STRUCTURE

The gabbro and dykes show little internal strain. Primary fabrics and relationships, such as cross-cutting dykes with sharp straight contacts, are well preserved and unstrained. Primary layering (S_1) is evident in the peridotite body and is defined by parallel lensoidal orthopyroxene grains, by more resistant orthopyroxene-rich layers that stand out against the more easily weathered rock, and by recessive partings that appear to be more olivine-rich. Spinel lenticles and thin (<1 cm thick) orthopyroxene porphyroclasts define rare tight to isoclinal, rootless, intrafolial folds with axial surfaces that parallel the primary layering. The layering is better developed to the east. The primary layering defines a steeply east-dipping panel with an average orientation of 031°/58° (strike and dip, right-hand rule for this and subsequently reported orientations of planar structures; Fig. 5). Minor variations in orientation suggest folding about an east-plunging fold axis. The primary layering is interpreted as a record of ductile flow and shearing in the mantle (Nicolas, 1995; Nicolas and Violette, 1982). The tight to isoclinal, intrafolial folds, the presence of lensoidal orthopyroxene grains, and orthopyroxene-rich layering are all consistent with high-temperature ductile flow and recrystallization. These fabrics are commonly developed in mantle tectonites and are attributed to shearing of hot lithosphere (Dick and Sinton, 1979; Nicolas, 1995; Nicolas and Violette, 1982).

A spaced cleavage (S_2) is present throughout the harzburgite body and consists of regularly spaced fissile partings that preferentially weather out. Where closely spaced, the cleavage imparts a flaggy appearance to the rock. Locally, where the rock is well jointed and fissile, the cleavage is irregular and difficult to distinguish from the joint sets. The cleavage strikes parallel to the east-trending ridge that runs through Harzburgite Peak, and dips regularly to the south, with a mean orientation of 096°/71° (Fig. 5). The cleavage parallels the contact with the gabbro and sheeted dykes to the north.

Cleavage (S_2) and primary layering (S_1) intersect in a moderately east-southeast-plunging intersection lineation (L_2; Fig. 5). This east-southeast-plunging line is interpreted as the fold axis about which primary layering was folded. Cleavage is interpreted as being axial planar to these folds and to have developed during F_2 folding. The east-southeast-plunge of F_2 implies that eastward tilting has exposed deeper crustal levels to the west, and shallower levels to the east. The construction of a down-plunge projection shows the geometry of the rock units in profile (Fig. 6).

In profile it is evident that the structurally deepest parts of the peridotite body are exposed to the west in the region characterized by increased clinopyroxene content, indicating presumably more fertile mantle. These observations are consistent with the peridotite body being a steeply tilted section of mantle that shallows upward to the east. Measured perpendicular to the primary layering, which defines an open synform, it is evident that the mantle section at Harzburgite Peak is more than 5 km thick. The preservation of downward-increasing clinopyroxene content and decreasing shear fabrics suggests that this is an intact sheet of mantle that has not been structurally imbricated.

The peridotite body structurally overlies the gabbro and sheeted dyke complex (Figs. 2, 6). The primary layering within the peridotite ends down against, and is truncated by, the contact. Cleavage in the peridotite body parallels the contact. These relationships indicate that folding of the peridotite and related cleavage development occurred

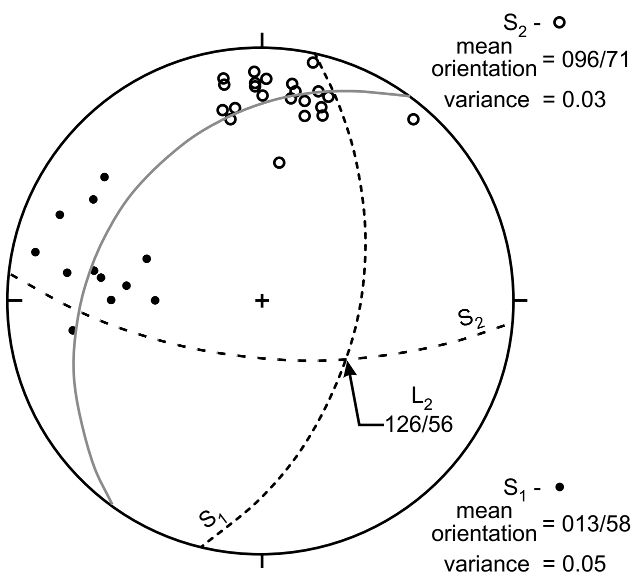

Figure 5. *Stereonet showing orientation data (poles to planar structures) for primary layering (S_1) and cleavage (S_2) in harzburgite tectonite. Mean orientations are given as strike and dip (right-hand rule) and shown as great circles on stereonet (S_1 – tightly dashed line; S_2 – spaced dashed line). The line of intersection (L_2) of S_1 and S_2, indicated by the arrow, is given as trend and plunge. The great circle shown in grey defines the plane perpendicular to the S_1 – S_2 intersection lineation and gives the orientation of the profile plane used in the construction of the cross-section A-B shown in Figure 6.*

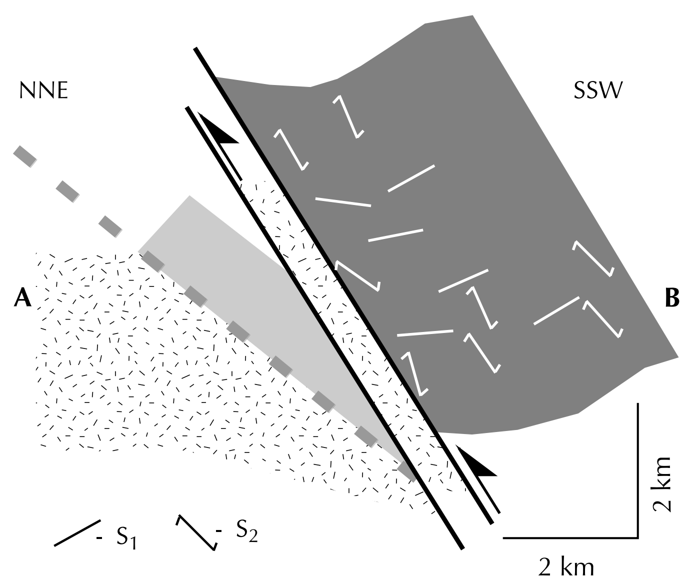

Figure 6. *Cross-section A-B, constructed by projecting surface data down-plunge using the technique described by Johnston (1999). Unit fills are as shown in Figure 2. Projected structural data in the peridotite include cleavage (S_2) and primary layering (S_1).*

in response to faulting of the peridotite body against the gabbro. The geometry of the fault, together with the juxtaposition of structurally deeper mantle in the hanging wall over top of shallower crustal gabbros and dykes in the footwall, suggests that the fault is a thrust fault. The fault cuts up-section through layering in the hanging wall toward the northeast, indicating that fault vergence was to the northeast. The steep orientation of the faults could indicate that they were rotated during movement over ramps in deeper seated thrust faults that would crop out further to the northeast.

DISCUSSION

The distinct spatial association of gabbro and harzburgite tectonite in the map area was recognized earlier by Tempelman-Kluit (1974). The recognition of sheeted dykes spatially associated with gabbro is new and significant for the overall regional interpretation of mafic and ultramafic rocks assigned to the Windy-McKinley Terrane in southwest Yukon. The sequence from north to south of gabbro, sheeted dykes and harzburgite tectonite is convincing evidence that these rocks belong to part of a coherent ophiolite. The location of sheeted dykes between harzburgite and gabbro is out of sequence, but is likely the result of fault imbrication. The mantle section has been thrust northward over the sheeted dykes, along a fault that parallels a foliation striking east-southeast in the harzburgite body (Fig. 6). The areal extent of the harzburgite body, its excellent state of preservation, and 5 km of structural thickness, make this one of the most exceptional mantle sections of ophiolite in Yukon.

Observations in the study area are difficult to extend to the immediate area of Wellesley basin due to poor exposure and only reconnaissance mapping. Regional aeromagnetic surveys of the area (Lowe et al., 1994) are particularly helpful in this regard, however, and coupled with a recent geological compilation (Gordey and Makepeace, 1999) reveal some regionally significant

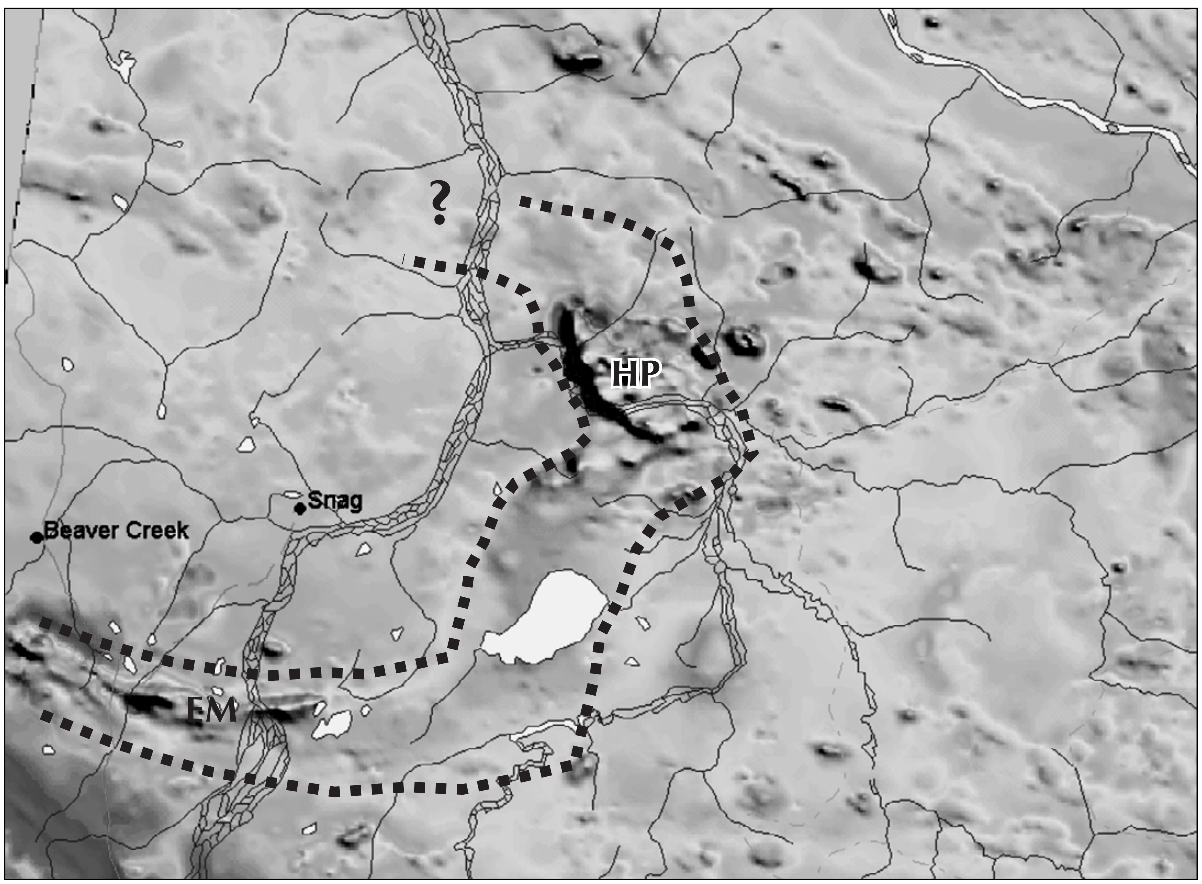

Figure 7. *Aeromagnetic image for southwest Yukon (Gordey and Makepeace, 1999; Lowe et al., 1994). Dashed lines outline an arcuate aeromagnetic anomaly traceable from the study area near Harzburgite Peak (HP) through Wellesley basin to Eikland Mountain (EM).*

correlations. The sequence of ophiolitic rocks observed in the study area surrounding Harzburgite Peak defines a strong magnetic anomaly (Fig. 7), the source of which is likely magnetite produced by serpentinization of the harzburgite. This magnetic anomaly can be traced from Harzburgite Peak along an arcuate pattern in the subsurface of Wellesley basin to Eikland Mountain (Fig. 1, 6), where a strong spatial association of gabbro, harzburgite and "greenstone grading into gabbro" was observed by Tempelman-Kluit (1974). The latter statement is re-interpreted here to represent sheeted dykes spatially associated with gabbro, as observed in this study north of Harzburgite Peak. The arcuate magnetic anomaly is interpreted to define a ~100-km-long ophiolite that constitutes an antiform, plunging gently southeast in a klippe thrust over crystalline rocks of the underlying Yukon-Tanana Terrane.

Unfortunately, there is no age control on mafic and ultramafic rocks in Wellesley basin. Previous work can accommodate many possibilities and interpretations. Mafic and ultramafic rocks in the study area were assigned Devonian ages, based on correlation of an unfossiliferous limestone in Wellesley basin with Devonian-aged corals and stromatoporoids in a limestone hundreds of kilometres away in adjoining Nabesna Quadrangle in Alaska (Richter, 1976). Rock types in the study area and described elsewhere in Wellesley basin, however, bear a remarkable geological and petrographical similarity to several tens of isolated occurrences of ultramafic rocks in the Yukon-Tanana Uplands and along the Salcha River to the northwest in Alaska (Foster and Keith, 1974; Keith et al., 1981; Patton et al., 1994; Shellnutt et al., 2001). The latter show strong and locally coherent associations of harzburgite tectonite with gabbro and greenstone, and show evidence for being overthrust on crystalline rocks of Yukon-Tanana Terrane (Foster et al., 1985).

Ultramafic rocks in the Yukon-Tanana Uplands and Salcha River area have Permian ages, based on fossiliferous limestone and chert associated with greenstones, and have been included in the Salcha-Seventy Mile Terrane, equivalent to Slide Mountain Terrane in Yukon (Foster et al., 1994; Patton et al., 1994). If the correlation is made between these rocks and the ophiolite sequence traceable throughout Wellesley basin, then the latter is likely part of Slide Mountain Terrane, and may be Permian rocks thrust over Yukon-Tanana Terrane, as originally inferred by Tempelman-Kluit (1976). If true, then these and similar rocks need not belong to Windy-McKinley Terrane, which on this basis may require revision and/or abandonment. Future work focusing on the geochronology of gabbro bodies in the study area could test this hypothesis.

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Yukon Targeted Geoscience Initiative, Part 1: Results of accelerated bedrock mapping in Glenlyon (105L/1-7, 11-14) and northeast Carmacks (115I/9,16) areas, central Yukon

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ABSTRACT

The core of Glenlyon and northeastern Carmacks map areas is underlain by a northwest-trending belt of metasedimentary, metavolcanic and (meta)plutonic rocks of the Yukon-Tanana Terrane. It includes two successions of Carboniferous arc volcanic rocks, associated plutonic suites of Mississippian age, Devonian-Mississippian metaclastic rocks, and their basement complex. To the southwest, Yukon-Tanana Terrane is juxtaposed with the Semenof block — a belt of mafic metavolcanic rocks of uncertain terrane affinity — along the Needlerock and Big Salmon faults. To the northeast, the Tummel fault zone delineates the contact between Yukon-Tanana and Cassiar terranes. The narrow belt of chert, argillite and greenstone which occurs within the Tummel fault zone probably correlates with the Slide Mountain Terrane. The area is intruded by Early Jurassic and Cretaceous plutons and is dissected by a series of late faults, which results in approximately 56 km of dextral offset of the Yukon-Tanana Terrane.

RÉSUMÉ

Le coeur des région cartographiques de Glenlyon et de Carmacks nord-est est occupé par une ceinture de roches métasédimentaires, métavolcaniques, et (méta)plutoniques du terrane de Yukon-Tanana, d'orientation nord-ouest. Celle-ci inclue deux successions de roches volcaniques d'îles-en-arc datant du Carbonifère; les suites plutoniques mississippienne qui leur sont assoçiées; des roches métaclastiques du Dévonien-Mississippien; et leur socle rocheux. Au sud-ouest, le terrane de Yukon-Tanana est en contact avec le bloc de Semenof — une ceinture de roches métavolcaniques mafiques dont l'affinité tectonique est inconnue — le long des failles de Needlerock et de Big Salmon. Au nord-est, la zone de faille de Tummel définie le contact entre les terranes de Yukon-Tanana et de Cassiar. L'étroite ceinture de cherts, d'argillites et de roches vertes que l'on retrouve au sein de la zone de faille de Tummel appartient probablement au terrane de Slide Mountain. La région contient aussi des plutons d'âges jurassiques et crétacés. Elle est recoupée par une série de failles tardives qui résulte en un déplacement dextre du terrane de Yukon-Tanana d'environ 56 km.

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INTRODUCTION

Bedrock mapping in Glenlyon map area (105L) was initiated in 1998 to evaluate the possible correlation of Yukon-Tanana Terrane southwest of Tintina Fault with that of massive sulphide-hosting strata in the Finlayson Lake district, northeast of the fault, and to assess the potential of the area for volcanic-hosted massive sulphide deposits. The Glenlyon area lies along regional trend to the south of the Finlayson Lake district when ~425 km of dextral displacement is restored along Tintina Fault (Fig. 1).

Between 1998 and 2001, 1:50 000-scale mapping focused on areas of better exposure in northwest Glenlyon map area (105L/13; Colpron, 1998; 1999a) and near Little Salmon Lake, to the south (105L/1,2,7; Colpron, 2000; Colpron and Reinecke, 2000; Gladwin et al., 2002b). This detailed mapping has defined the stratigraphic framework of Yukon-Tanana Terrane in the area. In particular, it has identified successions of Carboniferous arc volcanic rocks, associated plutonic suites of Mississippian age, and their potential basement complex (Colpron, 2001). This work also uncovered indications that hydrothermal systems capable of producing volcanogenic massive sulphide deposits operated during volcanism, including a small massive sulphide occurrence (Yukon MINFILE 105L 062; Colpron, 1999b) and an occurrence of Mn chert exhalite in the Little Salmon formation.

This detailed work laid the foundation for regional, helicopter-supported bedrock mapping in poorly exposed areas of Glenlyon and northeastern Carmacks map areas during the 2002 summer. This program was conducted in conjunction with a till geochemistry survey of the area (Bond and Plouffe, this volume). The bedrock mapping and till sampling programs constitute the final contribution to the Yukon Targeted Geoscience Initiative, a program of the Geological Survey of Canada which supplemented ongoing mapping projects by the Yukon

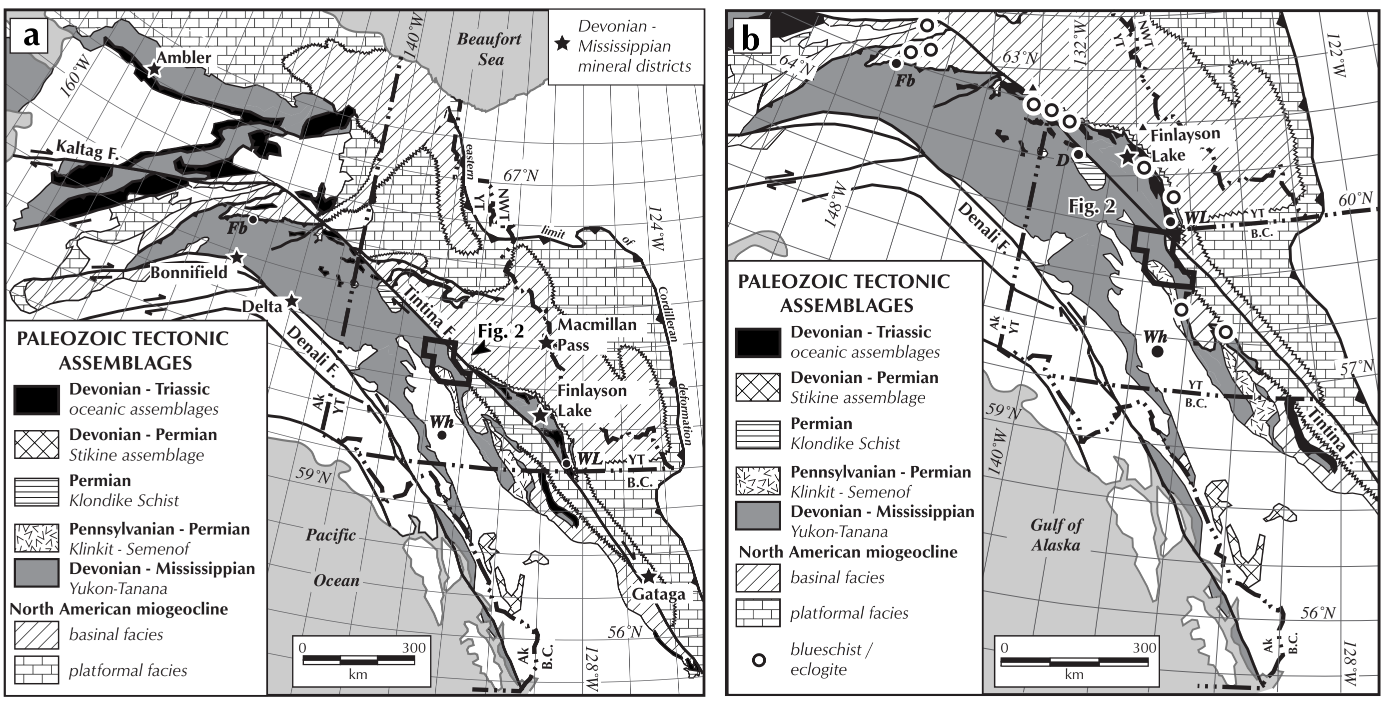


__Figure 1. (a)__ Location of the study area on a map of Paleozoic tectonic assemblages of the northern Cordillera (modified after Wheeler and McFeely, 1991; Silberling et al., 1992; and Foster et al., 1994). __(b)__ Distribution of Paleozoic tectonic assemblages prior to displacement along Tintina Fault. Approximately 425 km of post-Late Cretaceous displacement has been restored along Tintina Fault. In this reconstruction, the study area lies along stike to the south of the Finlayson Lake district. Abbreviations: Ak – Alaska; B.C. – British Columbia; D – Dawson; Fb – Fairbanks; NWT – Northwest Territories; Wh – Whitehorse; WL – Watson Lake; YT – Yukon Territory. Blueschist and eclogite occurrences are from Dusel-Bacon (1994) and Erdmer et al. (1998).

Geology Program and the Geological Survey of Canada undertaken under the auspices of the Ancient Pacific Margin National Mapping (NATMAP) project. This paper presents the results of the accelerated bedrock mapping component of the project. It is companion to the preliminary geological map of Glenlyon and northeast Carmacks areas (Colpron et al., 2002). The result of the till geochemistry survey are presented elsewhere in this volume (Bond and Plouffe, this volume).

The accelerated bedrock mapping program in Glenlyon and northeastern Carmacks areas aimed at determining (1) the regional extent of Carboniferous volcanic rocks of Yukon-Tanana Terrane and their local basement; (2) the nature of the contact between Yukon-Tanana and Cassiar terranes; and, (3) the composition of volcanic rocks at the northern end of the Semenof block (Tempelman-Kluit, 1984) and their relationship to Yukon-Tanana Terrane. In addition, this study provides new insights into the relationship between the Yukon-Tanana Terrane, the enigmatic Semenof block, and rocks of the Stikine Terrane. It also sheds new light on the history of post-accretionary faulting in central Yukon.

BEDROCK GEOLOGY OF GLENLYON AND NORTHEAST CARMACKS AREAS

The study area extends from displaced North American miogeoclinal strata of Cassiar Terrane in the northeast to the accreted arc volcanic and clastic rocks of Stikine Terrane in the southwest (Fig. 2; Colpron et al., 2002). The core of the area is underlain by a northwest-trending belt of metasedimentary, metavolcanic and (meta)plutonic rocks of the Yukon-Tanana Terrane. To the southwest, Yukon-Tanana Terrane is juxtaposed with the Semenof block — a belt of mafic metavolcanic rocks of uncertain terrane affinity (Tempelman-Kluit, 1984) — along the Needlerock and Big Salmon faults (Fig. 2). To the northeast, the Tummel fault zone delineates the contact between Yukon-Tanana and Cassiar terranes. The narrow belt of chert, argillite and greenstone which occurs within the Tummel fault zone probably correlates with the Slide Mountain Terrane. The area is intruded by Early Jurassic and Cretaceous plutons and is dissected by a series of late faults.

CASSIAR TERRANE

Mapping of Cassiar Terrane rocks in 2002 was limited to the west-half of 105L/11 (Colpron et al., 2002). In this area, Cassiar Terrane is underlain primarily by strata of the Silurian-Devonian Askin Group and Devonian-Mississippian Earn Group. The Askin Group is composed of dolostone and limestone, and lesser quartz sandstone. The Earn Group consists of black siliceous slate, quartz-chert greywacke, chert-granule grit and chert-pebble to -cobble conglomerate. North of Pelly River (105L/14), Earn Group strata host the Clear Lake deposit (Yukon MINFILE 105L 045).

Along Tummel River, a few outcrops of grey calcareous slate are attributed to the Cambrian-Ordovician Kechika Group (Colpron et al., 2002). Equivalents of the Kechika and Askin groups that are metamorphosed to amphibolite facies are also present in the southeast portion of the study area (105L/1) and are described in more detail in Gladwin et al. (this volume).

YUKON-TANANA TERRANE

Yukon-Tanana Terrane occupies a 19- to 46-km-wide, northwest-trending belt in the centre of the study area (Fig. 2; Colpron et al., 2002). It includes (Fig. 3): (1) Devonian and older polymetamorphic and polydeformed rocks of the Snowcap complex; (2) Devonian-Mississippian metaclastic rocks of the Drury and Pelmac formations; (3) Carboniferous metavolcanic rocks of the Little Kalzas and Little Salmon formations (and their subvolcanic intrusions); and (4) distal turbidites of the Bearfeed formation.

A number of new stratigraphic terms for Yukon-Tanana Terrane are introduced informally in this report and on the accompanying map (Colpron et al., 2002). These new stratigraphic units will be formally defined in a future bulletin.

SNOWCAP COMPLEX

The Snowcap metamorphic/plutonic complex constitutes the basement upon which Upper Devonian-Carboniferous strata of Yukon-Tanana Terrane were deposited (Fig. 3). It comprises predominantly psammitic schist, quartzite, dark grey carbonaceous schist and calc-silicate rocks which typically have amphibolite-grade metamorphic mineral assemblages (Fig. 4a). Coarse-grained garnet amphibolite and greenstone occur locally.

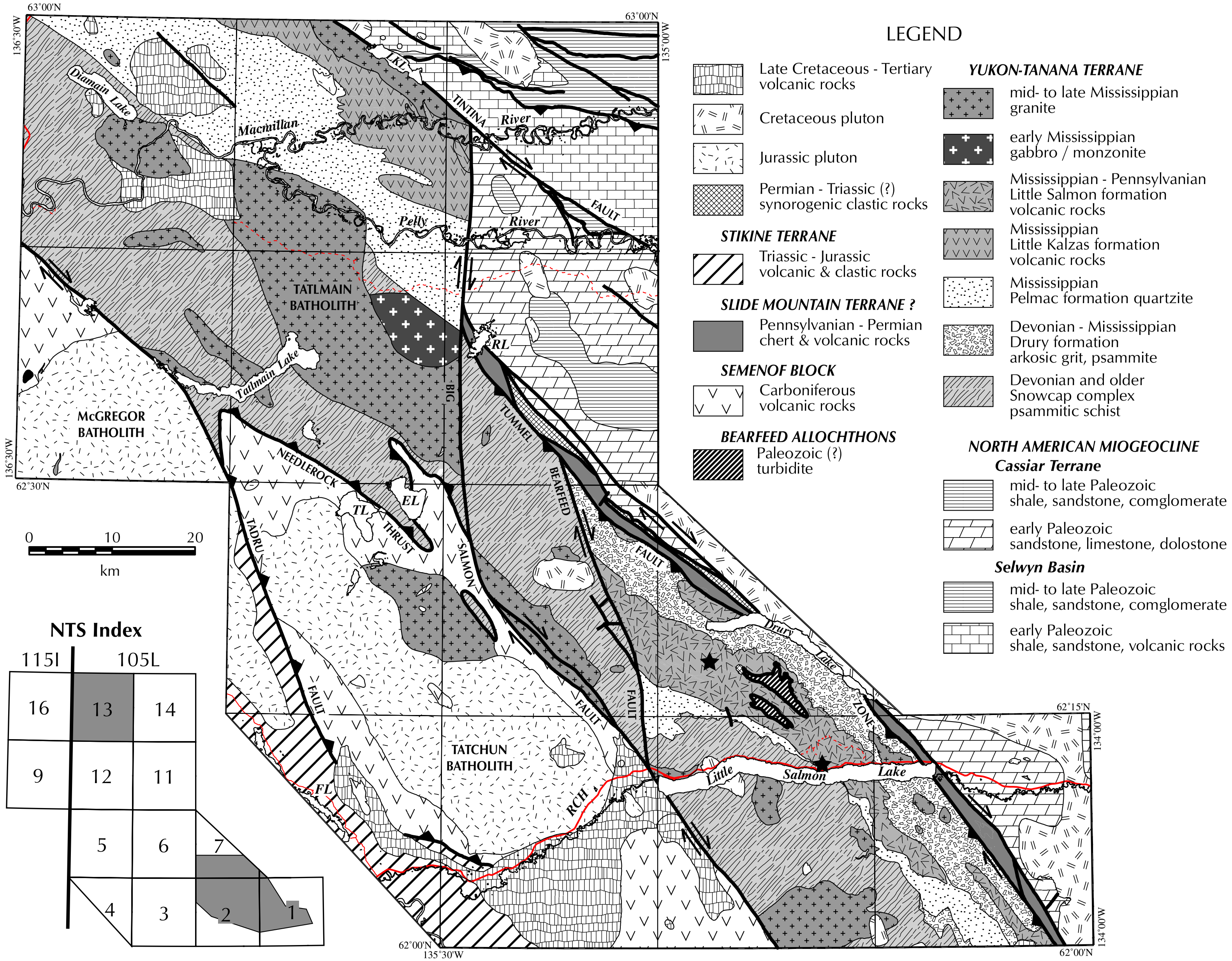


Figure 2. *Simplified geological map of Glenlyon and northwest Carmacks map area (modified after Colpron et al., 2002). Inset at lower left shows index to NTS 1:50 000-scale topographic maps. Grey-shaded areas were the focus of detailed (1:50 000-scale) mapping between 1998 and 2001 (Colpron, 1998; Colpron, 2000; Gladwin et al., 2002a). Star along the shore of Little Salmon Lake indicates the location of a small massive sulphide occurrence at the base of the Little Salmon formation (Yukon MINFILE, 2002, 105L 062). Star south of Drury Lake shows location of Mn chert near the top of the Little Salmon formation. Abbreviations: EL – Ess Lake; FL – Frenchman Lake; LKL – Little Kalzas Lake; RCH – Robert Campbell Highway; RL – Ragged Lake; TL – Tadru Lake.*

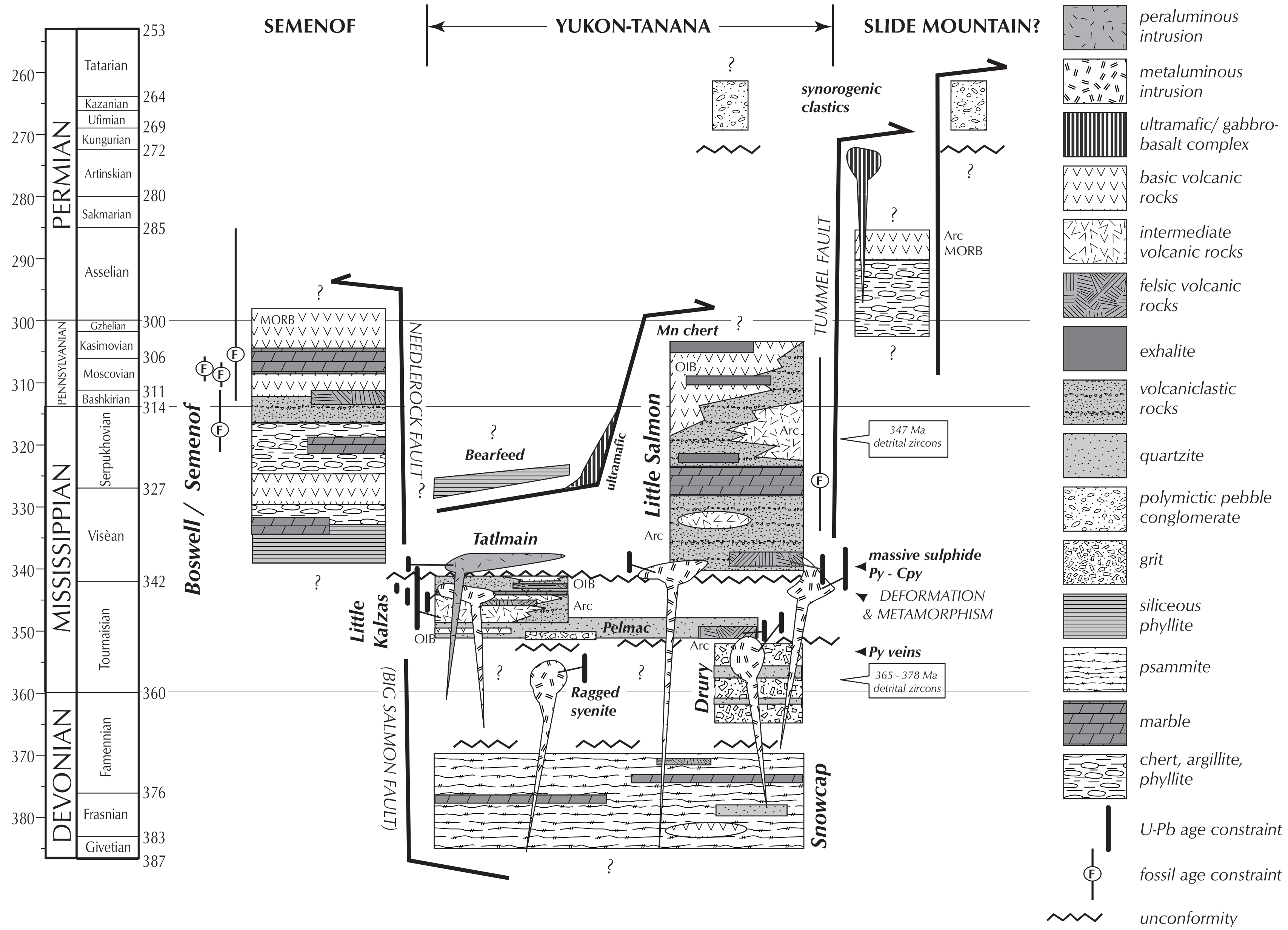
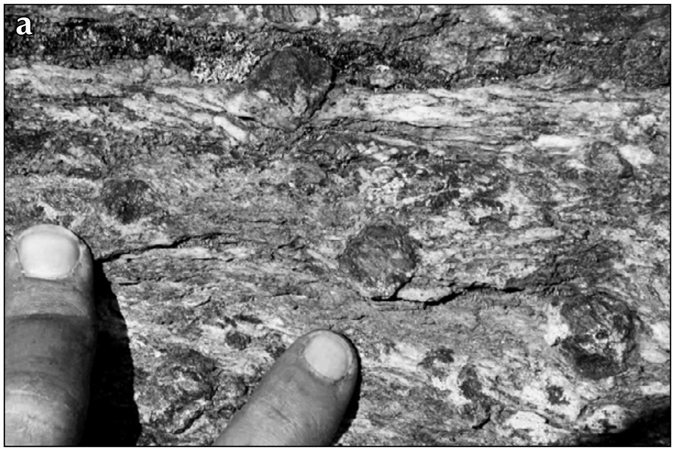
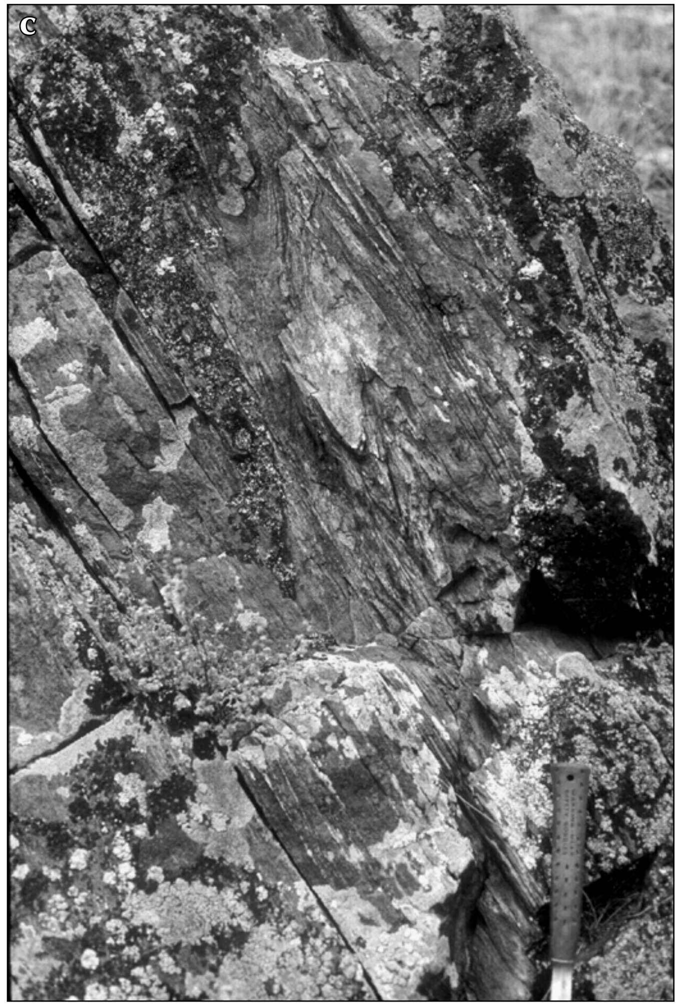


Figure 3. *Stratigraphic relations of Yukon-Tanana and affiliated terranes in Glenlyon and northeast Carmacks areas. Petrogenetic affinity of volcanic rocks: Arc = volcanic arc basalt/andesite ; MORB = mid-ocean ridge basalt; OIB = ocean-island basalt (alkalic). Time scale of Okulitch (2002). SMT? – Slide Mountain Terrane; Py – pyrite; Cpy – chalcopyrite.*

They are most common near Little Salmon Lake (105L/2; Colpron, 2000; Colpron et al., 2002) where they are locally intercalated with dolomitic marble. Amphibolite and greenstone have the geochemical characteristics of enriched mid-ocean ridge basalts (E-MORB) to transitional within-plate tholeiites (OIB; Colpron, unpublished data).

Marble locally defines good marker horizons that can be followed for tens of kilometres, such as near Little Salmon Lake (105L/2) and north of Tatlmain Lake (105L/12, 115I/9,16; Colpron et al., 2002). These occur with different lithologic associations and at different structural levels, suggesting that a number of carbonate intervals are present within the complex, rather than a single repeated





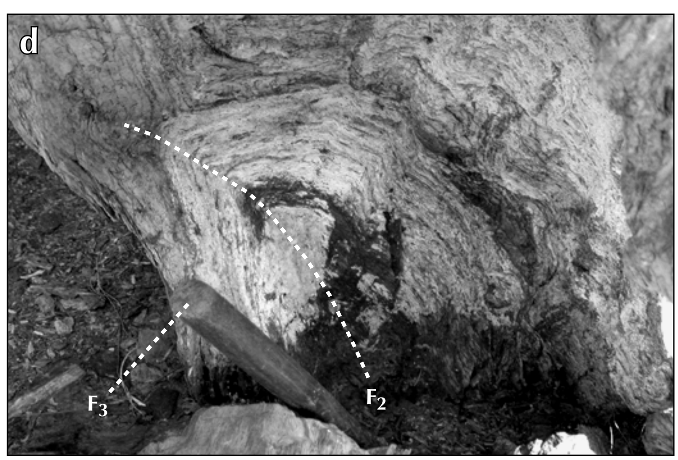


Figure 4. ***(a)*** *Garnet porphyroblasts in quartz-muscovite-actinolite schist, Snowcap complex south of Ragged Lake (105L/11). The garnets are late tectonic with respect to the foliation and partially retrograded to chlorite (dark rims).* ***(b)*** *Actinolite porphyroblasts in muscovite-quartz-feldspar schist (felsic metavolcanic ?) of the upper part of the Snowcap complex, south of Ragged Lake (105L/11).* ***(c)*** *Intrafolial isoclinal folds in metatonalite of the Snowcap complex, north of Tatlmain Lake (115I/9).* ***(d)*** *Polyphase deformation in psammitic schist of the Snowcap complex, south of Ragged Lake (105L/11). The dominant foliation is deformed by isoclinal folds (F_2, axial plane indicated by dashed line). Both dominant foliation and isoclinal folds are deformed by a younger set of open folds (F_3, axial plane indicated by dashed line).*

unit. At Little Salmon Lake, marble passes laterally into a polymictic pebble to boulder conglomerate (Colpron and Reinecke, 2000).

Distinctive muscovite-amphibole schist occurs locally near the top of the Snowcap complex. This rock is characterized by the presence of large green amphibole rosettes randomly oriented along the dominant foliation in cream-coloured muscovite schist (Fig. 4b). This unit may represent a metavolcanic horizon of intermediate to felsic composition. It is locally pyrite-banded and commonly associated with a light green muscovite-chlorite calcareous schist that contains abundant albite porphyroblasts.

Metasedimentary rocks of the Snowcap complex are intruded by numerous bodies of tonalite, granodiorite and granite, which are typically strongly foliated and lineated (Fig. 4c). These intrusive bodies are for the most part undated and may be coeval with Mississippian plutonic suites described below. South of Little Salmon Lake (105L/2; Fig. 2), plutons of the Little Salmon and Telegraph plutonic suites (338-340 Ma and 348-349 Ma, respectively; J.K. Mortensen, pers. comm., 2002) intrude the Snowcap complex. The Snowcap complex is unconformably overlain by Upper Devonian-Lower Mississippian strata of the Drury and Pelmac formations. It is therefore constrained as Late Devonian or older.

Rocks of the Snowcap complex have experienced a more complex deformational and metamorphic history than overlying Carboniferous strata. Psammitic and pelitic rocks of the Snowcap complex typically have garnet-grade metamorphic mineral assemblages and record multiple metamorphic events. Syn-tectonic garnet porphyroblasts are commonly partially to completely retrograded to chlorite. Rectangular aggregates of muscovite are likely pseudomorphs after an aluminosilicate phase (kyanite?; Colpron and Reinecke, 2000). Dominant, tight to isoclinal folds typically deform an earlier foliation (Fig. 4d).

RAGGED PLUTON

A body of coarse-grained augite gabbro and K-feldspar porphyritic syenite is inferred to intrude deformed rocks of the Snowcap complex west of Ragged Lake (105L/12; Colpron et al., 2002). The intrusive rock is unfoliated and intruded by granite of the adjacent Tatlmain Batholith. The Ragged pluton has yielded a preliminary Early Mississippian U/Pb zircon age (ca. 357 Ma; J.K. Mortensen, pers. comm., 2001). It is the oldest plutonic rock in the study area and predates all volcanic rocks in the area.

Figure 5. (a) *Coarse-grained arkosic grit of the Drury formation, along Robert Campbell Highway (105L/1). White grains are coarse, angular feldspar clasts. Hammer pick at top of photo for scale. Field of view is approximately 25 cm.* ***(b)*** *Well bedded quartzite of the Pelmac formation, north of Macmillan River (105L/13).*

DRURY FORMATION

The Drury formation consists predominantly of coarse-grained arkosic grit with up to 20% angular feldspar granules (Fig. 5a), grey and light green quartzite, psammitic schist, and green and grey phyllite. Recessive, dark grey, carbonaceous phyllite is likely an important constituent of the Drury formation. South of Little Salmon Lake, the Drury formation also includes calcareous phyllite and marble (Gladwin et al., this volume). Marble lenses are also locally present north of Little Salmon Lake. Detrital zircons from two samples of arkosic grit have yielded Late Devonian U/Pb ages exclusively (G. Gehrels, pers. comm., 2002). The Drury formation is intruded by granodiorite plutons of the 348-349 Ma Telegraph plutonic suite and is overlain by ca. 350 Ma metavolcanic rocks of the Lokken member of the Pelmac formation along the southeastern margin of the study area (105L/1). The Drury formation is therefore constrained as Upper Devonian to Early Mississippian.

PELMAC FORMATION

The Pelmac formation consists predominantly of massive to well bedded orthoquartzite (Fig. 5b). It is an extensive map unit in the northern part of the area, where more than 3 km of quartzite underlies volcanic rocks of the Little Kalzas formation (Fig. 2). To the south, the Pelmac quartzite has an average thickness of 400-600 m, but is only 10 m thick at Little Salmon Lake. It unconformably overlies the Snowcap complex and Drury formation, and is unconformably overlain by the Little Salmon formation. The quartzite commonly displays white to medium grey wispy banding. It is progressively more micaceous up-section, where it is locally intercalated with dark grey phyllite and dolomitic marble.

Near Pelly River, the quartzite is inferred to pass laterally into coarse-grained dolomitic grit and beige-weathering, medium to dark grey quartz-muscovite-dolomite schist (Colpron, 1998; Colpron et al., 2002). Dark grey dolomitic quartzite and minor light green quartz-muscovite-chlorite-dolomite (± biotite) schist are also intercalated with the grit and beige dolomitic schist that dominate this member of the Pelmac formation. The ubiquitous presence of dolomite distinguishes this unit from other parts of the Pelmac formation in the area. Along the banks of Pelly River, the dolomitic grit unit contains quartzite-pebble to -cobble conglomerate and minor carbonaceous phyllite.

Volcanic members

Bimodal metavolcanic and metavolcaniclastic rocks are locally associated with the Pelmac formation. In the southeastern part of the study area (105L/1), the Pelmac formation is underlain by quartz-feldspar porphyry, light green volcaniclastic rocks and minor mafic volcanic rocks (Lokken member; Gladwin et al., this volume). The quartz-feldspar porphyry yielded a preliminary U/Pb zircon age of ca. 350 Ma (J.K. Mortensen, pers. comm., 2002), which provides an upper age limit for the Pelmac formation. A sample of metabasalt has the geochemical characteristics of enriched mid-ocean ridge basalts (E-MORB; Colpron, unpublished data).

In the north (105L/13), volcanic rocks occur within the Pelmac quartzite. They consist predominantly of light green volcaniclastic sandstone and arkosic grit. Mafic volcanic (flow?) rocks are restricted to a few exposures within the volcaniclastic unit. They have trace element geochemical characteristics of within-plate alkali basalt (OIB; Colpron, 2001).

LITTLE KALZAS FORMATION

Metavolcanic and metavolcaniclastic rocks of the Little Kalzas formation form a northwest-trending belt in the northeast half of Little Kalzas Lake map area (105L/13; Fig. 2). The volcanic rocks are divided by a marble horizon into a lower and an upper unit (Colpron, 1998; 1999a). Below the marble, the volcanic succession consists predominantly of massive, plagioclase-phyric andesite and minor rhyolite. The andesite passes both upward and laterally to the southeast into a sequence of volcaniclastic rocks which is dominated by light green epiclastic sandstone and argillite. South of Macmillan River, epiclastic and tuffaceous rocks comprise the bulk of the lower unit. Outcrops of massive andesite occur sporadically within the volcaniclastic rocks.

Marble of the Little Kalzas formation forms a relatively continuous band of exposures in the northern part of Glenlyon map area (105L/13; Colpron et al., 2002). The marble varies in thickness from a few tens of metres to several hundred metres. South of Macmillan River, and at the northern edge of the map area, the marble forms large massifs which are likely the result of structural thickening. Marble also occupies a synclinal keel near Pelly River. There it passes laterally to the southeast into light green to grey chert. Marble of the Little Kalzas formation yielded Early(?) Carboniferous conodonts (M.J. Orchard, pers. comm., 1999).

Above the marble, the Little Kalzas formation consists of a mixture of metasedimentary and metavolcanic rocks (Colpron, 1999a). Carbonaceous phyllite and quartzite are dominant north of Macmillan River. Plagioclase-phyric andesite occurs only locally north of Macmillan River, and a rhyolitic tuff is exposed on the south-facing slope above the river. South of the river, light green epiclastic argillite, sandstone and grit make up the bulk of the upper unit. The sequence is capped by a dolomitic quartzite. Massive basalt outcrops are restricted to a small creek to the southwest of the dolomitic quartzite exposures.

Andesites of the Little Kalzas formation have calc-alkaline geochemistry typical of arc environments (Colpron, 2001). Basaltic rocks have the geochemical characteristics of alkali basalt of within-plate affinity (OIB, Colpron, 2001). Rhyolites have yielded preliminary U/Pb zircon ages of 345-346 Ma and show Proterozoic inheritance (J.K. Mortensen, pers. comm., 1999).

Little Kalzas and Telegraph plutonic suites

Granitoids of the Little Kalzas plutonic suite are broadly coeval with volcanic rocks of the Little Kalzas formation (343-346 Ma, Colpron et al., 2000) and are likely their subvolcanic equivalent. They occur as a large intrusive complex and small plutons southwest of Little Kalzas Lake (105L/13; Fig. 2). The dominant phase of the Little Kalzas suite consists of a fine- to medium-grained biotite (± hornblende) diorite, which is locally intruded by a granitic phase. Along Macmillan River, the Little Kalzas suite occurs as a sill complex of K-feldspar megacrystic granite. These rocks are strongly foliated and locally contain abundant xenoliths of country rocks.

South of Little Salmon Lake, foliated, hornblende-biotite quartz diorite to granodiorite plutons of the Telegraph suite intrude metasedimentary rocks of the Drury and Pelmac formations, as well as the Snowcap complex (NTS 105L/1,2; Colpron et al., 2002; Gladwin et al., this volume). These rocks yielded preliminary U/Pb zircon ages of 348-349 Ma (J.K. Mortensen, pers. comm., 2002).

LITTLE SALMON FORMATION

The Little Salmon formation is exposed in a 4- to 8-km-wide belt which extends northwesterly for approximately 50 km from south of Little Salmon Lake to northwest of Drury Lake, where it is truncated by the Bearfeed Fault (Fig. 2). It occupies a broad synclinorium and rests unconformably on arkosic grit and quartzite of the Drury formation, to the northeast, and on quartzite of the Pelmac formation to the southwest (Colpron, 2000). Near Little Salmon Lake, a quartzite-pebble to -boulder conglomerate locally marks the base of the Little Salmon formation (Gladwin et al., this volume).

The Little Salmon formation is dominated by volcaniclastic rocks (both epiclastic and tuffaceous; Colpron and Reinecke, 2000). A prominent marble unit of Late Mississippian-Early Pennsylvanian age (E.W. Bamber, *in:* Colpron and Reinecke, 2000) occurs in the lower part of the Little Salmon formation (Fig. 3). Dacite and quartz-feldspar porphyry mark the base of the sequence near Little Salmon Lake, along the western flank of the synclinorium. A small sulphide occurrence is present at the base of the felsic volcanic unit (Yukon MINFILE, 2002, 105L 062; Colpron, 1999b). Zircons from the quartz-feldspar porphyry yielded a U-Pb age of ca. 340 Ma and show Proterozoic inheritance (Colpron et al., 2000).

Volcanic rocks of intermediate composition (with subordinate mafic and felsic phases) form prominent exposures on the south-facing slopes overlooking Little Salmon Lake. These rocks are generally massive; pillow structures were observed at only one locality. Intermediate volcanic rocks grade laterally into tuffaceous rocks and epiclastic phyllite and sandstone. Along strike to the northwest, they occur as isolated lenses within the volcaniclastic rocks. These intermediate volcanic rocks have the geochemical character of calc-alkaline volcanic rocks of arc affinity.

South of Drury Lake (105L/7), the basal part of the Little Salmon formation locally contains a K-feldspar-crystal grit and granule conglomerate which yielded a concordant U/Pb zircon age of ca. 347 Ma (Mortensen, pers. comm., 2000). Similar rocks are also found south of Macmillan River (105L/14) where they occur near K-feldspar megacrystic granite of the Little Kalzas suite which is a likely source for the immature grits in the Little Salmon formation.

A distinctive plagioclase-phyric volcanic unit of intermediate composition is ubiquitous above the marble in the northwestern exposures of the Little Salmon formation. It contains up to 40-50% coarse (up to 3 cm), subhedral to euhedral plagioclase crystals in a fine-grained chloritic matrix. The abundance and large size of the plagioclase crystals suggest that these rocks may represent high-level subvolcanic intrusions. However, fine intercalations of dolostone and epiclastic sandstone with the crystal-rich volcanic rocks indicate that at least part of this unit has an extrusive origin.

Between Bearfeed Creek and Drury Lake, the Little Salmon formation contains a higher proportion of mafic flows and agglomerates than volcaniclastic rocks (Colpron, 2001; Colpron et al., 2002). Plagioclase- and hornblende-phyric basalts are dominant lithologies. The basalts commonly display well preserved pillow structures. Fragmental units, including pillow breccias and mass-flow deposits (poorly sorted, polymictic breccia with sericitic and/or hematitic matrix), are common adjacent to basaltic flow units. The basalts are intercalated with lapilli tuffs and reworked volcaniclastic rocks. Basaltic rocks of the

Little Salmon formation have subalkaline to alkaline affinities typical of rift environments (Colpron, 2001).

Two cherty horizons (1-10 m) occur in the upper part of the Little Salmon formation south of Drury Lake (Colpron et al., 2002). These siliceous rocks can be traced for up to 4 km along strike (Colpron, 2000). They were originally mapped as rhyolite on account of their very fine grain size and massive appearance (Colpron, 2000). However, their high silica (80-95% SiO_2), low potassium (<0.25% K_2O), and low zirconium (<50 ppm Zr) contents do not reflect a rhyolitic composition (Colpron, unpublished data). The lower horizon is light grey to light green and commonly contains brown-weathering dolomitic pods. Adjacent basalt exposures also contain dolomitic pods. The upper siliceous horizon is light grey, purple and pink, and is gradationally overlain by a 50-cm-thick red piemontite (Mn-rich epidote) chert horizon. This horizon is interpreted as an exhalative unit.

Tatlmain Batholith

The Tatlmain Batholith and Little Salmon plutonic suite comprise the sub-volcanic equivalent of the Little Salmon formation. The post-tectonic Tatlmain Batholith intrudes deformed Early Mississippian strata of Yukon-Tanana Terrane in northwest Glenlyon map area (Fig. 2). Tatlmain Batholith is an undeformed, homogeneous, coarse-grained biotite (± hornblende) quartz diorite to granite over its entire area. It intrudes the Snowcap complex and the Ragged pluton, and imposes a metamorphic aureole on quartzite and calc-silicate rocks of the Pelmac formation south of Pelly River. Near Diamain Lake, the coarse-grained granite contains xenoliths of foliated, fine-grained granodiorite similar to the main phase of the 343-346 Ma Little Kalzas plutonic suite. The Tatlmain Batholith is likely comagmatic with dacites of the Little Salmon formation (Colpron, 2001). A Late Triassic-Early Jurassic age was assigned to Tatlmain Batholith based on biotite K-Ar cooling dates in Carmacks map area (Stevens et al., 1982; Tempelman-Kluit, 1984). Preliminary U-Pb zircon age data indicate a mid-Mississippian age (ca. 340 Ma, Colpron et al., 2000).

Little Salmon plutonic suite

Near Little Salmon Lake, units underlying the Little Salmon formation (Drury and Pelmac formations and Snowcap complex) are intruded by plutons which have preliminary U/Pb ages similar to that of Tatlmain Batholith (J.K. Mortensen, pers. comm., 2000). These intrusions are included in the Little Salmon plutonic suite.

At the east end of Little Salmon Lake, a granodiorite pluton intrudes the Drury formation (Colpron, 2000). Zircons from this pluton yielded a discordant U-Pb age of 353 ± 1.4 Ma (Oliver and Mortensen, 1998). Preliminary results on another sample from this pluton suggest that its age may be younger (ca. 340 Ma; J.K. Mortensen, pers. comm., 2000). The Drury pluton consists of variably foliated, homogeneous, fine- to medium-grained, equigranular biotite ± hornblende granodiorite. Farther west, near the centre of Little Salmon Lake (Fig. 2), a large body of quartz diorite to granodiorite intrudes the Snowcap complex. The rock is moderately to strongly foliated, fine- to medium-grained, and contains hornblende and, locally, biotite. Muscovite is a common constituent of this rock; it probably formed as a result of low-grade metamorphism of original K-feldspar in the granodiorite. Small skarn occurrences are locally developed in calcareous rocks near the contact with plutons of the Little Salmon suite.

BEARFEED FORMATION

The Little Salmon formation is structurally overlain by an allochthonous sheet of distinct dark grey siliceous phyllite and light grey graded sandstone of the Bearfeed formation, which represents a distal turbidite sequence. It locally contains dark grey marble and carbonate-cobble conglomerate. Rocks of the Bearfeed formation may correlate with the basal part of the Boswell formation of Tempelman-Kluit (1984). The base of the Bearfeed allochthon is marked by sheared serpentinite and mylonitic fabric in the underlying Little Salmon formation south of Drury Lake (105L/7, Colpron, 2000).

SEMENOF BLOCK

Rocks of the Semenof block were first mapped by Tempelman-Kluit (1984) in Laberge map area (105E), south of the Glenlyon area. Tempelman-Kluit (1984; and *in:* Gordey et al., 1991) has informally subdivided rocks of the Semenof block into a lower sedimentary formation (Boswell formation) and an upper volcanic formation (Semenof formation; Fig. 3). Carbonates from both formations in Laberge map area have yielded conodonts and fusulinids of early to middle Pennsylvanian age (Tempelman-Kluit, 1984; Poulton et al., 1999). The terrane affinity of the Semenof block remains uncertain. Wheeler et al. (1991) and Tempelman-Kluit (*In:* Gabrielse, 1991) included rocks of the Semenof block in Slide Mountain Terrane. Gordey and Makepeace (1999) considered rocks of the Semenof block as part of the Klinkit subterrane — a probable northern equivalent of Harper Ranch subterrane, the Paleozoic basement of the Quesnel Terrane in British Columbia — because the absence of ultramafic bodies and abundance of siliciclastic rocks is atypical of the Slide Mountain Terrane. More recently, Colpron and Yukon-Tanana Working Group (2001) have raised the possibility that Semenof block may be part of Yukon-Tanana Terrane. An ongoing study of the Semenof block in Laberge map area will likely resolve this problem (see Simard and Devine, this volume).

In Glenlyon map area, the Semenof block consists primarily of mafic (meta)volcanic and subordinate carbonate rocks (Colpron et al., 2002), which are likely correlative with the Semenof formation of Tempelman-Kluit (1984). Rocks of the Semenof formation are variably deformed and metamorphosed in the area. Near Frenchman Lake, the Semenof formation consists of foliated basalt, greywacke and volcanic-lithic sandstone, minor recrystallized limestone and pink feldspar-phyric dacite and dacite breccia (Fig. 6a). This volcanic sequence is underlain by dark grey siltstone and siliceous argillite, chert-pebble to -boulder conglomerate and a thick, continuous limestone, which are likely equivalent to the Boswell formation of Tempelman-Kluit (1984). In this region the Semenof block is juxtaposed with rocks of the Whitehorse Trough (Stikine Terrane) along the Tadru Fault (Fig. 2; Colpron et al., 2002). In the south-central part of the area (105L/2-3; Fig. 2), the Semenof formation consists of undeformed basalt and plagioclase-phyric diorite metamorphosed to chlorite grade (greenschist facies). In one outcrop southwest of Little Salmon Lake, basaltic and dioritic phases show evidence of magma mingling (Fig. 6b).

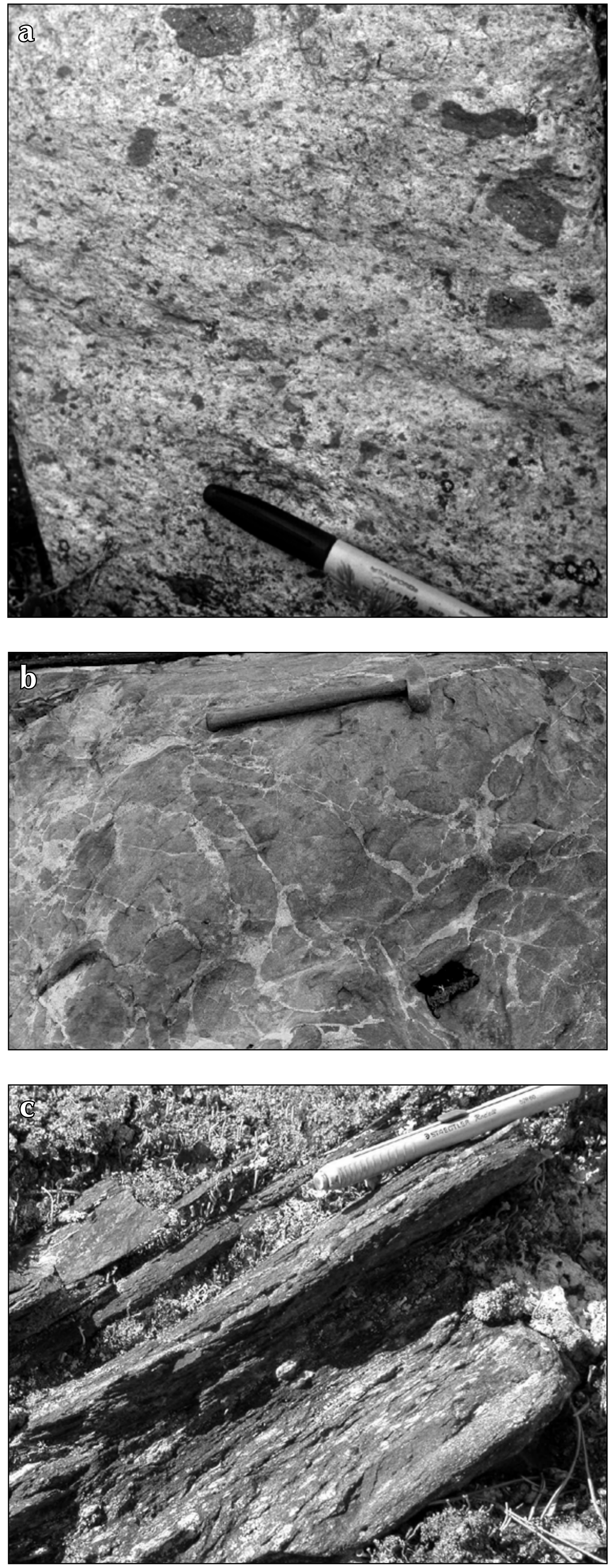


Figure 6. (a) *Dacite welded tuff with large maroon clasts, Semenof formation east of Frenchman Lake (105L/4).* ***(b)*** *Basalt (darker grey) intruded by fine- to medium-grained diorite, Semenof formation south of Robert Campbell Highway (105L/3). Contacts between the two phases are rounded and irregular. Relationships at this outcrop indicate that both basaltic and dioritic phases are coeval. Note that rocks are undeformed at this outcrop.* ***(c)*** *Feldspar-augen amphibolitic greenstone, Semenof formation east of Tatchun Batholith (105L/6). This rock is associated with fine-grained chlorite schist (metabasalt) which has the same composition as basalt in Figure 6b.*

Farther north, along the Bearfeed valley, between the Tatchun Batholith and the Big Salmon Fault (105L/6), the Semenof formation consists of strongly foliated, biotite-actinolite-grade, fine-grained to plagioclase-augen greenstone (Fig. 6c). Near Tadru Lake (105L/5,12), it is a strongly foliated and lineated, medium-grained (garnet) amphibolite intercalated with abundant white marble. Amphibolite, foliated diorite and ultramafic intrusions that are exposed west of Tatlmain Lake (north of McGregor Batholith; Fig. 2; Colpron et al., 2002) are likely part of Semenof block east of the Tadru Fault.

In a poorly exposed area south of Tadru Lake, the Semenof formation is apparently intruded by a strongly foliated hornblende tonalite to granodiorite which resembles plutonic rocks in the Snowcap complex to the east (Fig. 2; Colpron et al., 2002). This supports the notion that Semenof block and Yukon-Tanana Terrane may be genetically linked.

Rocks of the Snowcap complex are thrust onto the Semenof block along the Needlerock Fault, a folded thrust fault which marks the northern termination of the Semenof block between Tadru and Tatlmain lakes.

ROCKS OF THE TUMMEL FAULT ZONE

The Tummel fault zone is a 3- to 4-km-wide belt of imbricate fault slices extending from Ragged Lake to the southeast corner of the Glenlyon map area (Fig. 2; Colpron et al., 2002). It marks the contact between Yukon-Tanana and Cassiar terranes (see also Gladwin et al., this volume). Successive fault slices within the Tummel fault zone contain, from southwest to northeast, (1) chert, argillite and basalt correlated with Slide Mountain Terrane; (2) synorogenic polymictic conglomerate and wacke; and (3) miogeoclinal slate and carbonate of Cassiar Terrane (Fig. 2; Colpron et al., 2002).

CHERT-ARGILLITE-BASALT

The narrow belt of chert, argillite and basalt within the Tummel fault zone (Fig. 2) resemble rocks of the Pennsylvanian-Early Permian Campbell Range succession in the Finlayson Lake district, northeast of the Tintina Fault (Murphy et al., 2001; 2002). This belt comprises an association of chert, basalt, gabbro and serpentinite, which may represent a thin sliver of the Slide Mountain Terrane.

The chert is typically varicoloured (red, purple, pale green, and greenish-grey) and massive to thinly bedded, and weathers pale grey to tan. It is commonly interbedded with grey, red and black argillite. Chert and argillite make up the bulk of this belt north of Drury Lake (Colpron et al., 2002).

A unit of dark green, unfoliated basalt within the chert/argillite sequence shows flow breccia textures and altered glassy clast rims (Fig. 7a), typical of Sylvester Group basalts (Slide Mountain Terrane) in northern British Columbia (Nelson and Bradford, 1993).

Basalt is more extensive south of Little Salmon Lake where it is greenish-grey and variably foliated (see Gladwin et al., this volume). The basalt is locally intruded by medium- to coarse-grained hornblende leucogabbro. Serpentinite is also found locally within the basalt; it is commonly spatially associated with the leucogabbro (Gladwin et al., 2002a).

SYNOROGENIC CLASTIC ROCKS

North of Drury Lake (105L/6,7,11), fault slices northeast of the chert-argillite-basalt belt contain (1) polymictic pebble conglomerate; (2) light green, fine-grained arkosic sandstone; and (3) brown-weathering, black siliceous phyllite (Colpron et al., 2002). A similar polymictic pebble to cobble conglomerate and minor white and black quartzite also occur beneath the northeastern klippe of the Bearfeed allochthons (Colpron et al., 2002).

The conglomerate contains angular clasts of quartzite, black phyllite, greenstone, chert, and serpentinite supported by a light grey to light green fine-grained sandstone matrix (Fig. 7b). These clast compositions match closely with lithologies mapped in nearby exposures and, together with the angular shape of the clasts, suggest a proximal source for the conglomerate. In addition, a number of clasts are foliated, indicating that source rocks were deformed prior to deposition of the conglomerate. Black siliceous phyllite and arkosic sandstone are the dominant lithologies on a small hill southeast of Ragged Lake. The sandstone appears to contain detrital muscovite grains.

The polymictic conglomerate and arkosic sandstone are interpreted to be synorogenic clastic rocks that were deposited at the toe of advancing thrust sheets. The conglomerate resembles Permian-Triassic polymictic conglomerates that occur at the northeastern edge of Yukon-Tanana Terrane in Finlayson Lake and Watson Lake areas (Murphy et al., 2001; 2002; J.K. Mortensen, pers. comm., 2000). Occurrences of synorogenic polymictic conglomerate and sandstone both within the Tummel fault zone and beneath the Bearfeed allochthon suggest that thrust faulting was synchronous in both regions and, by correlation with the Finlayson Lake area, that deformation probably occurred during mid-Permian to Triassic time. Displacement indicators at the base of the Bearfeed allochthon show a top-to-the-east sense of transport (Colpron and Reinecke, 2000).

STIKINE TERRANE

Rocks of Stikine Terrane are exposed in the southwestern part of the map area (Fig. 2; Colpron et al., 2002). They comprise a lower unit of mafic volcanic rocks locally overlain by limestone (Lewes River Group), and an upper unit of immature clastic rocks of the Whitehorse Trough (Laberge Group). Stikine Terrane is juxtaposed with rocks of the Semenof block and Tatchun Batholith along Tadru Fault.

LEWES RIVER GROUP

The lowest unit observed in the area is a brown and green augite- (± olivine) phyric basalt. The rock is typically massive, although in the narrow belt between McGregor Batholith and Tadru Fault (105L/5) the basalt is commonly

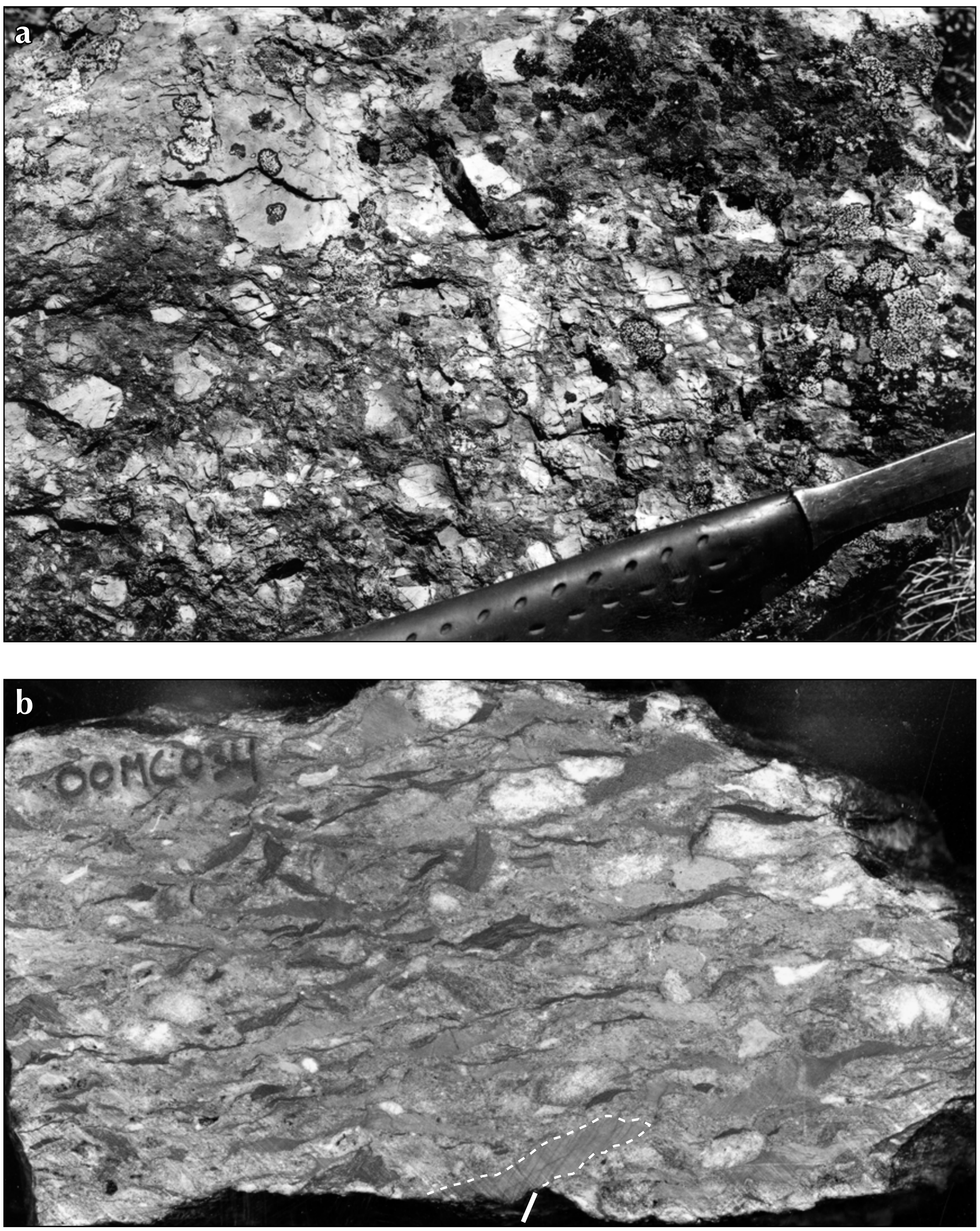


Figure 7. (a) *Flow breccia texture and altered glassy rims on clasts in basalt of the Tummel fault zone, north of Drury Lake (105L/7).* ***(b)*** *Slab sample of polymictic pebble conglomerate from the footwall of the northeastern klippe of the Bearfeed allochthons, south of Drury Lake (105L/7). Note foliated clast near bottom centre of the photo (dashed outline; solid line at bottom shows orientation of foliation in the clast). Sample is approximately 5 cm high.*

strongly foliated. In this area, a 2-m-thick horizon of foliated quartz-feldspar-phyric rhyolite occurs at one locality within the basalt. Near the southern edge of the map area (105L/3) the basalt locally shows pillow structures. Rare lapilli tuff is also present locally within this unit.

The mafic volcanic rocks are likely part of the Povoas Formation of the Lewes River Group, which is also characterized by abundant large augite phenocrysts (Tempelman-Kluit, 1984; Hart, 1997); however the presence of rhyolite and the local strong foliation in the basalt is more characteristic of the Late Mississippian Takhini assemblage of Hart (1997) and therefore these rocks could be of Paleozoic age.

Near Robert Campbell Highway, mafic volcanic rocks are locally overlain by fine-grained, massive limestone, which is probably equivalent to the Hancock member of the Aksala Formation (Lewes River Group; Tempelman-Kluit, 1984).

LABERGE GROUP

Rocks of the Lewes River Group are overlain by immature coarse-grained clastic rocks which are assigned to the Laberge Group. The predominant lithology is a red-weathering polymictic pebble to cobble conglomerate. Predominant clast types are plutonic and volcanic, and are supported by a matrix of graded sandstone. Red to dark brown siltstone occurs at one locality south of Robert Campbell Highway.

OVERLAP ASSEMBLAGE

TRIASSIC

Strata of probable Triassic age are exposed in two small outliers within Tummel fault zone (105L/6-7) and in the core of a syncline in Cassiar Terrane (105L/10; Colpron et al., 2002). They consist of finely laminated, soft, dark grey, buff-weathering shale and siltstone, fine-grained, grey sandstone and minor dark grey limestone. The siltstone and sandstone commonly contain detrital micas. These rocks resemble known Triassic strata elsewhere in Yukon.

TANTALUS FORMATION (?)

A single, isolated outcrop of light grey tuffaceous siltstone, lignite and tuff is exposed along Robert Campbell Highway (105L/3; Colpron et al., 2002). Tuff from this outcrop has yielded a U/Pb zircon age of 92 ± 1 Ma (L.E. Jackson, *in:* Breitsprecher et al., 2002). These rocks may be equivalent to the Tantalus Formation (Yorath, 1991), although the Late Cretaceous age from the tuff horizon is somewhat younger than the Late Jurassic-Early Cretaceous age (in part Albian; 99-111 Ma) typically assigned to the Tantalus Formation.

CARMACKS GROUP

Reddish brown-weathering basaltic rocks occur sporadically throughout the area (Fig. 2; Colpron et al., 2002). The largest extent of young basalt is in the southern part of the Glenlyon area (105L/3), where approximately 270 km^2 of dark green to black aphanitic basalt, amygdaloidal basalt and agglomerate are poorly exposed south of Robert Campbell Highway. Amygdules are commonly filled with agate. North of Robert Campbell Highway, a basalt outcrop yielded a K/Ar whole rock age of 73 Ma (Hunt and Roddick, 1992) indicating that these rocks correlate with the Carmacks Group (Grond et al., 1984). Exposures of Carmacks Group basalt south of Robert Campbell Highway were previously unrecognized. They were previously mapped as part of an extensive unit of volcanic rocks presumed to be Triassic or older (unit 16a of Campbell, 1967). Unit 16a is now shown to include volcanic rocks of the Carboniferous Semenof formation, Upper Triassic Lewes River Group and Upper Cretaceous Carmacks Group (Fig. 2).

A tongue of Carmacks basalt extends northwest to the vicinity of Frenchman Lake (105L/4; Fig. 2). East of Frenchman Lake, the basalt flows are beautifully exposed in a small canyon. Further north, the basalt abuts a small hill of limestone inferred to be part of the Boswell formation (Colpron et al., 2002). The Carmacks Group overlaps the Tadru Fault, which juxtaposes Semenof block and Stikine Terrane.

Carmacks Group volcanic rocks are also extensive in northeastern Carmacks area (115I/16; Fig. 2). Tempelman-Kluit (1984) considered these exposures of brown weathering, resistant, fresh andesitic basalt as part of the upper Carmacks Group. Up to 600 m of volcanic flows are exposed in benches northeast of Diamain Lake (115I/16). Near its contact with the underlying Tatlmain Batholith, the Carmacks Group locally contains volcanic breccia and sandstone. Exposures from Granite Canyon, on the Pelly River, and from hills northeast of Diamain Lake have yielded K/Ar whole rock dates of 64 Ma and 74 Ma, respectively (Wanless et al., 1979; Stevens et al., 1982; Tempelman-Kluit, 1984).

TERTIARY VOLCANIC ROCKS

Tertiary volcanic and high-level intrusive rocks also occur sporadically throughout the map area (Colpron et al., 2002). They consist of rhyolite flows and breccia, felsic to intermediate tuff, and quartz-feldspar porphyry. U/Pb zircon ages from two localities have yielded Late Paleocene ages (55-56 Ma; Breitsprecher et al., 2002). The rhyolite is locally flow-banded and/or spherulitic. Tertiary volcanic rocks are most common near exposures of Carmacks Group basalts.

JURASSIC PLUTONS

Intrusive rocks of Jurassic age are mostly found in the western part of the map area (Fig. 2). There, granitic rocks of probable Late Triassic - Early Jurassic age form two large plutons — the Tatchun and McGregor batholiths. These two intrusive bodies were previously mapped as a single continuous batholith (Campbell, 1967; Tempelman-Kluit, 1984) but our mapping shows that they are separated by the Tadru Fault and a narrow band of mafic metavolcanic rocks (Colpron et al., 2002).

The Tatchun and McGregor batholiths are both composed of three intrusive phases. The earliest phase is a variably foliated, coarse-grained equigranular hornblende-biotite granodiorite. It is locally hornblende porphyritic. Rare gabbro is also associated with this phase of the Early Jurassic plutons. Biotite gabbro appears to be the earliest phase at the north end of Tatchun Batholith (105L/5; Colpron et al., 2002). A small body of augite gabbro to pyroxenite also occurs in the northern McGregor Batholith (115I/9). The granodiorite phase is intruded by medium-grained K-feldspar megacrystic granodiorite. The megacrystic phase is locally weakly foliated. Both phases of granodiorite typically contain magmatic epidote indicating a minimum crystallization pressure of 6 kbar (Zen and Hammarstrom, 1984; Zen, 1989). The youngest phase is a beige-weathering, unfoliated, fine-grained leucogranite and aplite. Pegmatite dykes are locally associated with the aplite in the northern part of Tatchun Batholith. A sample of leucogranite from Tatchun Batholith yielded a preliminary U/Pb zircon age of ca. 197 Ma (J.K. Mortensen, pers. comm., 2001).

An altered gabbro to anorthosite pluton intrudes rocks of Cassiar Terrane in the northeastern part of the map area (105L/11; Colpron et al., 2002). This pluton is undated, but inferred to be Jurassic in age because its composition closely matches the gabbro described above.

Two small plutons of hornblende ± biotite quartz monzonite are exposed in the northern part of the area (105L/13; Colpron et al., 2002). The largest of these plutons (Cornolio pluton) has yielded an imprecise Permian U/Pb zircon age, but could well be of Early Jurassic age (J.K. Mortensen, pers. comm., 2000).

CRETACEOUS PLUTONS

Cretaceous granitic plutons intrude rocks of Yukon-Tanana and Cassiar terranes in the eastern part of the Glenlyon area (Fig. 2). The largest concentration of Cretaceous intrusive rocks is found in the Glenlyon Batholith, a large body of granodiorite, granite and rare pegmatite (see Black et al., this volume; and Gladwin et al., this volume, for more detailed descriptions). A single K/Ar whole rock date from hornfels near a satellite of the Glenlyon Batholith gives an age of 105 ± 4 Ma (Hunt and Roddick, 1990). This age is similar to a U/Pb monazite age of 109 ± 3 Ma obtained from the d'Abbadie pluton in Laberge map area (de Keizjer, 2000). D'Abbadie pluton is likely a southern extension of the Glenlyon Batholith (Gordey and Makepeace, 2000). A similar age (U/Pb zircon — 108.1 ± 0.2 Ma) was also obtained from a porphyry encountered in drill core at the Clear Lake deposit to the north (105L/14; Breitsprecher et al., 2002). Based on these age determinations, the Glenlyon Batholith can be indirectly dated as Early Cretaceous.

A series of smaller plutons intrude rocks of Yukon-Tanana Terrane between Tummel and Big Salmon faults (Fig. 2). These plutons are granitic, with medium-grained, equigranular biotite-bearing and K-feldspar megacrystic phases. Two plutons near Little Salmon Lake (105L/2; Colpron et al., 2002) yielded imprecise U/Pb zircon ages between 93-96 Ma (J.K. Mortensen, pers. comm., 2001).

STRUCTURE

Rocks of Yukon-Tanana Terrane in Glenlyon map area have experienced several episodes of deformation, which all resulted in foliation development and folding. The Snowcap complex records the most complex deformational history in the area, with some of its fabrics having clearly developed before deposition of overlying Carboniferous strata. The best constrained deformational event is the development of a foliation in rocks of the Pelmac formation in the northern part of the map area (105L/13) prior to intrusion of the undeformed Tatlmain Batholith at ca. 340 Ma. Elsewhere, the deformation is clearly younger than Mississippian (i.e. deforms rocks younger than 340 Ma) but is difficult to distinguish from the Mississippian fabrics. Development of the dominant regional folds and associated foliation is tentatively considered to be Permian to Jurassic in age. $^{40}Ar/^{39}Ar$ mica cooling ages from Yukon-Tanana Terrane in the area are consistently between 180-190 Ma, suggesting that the whole area cooled below ca. 300°C in Early Jurassic time. This would indicate that greenschist facies foliations developed before the Early Jurassic. More detailed descriptions of fabric relationships and mesoscopic scale structures will be presented in a bulletin in preparation.

One of the main contributions of the 2002 accelerated bedrock mapping program was to identify and delineate the major fault systems in Glenlyon and northeast Carmacks map areas (Fig. 2). These faults are described below.

TUMMEL FAULT ZONE AND BEARFEED ALLOCHTHONS

The Tummel fault zone marks the contact between Yukon-Tanana, to the southwest, and Cassiar terranes, to the northeast (Fig. 2). It comprises a series of imbricate fault slices of chert, basalt, polymictic conglomerate and metasedimentary rocks of Cassiar Terrane (see descriptions above and Gladwin et al., this volume). The Tummel fault zone contains both ductile fabrics and superimposed younger brittle fabrics, evidence of a complex structural evolution. Individual faults within this zone generally dip steeply to the southwest or are sub-vertical. Lithologic correlations suggest that rocks as young as Middle Permian and possibly Triassic are deformed in the Tummel fault zone. Occurrence of post-kinematic, low-pressure metamorphic assemblages (likely part of the contact aureole of the Glenlyon Batholith) across the fault zone suggest that minimal displacement has taken place after intrusion of the Early Cretaceous Glenlyon Batholith (Gladwin et al., this volume). Thus, deformation within the Tummel fault zone can be constrained to be between Late Permian and Early Cretaceous.

As discussed above, the polymictic conglomerates that occur in fault slices of the Tummel fault zone are interpreted as synorogenic clastic rocks that were deposited during emplacement of Yukon-Tanana Terrane onto the North American miogeocline (Cassiar Terrane). Thus the polymictic conglomerates may be genetically linked to the early stages of deformation within the Tummel fault zone.

A similar polymictic conglomerate also occurs at the base of the Bearfeed allochthons (Colpron et al., 2002). The basal contact of the eastern klippe of the Bearfeed allochthons is marked by sheared serpentinite and mylonitic fabric in the footwall of the fault. Rotated porphyroclasts in mylonitic metavolcanic rocks of the Little Salmon formation indicate northeasterly emplacement of the allochthons (Colpron and Reinecke, 2000). The Bearfeed allochthons and Tummel fault zone may have formed part of an easterly directed thrust stack of Middle Permian-Triassic age.

NEEDLEROCK THRUST

The Needlerock Thrust marks the northern termination of the Semenof block (Fig. 2). It juxtaposes psammitic schist and quartzite of the pre-Upper Devonian Snowcap complex, to the north, with greenstone, amphibolite and marble of the Carboniferous Semenof formation, to the south. A spectacular exposure of the thrust is present northeast of Ess Lake (105L/12; Fig. 8), where greenstone of the Semenof formation show progressive fabric development in the immediate footwall of the fault. Footwall fabrics from this locality suggest top-to-the-south thrusting. Elsewhere, the Needlerock Thrust is largely unexposed and was traced on the basis of the distribution of the contrasting Snowcap and Semenof lithologic assemblages. An isolated occurrence of serpentinite south of Tatlmain Lake may lie along the Needlerock Thrust (Colpron et al., 2002). The trace of the fault suggests that it is folded and therefore predates the map-scale folds in the area. Relationships that might show its temporal relationship to the Early Jurassic plutons were not seen. The Needlerock Thrust is cut off by the steeper Big Salmon (to the east) and Tadru faults (to the west). Timing of displacement along Needlerock Thrust is poorly constrained but may be Triassic-Jurassic.

TADRU FAULT

The Tadru Fault is the most westerly of the faults mapped in the Glenlyon-northeast Carmacks area (Fig. 2). In southwestern Glenlyon, it marks the contact between Semenof block on the east, and Stikine Terrane on the west. West of Tatlmain Lake (115I/9), it juxtaposes rocks of the Snowcap complex to the northeast with the Early Jurassic McGregor Batholith and amphibolite which is possibly correlative with the Semenof formation, to the southwest. The Tadru Fault has an apparently moderate northeast dip, east of Frenchman Lake. Farther north, the trace of the fault suggests that it dips more steeply to the east-northeast (Fig. 2). Shear bands in greenstone of the Lewes River Group in the footwall of the fault indicate top-to-the-southwest displacement. Similar structures in a mylonitic part of the early phase of Tatchun Batholith, east of the fault, indicate oblique top-to-the-northwest displacement. Ductile deformation of the Tatchun Batholith in the hanging wall of the fault also indicates that at least part of the displacement along Tadru Fault is Early Jurassic in age. Similar structures are also observed in the northern part of McGregor Batholith, in the footwall of Tadru Fault, west of Tatlmain Lake. The right-lateral offset of Tatchun and McGregor batholiths may indicate a history of strike-slip displacement along part of the Tadru Fault. Displacement along the Tadru Fault predates deposition of basalts of the Upper Cretaceous Carmacks Group, which overlap the fault near Frenchman Lake (105L/4; Fig. 2).

The Tadru Fault in Glenlyon map area occupies the same structural position as Teslin Fault farther south (Gordey and Makepeace, 2000).

BIG SALMON AND BEARFEED FAULTS

The Big Salmon and Bearfeed faults are relatively young, with well-defined topographic lineaments (Fig. 9). The Big Salmon Fault trends northwesterly between the southern edge of the map area and Ess Lake, where it juxtaposes Yukon-Tanana Terrane, on the east, with Semenof block, on the west (Fig. 2). East of Ess Lake, Big Salmon Fault becomes north-trending and juxtaposes rocks of Yukon-Tanana Terrane on both sides. From Ragged Lake to its termination against Tintina Fault, it marks the contact between Cassiar, on the east, and Yukon-Tanana terranes, on the west (Fig. 2). The fault itself is not exposed, but its map pattern suggests that it is subvertical. Structures in mylonitic marble along the Bearfeed valley indicate top-to-the-southwest kinematics, suggesting that at least part of the Big Salmon Fault has reverse displacement.

The Bearfeed Fault is a splay of the Big Salmon Fault (Fig. 2). It diverges from the Big Salmon Fault near the west end of Little Salmon Lake and trends north-northwesterly until it merges with the northern part of the Tummel fault zone, near Tummel River. Bearfeed Fault juxtaposes Carboniferous rocks of the Little Salmon formation, on the east, to pre-Upper Devonian (?)

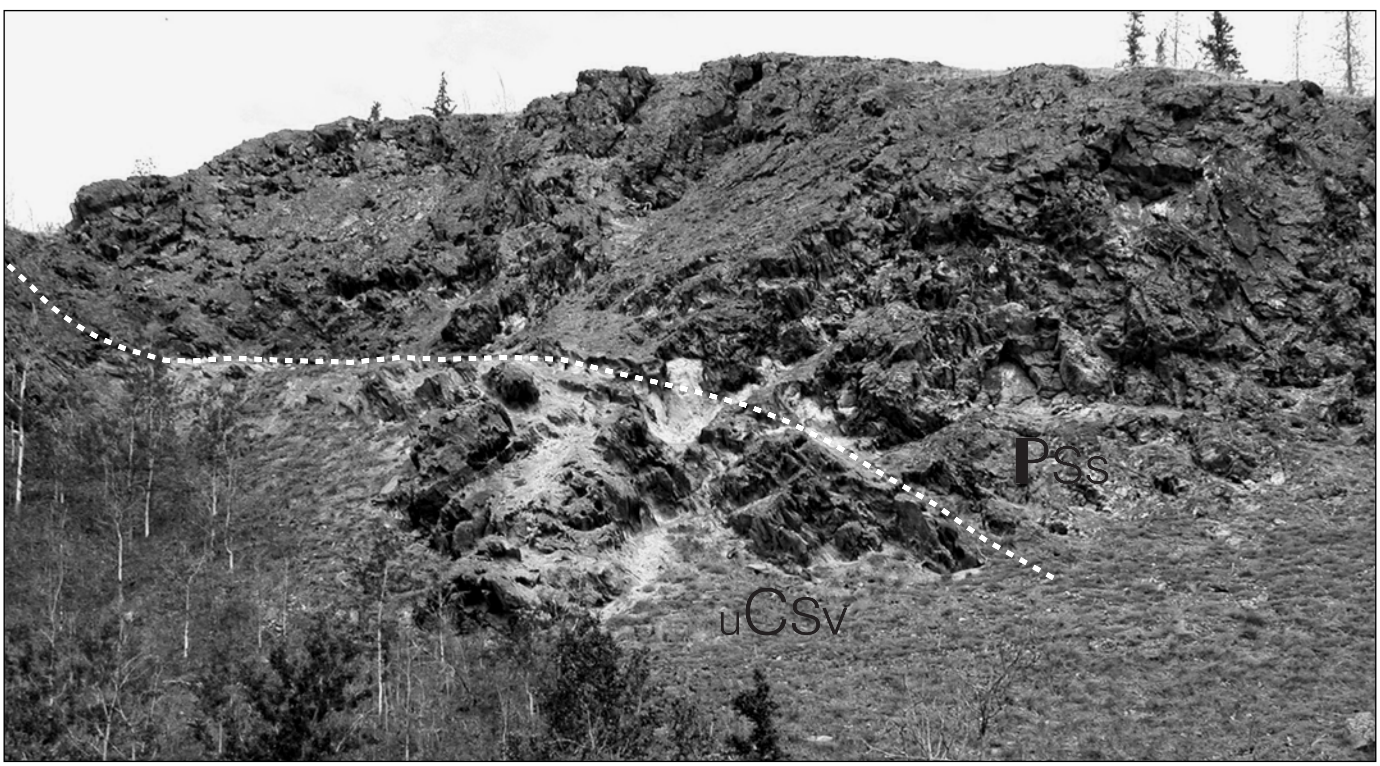


Figure 8. *Looking west at the only exposure of the Needlerock Thrust (dash line), north of Ess Lake (105L/12). Brown-weathering psammite of the Snowcap complex (PSs) overlies greenstone of the Semenof formation (uCSv) in the footwall of the fault.*

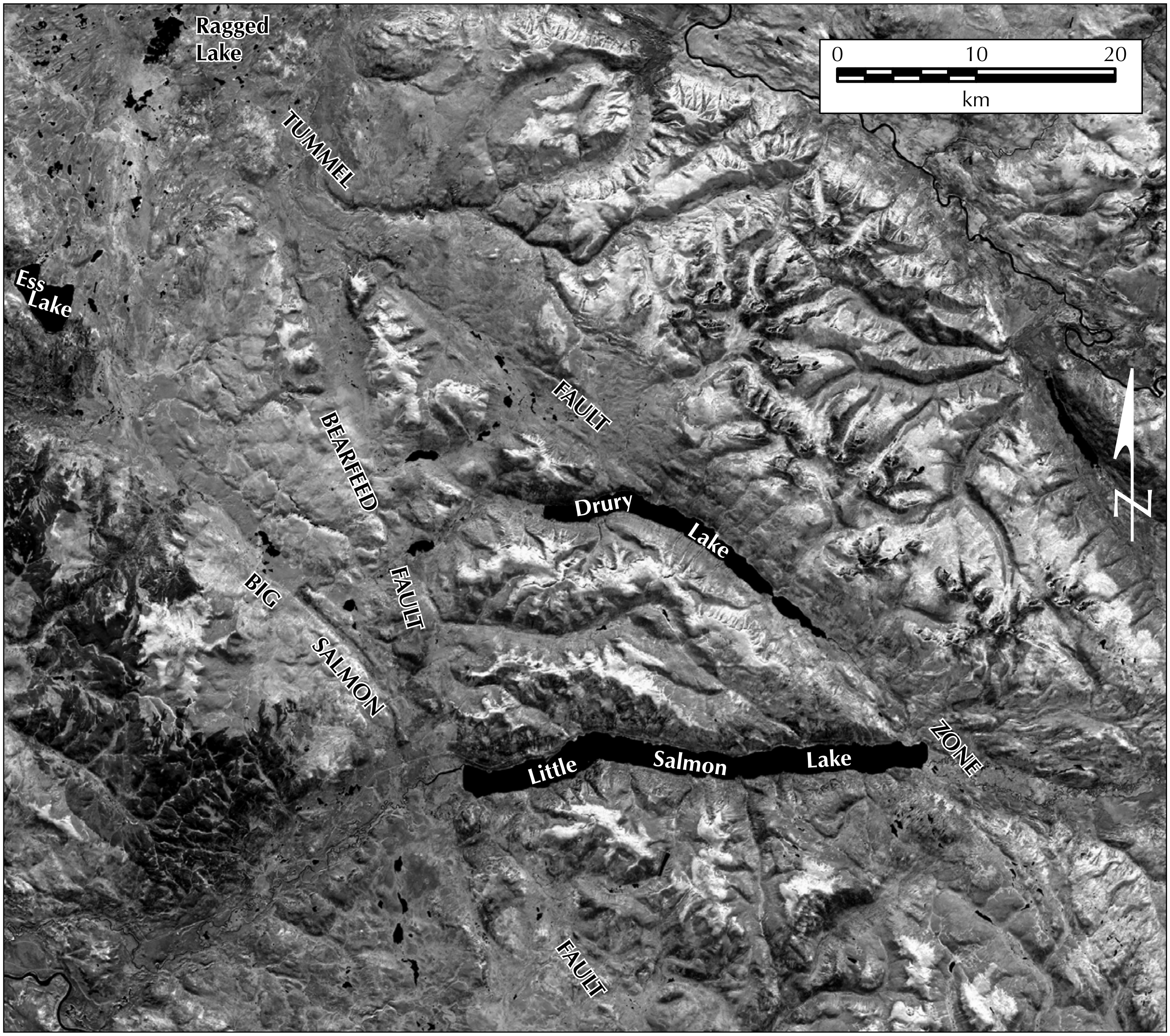


Figure 9. *Landsat 7 image of the southeast corner of the Glenlyon map area (image courtesy of Geomatics Yukon). Late faults in the area (labelled) are locally expressed by well defined topographic lineaments.*

basement rocks of the Snowcap complex, on the west, thus suggesting an apparent down-to-the-east normal displacement.

Right-lateral offset of the Pelmac formation (approximately 56 km) across the Glenlyon map area provides the best estimate for displacement along the Big Salmon-Bearfeed fault system (Fig. 2). The Big Salmon Fault truncates basalt of the Upper Cretaceous Carmacks Group at the west end of Little Salmon Lake and possibly offsets Tertiary rocks south of the lake. This suggests that at least part of the displacement along the Big Salmon-Bearfeed fault system must have occurred in Late Cretaceous-Early Tertiary time, possibly concurrently with displacement along Tintina Fault. On the other hand, this system is truncated by the Tintina Fault and must therefore predate the latest displacement along the Tintina Fault (Fig. 2).

MINERAL POTENTIAL

VOLCANIC-HOSTED MASSIVE SULPHIDES

The Carboniferous volcanic rocks of the Yukon-Tanana Terrane (Little Kalzas and Little Salmon formations) remain under-explored for volcanic-hosted massive sulphides. In particular, the Little Salmon formation is host to a small massive sulphide occurrence (Yukon MINFILE, 2002, 105L 062; Colpron, 1999b) and to Mn exhalites (Colpron and Reinecke, 2000). Geochemistry of till samples shows that the Little Salmon formation is anomalous in copper and gold (see Bond and Plouffe, this volume). Trace element geochemistry of the volcanic rocks suggests that the northwestern part of the Little Salmon formation may represent a rifted arc environment conducive to formation and preservation of massive sulphides (Colpron, 2001).

Rocks of the Semenof block have also seen little exploration activity. They mostly consist of mafic (meta)volcanic rocks and carbonate. However, the Semenof block locally contains felsic volcanic and tuffaceous rocks. Blocks of malachite-azurite in quartz were found near an occurrence of felsic volcanic rocks east of Frenchman Lake. Similar mineralized clasts were also found in a till sample and the geochemistry of the till yielded a copper anomaly in this area (Bond and Plouffe, this volume).

INTRUSION-RELATED MINERALIZATION

The map area contains numerous plutons of Mississippian, Jurassic and Cretaceous ages. Small skarn occurrences have been noted near some of the Mississippian plutons (Yukon MINFILE, 2002, 105L 008, 105L 011). Gossans are also locally present near Mississippian plutons. An extensive zone of gossan containing up to 2% pyrite can be traced for up to 5 km in the east-facing cliffs overlooking the southern part of Drury Lake (105L/7; Colpron, 2000). It lies along strike from granodiorite of the Drury pluton and just east of a small Mississippian gabbroic intrusion. Gossans are also present in psammitic schist at the southern margin of the Tatlmain Batholith (105L/12; at the contact and in a pendant within the pluton).

The Jurassic Tatchun and McGregor batholiths underlie a large portion of the western part of the map area. Both plutons have similar compositions. Samples of stream sediment and till from the McGregor Batholith yielded anomalous gold values (see Bond and Plouffe, this volume).

Cretaceous plutons in the eastern part of the area also have potential to host intrusion-related mineralization. A few skarn occurrences near the contact with the Glenlyon Batholith have seen some exploration activity (Yukon MINFILE, 2002, 105L 001, 105L 003) for lead-zinc-silver mineralization. Geochemistry of till samples from near Cretaceous plutons suggest that these plutons may also be suitable targets for intrusion-related gold deposits (see Bond and Plouffe, this volume). In particular, the small pluton of presumed Cretaceous age exposed to the south of Safety Pin Bend on the Pelly River (105L/11) yielded coincident Au, As and Sb anomalies (Bond and Plouffe, this volume).

FAULT-RELATED EPITHERMAL GOLD

Cretaceous-Early Tertiary faults of the Big Salmon-Bearfeed system should be considered for their potential to control distribution of epithermal gold mineralization in the area. Strong argillic alteration and quartz veining in gossaneous, brecciated rocks were noted in creek exposures along the Bearfeed Fault (105L/6). A sample of till collected along the Big Salmon Fault has returned anomalous values of Au, As, Sb and Pb (see Bond and Plouffe, this volume).

DISCUSSION

Bedrock mapping of Yukon-Tanana Terrane in Glenlyon map area has established the stratigraphic framework of the terrane southwest of Tintina Fault (Figs. 2,3). Yukon-Tanana consists of a basement complex of metasedimentary and metaplutonic rocks (Snowcap complex) overlain by a mainly Carboniferous volcano-sedimentary succession. This succession is subdivided into four formations — the Drury, Pelmac, Little Kalzas and Little Salmon formations — based on lithologic characteristics and preliminary age determinations. Regional mapping in 2002 shows that volcanic rocks of the Little Kalzas and Little Salmon formations, which are most prospective for VMS-style mineralization, are essentially restricted to areas previously mapped in detail (Fig. 2; Colpron, 1998; Colpron, 2000; Gladwin et al., 2002a). Both Little Kalzas and Little Salmon formations terminate abruptly against the Big Salmon-Bearfeed fault system — a series of Cretaceous-Early Tertiary dextral strike-slip faults which dissect Yukon-Tanana Terrane in the area.

The new mapping and ongoing geochronological studies have shown that plutonism and volcanism in Glenlyon map area are broadly contemporaneous with that of the Finlayson Lake area. The Little Kalzas formation, which consists predominantly of intermediate to mafic volcanic and sedimentary rocks of island arc affinity, is coeval with carbonaceous phyllite and felsic metavolcanic rocks of the Wolverine succession in Finlayson Lake map area, which have back-arc geochemical signatures (Piercey et al., 2000; Piercey et al., 2001; Piercey et al., 2002). As well, subvolcanic plutons of the Little Kalzas suite are coeval with the younger metaluminous plutons of the Simpson Range plutonic suite in the hanging wall of the Money Creek Thrust (Mortensen, 1992). Both the Little Kalzas and Simpson Range plutonic suites have calc-alkaline arc geochemical signatures (Grant et al., 1996; Piercey and Murphy, 2000; Colpron, 2001). Hence, the Little Kalzas formation, its subvolcanic plutons, and the Simpson Range plutonic suite probably define part of the arc system that laid in front of the Wolverine back-arc.

To the northeast, Yukon-Tanana Terrane is juxtaposed with Cassiar Terrane along the Tummel fault zone (Fig. 2). The Tummel fault zone comprises fault-bounded slices of (1) Pennsylvanian-Permian (?) chert-argillite-basalt of Slide Mountain Terrane; (2) Permian-Triassic (?) synorogenic clastic rocks; and (3) miogeoclinal rocks of Cassiar Terrane (Colpron et al., 2002). The Tummel fault zone is inferred to have originated as a southwest-dipping, easterly-directed thrust stack of Middle Permian to Triassic age. The thrusts were steepened and modified during subsequent Mesozoic (?) deformation. The structural stacking within the Tummel fault zone is similar to that at the leading edge of Yukon-Tanana Terrane in the Finlayson Lake area, northeast of Tintina Fault, where dark grey phyllite, chert and clastic rocks of the Finlayson succession are overlain by varicoloured chert and basalt of the Pennsylvanian-Permian Campbell Range succession (parautochthonous equivalent of Slide Mountain Terrane) and thrust onto rocks of Ancestral North America along the Inconnu Thrust (Murphy et al., 2001; 2002). Imbricates of Permian-Triassic, locally derived synorogenic clastic rocks locally occur along Inconnu Thrust. This zone is 10-15 km wide in Finlayson Lake area. Its equivalent in Glenlyon area is only 3-4 km wide.

This study also provides new data about the enigmatic Semenof block. Amphibolites north of Tatchun Batholith were previously considered a part of Yukon-Tanana Terrane (Campbell, 1967; Gordey and Makepeace, 2000). The new mapping now shows them to be the higher grade equivalents of basalt and diorite of the Semenof formation south of the batholith (Colpron et al., 2002). However, the presence of a foliated tonalite to granodiorite pluton (similar to those in the Snowcap complex) apparently intruding Semenof block south of Tadru Lake suggests that Semenof block and Yukon-Tanana Terrane may share a common history. North of Tadru and Ess lakes, the Needlerock Thrust juxtaposes rocks of the Snowcap complex in its hanging wall, with those of the Semenof formation in its footwall. The age of the Needlerock Thrust is unknown; it is apparently folded and therefore predates development of the regional scale, northwest-trending folds in the area.

Finally, this study sheds new light on the history of post-accretion faulting in the region. The Big Salmon and Bearfeed faults are part of a dextral strike-slip system which dissects the Yukon-Tanana Terrane in the area (Fig. 2). Dextral offset of the Pelmac formation suggests approximately 56 km of displacement along this fault system. The Big Salmon Fault is truncated to the north by the Tintina Fault. This implies that a matching counterpart of this fault must be present northeast of Tintina Fault approximately 425 km to the southeast, in the vicinity of Watson Lake. The regional significance of these post-accretionary structures has yet to be resolved.

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Yukon Targeted Geoscience Initiative, Part 2: Glacial history, till geochemistry and new mineral exploration targets in Glenlyon and eastern Carmacks map areas, central Yukon

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ABSTRACT

A regional till geochemistry project was completed in conjunction with bedrock mapping across rocks of Yukon-Tanana Terrane and North American affinity in central Yukon. The high mineral potential of the area is based on recent discoveries in the Finlayson Lake area to the southeast, an area thought to juxtapose the Glenlyon area prior to displacement on the Tintina Fault.

The study area lies at the limit of the Late Wisconsinan McConnell glaciation. Ice flow was largely directed by topography. Soil profiles reveal a veneer of White River ash and loess over most till deposits.

Geochemical results from 285 till samples highlight new anomalies in gold, gold/arsenic (intrusive- and fault-related), copper (veins), copper/nickel (ultramafic rocks) and zinc (sedimentary-exhalative (SEDEX) and epithermal). An orientation survey was completed at the Clear Lake SEDEX deposit to evaluate the extent of glacial dispersion down-ice from mineralization.

RÉSUMÉ

Un programme d'échantillonnage régional du till a été complété conjointement avec la cartographie de la roche en place au-dessus des roches du terrane de Yukon Tanana et d'affinitées nord américaine dans la partie centrale du Yukon. Le fort potentiel de minéralisation dans cette région est basé sur les découvertes récentes au sud-est dans le secteur du lac Finlayson, une région qui était juxtaposée à la région de Glenlyon avant son déplacement de long de la faille de Tintina.

La région d'étude est sise à la limite de la glaciation de McConnell du Wisconsinien tardif. Les écoulements glaciaires y étaient grandement contrôlés par la topographie. Les profils dans le sol montrent que les dépôts de till sont recouverts d'un placage de cendres volcaniques de White River et de loess.

Les résultats de l'analyse géochimique de 285 échantillons de till pointent vers de nouvelles anomalies en or, or et arsenic (reliées à des intrusions ou des failles), cuivre (veines), cuivre et nickel (roches ultramafiques) et zinc (minéralisation épithermale et sédimentaire exhalatif). Un échantillonnage détaillé a été complété au-dessus de la zone minéralisée de type sédimentaire exhalatif de Clear Lake pour évaluer l'étendue de la dispersion glaciaire en aval de la minéralisation.

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INTRODUCTION

The Glenlyon (NTS 105L) and eastern Carmacks (NTS 115I) map areas were the focus of the Yukon Targeted Geoscience Initiative (TGI) in its third year. In continuing the program of bedrock mapping and till geochemistry across prospective tracks of Yukon-Tanana Terrane (YTT), the focus shifted northwest towards the Glenlyon map area (Fig. 1). Last year, TGI efforts were focused in the Finlayson Lake region where a large tract of YTT remained poorly mapped amidst areas of high mineral potential. The geology of the Glenlyon map area was suspected to mirror the Finlayson Lake district following restoration of 450 km displacement along the Tintina Fault (Colpron, 1999a). Although the geological relationship seemed favourable in the Glenlyon region, vast areas of poorly understood geology are blanketed by glacial deposits. Furthermore, drainage is poorly developed in the plateau region of the Glenlyon map area, which is reflected by a low sample density of stream sediments (Hornbrook and Friske, 1988). Consequently, to further evaluate the mineral potential of the Glenlyon and eastern Carmacks map areas, a till sampling program was conducted, focusing on areas of high mineral potential, widespread till cover, and poor RGS (Regional Geochemical survey) coverage (Hornbrook and Friske, 1988). Similar to the Finlayson TGI (Bond and Plouffe, 2002), till was favoured as a sampling medium for the following reasons: 1) it occurs abundantly on plateaus and hills in areas of poor bedrock exposure; and 2) it is considered a first-order derivative of bedrock (Shilts, 1976, 1993).

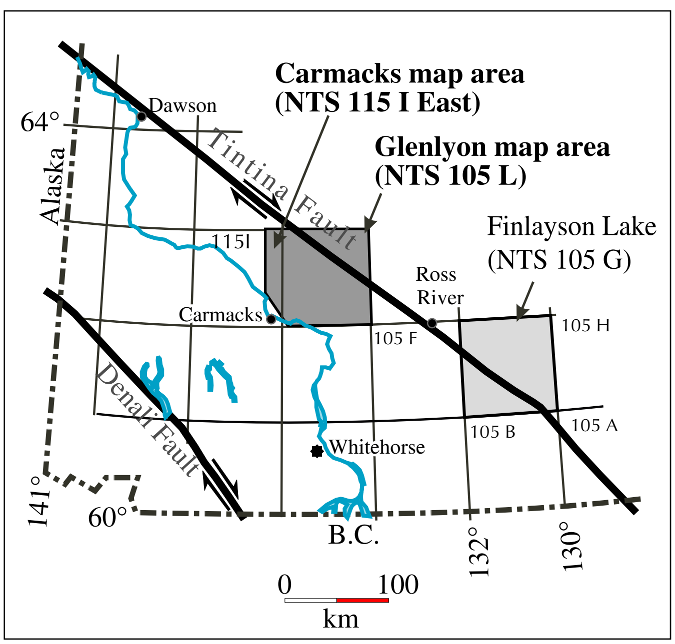


Figure 1. Location of the Glenlyon and Carmacks map areas.

PREVIOUS STUDIES

Quaternary stratigraphic investigations and surficial mapping were completed by Ward (1989; 1993), Ward and Jackson (1992; 2000) and Jackson (2000) for the Glenlyon and eastern Carmacks map areas. Surficial geological mapping was completed at 1:100 000 scale for both areas and provided the background for this work. Related studies, to the north of Glenlyon and Carmacks map areas, include surficial mapping by Hughes (1982) in Mayo (105M) and placer gold deposit studies in the Mayo mining district (LeBarge et al., 2002). Surficial mapping and Quaternary stratigraphy investigations were undertaken to the northwest in McQuesten (115P; Bond, 1997). More recently, a drift prospecting and surficial mapping study was completed to the east in the Anvil district (Bond, 2001).

Initial bedrock geological mapping was undertaken by R.B. Campbell of the Geological Survey of Canada (Campbell, 1967). Recent geological mapping by Colpron (1999a; 2001) in the Glenlyon area refined the bedrock framework and placed it in context with YTT elsewhere in Yukon.

PHYSIOGRAPHY AND BEDROCK GEOLOGY

The study area is divided into four physiographic regions (Mathews, 1986): the Lewes Plateau, the Pelly Mountains, the Tintina Trench and the MacMillan Highland. Most of the study area lies within the Lewes Plateau, which is a subdivision of the Yukon Plateau, and consists of a broad rolling lowland with poorly developed drainage and abundant small lakes (Fig. 2). Large meltwater channels containing underfit streams dissect the Lewes Plateau (Fig. 3). The Glenlyon Range is the northwestern extension of the Pelly Mountains. The highest summits in the range reach above 1970 m (6500 ft). Numerous cirques, many of which contain tarn lakes, are developed in the range (Fig. 4). Few rock glaciers are present in the southeast part of the highland. The Tintina Trench, a prominent low intermontane valley, dissects the Glenlyon Range to the north (Fig. 5). The MacMillan Highland occupies the region north of the trench and consists of a mountainous region lower in elevation and less rugged than the Glenlyon Range.

Figure 2. *The north-central lowland in the Glenlyon map area. Low relief and poor drainage characterize this region.*

Figure 3. *A McConnell meltwater channel cutting the Tatchun Hills near Frenchman Lake.*

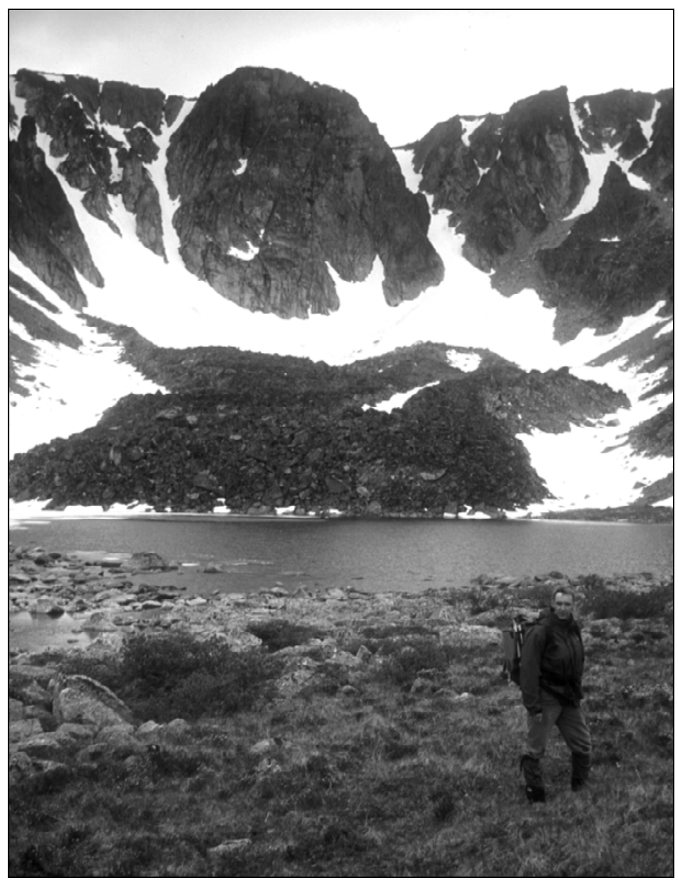


Figure 4. *A well developed north-facing cirque in the Glenlyon Range. Note the tarn in the middle ground. A debris-covered glacier blankets the back of the cirque.*

The study area lies at the boundaries of ancient North America, Yukon-Tanana and Stikinia terranes. The North American terrane is composed of rocks of the Cassiar Platform, including Earn Group strata that host the Clear Lake sedimentary-exhalative (SEDEX) deposit (Yukon MINFILE 2002, 105L 045). Yukon-Tanana Terrane is composed of two Carboniferous volcanic arc successions, associated subvolcanic plutonic suites and pre-Mississippian metasedimentary basement rocks. A series of northwest-trending strike-slip faults occur in the area. Early Jurassic batholiths intrude the western sector, whereas small mid-Cretaceous plutons intrude the eastern part. See Colpron et al. (this volume) for details on the bedrock geology.

METHODOLOGY

Preparatory investigations involved air photo interpretation and analysis of existing surficial geology (Jackson, 2000; Ward and Jackson, 2000), bedrock geology (Colpron, 2000) and geophysical maps (Gordey and Makepeace, 1999), Yukon MINFILE (2002) and regional stream sediment geochemistry (Hornbrook and Friske, 1988) to determine high mineral potential areas with a till veneer or blanket, which are most suitable for drift prospecting. During the field season, new target areas were defined for till sampling as the bedrock mapping progressed.

Fieldwork was completed from a base camp located on the Frenchman Lake Road approximately 1 km east of the Klondike Highway. The Robert Campbell Highway, Frenchman Lake Road and Klondike Highway provided staging points into the study area. Access to more remote

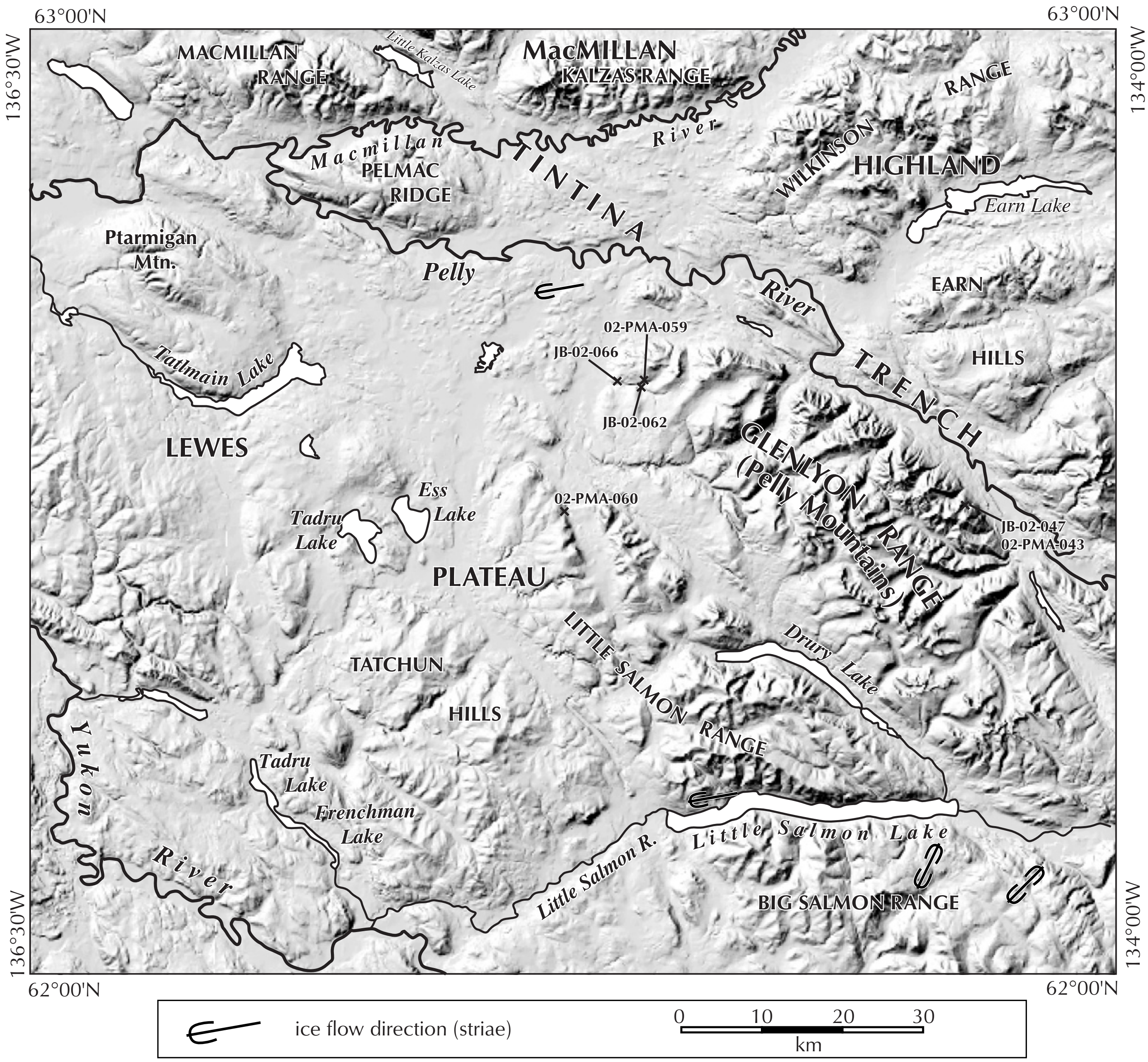


Figure 5. *Physiography of the study area represented on a digital elevation model (Department of Environment, Yukon Government).*

parts of the field area was provided by a Bell 206 helicopter. All samples were collected during daily foot traverses. Sample lines were oriented perpendicular to the paleo-ice flow direction to maximize geochemical exposure to the underlying bedrock. Sample spacing was approximately 1 km and an average of 6-8 samples were collected on daily foot traverses.

A total of three samples were collected at each station. This included a 2 kg and a 1 kg bulk till sample for geochemical analysis of the silt plus clay-size fraction (-230 mesh or <0.063 mm) and the clay-size fraction (<0.002 mm), respectively. The third sample, comprising 50 pebbles, was collected for lithological characterization of the till. Lodgement till and colluviated lodgement till were the primary sample mediums. Each till pit was dug to a depth of about 50 cm to collect till from the C-horizon that represents unweathered parent material (Fig. 6). Where possible, till was sampled from natural exposures during stratigraphic investigations. This is beneficial when thick till deposits are encountered, and enables assessment of the vertical variability of the till geochemistry and lithology.

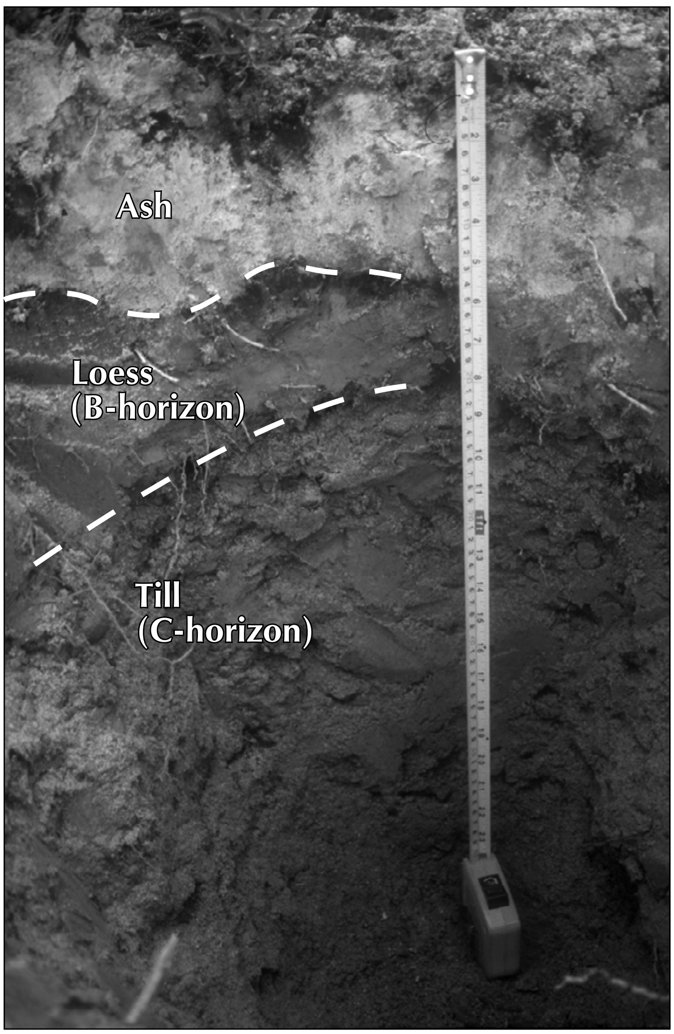


Figure 6. *A typical soil profile from the study area. Loess cover is widespread in the area and often forms the B-horizon in the profile. Pit depth is 60 cm.*

Figure 7. *Taking field notes using a Compaq iPAQ handheld computer.*

Sample information was recorded and digitized in the field using a hand-held computer (Compaq iPAQ; Fig. 7). The information was downloaded at base camp and incorporated into a database. This data, combined with till geochemistry results, will be released on a CD-ROM in 2003.

Exposures of Quaternary sediments located along streams were described with respect to their colour, texture, sedimentary structures, clast lithologies, contacts and lateral continuity. Sections were logged to provide a better understanding of the glacial history, which serves to constrain the interpretation of the regional till geochemistry.

SAMPLE PREPARATION AND ANALYSIS

The till samples were sent to Acme Analytical Laboratories in Vancouver, British Columbia for 1) separation of the silt and clay-size fraction (2 kg sample) and 2) geochemical analysis. Samples were oven-dried at 40°C and dry-sieved to separate the silt- and clay-size fractions (<0.062 mm or -230 mesh). Samples of 30 g were analysed for 39 elements by inductively coupled plasma mass spectrometry (ICP-MS) after an aqua regia digestion. Aqua regia acts as a near total digestion on sulphide minerals and a partial leach on silicate minerals (Hall, 1991). Detection limits for the ICP-MS analyses are shown in Table 1. Results of the geochemical analyses of the clay-size fraction were not available at the time this paper was prepared, but will be released in a later publication, together with the 2001 clay-size results (see Bond and Plouffe, 2002).

QUALITY CONTROL

With the 285 samples submitted for analysis, 29 field and 10 laboratory duplicates, and 37 control standards were randomly inserted to monitor analytical precision and accuracy. A mixture of field and laboratory duplicates was utilized to evaluate the combined sampling and analytical precision. Five different standards were used: two provided by the analytical laboratory, and Till-1, Till-2, and Till-4 obtained from the Canada Centre for Mineral and Energy Technology. Based on a positive correlation between field and laboratory duplicate pairs, the analytical and sampling precision is deemed satisfactory, and is best for lead, zinc, and copper, but worst for gold, probably due to the nugget effect: the heterogeneous distribution of gold particles in the sediment (Fig. 8). Given the low reproducibility of gold anomalies, extensive follow-up field work should not be conducted prior to reproducing gold anomalies herein reported. Analytical accuracy is also deemed satisfactory based on the comparison of the reported average concentrations of the standard samples and the values obtained as part of this study (Table 2).

Table 1. *Detection limits for elements analysed by ICP-MS in the 2002 study.*

Element	Detection	limit
Au	0.2	ppb
Ag	2	ppb
Al	0.01	%
As	0.1	ppm
B	1	ppm
Ba	0.5	ppm
Bi	0.02	ppm
Ca	0.01	%
Cd	0.01	ppm
Co	0.1	ppm
Cr	0.5	ppm
Cu	0.01	ppm
Fe	0.01	%
Hg	5	ppb
Ga	0.02	ppm
K	0.01	%
La	0.5	ppm
Mg	0.01	%
Mn	1	ppm
Mo	0.01	ppm

Element	Detection	limit
Na	0.001	%
Ni	0.1	ppm
P	0.001	%
Pb	0.01	ppm
Pd	10	ppb
Pt	2	ppb
S	0.02	%
Sb	0.02	ppm
Sc	0.1	ppm
Se	0.1	ppm
Sr	0.5	ppm
Te	0.02	ppm
Th	0.1	ppm
Ti	0.001	%
Tl	0.02	ppm
U	0.1	ppm
V	2	ppm
W	0.2	ppm
Zn	0.1	ppm

Table 2. *Elemental concentrations of standards Till 1, 2 and 4 obtained in this study compared to reported values (Lynch, 1996).*

Elements	Pb ppm	Zn ppm	Cu ppm	Ba ppm	Ni ppm	Cr ppm	Co ppm	Au ppb	Ag ppb	As ppm	Sb ppm	Hg ppb
Till-1*	12	63	45	84	19	27	13	7	208	15	6	90
Till-1+	12	70	48	84	18	30	12	n/d	200	13	n/d	92
Till-2*	22	109	147	95	32	35	13	2	221	23	0.4	61
Till-2+	21	116	149	95	31	40	13	n/d	200	22	n/d	74
Till-4*	35	61	245	67	15	24	6	4	154	105	0.64	59
Till-4+	36	63	254	71	15	26	6	n/d	<200	102	n/d	39

**average value from this study +average value Lynch (1996)*
n/d – no data

REGIONAL QUATERNARY GEOLOGICAL CONTEXT

Central Yukon has been repeatedly glaciated since the Late Pliocene. At least six glaciations have been recognized in the Yukon, but only deposits of the three youngest glaciations (McConnell, Reid, and younger pre-Reid) are found within the study area (Duk-Rodkin and Froese, 2001; Jackson, 2000; Ward and Jackson, 2000). Dating of these events, including radiocarbon, K-Ar, Ar-Ar, paleomagnetism and tephrochronology, indicates that the McConnell Glaciation is equivalent to the Late Wisconsinan or marine oxygen isotope stage 2, approximately 26 000 to 10 000 years BP (Matthews et al., 1990; Jackson and Harington, 1991), and that the Reid Glaciation is of marine oxygen isotope stage 8, about 250 000 years BP (Huscroft et al., 2001; Westgate et al., 2001a; 2001b). The pre-Reid glacial sediments of the study area most likely correlate to the informal Fort Selkirk glaciation, which occurred about 1.5 my ago (Huscroft et al., 2001; Westgate et al., 2001b). The area under investigation was glaciated during each of these events but the western sector and some of the highest mountains remained unglaciated during the younger pre-Reid, Reid and McConnell glaciations. Because each glacial event

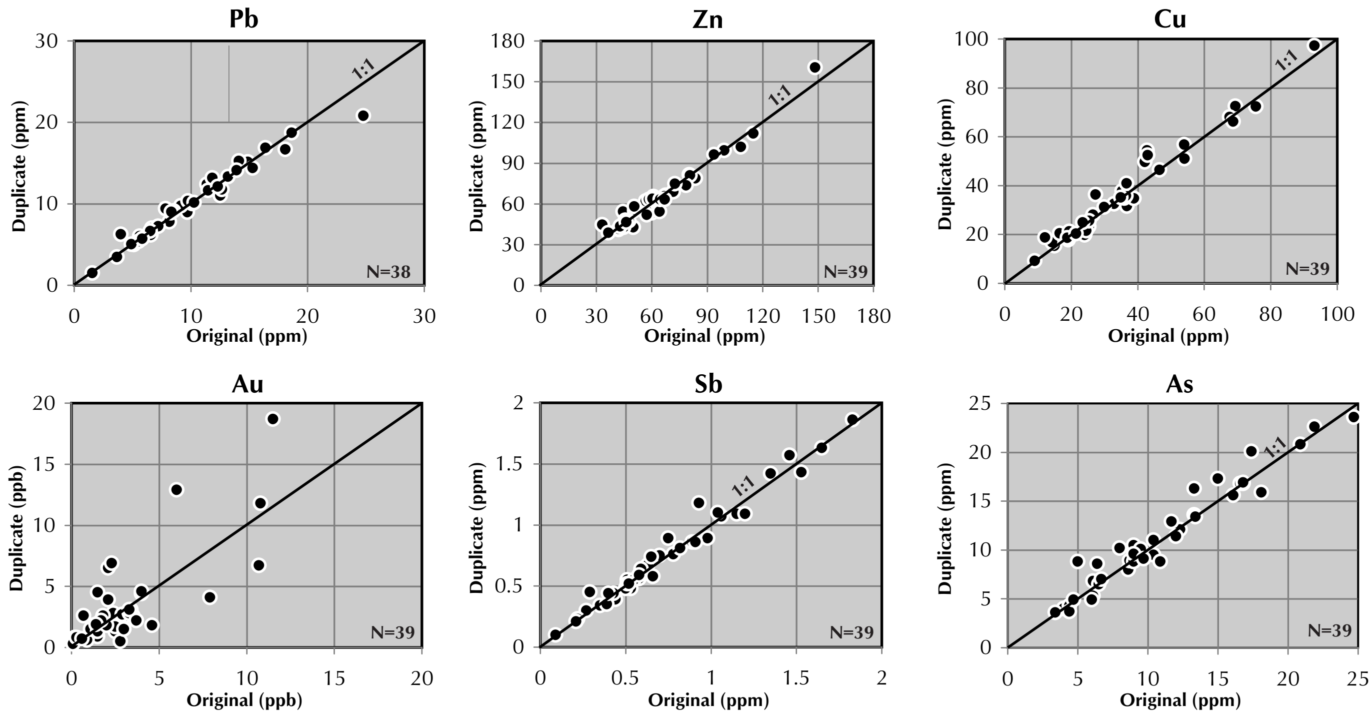


Figure 8. *Correlation plots of field and laboratory duplicates. N = number of samples.*

was less extensive than the preceding one, glacial limits within the study area decrease in elevation with decreasing age (Bostock, 1966; Hughes et al., 1969; Jackson et al., 1996).

Two ice lobes covered the study area during the McConnell Glaciation: the Selwyn Lobe, which had a source area in the Selwyn Mountains, flowed in a general northwest direction, north of the Pelly Mountains (Campbell, 1967; Hughes et al., 1969); the Cassiar Lobe, which originated from the Cassiar Mountains, flowed northwesterly south of the Pelly Mountains (Wheeler, 1961; Hughes et al., 1969). Most of the study area was affected by the Selwyn Lobe but both lobes coalesced in the southern sector of the study area (Ward and Jackson, 2000).

QUATERNARY SEDIMENTS AND STRATIGRAPHY

The Quaternary stratigraphy of the Glenlyon (105L) and Carmacks (115I) map areas is described in Ward and Jackson (2000) and Jackson (2000), respectively. This paper only describes and interprets stratigraphic data collected during the 2002 field season (Fig. 9).

PRE-REID SEDIMENTS

Sediments associated with a Pre-Reid event were not found during the 2002 field season. However, pre-Reid sediments were reported along the Pelly River by Ward and Jackson (2000) and on the Carmacks map sheet by Jackson (2000). Pre-Reid stratigraphy within the Carmacks map area includes Late Tertiary to Quaternary volcanic rocks and glacial and non-glacial sediments (Jackson, 2000).

SEDIMENTS OF THE REID GLACIATION

Evidence of Reid Glaciation may be exposed in section 02-PMA-059 (Fig. 9). Here, the lowest diamicton is massive and well compacted, contains abundant striated clasts, and is interpreted to be a till. Because it is overlain by the McConnell Glaciation succession, the lowest till could correspond to the Reid Glaciation. Alternatively, in the absence of numerical dating, paleosols or interglacial sediments, the lowest till and the upper tills (see below) could all correlate to the McConnell Glaciation and simply reflect a fluctuation of the ice front during ice advance or retreat.

As part of the regional till geochemistry survey, till of the Reid Glaciation was sampled beyond the McConnell

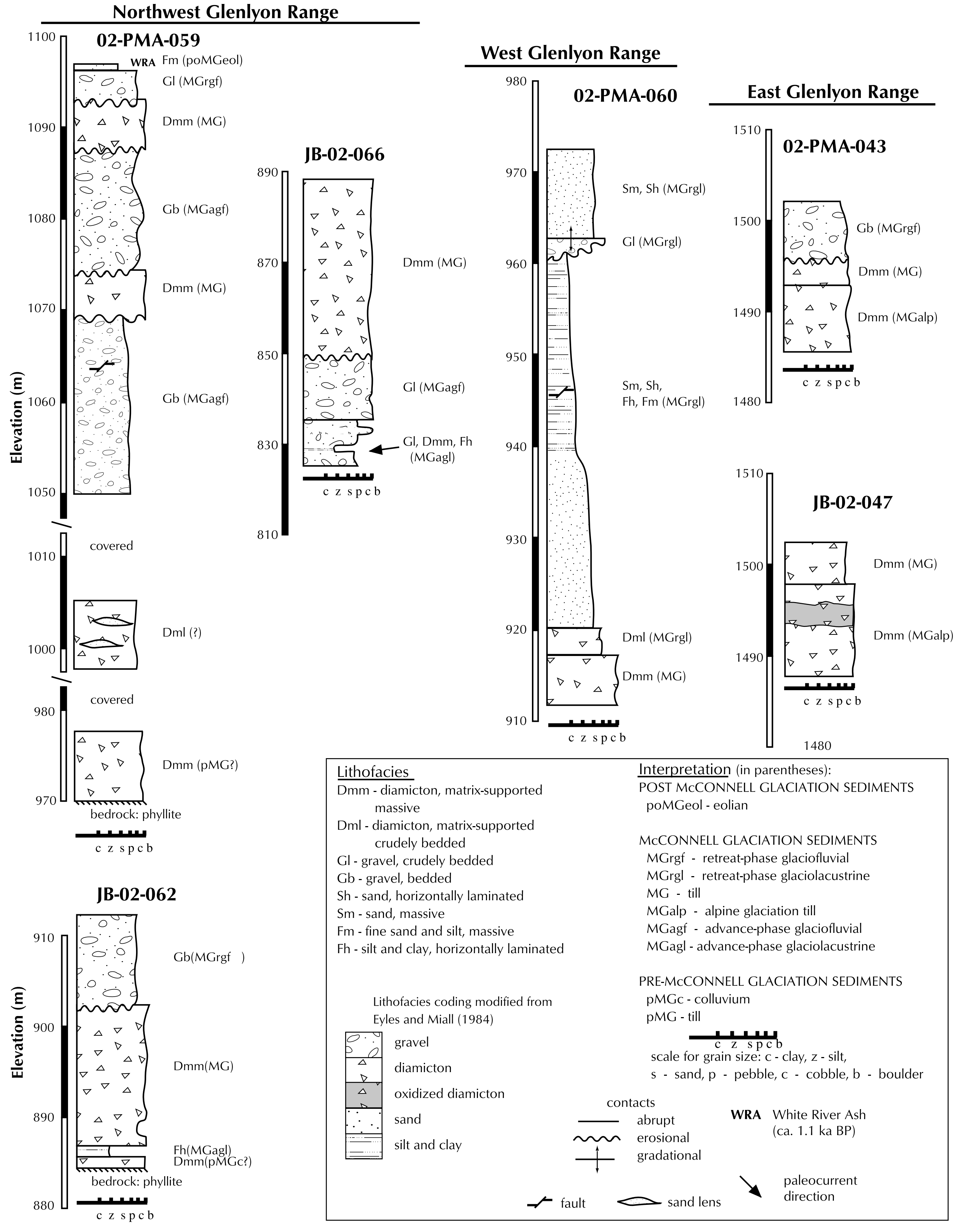


Figure 9. *Quaternary stratigraphy logged during the 2002 field season. Note the different vertical scale for station JB-02-062.*

glacial limit mapped by Ward and Jackson (2000). Reid till is characterized by a solum depth generally in excess of 60 cm, an abundance of weathered clasts, and in a few places, clay skins on some clasts. These criteria correspond to the description of the Diversion Creek paleosol, which developed on much of the Yukon landscape following the Reid glaciation (Smith et al., 1986).

SEDIMENTS OF THE McCONNELL GLACIATION

The majority of the sediments exposed within sections were deposited during the McConnell Glaciation. These sediments were deposited either at the ice front or underneath the glacier during ice advance and retreat at stations JB-02-062, JB-02-066, and 02-PMA-060. Massive to horizontally laminated units of well sorted fine sand and silt with minor clay were observed below and above McConnell till. These units commonly contain soft sediment deformations and interbeds and lenses of gravel and diamicton (Fig. 10). The fine sand, silt and clay were deposited in low energy environments of glacial lakes. Gravel lenses and interbeds reflect sedimentation at the mouth of meltwater streams that entered the glacial lakes. The diamicton within the glacial lake sediments was deposited by sediment gravity flows derived from the reworking of till and outwash deposits. Glacial lake sediments indicate that the drainage was blocked during ice advance or retreat. Part of the sediment deformation is thought to be due to the melting of supporting ice. Similar glacial lake sediments were described by Ward and Rutter (2002) for the Pelly River valley.

Massive to well bedded clast-supported gravel units are present above and underneath McConnell till (stations JB-02-062, JB-02-066, 02-PMA-043, and 02-PMA-059; Fig. 9). The gravel is pebbly to bouldery and moderately to poorly sorted. These deposits are thought to reflect glaciofluvial sedimentation and indicate free drainage conditions at the ice front.

Figure 10. *Folds in glaciolacustrine sediments at site 02-PMA-060 are indicative of soft sediment deformation following the melting of supporting ice.*

Well compacted massive diamictons containing abundant striated clasts and lithologies of distal sources were observed at all stations. The diamicton units contain clasts of pebble to boulder size in a poorly sorted matrix of sand, silt and clay. They are on average 3 to 10 m thick and are continuous across the exposures. A fabric measurement of 10 elongated clasts in the diamicton unit at station JB-02-062 indicates that clasts are dominantly parallel to both the east-trending valley and the interpreted local ice flow. Based on these criteria the diamictons are interpreted to be till. Except at station 02-PMA-059 where a pre-McConnell till might be present, all diamicton units interpreted to be till are assigned to the McConnell Glaciation because they are correlated to the McConnell till present at surface throughout the region (see Ward and Jackson, 2000).

Two till units correlated to the McConnell Glaciation at section 02-PMA-059 are interpreted to reflect a fluctuation of the ice front probably during deglaciation. Further evidence for ice readvance at the end of the McConnell Glaciation was suggested in south-central Yukon by Plouffe and Jackson (1992), Jackson (2000), Ward and Jackson (2000), and Bond (2001). Two till units observed in the Glenlyon Ranges at stations 02-PMA-043 and JB-02-047 (Fig. 9) are thought to reflect ice advance from two different source regions. The lower till at both sites contains abundant large boulders of local intrusive rocks with an average diameter of 2 to 3 m; its matrix is very sandy, and the unit is gently dipping down-valley (Fig. 11). The lower till is sharply overlain by an upper till which contains smaller clasts and a more silty-clayey matrix compared to the lower till. Clasts of erratic lithologies (fine-grained sedimentary and volcanic rocks) are more abundant in the upper till than in the lower till. The lower till is thought to have been deposited by Glenlyon Range alpine glaciers at the onset of the McConnell Glaciation, and the upper till by the Selwyn Lobe. This interpretation suggests that the Selwyn Lobe overrode alpine glaciers in the Glenlyon Range and that these alpine glaciers did not make a significant contribution to the Selwyn Lobe. This interpretation corroborates Ward and Jackson's (1992) conclusions and has important implications for tracking till/soil geochemistry in this area.

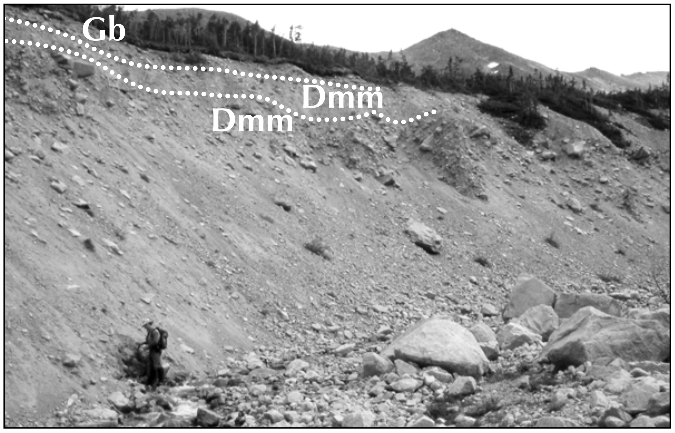


Figure 11. *Quaternary sediment exposure at station 02-PMA-043 showing a lower bouldery till (Dmm) of local provenance overlain by a second till (Dmm) deposited by the Selwyn Lobe. The gravel (Gb) was deposited by glacial meltwater at ice retreat.*

Till of the McConnell Glaciation was widely sampled as part of the regional till geochemistry survey. McConnell till is characterized by a shallow solum depth of 30 to 40 cm on average and a matrix with more silt and clay compared to Reid Till.

POSTGLACIAL SEDIMENTS

Following deglaciation, sediments left on steep slopes were subjected to gravity processes and redeposited as colluvium. In valleys, streams reworked the glacial sediments and went from a phase of aggradation to degradation. Organic sediments accumulated in poorly drained depressions.

A discontinuous veneer of eolian sediments (loess), consisting of well sorted, massive, very fine sand and silt, occurs over most of the area. It has an average thickness of 10 to 40 cm but locally may be as thick as 1 m. Where eolian sediments are greater than 30 cm thick, they were found to be an impediment to till sampling. Considering that eolian sediments are composed of fine-grained particles derived from a mixture of glacial sediments, their geochemistry reflects regional background metal concentrations and not the underlying bedrock geology. Consequently, eolian sediments were not sampled during this survey and should be avoided during a soil survey (soil B-horizon sampling). Soil samplers should be trained to recognize the eolian sediments and to distinguish them from till, which is the most preferable sediment type to sample during a soil survey.

The White River Ash, dated at 1147 calendric years BP (Clague et al., 1995), was observed in sample pits and sections and generally varies in thickness from 10 to 20 cm over the area (Fig. 12).

GLACIAL STRIATION RECORD

Four bedrock outcrops with glacial striations were examined. Three of which are located in the Little Salmon Lake region and a fourth one northeast of Glenlyon Range near the Pelly River valley (Fig. 5, 13). None of those outcrops show multiple sets of striations and consequently the striations are thought to reflect the direction of the last ice movement in each region. The lack of glacial striations is attributed to the general low abundance of fresh bedrock outcrops on which these micro-landforms are generally preserved.

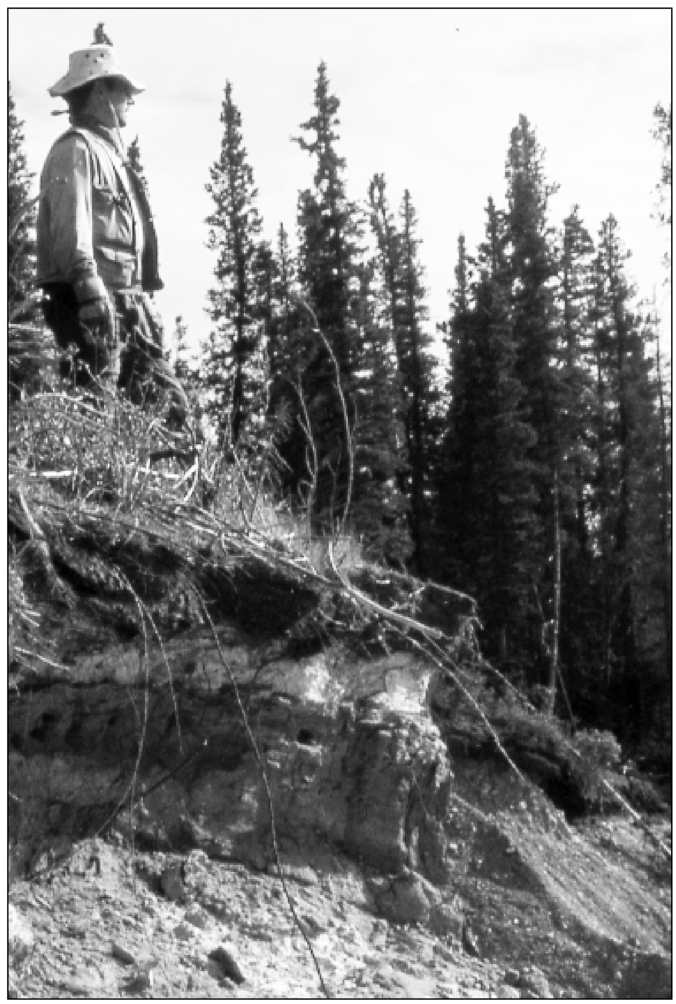


Figure 12. *White River ash (white layer) exposed in the top part of section 02-PMA-059.*

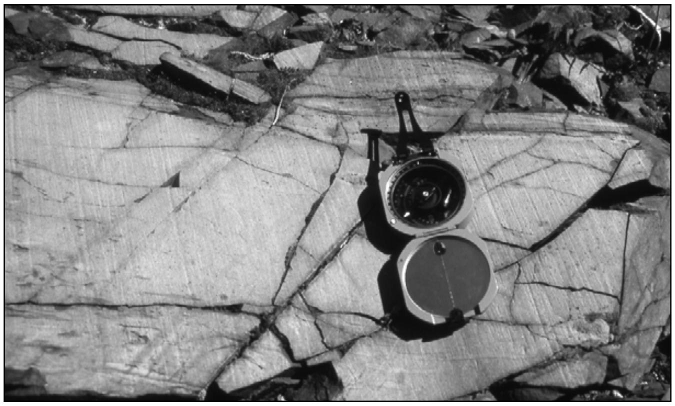


Figure 13. *Glacial striations on orthoquartzite bedrock northeast of Glenlyon Range (see Figure 5 for location).*

QUATERNARY HISTORY

The ice-flow patterns of the Reid Glaciation can only be reconstructed beyond the limit of the McConnell Glaciation. Following that reconstruction, it can be assumed that ice-flow patterns during the Reid Glaciation were similar to the McConnell Glaciation with minor modifications due to thicker ice cover during the Reid Glaciation (Jackson, 2000).

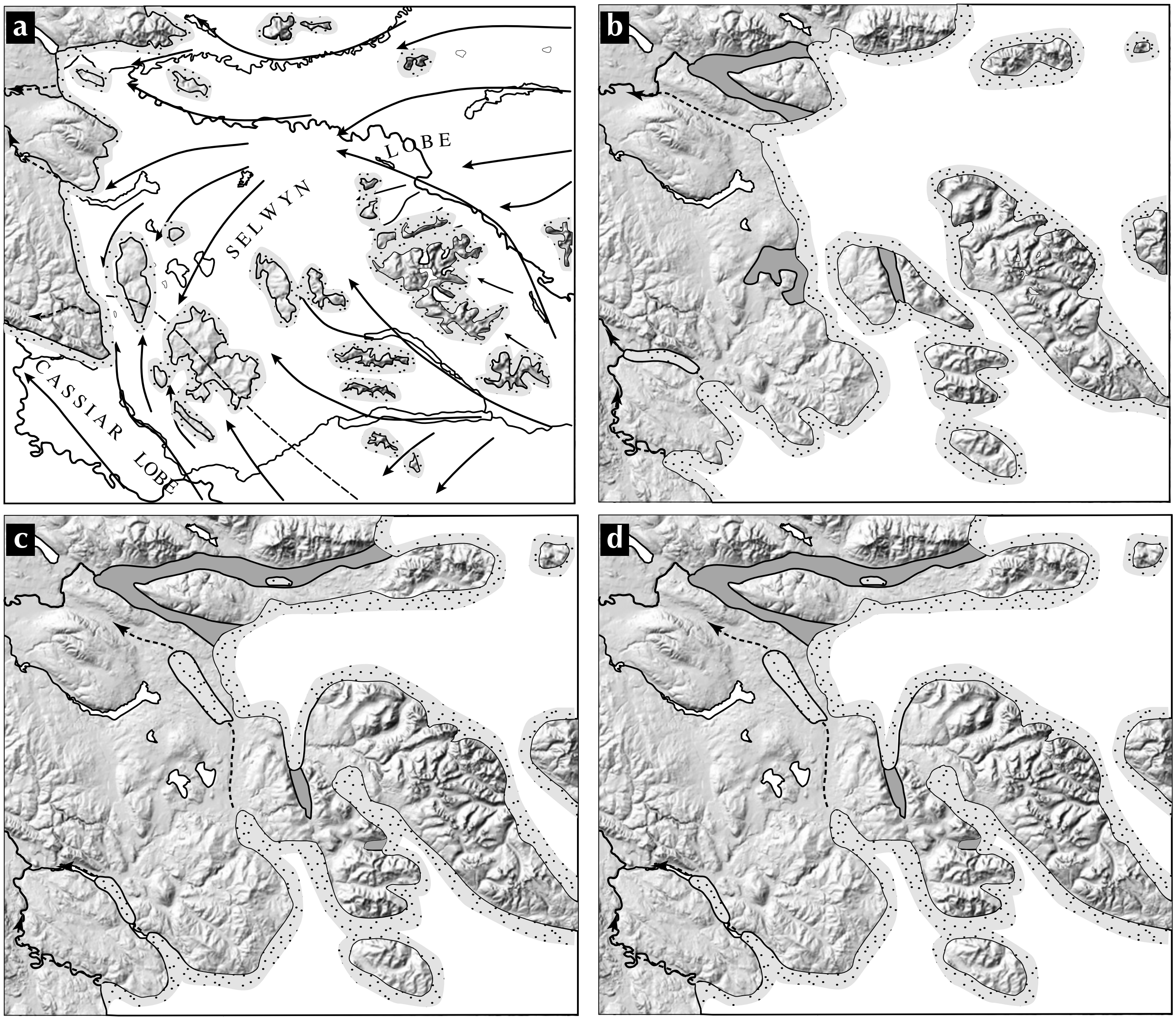
Pedological and palynological investigations indicate that the nonglacial interval between the Reid and McConnell glaciations was warmer and somewhat moister than present conditions (Smith et al., 1986; Schweger and Matthews, 1991). No evidence of an early Wisconsinan glaciation is present in the study area.

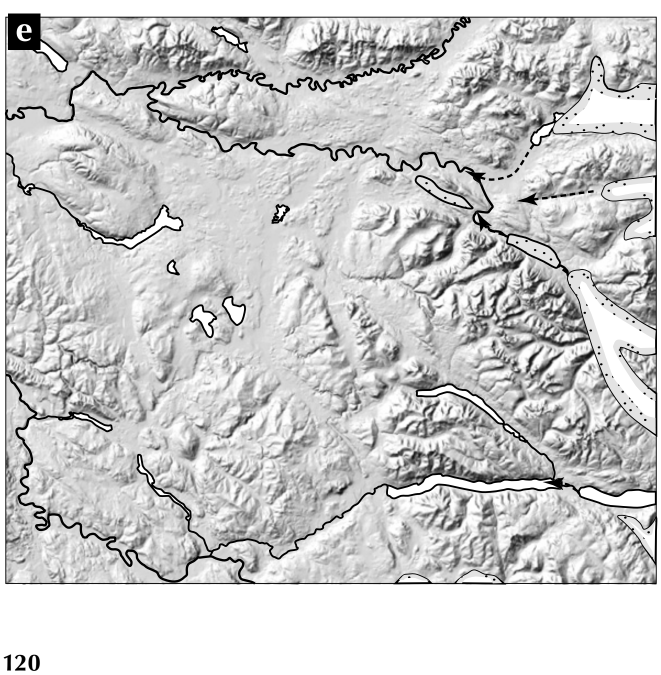
Based on radiocarbon chronology, at the onset of McConnell Glaciation, ice advanced into the major valley systems of south-central Yukon sometime after 26 ka (Jackson and Harington, 1991; Jackson et al., 1991). At that time, ice tongues advanced in the major valleys of the eastern sector of the study area, and alpine glaciers formed in the Glenlyon Ranges perturbing the drainage. Glacial lakes developed in tributary valleys blocked by ice (e.g., near station JB-02-062), and outwash fans formed at the ice front in places where the glacier was advancing downslope (e.g., near station 02-PMA-059). At glacial maximum (Fig. 14a), 1) the Selwyn and Cassiar ice lobes abutted in the southwestern sector, 2) some of the highest mountains remained unglaciated, 3) local ice accumulation in the Glenlyon Range had a limited extent, and 4) ice-flow patterns were influenced by topography (Ward and Jackson, 1992; Jackson, 2000; Ward and Jackson, 2000).

The retreat of the Cordilleran Ice Sheet is thought to have occurred through a combination of downwasting, stagnation, and complex frontal retreat (Clague, 1989; Jackson et al., 1991). Areas where the ice was thinnest were the first to be deglaciated. Within the study area, the ice generally retreated from west to east. A schematic pattern of ice retreat for the study area is here proposed which takes into account the position of moraines and lateral and direct overflow meltwater channels, along with the distribution of glaciofluvial and glaciolacustrine sediments mapped by Ward and Jackson (2000) and Jackson (2000; Fig. 14). A synchronous pattern of ice retreat between the Selwyn and Cassiar lobes was assumed in constructing the phases of deglaciation.

During deglaciation, as a result of ice or sediment dams, glacial lakes formed in the Tadru, Ess Lake and Pelly River valleys, and in the northern Little Salmon Range (Fig. 14b). Large masses of stagnant ice became detached from the retreating ice front and stagnated in situ, resulting in terrain with complex hummocky topography (Figs. 14c, 15; Ward and Jackson, 2000). As ice retreated further east, glacial lakes formed in the Drury Lake and Little Salmon River valleys (Fig. 14d). Glacial lakes drained following the collapse of the sediment or ice dams (Fig. 14e; Lye et al., 1990).

This simplified model of deglaciation provides indication of the evolution of ice-flow direction and glacial transport from glacial maximum to the end of the deglaciation. The greatest amount of glacial transport likely occurred at glacial maximum but transport also took place during glacial retreat. Ice flow, in general, was perpendicular to the ice front during deglaciation, and thus the evolution of ice flow presented in this model should be taken into account for the interpretation of the till geochemistry presented in this report.





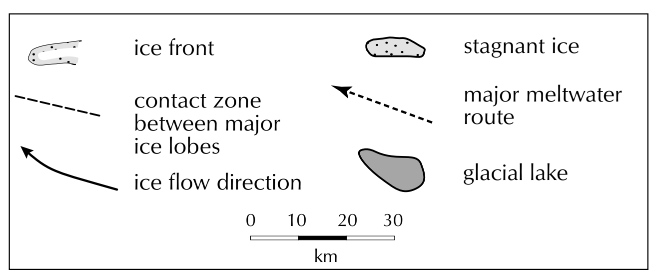


Figure 14. *Schematic representation of the deglaciation of the study area (shown in Figures 5 and 16) based on the surficial geology mapping of Jackson (2000) and Ward and Jackson (2000). It assumes a synchronous pattern of ice retreat between the Selwyn and Cassiar lobes.* ***(a)*** *Ice flow at glacial maximum and approximate contact zone between ice lobes (Ward and Jackson, 2000);* ***(b-e)*** *phases of ice retreat.*

Figure 15. *Ice stagnation terrain at the McConnell glacial limit near Frenchman Lake.*

TILL GEOCHEMISTRY: RESULTS

ORIENTATION SURVEY – CLEAR LAKE

An orientation survey was completed at the Clear Lake sedimentary-exhalative (SEDEX) deposit (Yukon MINFILE 2002, 105L 045), 75 km east of Pelly Crossing. This survey was conducted to establish the length of glacial dispersal and the elemental signatures associated with massive sulphide mineralization in a physiographic and geological setting typical of the study area (Fig. 16). The ore body subcrops under 10 to 25 m of McConnell till and would have been directly exposed to glacial erosion by the Cordilleran Ice Sheet. This provides an ideal setting to characterize the dispersal train down-ice from a known massive sulphide body.

The deposit is hosted by carbonaceous argillite, siltstone, chert and tuff of the Devono-Mississippian Earn Group (*ibid.*). The Tintina Fault is located to the northeast of the property. In plan view, the deposit is a sigmoidal-shaped

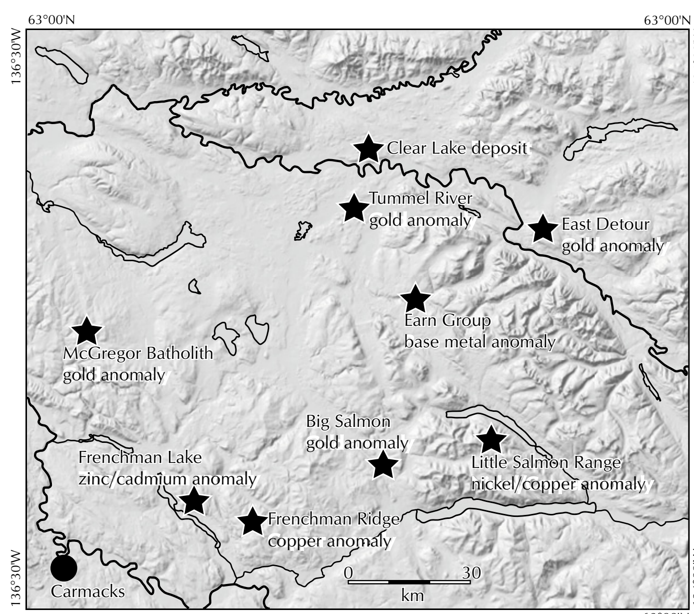


Figure 16. *Distribution of anomalies discussed in the till geochemistry section (larger map shown in Figure 5).*

sulphide body, approximately 1000 m long and up to 100 m thick (Fig. 17; *ibid.*). Geological reserves are 6.1 million tonnes grading 11.34% Zn, 2.15% Pb and 40.8 g/t Ag, using a cutoff grade of 7% of combined Zn and Pb (*ibid.)*.

Permafrost is present in the area, and the active layer thickness is reduced where loess, an impermeable sediment, is more than 30 cm thick. In some sampling pits, west of the deposit, loess thickness exceeded 100 cm, which hindered and prevented till sampling. Local drainage is primarily through groundwater, and is reflected in Clear Lake which has a pH of <3.0 (K. Fletcher, pers. comm., 2002). Lake-bottom sediment samples assayed up to 19 000 ppm Zn (Yukon MINFILE 2002).

In total, 25 till samples were collected, beginning 250 m up-ice and ending approximately 2300 m down-ice, in an easterly direction parallel to McConnell ice flow (Fig. 17). Sample spacing increased from 25 m over the deposit to greater than 200 m near the end of the line.

Lead

Lead concentrations are anomalous immediately west of the deposit, with concentrations as high as 344 ppm (Fig. 18). At 600 m west of the deposit, values decreased to 45 ppm Pb, and 2300 m west of the deposit, concentrations are below 19 ppm. High concentrations in the three samples immediately west of the deposit are the result of glacial transport of material from the main massive sulphide body. The outlying anomaly, 600 m west of the deposit, may also represent glacial transport or possibly a concealed mineralized zone. Previous geologic interpretations have speculated that additional mineralization may occur in Earn Group stratigraphy near the footwall of the Askin thrust fault (R. Zuran, pers. comm., 2002) and that movement on the fault may have brought mineralized rock to the surface.

Zinc

Zinc distribution in till at Clear Lake does not correlate with the lead distribution and shows no abrupt increase down-ice from the deposit. The average value of 72 ppm in the vicinity of the deposit (Fig. 19) equates to the 75th percentile from the regional data. Much higher concentrations were expected from a SEDEX deposit containing significant zinc grades dominantly bound up in sphalerite. The low zinc concentrations in till may be linked to acid weathering, as a result of the underlying massive

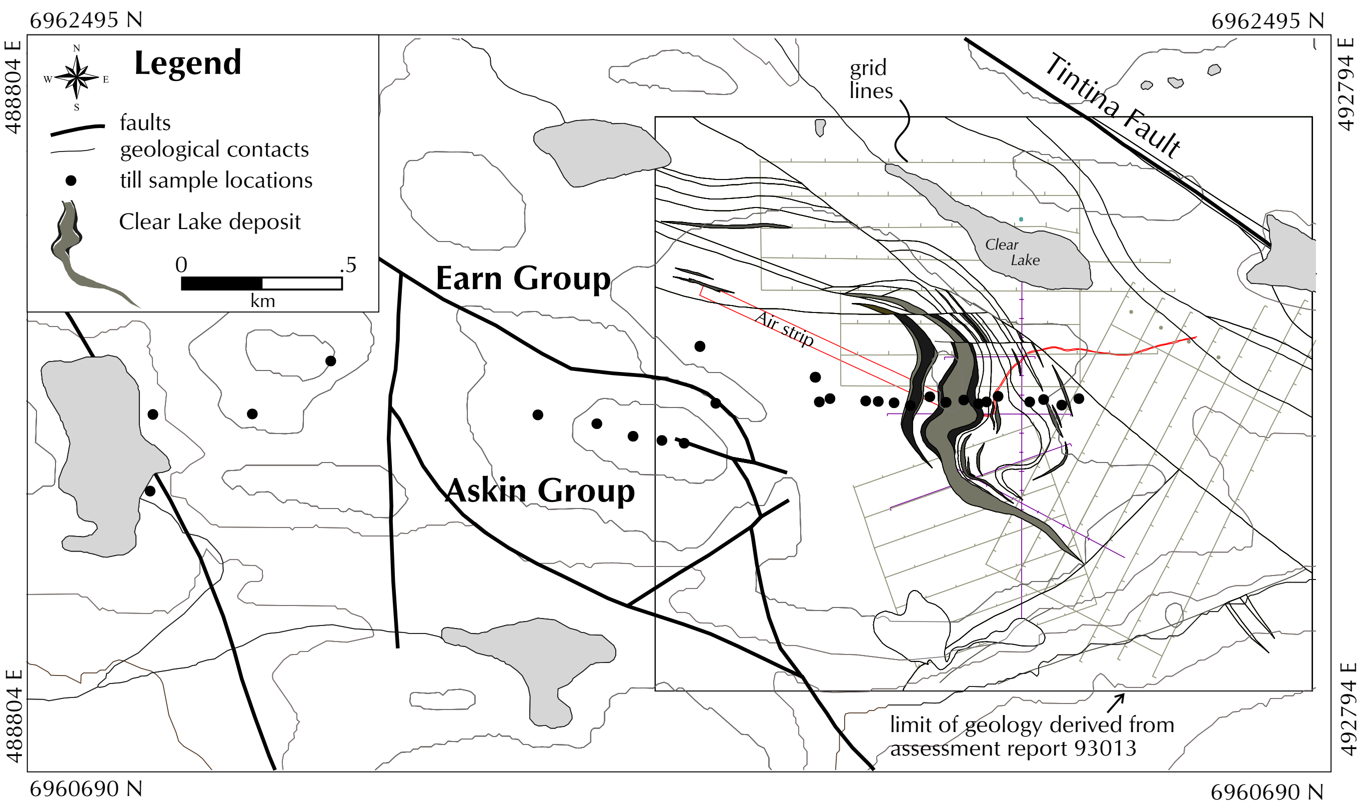


Figure 17. *Location of till samples relative to the subcropping Clear Lake deposit.*

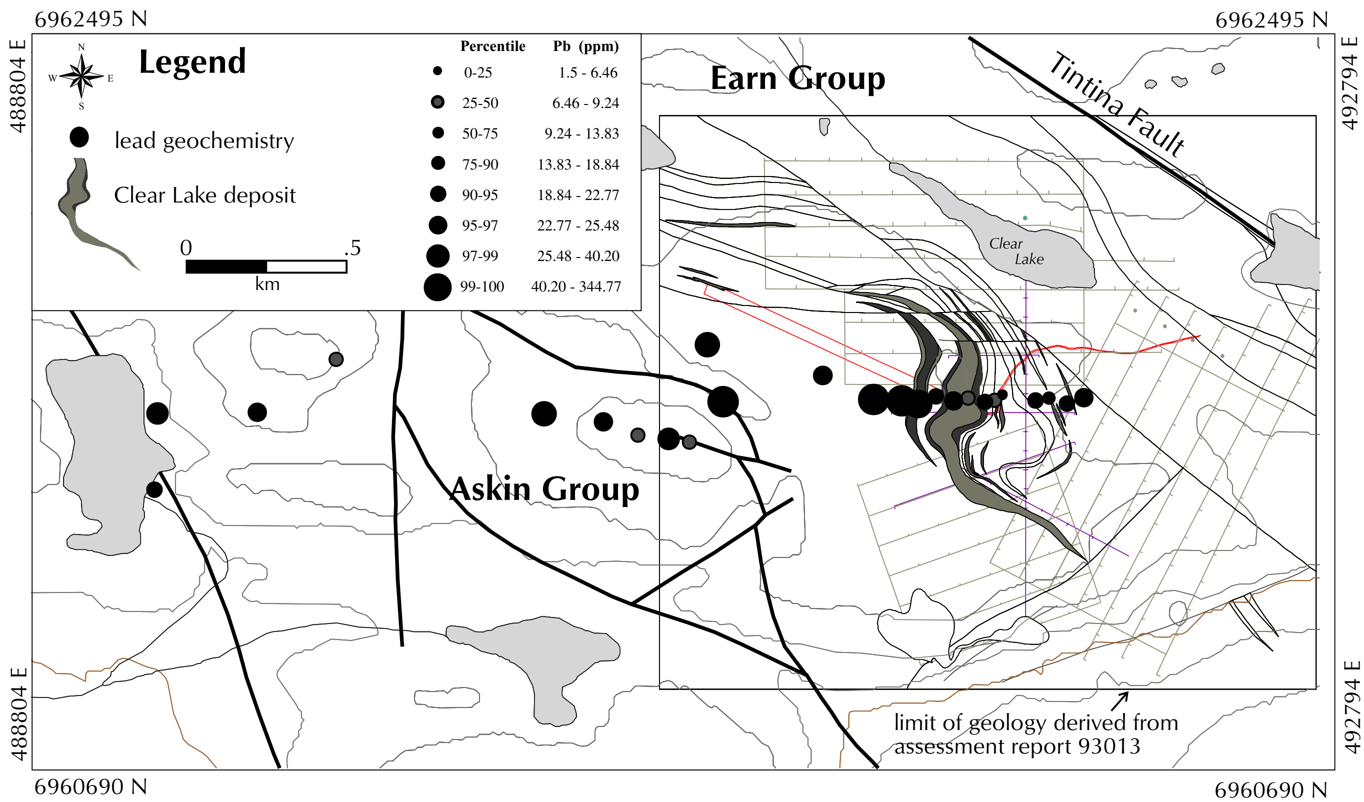


Figure 18. *Lead concentrations in till at the Clear Lake deposit.*

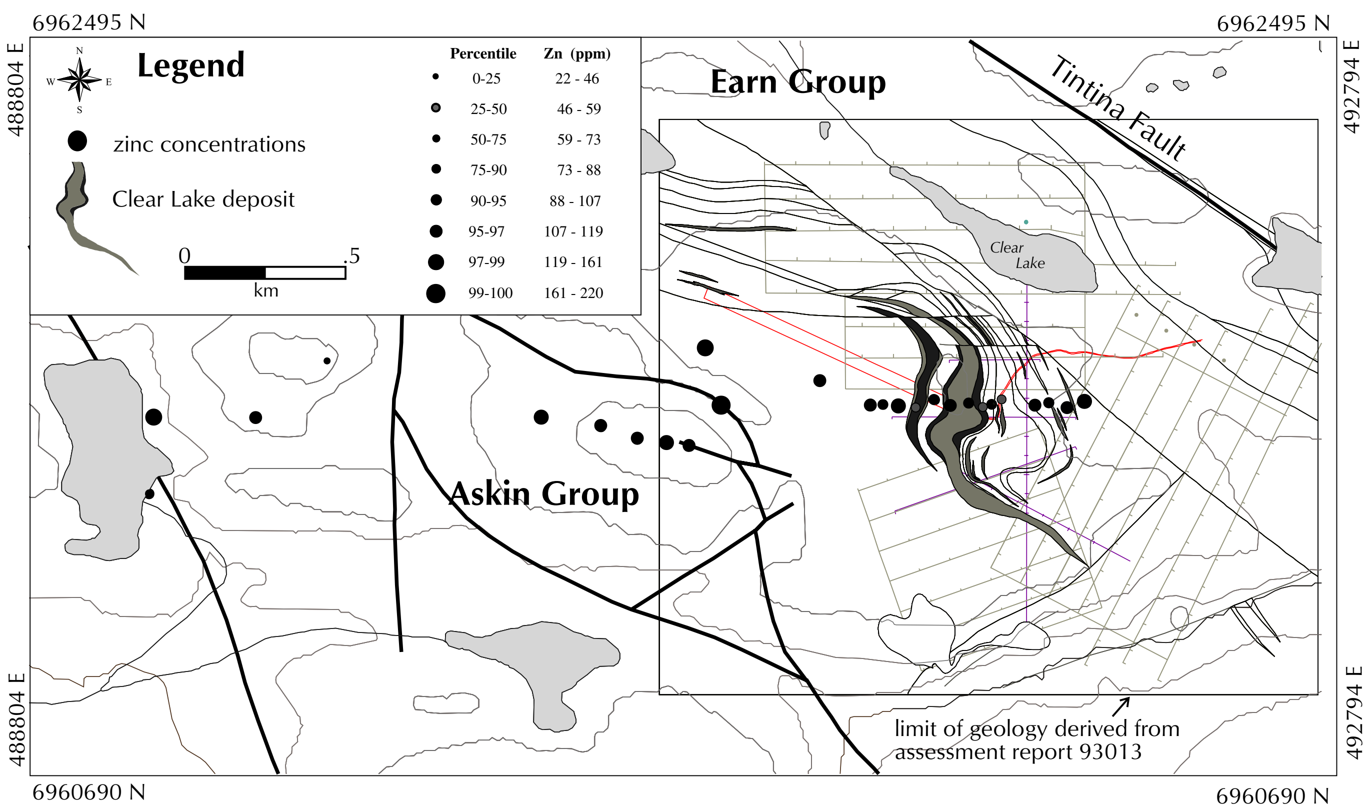


Figure 19. *Zinc concentrations in till at the Clear Lake deposit.*

sulphide deposit, which probably leached most of the sphalerite (K. Fletcher, pers. comm., 2002). Acid leaching would also account for the high Zn values in lake-bottom sediments from Clear Lake. The highest zinc concentrations near the deposit are found in till containing limestone clasts. The presence of limestone in the till, derived from the up-ice region, would act as a buffering agent and reduce acid weathering. More intense acid conditions over the deposit, however, may have removed the limestone clasts and their ability to buffer zinc leaching (K. Fletcher, pers. comm., 2002). Calcium concentrations in till are found to mimic the percentage of limestone clasts and therefore could be used as an indication of buffering potential of the till. The outlying zinc anomaly 600 m west of the deposit corresponds with the high lead value discussed earlier. At Clear lake, zinc is not considered to be a reliable pathfinder element to define the presence of concealed massive sulphide mineralization.

Mercury

Previous soil surveys at Clear Lake identified mercury to be a useful pathfinder element (R. Zuran, pers. comm., 2001). Mercury concentrations in till reach 1743 and 1452 ppb immediately west of the deposit, 143 ppb over the deposit, and 281 ppb 600 m down-ice (Fig. 20). This data supports mercury as a useful pathfinder element in till at Clear Lake.

Barium

Massive barite was intersected in several drill holes and is interpreted to be peripheral to the Clear Lake deposit (Yukon MINFILE 2002, 105L 045). Anomalous barium concentrations were identified both up-ice and down-ice of the deposit (Fig. 21). This may reflect the underlying geology or alternatively, it could be an acid leach feature creating a depletion zone. Barium is considered a reliable pathfinder element at Clear Lake. It should be noted that barite is only partially leached in aqua regia, and that a stronger leach should be used to better define the barium content of till in the vicinity of Clear Lake.

Silver

Silver grades in the main ore body average 40.8 g/t (*ibid.*). A distinct dispersal train of silver values, similar to Pb and Hg, is visible immediately west of the deposit (Fig. 22). Anomalous values are also present east of the deposit, which may suggest above background values for the local area and a depletion zone over the deposit.

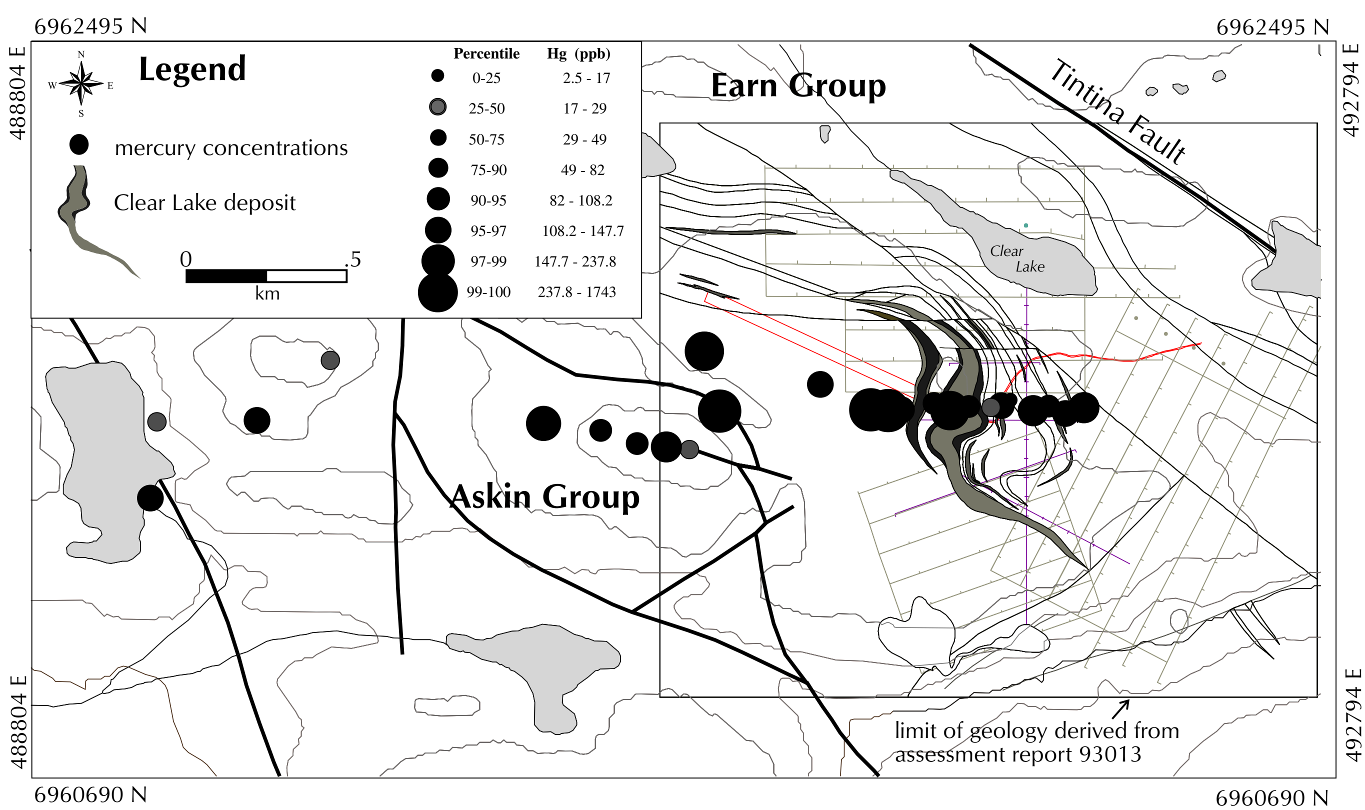


Figure 20. *Mercury concentrations in till at the Clear Lake deposit.*

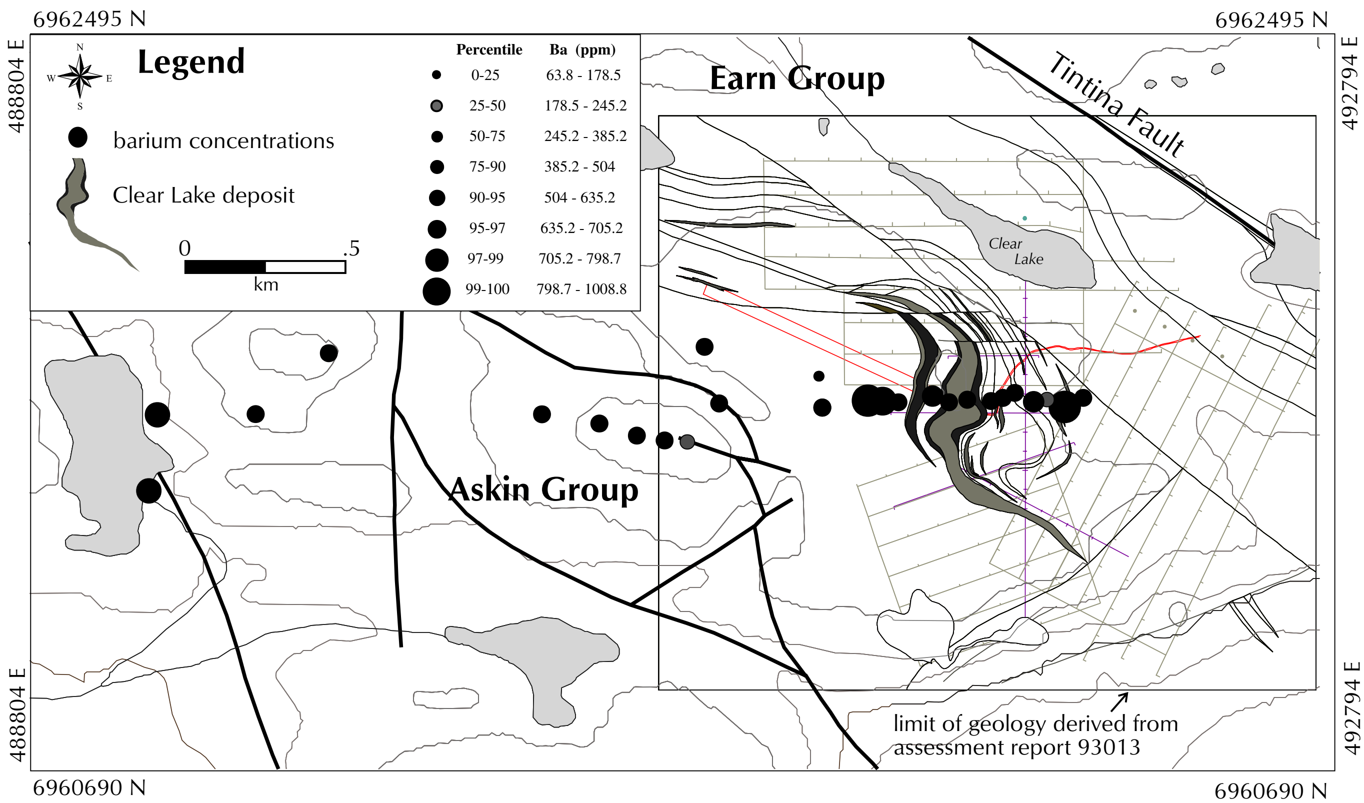


Figure 21. *Barium concentrations in till at the Clear Lake deposit.*

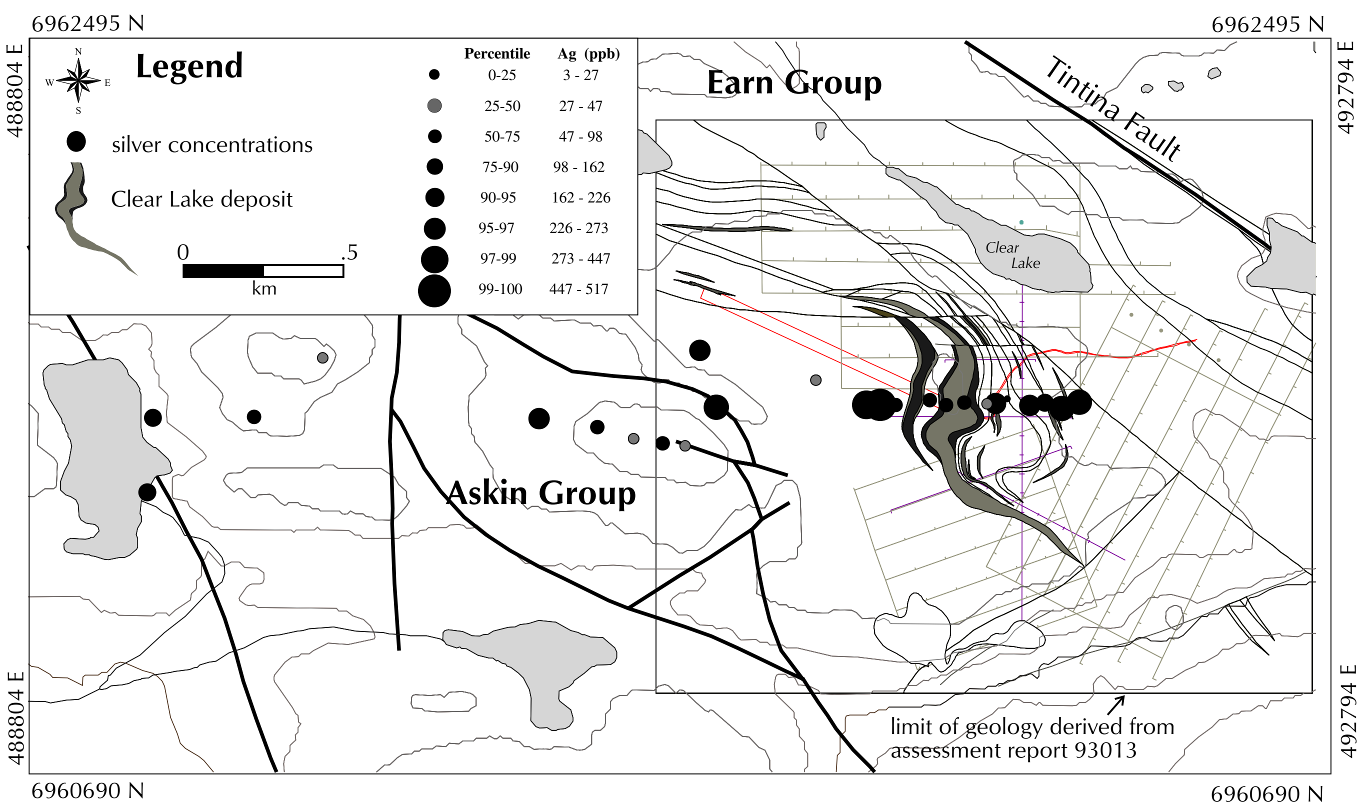


Figure 22. *Silver concentrations in till at the Clear Lake deposit.*

Summary

The till geochemistry at Clear Lake supports the drift prospecting methodology employed in this study. Distinct geochemical anomalies in Pb, Hg, Ba and Ag were noted immediately down-ice of the deposit. Zinc appears to have been leached from the till by acid weathering and is not a reliable pathfinder element, despite the high zinc concentrations in the deposit. The length of the glacial dispersal train for the pathfinder elements discussed above is approximately 600 m.

REGIONAL TILL GEOCHEMISTRY

A total of 285 till samples were collected in the Glenlyon and eastern Carmacks map areas (Fig. 23). Highlights from the geochemical survey are presented in this section with special attention paid to multi-element associations that have significance to mineral exploration. References to the bedrock geology are derived from Colpron et al. (2002) and Gordey and Makepeace (1999). The term anomaly used in this report designates elemental concentrations that are above the 95th percentile of the regional data.

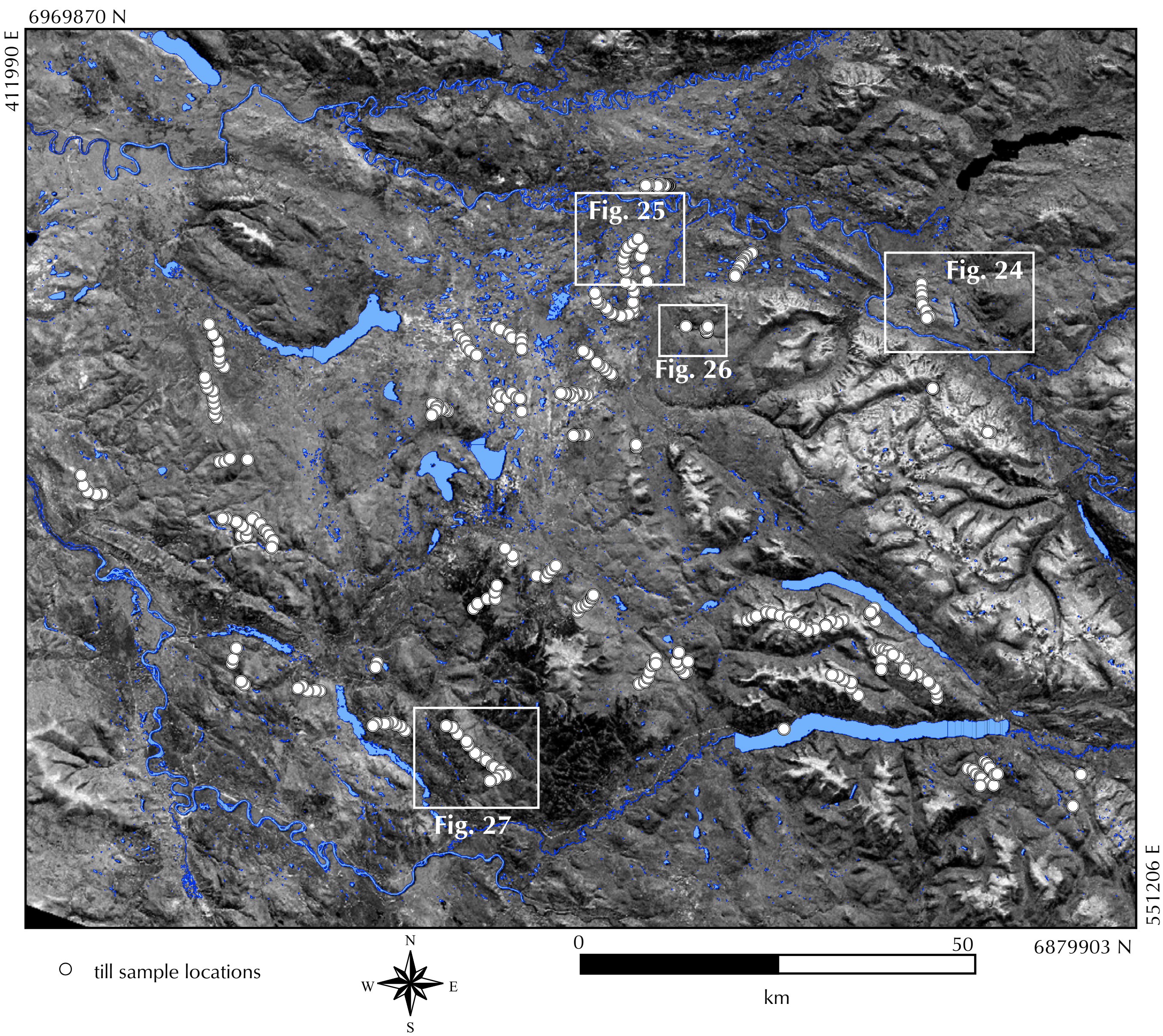


Figure 23. *Map of the study area on satellite photo background showing the distribution of regional till samples collected in 2002.*

GOLD

Bedrock lithologies and structure within the study area are favourable for both epithermal and intrusion-related gold mineralization. The mean gold concentration is 4 ppb, the 97^{th} percentile equaled 16 ppb, and the highest value equaled 34 ppb.

East Detour Gold Anomaly

The highest gold value (34 ppb) was obtained from the northeast part of the study area near the Tintina Fault and Pelly River in Selwyn Basin rocks consisting of chert, siltstone, phyllite, limestone and conglomerate of the Rabbitkettle formation (Gordey and Makepeace, 1999; Fig. 16). It is termed the 'East Detour' gold anomaly and has a multi-element signature in Au, As, Pb, Bi and Sb that is suggestive of a plutonic association. Arsenic is perhaps the most anomalous element in this region, with six out of eight samples containing >42 ppm (98^{th} percentile) (Fig. 23, 24). The station with the highest arsenic value (02-PMA-114, 212 ppm) also corresponds to the highest gold (34 ppb) and bismuth concentrations (0.73 ppm). Gold concentrations are not high at other sites along the sample line.

The presence of mid-Cretaceous intrusions 19 km up-ice from the sample line, together with the till geochemistry, suggests that the source of gold might be intrusion-related mineralization as observed elsewhere within the Tintina Gold Belt. Mid-Cretaceous intrusions could lie in the subsurface closer to the sample line, and hornfels in the Rabbitkettle formation may host the mineralization. This is assumed because of the dominance of arsenic and antimony, and lack of tungsten (Hart et al., 2000). The regional airborne geophysical data shows both a magnetic high and a low, up-ice flow from the sample line, which may outline a subsurface intrusion. Given the usually short length of gold dispersal trains, the source of the gold likely lies a few hundred metres to the southeast (up-ice). As part of a follow-up survey more till samples could be collected at station 02-PMA-114 (522721E, 6948736N) and up-ice from it. Access into the area includes the Detour/Clear Lake winter road which terminates at an air strip 8 km west of the sample line across the Pelly River.

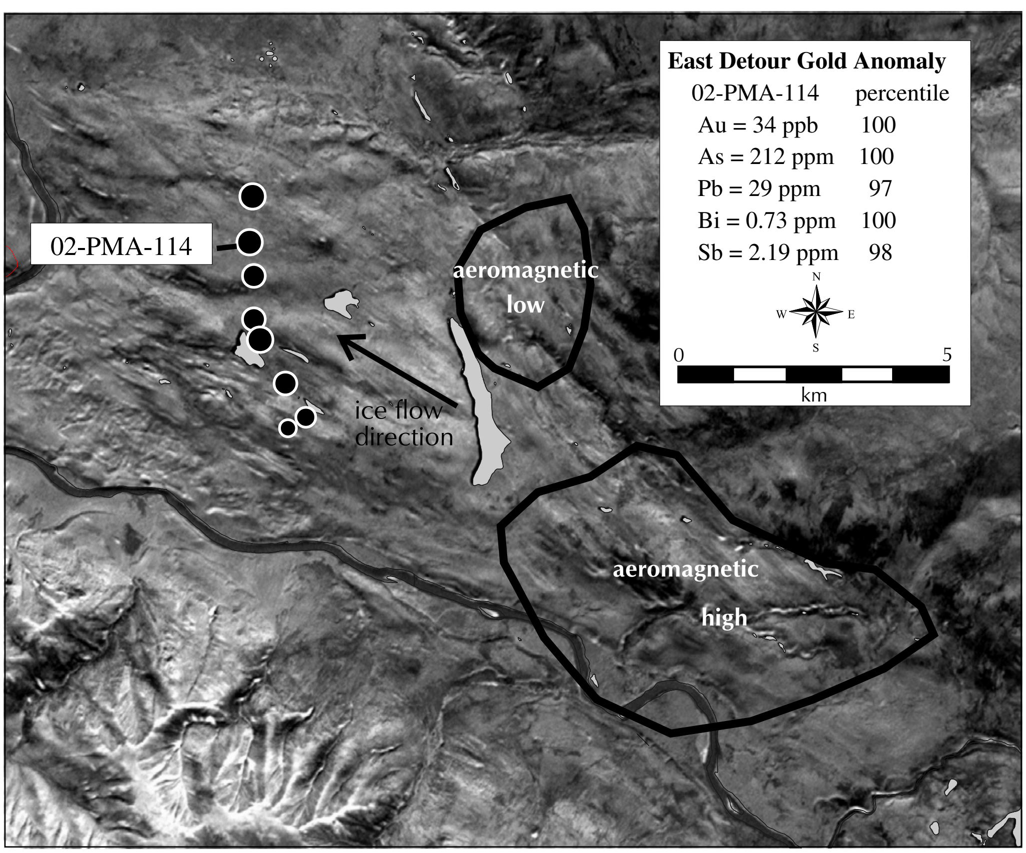


***Figure 24**. Detailed map of the East Detour gold anomaly. The samples are shown relative to an aeromagnetic high and low that may indicate buried intrusive rocks responsible for the anomalous plutonic signature. Arsenic concentrations are shown on the sample line. UTM = 522721E, 6948736N for sample 02-PMA-114.*

The area is also accessible by float plane into an unnamed lake.

Tummel River Gold Anomaly

The Tummel River gold anomaly is defined along a sample line located west of the Tummel and south of the Pelly rivers (Fig. 16). The most anomalous samples along the line are 02-PMA-074 (As 37 ppm, Sb 2.06 ppm) and 02-PMA-076 (Au 16.8 ppb; Fig. 23, 25). The multi-element association and the proximity to known granite suggest that the anomalies might be intrusion-related, similar to the East Detour anomaly. The Tummel River gold anomaly is associated with a geophysical anomaly similar to the one at Tombstone Mountain, north of Dawson City, where a magnetic high is caused by the presence of pyrrhotite in the altered country rock (Hart et al., 2000). A magnetic high is present adjacent to and up-ice flow from the mapped granite, directly underlying the samples with the highest metal concentrations (Fig. 25).

This anomaly likely has a transport distance of less than 4 km. The ice-flow trajectory is trending at approximately 256 degrees. In tracing the anomaly up-ice flow, 76 degrees should be used as a general direction to source. The Clear Lake/Detour winter road lies 1 km north of the anomalous sample and the Pelly River is 4 km north. The UTM coordinates for sample 02-PMA-076 are 487617E, 6954574N.

McGregor Batholith Gold Anomalies

The McGregor Batholith is situated immediately east of the Yukon River and Klondike Highway and north of Tatchun Lake (Fig. 16). The batholith is an early Jurassic granodiorite (Colpron et al., this volume). Anomalous gold values were obtained from two till sample locations, JB02-132 (29.2 ppb) and 02-PL-001 (23.3 ppb). These sites lie outside the McConnell glacial limit and within deposits of the Middle Pleistocene Reid glaciation. Regional stream geochemical data shows anomalous gold values near 02-PL-001 and near the north edge of the batholith at the Tatlmain mineral occurrence (Yukon MINFILE 2002, 115I 114). Stream sediment geochemistry at Tatlmain shows anomalous values for gold, arsenic and tungsten (*ibid.*).

The ice flow history in this part of the study area is poorly defined due to weathering of glacial landforms. Generally,

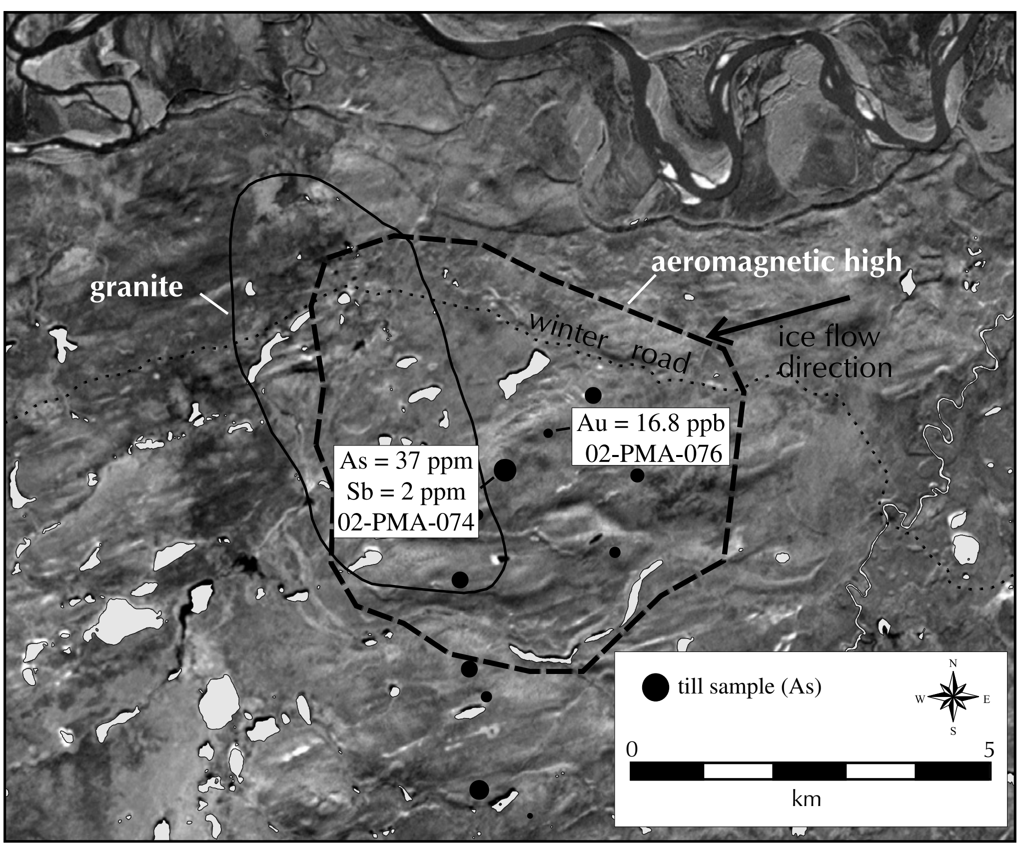


Figure 25. *The Tummel River gold anomaly is located proximal to a probable mid-Cretaceous granite and an aeromagnetic high. Potential mineralization is suspected in the hornfels aureole adjacent to the granite. UTM = 487019E, 6954089N.*

an east to west transport history should be inferred for till deposits on ridge crests, whereas topographically directed ice flow likely occurred in valley bottoms. Loess deposits can become increasingly thick outside the McConnell limit and should be avoided during soil sampling programs.

Big Salmon Fault Gold Anomaly

A weak gold/arsenic regional stream geochemical anomaly adjacent to the Big Salmon Fault was investigated using till geochemistry (Hornbrook and Friske, 1988; Fig. 16). The original anomaly is located 8.5 km north of the Robert Campbell highway on Bearfeed Creek. Seven till samples were taken in the vicinity of the stream sediment anomaly. Anomalous arsenic (99th percentile, 53.8 ppm), gold (98th percentile, 18.7 ppb), antimony (99th percentile, 2.92 ppm) and lead (99th percentile, 40 ppm) were recovered from till in the area. Potential mineralization is most likely associated with the Big Salmon Fault in a hydrothermal setting.

Basal lodgement till is the dominant surficial sediment in the area, with glacial transport to the northwest, parallel to the fault. Bedrock outcrops along Bearfeed Creek on the fault graben rim. UTM coordinates for sample JB02-032 are 492875E, 6903560N.

ZINC

Earn Group Base Metal Anomaly

Earn Group stratigraphy outcrops in Cassiar Terrane in the northeast part of the Glenlyon map area (Fig. 16). Samples were collected from Quaternary stratigraphic sections on an unnamed creek that flows into the Tummel River. Elevated zinc concentrations were obtained from three till sample sites including JB02-062 (Zn 220 ppm), JB02-066 (Zn 180 ppm) and 02-PMA-059-2 (Zn 146 ppm; Figs. 23, 26). In addition to zinc, sample JB02-062 contains anomalous concentrations of Ag (99th percentile, 458 ppb), Mo (100th percentile, 9.4 ppm) and Pb (95th percentile, 22.5 ppm). These high metal concentrations from this sample were initially considered to be background levels over Earn Group black shales. However, other samples collected on Earn Group strata to the west contain lower base metal levels.

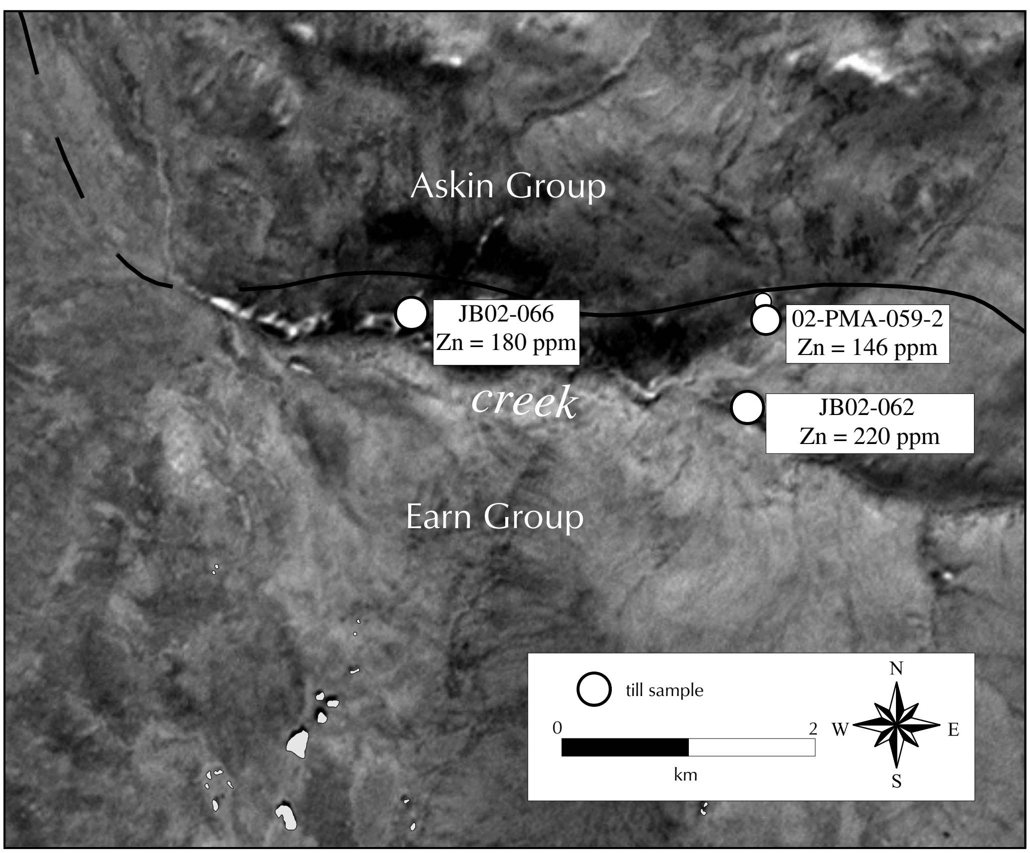


Figure 26. *Map showing the distribution of zinc anomalies over Earn Group rocks. UTM = 496595E, 6874575N for sample JB02-062.*

The Earn Group base metal anomaly may highlight an area of sedimentary-exhalative (SEDEX) deposit potential with geology similar to the Clear Lake deposit. Ice flow in this area is poorly understood because of its position near the confluence of two glaciers. Preliminary till fabric analyses from JB02-062 (496595E, 6943707N) suggest an ice flow direction of 260 degrees or from east to west. A graphitic phyllite comprises the local bedrock.

Frenchman Lake Zinc Anomaly

A sample located about 3 km east of Frenchman Lake (Fig. 16) contains the following elemental concentrations: Zn (187 ppm, 99th percentile), Pb (23 ppm, 96th percentile), Au (16 ppb, 97th percentile), Sb (1.97 ppm, 99th percentile), Mo (3.41 ppm, 99th percentile), Hg (134 ppb, 96th percentile), Cd (2.27 ppm, 100th percentile) and Ag (287 ppb, 97th percentile), suggestive of epithermal mineralization (C. Hart, pers. comm., 2002). Mercury is also anomalous at other stations on this sample line. The geology of the area consists of lower Jurassic Laberge Group conglomerate, sandstone, siltstone, and brecciated limestone of the Whitehorse Trough.

Till in this area was deposited by ice from the Cassiar lobe. Ice flow was to the north at 344 degrees. A source for this anomaly likely lies within 2 km to the south of sample 02-PMA-034. UTM coordinates for sample 02-PMA-034 are 458220E, 6896171N.

NICKEL/COPPER/CHROMIUM

Little Salmon Range Nickel/Copper/Chromium Anomaly

The Little Salmon Range hosts a nickel-copper-chromium anomaly in middle Mississippian – Pennsylvanian intermediate to mafic metavolcanic rocks (Fig. 16). Locally, ultramafic rocks exposed on a ridge may be more widespread than previously expected. The highest multi-element anomaly is located down-ice flow from known ultramafic rocks. Station 02-PMA-164 has anomalous concentrations of nickel (145 ppm, 99th percentile), copper (106 ppm, 99th percentile), and chromium (342 ppm, 100th percentile). Other samples in the Little Salmon Range further to the west are anomalous in cobalt (42 ppm, 100th percentile) and gold (25.7 ppm, 99th percentile). Ice flow in the area is topographically controlled, trending approximately west-northwest.

The Drury mineral occurrence (Yukon MINFILE 2002, 105L 014) is a copper vein 2 km northwest of 02-PMA-164 in the Little Salmon Range. Many of the anomalous copper values in till were obtained down-ice flow of this showing, but additional concealed veins could be present on the ridge. The base metal potential of the Little Salmon Range is addressed further by Colpron et al. (this volume).

COPPER

Frenchman Ridge Copper Anomaly

Two sample lines were completed on an unnamed ridge east of Frenchman Lake following the discovery of malachite float (Frenchman, Yukon MINFILE 2002, 105L 066) during the bedrock mapping conducted as part of this TGI project (Figs. 16, 23, 27). For reference purposes the ridge is called Frenchman ridge, after the nearby lake. Sample JB02-144 (466157E, 6894763N) was collected at the northwest end of the ridge, and confirmed the presence of copper in bedrock. A concentration of 130 ppm Cu (100th percentile) was obtained from this sample. Additional malachite float was found in an outwash channel crosscutting the ridge about 1 km southeast of this anomalous sample.

Frenchman ridge is underlain by volcanic rocks of the Upper Carboniferous Semenof formation. They consist of andesite, basalt, diorite, amphibolite, greenstone and marble. A rhyolite unit and felsic tuff also outcrops on the ridge closer to the malachite occurrence.

McConnell ice flow trends sub-parallel to Frenchman ridge in a north-northwest direction, and reaches a higher elevation on the south side versus the north side of the ridge. This suggests that the Cassiar Lobe compressed against the south-facing flank. However, the ridge summit is above the McConnell limit and is veneered with Reid till. There is no clear ice-flow indicator of Reid age on Frenchman ridge, but assuming ice-flow patterns were generally similar during the McConnell and Reid glaciation, ice flow during the Reid glaciation would have overtopped the ridge from south to north. Thus, the Reid till on the summit would have originated from bedrock material eroded on the southwest side of the ridge. Some ridge-parallel transport to the northwest could also be expected during Reid deglaciation.

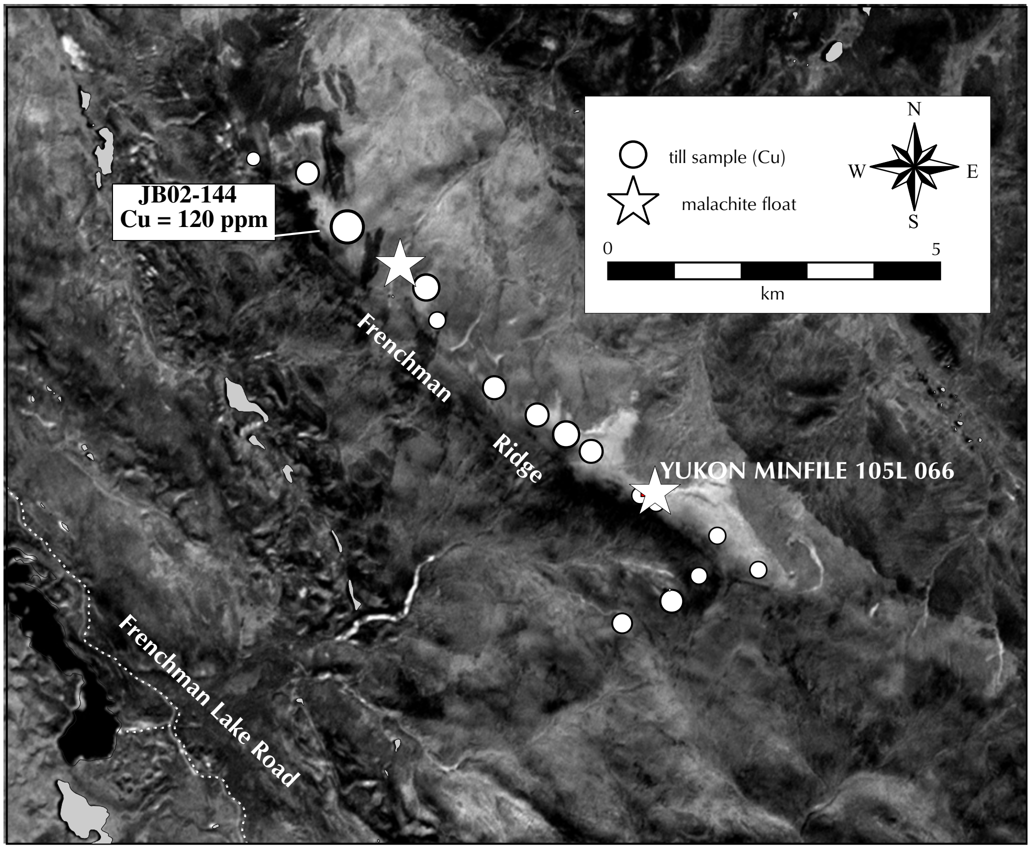


Figure 27. *Local scale map showing copper in till samples from Frenchman Ridge. Two occurrences of malachite float were found on the ridge in 2002. UTM = 466157E, 6894763N.*

CONCLUSIONS

The Glenlyon and eastern Carmacks map areas are located at the limit of the last glaciation. The Cordilleran Ice Sheet at this point was relatively thin, and isolated plateau nunataks protruded through the ice mass. Two ice lobes, the Selwyn and Cassiar, with differing flow trajectories, converged in the southwestern part of the study area. Local ice accumulations were limited to minor advances in the Glenlyon Range, and had no significant contribution to the regional ice sheets. Recessional features, widespread across the study area, indicate a complex ice retreat history. Large abandoned outwash channels and glacial lake deposits are common features.

An orientation study of till geochemistry at the Clear Lake SEDEX deposit indicates that lead, mercury, barium and silver are useful exploration indicators. Zinc is not a good indicator despite the high zinc grades in the deposit. Acid weathering may play an important role in the depletion of zinc in the till. The survey identified a dispersal train at least 600 m long that may be topographically controlled.

Regional till geochemistry results identify anomalies in gold, zinc and copper. Intrusion-related gold associated with mid-Cretaceous and Jurassic granite, and hydrothermal gold near Big Salmon fault are the primary precious metal settings. A base metal anomaly in Earn Group rocks of the Cassiar platform suggests SEDEX potential south of the Clear Lake deposit. Nickel-copper-chromium-copper values are anomalous in Mississippian rocks of the Little Salmon Range. Lastly, anomalies in zinc and copper were identified in Stikine Terrane in the southwest part of the study area.

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Bedrock geology at the boundary between Yukon-Tanana and Cassiar terranes, Truitt Creek map area (NTS 105L/1), south-central Yukon

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ABSTRACT

The Tummel fault zone, a northwest-trending belt of rocks of uncertain age and/or tectonic affinity, separates Paleozoic miogeoclinal strata of Cassiar Terrane from Yukon-Tanana Terrane metavolcanic and metasedimentary rocks. Northeast of the fault, Cassiar Terrane comprises pelitic and semipelitic rocks with rare amphibolite, which are correlated with the Kechika Group. These are overlain by carbonate correlated with the Askin Group. Southwest of the fault, in Yukon-Tanana Terrane, Devono-Mississippian siliciclastic rocks are overlain by Mississippian arc volcanic rocks. Granodiorite and diorite of the Telegraph Plutonic Suite (348-350 Ma) intrude the siliciclastic rocks. Foliated greenstone, leucogabbro intrusions, serpentinite and chert occur in the Tummel fault zone.

The Early Cretaceous Glenlyon Batholith intrudes strata of Cassiar Terrane. Contact metamorphism recognized across the Tummel fault zone is interpreted to have been imposed by the Glenlyon Batholith. If correct, this interpretation requires that post-mid-Cretaceous displacement across the Tummel fault zone has been minimal (~5 km).

RÉSUMÉ

La zone de failles de Tummel, une zone de roches à direction nord-ouest d'âge incertain et d'affinité tectonique imprécise, sépare les couches de plate-forme paléozoïques du terrane de Cassiar des roches métasédimentaires et métavolcaniques du terrane de Yukon-Tanana. Au nord-est de la faille, le terrane de Cassiar comprend les roches pélitiques et semi-pélitiques du Groupe de Kechika (?) avec de l'amphibolite rare, que recouvrent des roches carbonatées du Groupe d'Askin (?). Au sud-ouest de la faille, dans le terrane de Yukon-Tanana, des roches silicoclastiques dévono-mississippiennes sont sous-jacentes à des roches d'arc volcanique du Mississippien. La granodiorite et la diorite de la suite plutonique de Telegraph (348-350 Ma) recoupent les roches silicoclastiques. La zone de failles de Tummel comprend des roches vertes foliées, des intrusions de leucogabbro, de la serpentinite et du chert.

Le batholite de Glenlyon du Crétacé moyen recoupe les strates du terrane de Cassiar. Le métamorphisme de contact que l'on observe à travers de la zone de faille de Tummel est vraisemblablement associé au batholite de Glenlyon. Cette interprétation requiert donc que le déplacement le long de la zone de faille de Tummel soit minimal (~5 km) suite à l'intrusion du batholite au Crétacé moyen.

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INTRODUCTION

A northwest-trending fault system regionally separates lower Paleozoic platformal and basinal metasedimentary rocks of Cassiar Terrane to the east from mid-Paleozoic metasedimentary and metavolcanic rocks of Yukon-Tanana Terrane to the west (Fig. 1). The nature of this contact in Glenlyon and Laberge map areas is controversial. In eastern Laberge map area (NTS 105E; Fig. 2), the southern part of this fault system is the d'Abbadie Fault of Tempelman-Kluit (1984), who interpreted it as a pre-Cretaceous east-verging thrust fault that emplaced Yukon-Tanana Terrane over Cassiar Terrane. Hansen (1989)

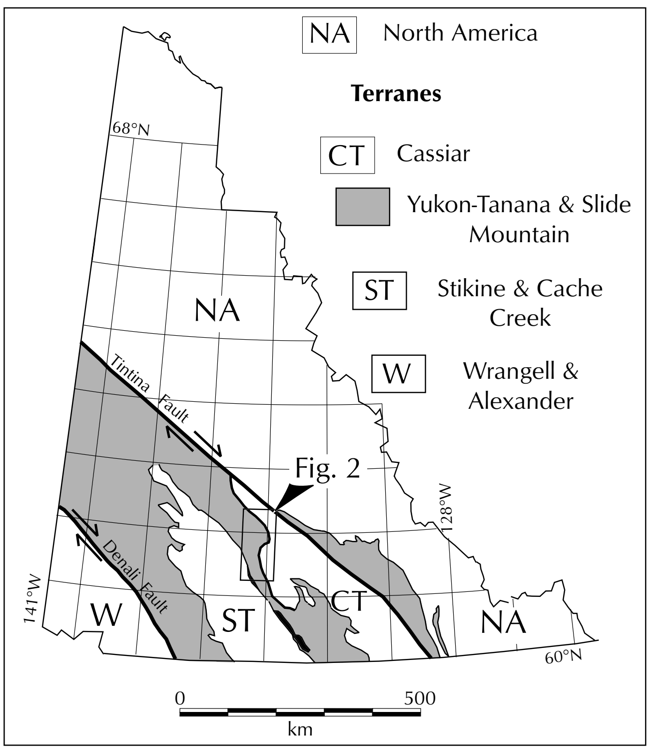


Figure 1. *Location of the study area in the southeast corner of Glenlyon map area (NTS 105L). Simplified tectonic boundaries are modified after Wheeler and McFeely (1991).*

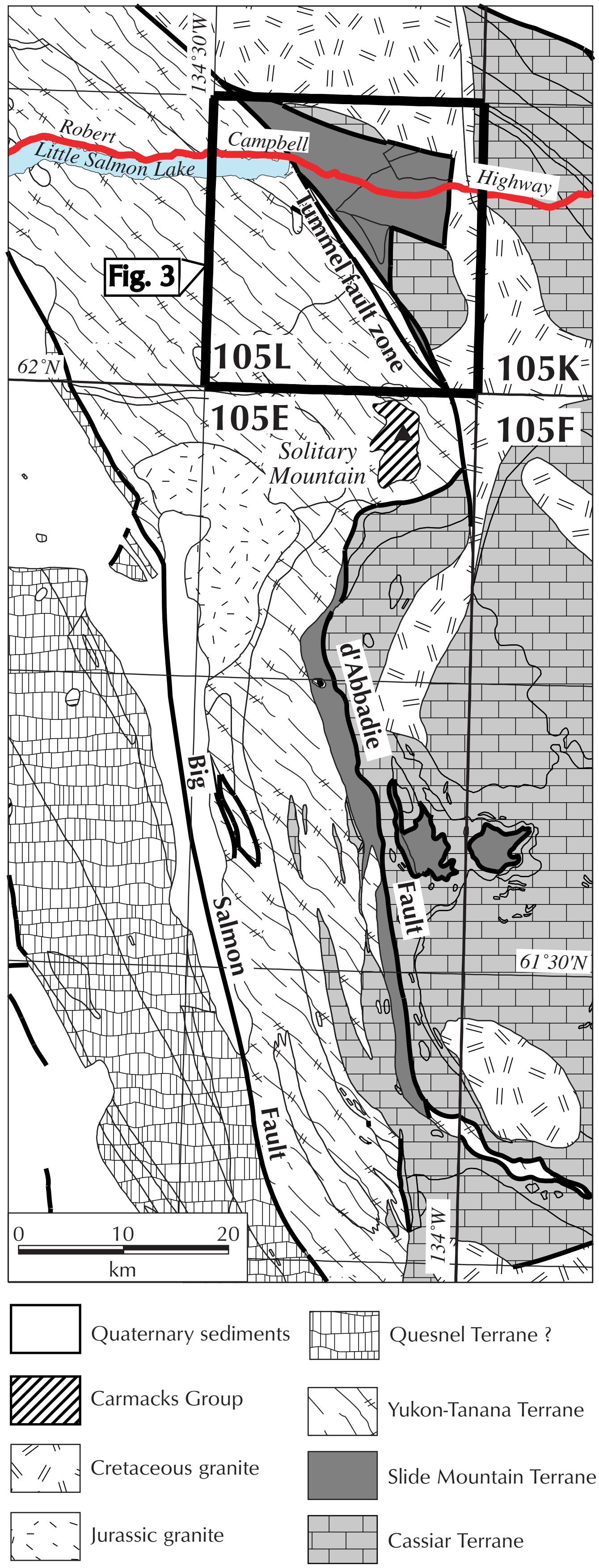


Figure 2. *Regional geological map along the boundary of Yukon-Tanana and Cassiar terranes, and region surrounding the study area (from Gordey and Makepeace, 1999). In this compilation, rocks east of the Tummel fault zone along Robert Campbell highway are interpreted as part of Slide Mountain Terrane. Gladwin et al. (2002a) have reinterpreted these rocks as part of Cassiar Terrane. TFZ – Tummel fault zone.*

reinterpreted it as a Jurassic strike-slip fault that formed the eastern boundary of a transpressional shear zone. Right-lateral strike-slip displacement of 4 km was estimated on this fault by Harvey et al. (1997) from offset of similar stratigraphy. Harvey et al. (1997) also demonstrated that d'Abbadie Fault is intruded by the synkinematic Last Peak granite, dated by Brown et al. (1998) at 98 Ma. De Keijzer et al. (1999) interpreted the d'Abbadie Fault as a brittle normal fault that cuts an earlier thrust fault that emplaced Yukon-Tanana Terrane onto Cassiar Terrane. Tempelman-Kluit (1984) reported an ~83 Ma K-Ar age from the Quiet Lake Batholith, which apparently truncates the d'Abbadie Fault.

When traced northward, d'Abbadie Fault takes a sharp northeast-trending bend in the northeast corner of Laberge map area (south of Solitary Mountain; 105E; Fig. 2), where it merges into the northwest-trending fault system, which extends into southeastern Glenlyon map area (105L, Fig. 3; Campbell, 1967). This fault system — the Tummel fault zone (Colpron et al., 2002) — is the focus of this study.

Recent paleomagnetic studies from Late Cretaceous volcanic rocks that sit disconformably on the Yukon-Tanana Terrane at Solitary Mountain, in northern Laberge map area, have focused attention on the Tummel fault zone. The basalt flows that underlie Solitary Mountain, immediately west of the Tummel fault zone, are the easternmost occurrence of the Carmacks Group (Gordey and Makepeace, 2000). Calculated paleolatitudes require large-scale (~2000 km) dextral displacement since Late Cretaceous time, consistent with paleomagnetic results from coeval volcanic rocks across central Yukon (Johnston, 2001; Johnston et al., 2001; Wynne et al., 1998). Currently recognized geological structures east of Solitary Mountain can accommodate a maximum of 450 km of dextral displacement (Gabrielse, 1985; Roddick, 1967). If the calculated paleolatitude is correct, northward translation of Yukon-Tanana Terrane requires a major Late Cretaceous-Early Tertiary structure northeast of Solitary Mountain.

This paper presents the results of bedrock geological mapping of the Truitt Creek area (105L/1; Gladwin et al., 2002b) and discusses the implications of these results for the interpretation of the Tummel fault zone. Detailed mapping of the Truitt Creek area was conducted during the summers 2001 and 2002. It is a contribution to the Yukon Targeted Geoscience Initiative — a joint program of accelerated bedrock mapping and till geochemistry conducted in Glenlyon and northeastern Carmacks areas in 2002 by the Yukon Geology Program and the Geological Survey of Canada (Colpron et al., 2003, this volume; Bond et al., 2003, this volume).

TRUITT CREEK MAP AREA

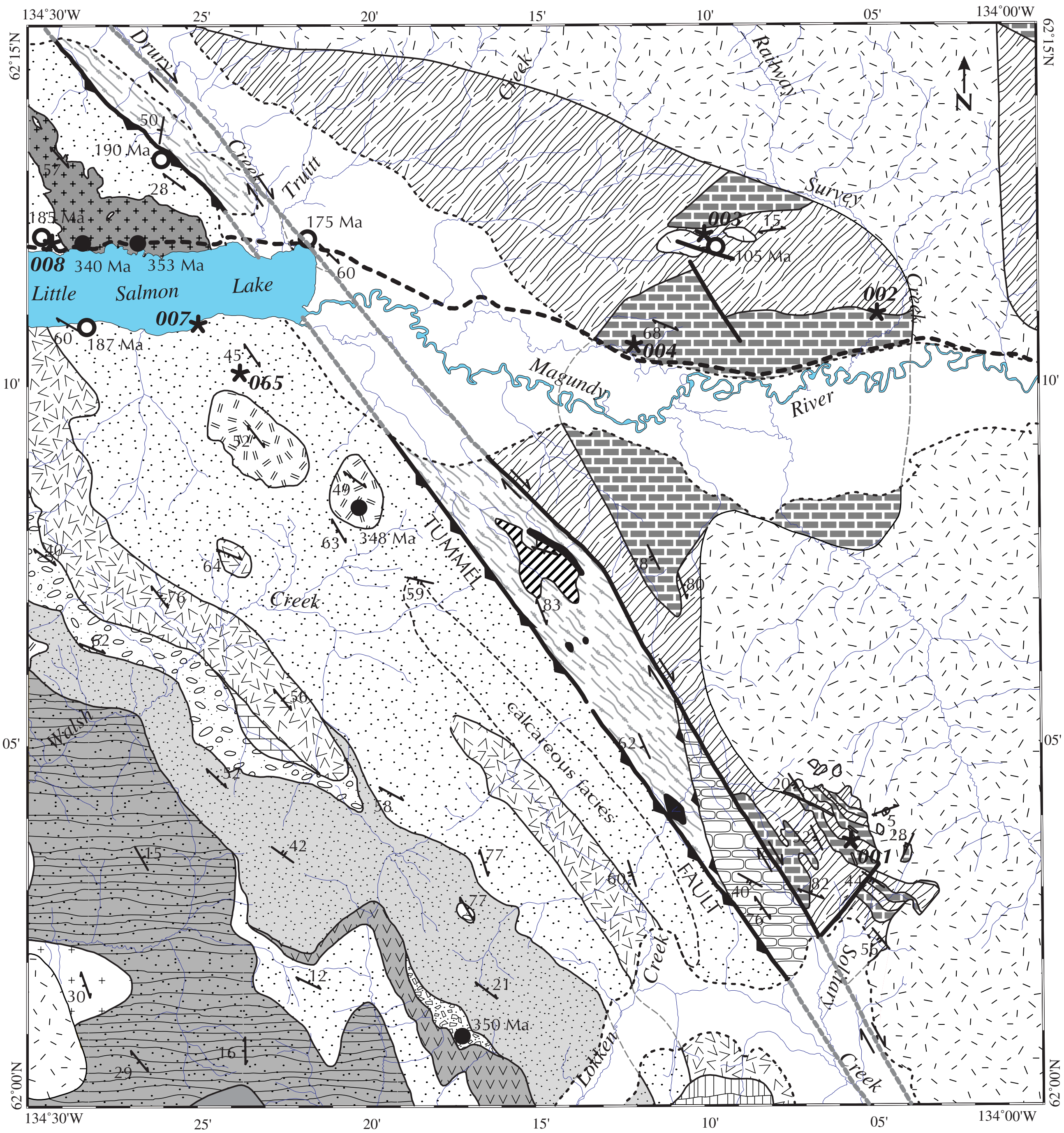
The Truitt Creek map area (105L/1) includes the eastern end of Little Salmon Lake, in the southeast corner of Glenlyon map area (105L) in south-central Yukon (Fig. 1-3). Reconnaissance mapping of the area was first conducted by Campbell (1967) at a scale of 1:250 000. More recent mapping by Colpron (2000) has established the stratigraphic framework of Yukon-Tanana Terrane in the area.

In the Truitt Creek area, lower Paleozoic metasedimentary rocks of Cassiar Terrane, in the northeast part of the map area, are separated from mid-Paleozoic metasedimentary and metavolcanic rocks of Yukon-Tanana Terrane to the southwest, by the northwest-trending Tummel fault zone (Fig. 3; Colpron et al., 2002). The Tummel fault zone has a complex deformational history, including lateral and thrust displacements under ductile and brittle conditions. Although it intersects the d'Abbadie Fault in eastern Laberge map area, the Tummel fault has been distinguished from the d'Abbadie because the extent of shared history is unknown.

CASSIAR TERRANE

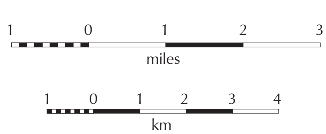
Cassiar Terrane is a crustal fragment of platformal rocks that has been interpreted either as displaced North American miogeocline that is not far-travelled (Fritz et al., 1991), or as a far-travelled exotic terrane (Johnston, 2001; Pope and Sears, 1997). In Truitt Creek map area, Cassiar Terrane comprises two units: a lower phyllite-dominated unit and an overlying marble unit.

Along Robert Campbell Highway, grey to black, locally calcareous phyllite with rare sandy layers is exposed in several road cuts and borrow pits. Outcrops commonly exhibit iron-oxide staining. Adjacent to the batholith, correlative rocks are contact metamorphosed, up to amphibolite grade. Quartz-muscovite ± biotite ± garnet schist is the most abundant lithology, with minor pale green to white quartzite, marble, calc-silicate rocks and amphibolite. Centimetre-scale intercalations of siliceous and calcareous sedimentary rocks are common in the southeast. Schistosity dips shallowly to the west, and parallels compositional layering. Metamorphic grade decreases away from the batholith to the southwest. Skarn mineralization is developed in several places, and



TRUITT CREEK (NTS 105L/1)

YUKON TERRITORY



SYMBOL LEGEND

- Robert Campbell Highway
- dextral strike-slip fault
- approximate fault continuation
- geological contact
- inferred thrust fault
- 001 Yukon MINFILE (2002) occurrence
- U-Pb zircon age date
- K-Ar and Ar/Ar age date
- 62 bedding
- 40 compositional layering
- 45 foliation

some exploration work has been done in the area (Lokken occurrence: MINFILE 2002, 105L 001).

Fine- to coarse-grained, light grey to black, locally graphitic marble occurs structurally above the phyllite. At the highway, the marble is massive, fine-grained, dark grey to black, and heavily veined with calcite. At the Moule occurrence (Yukon MINFILE 2002, 105L 004), malachite-bearing calcite veins are present within the marble unit. In the central and southeastern parts of the map area, this unit is medium- to coarse-grained, and medium grey to white.

Samples from two narrow (1-5 m) laterally continuous amphibolite bodies within the schist were analysed for major and trace elements (Appendix I). Amphibolite

LEGEND

Quaternary
unconsolidated alluvium, colluvium and glacial deposits

OVERLAP ASSEMBLAGE

INTRUSIVE ROCKS

Early Cretaceous
biotite granite, biotite-muscovite granite

Early Jurassic (?)
hornblende-biotite gabbro

LAYERED ROCKS

Upper Cretaceous
Carmacks Group - basalt flows, agglomerate

SLIDE MOUNTAIN TERRANE (?)

Permian (?)
medium- to coarse-grained hornblende leucogabbro

Permian (?)
coarse-grained serpentinized harzburgite

Pennsylvanian to Lower Permian (?)
white, green, & black chert, quartzite, black slate

Pennsylvanian to Lower Permian (?)
basalt, basaltic andesite, greenstone

YUKON-TANANA TERRANE

INTRUSIVE ROCKS

Middle Mississippian
Little Salmon Plutonic Suite - hornblende quartz diorite, granodiorite

Early Mississippian
Telegraph Plutonic Suite - hornblende-biotite granodiorite, quartz diorite

Devonian - Mississippian
hornblende-biotite tonalite, hornblende diorite to granodiorite

YUKON-TANANA TERRANE

LAYERED ROCKS

Upper Mississippian - Middle Pennsylvanian
Little Salmon - dark grey biotite marble

Middle Mississippian - Pennsylvanian (?)
Little Salmon - green banded volcaniclastic rocks

Middle Mississippian
Little Salmon - quartzite-clast conglomerate, quartz-chlorite schist

Lower Mississippian
Pelmac formation - quartzite, quartz-mica schist

Lower Mississippian
Lokken member - quartz-feldspar porphyry, volcaniclastic rocks

Lower Mississippian
Intermediate volcaniclastic rocks, minor marble and psammite

Devono - Mississippian
Drury formation - arkosic grit, quartzite, psammite, marble

Devonian and older (?)
Snowcap complex - quartzite, psammitic and pelitic schist

CASSIAR TERRANE

LAYERED ROCKS

Silurian - Devonian
Askin Group (?) - marble, calc-silicate rocks, quartz-mica schist

Cambrian - Ordovician
phyllite, quartz-mica schist, quartzite, marble, amphiboliite

Figure 3. *(preceding page and legend above) Geological map of Truitt Creek area (NTS 105L/1), based on mapping completed in 2001 and 2002. Location shown in Figure 2.*

layers are both parallel and crosscutting with respect to compositional layering in surrounding schist. They are interpreted as mafic dykes that were metamorphosed along with the host rock by the intrusion of Glenlyon Batholith. These amphibolite dykes have trace element geochemical characteristics of alkali basalts (Fig. 4a), consistent with a within-plate tectonic setting such as a continental rift. On primitive mantle-normalized plots, amphibolite of the Cassiar Terrane has trace element patterns similar to volcanic rocks of the Cambrian-Silurian Menzies Creek Formation from the Faro region (Fig. 4b).

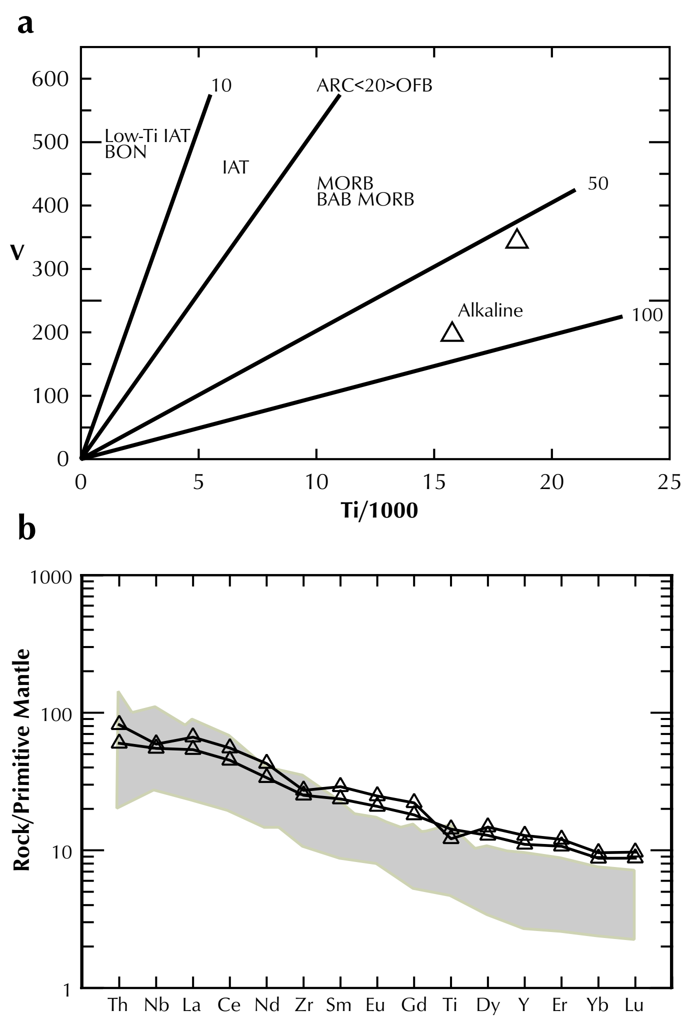


***Figure 4. (a)** V vs Ti/1000 diagram showing amphibolite dykes (triangles) in Kechika Group rocks in the southeastern part of the map area (diagram after Shervais, 1982). **(b)** Trace element pattern of amphibolite dyke samples normalized to primitive mantle values of Sun and McDonough, 1989. Samples from Truitt Creek area are superimposed on range of analyses from volcanic rocks of Menzies Creek Formation from the Faro region (shaded region; data from L.C. Pigage, pers. comm, 2002).*

The phyllite/schist and marble units of Cassiar Terrane in Truitt Creek area are tentatively correlated with the Cambrian-Ordovician Kechika Group and the Silurian-Devonian Askin Group, respectively.

YUKON-TANANA TERRANE

Yukon-Tanana Terrane southwest of the Tummel fault zone includes (1) pre-Late Devonian metasedimentary and metaplutonic rocks of the Snowcap complex; (2) Devonian-Mississippian metasedimentary and minor metavolcanic rocks of the Drury and Pelmac formations; (3) intermediate intrusive rocks of the Telegraph Plutonic Suite; and (4) Carboniferous metasedimentary and metavolcanic rocks of the Little Salmon formation. A number of new stratigraphic units in Yukon-Tanana Terrane, some of which are described below, were informally introduced by Colpron et al. (2002). These units will be formally defined in a bulletin in preparation.

The oldest rocks in Yukon-Tanana Terrane are psammitic schist and quartzite of the Snowcap complex exposed in the southwestern corner of the map area (Fig. 3). The Snowcap complex is the most extensive unit of Yukon-Tanana Terrane in Glenlyon map area (Colpron et al., 2002; Colpron et al., 2003, this volume). In Truitt Creek area, the Snowcap complex consists of light grey garnet-quartz-muscovite schist, dark grey quartzite, minor dark grey muscovite schist and foliated grey hornblende tonalite. The rocks are typically strongly foliated and coarsely recrystallized.

The Drury formation overlies the Snowcap complex. It extends northwest of the study area to the east shore of Drury Lake (Colpron et al., 2003, this volume). The Drury formation includes coarse-grained arkosic grit, light to dark grey quartzite, micaceous quartzite and psammitic schist. The Drury formation locally comprises a unit of dark grey to black phyllite and light calcareous sandy layers intercalated with 5- to 20-cm thick layers of light grey marble.

The age of the Drury grit is bracketed as lower Mississippian from the ages of detrital zircons and a crosscutting pluton. Two samples of grit from the Drury formation (Fig. 3) yielded Upper Devonian detrital zircons (G. Gehrels in Colpron et al., 2003, this volume).

Fine- to medium-grained, foliated hornblende quartz diorite to granodiorite of the Drury pluton intrudes coarse-grained arkosic grit and psammite of the Drury formation at the eastern end of Little Salmon Lake, along Robert Campbell Highway. Zircons from this pluton yielded a discordant U/Pb age of 353.0 ± 1.4 Ma (Oliver and Mortensen, 1998). Results from another sample of the same pluton yield a somewhat younger age, correlative with the 338-340 Ma Little Salmon Plutonic Suite — the plutonic root to the volcanic rocks of the Little Salmon formation (Colpron, 2001). In either case, a lower Mississippian age is indicated for the Drury grit.

LOKKEN MEMBER AND PELMAC FORMATION

Near the southern edge of the map area, the Pelmac formation overlies the Drury formation. The lower part of the Pelmac formation, the Lokken member, consists of mint- to yellow-green intermediate volcanic and volcaniclastic rocks, overlain by thinly layered, green to maroon, tuffaceous volcaniclastic rocks, and an upper white, fine- to medium-grained, foliated quartz-feldspar porphyry. In some exposures, up to 50% of the porphyry is made up of feldspar and quartz phenocrysts. The porphyry is interpreted as a volcanic rock, although a high-level intrusive protolith is possible. It has yielded a preliminary U-Pb zircon date of ca. 350 Ma (J.K. Mortensen, pers. comm., 2002).

The remainder of the Pelmac formation above the porphyry consists of a distinct and laterally extensive quartzite unit that can be traced across the Glenlyon map area to the northwest (Colpron et al., 2003, this volume). In the western part of Truitt Creek map area, the quartzite is white or pale green and massive. Southwest of Walsh Creek, 2-cm-thick horizons of quartz-chlorite schist are intercalated with 3- to 10-cm-thick quartzite beds (Fig. 5).

TELEGRAPH PLUTONIC SUITE

Rocks of the Snowcap complex, Drury formation, and Pelmac formation are intruded by plutons of the Telegraph Suite in the central and western part of the map area (Fig. 3). The Telegraph Plutonic Suite includes medium- to coarse-grained hornblende ± biotite granodiorite and hornblende quartz diorite. A moderate to strong foliation, defined by alignment of hornblende, parallels foliation in surrounding country rock. Preliminary U-Pb zircon analyses indicate crystallization ages of 348-349 Ma (J.K. Mortensen, pers. comm., 2002).

Figure 5. *Quartzite with thin bands of intercalated quartz-chlorite schist in the Pelmac formation. Rock hammer and magnet for scale.*

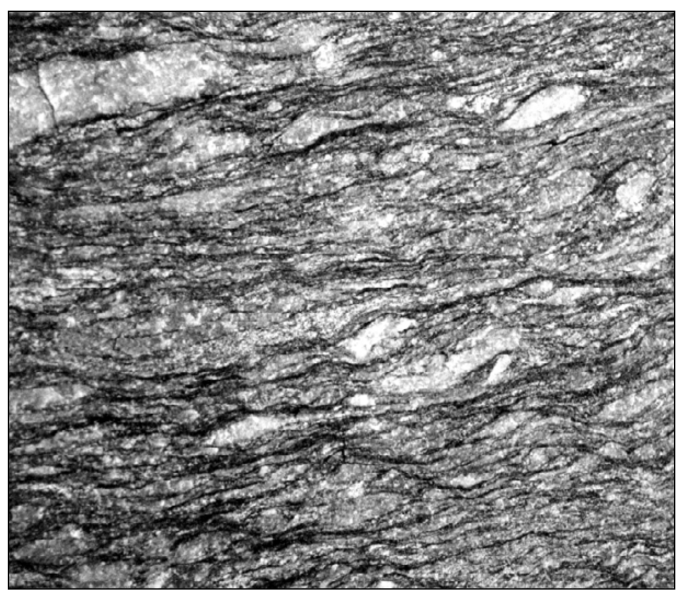


Figure 6. *Basal conglomerate of the Little Salmon formation: quartzite pebbles and cobbles in a chloritic matrix. Field of view is approximately 40 cm across.*

LITTLE SALMON FORMATION

Conglomerate, marble, and intermediate volcaniclastic rocks occur in a narrow northwest-trending belt in the western central part of the map area. The base of the succession is marked by a quartzite-pebble to -boulder conglomerate which has subangular to subrounded clasts of grey quartzite supported by a green-grey chloritic sandstone matrix (Fig. 6). Tightly folded fabric observed within some of the boulders indicates derivation from a deformed and metamorphosed source terrane.

A biotite marble occurs between the lower conglomerate member and upper volcaniclastic member of the Little Salmon formation on one ridge in the western central part of the study region. This unit was not found elsewhere in the map area, but may correlate with marble that occurs near the base of the Little Salmon formation along strike to the northwest (Colpron, 2000). The biotile marble is interpreted to stratigraphically overlie the conglomerate unit.

Chlorite-epidote ± biotite ± magnetite schist is the uppermost member of the Little Salmon formation. The schist sits conformably above the marble unit, and forms synformal keels in the gentle folds of regional foliation. North of Little Salmon Lake, a dacite at the base of the Little Salmon formation has yielded a preliminary U/Pb zircon age of ca. 340 Ma (J.K. Mortensen, pers. comm., 1999).

ROCKS OF THE TUMMEL FAULT ZONE

The central and northwestern sections of the Tummel fault zone are made up of metamorphosed basalt and mafic volcaniclastic rocks. These are fine-grained and foliated, moderately to highly altered, light to dark green rocks, with relict plagioclase and rare clinopyroxene (Fig. 7). Highly altered samples contain significant amounts of epidote chlorite, calcite and serpentine.

At the southeastern end of the Tummel fault zone, and along Robert Campbell Highway, chert is the dominant lithology, with lesser quartzite, micaceous quartzite, and locally graphitic black slate. At the highway, the chert is pale green and massive, with large (7-8 mm) pyrite porphyroblasts in some places; in the southeast, the chert is massive and black or white. On the south side of the Lokken Creek valley, an east-verging thrust fault places greenstone over chert. To the north, Colpron et al. (2003, this volume) have observed the chert and basalt in stratigraphic contact.

The greenstone is intruded by medium- to coarse-grained hornblende leucogabbro in the central part of the map area. Xenoliths of greenstone are found within the intrusion. The leucogabbro is spatially associated with coarse-grained, serpentinized harzburgite, especially in a northwest-trending belt along the eastern side of the large pluton in the centre of the map area. The harzburgite locally has thin (<1 cm) quartz-carbonate or antigorite

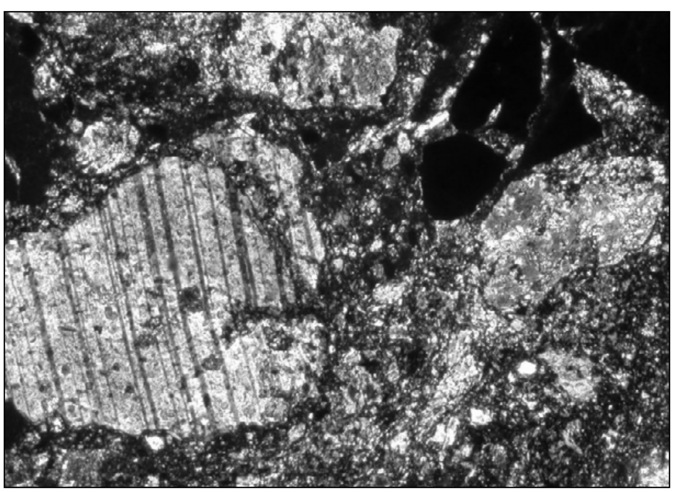


Figure 7. *Photomicrograph of relict plagioclase and clinopyroxene in greenstone from the Tummel fault zone. Field of view is 3 mm across.*

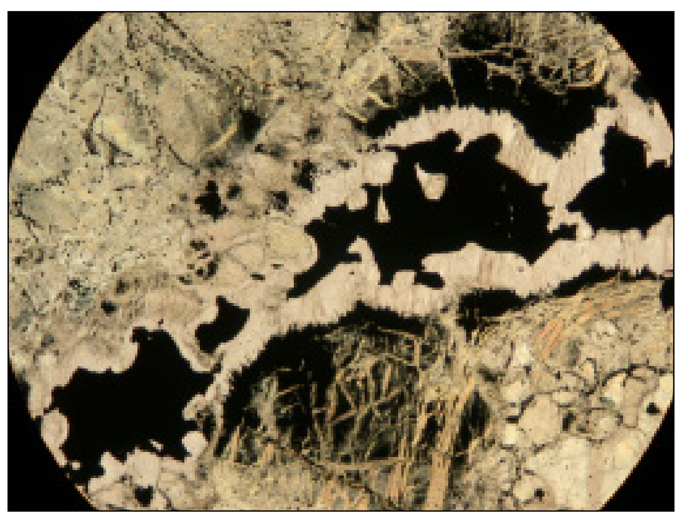


Figure 8. *Photomicrograph of magnetite porphyroblast in harzburgite with 'holly-leaf texture' indicative of high-temperature (>1200°C) deformation. Chlorite has replaced plagioclase in the surrounding corona. Field of view is 5 mm across.*

veins. In places, white crystals of carbonate, 1-3 mm in diameter with a radiating habit, give the rock a distinct speckled appearance. Large (4-6 mm) pseudomorphs of orthopyroxene characterize the peridotite, and are locally strung out over distances of >30 cm. Magnetite and chlorite have replaced spinel and associated plagioclase coronae, respectively (Fig. 8).

Contacts between harzburgite and adjacent units, while not observed, can be spatially constrained. Greenstone occurs east and west of the elongate band of ultramafic rocks in the central part of the Tummel fault zone (Fig. 3). Gabbro was only observed west of the ultramafic rocks. However, a black and white, medium-grained, altered and mylonitized hornblende-chlorite-saussurite rock, probably derived from a leucogabbro protolith, occurs 100 m northeast of the ultramafic exposure. The fabric in this outcrop dips steeply (84°) to the south-southwest and the altered leucogabbro projects beneath the harzburgite.

The 'holly-leaf' shape of magnetite (originally spinel) crystals observed in thin sections of the harzburgite (Fig. 8), and the coarse grain size of the harzburgite porphyroclasts require recrystallization at mantle temperatures (~1250°C; Nicolas, 1995). In an intrusive body, spinel crystals that crystallized at lower temperatures have a coherent cubic shape. In addition, deformation at lower temperatures (<1000°C and less) would produce a significantly finer grained rock (Nicolas, 1995). The strung-out orthopyroxene porphyroclast texture is also commonly produced as a result of solid-state deformation in the mantle (D. Canil, pers. comm., 2002). Petrographic observations, together with fabric relationships in the ultramafic harzburgite and adjacent rocks, suggest that harzburgite of the Tummel fault zone originated as mantle tectonite. However, the spatial association of harzburgite with gabbroic intrusions and the distribution of ultramafic rocks throughout basalts of the Tummel fault zone are also consistent with an intrusive origin for the ultramafic rocks.

The association of basalt, chert, leucogabbro and ultramafic rocks in the Tummel fault zone in the Truitt Creek map area resembles the Campbell Range succession of the Finlayson Lake area (Murphy et al., 2001; Colpron et al., 2003, this volume). Similar to ultramafic rocks in the Tummel fault zone, ultramafic rocks in the Campbell Range have a spatial association with bodies of leucogabbro. The presence of coarse-grained cumulate textures, geometric relationships, and occurrences of calc-silicate hornfels near ultramafic bodies all suggest that ultramafic rocks of the Campbell Range are intrusions (Murphy, 2001).

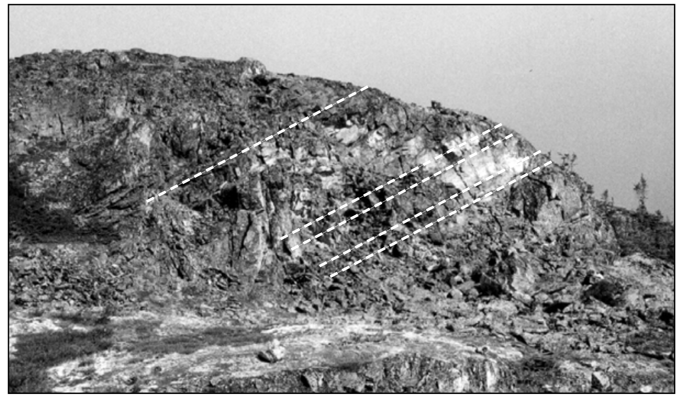


Figure 9. *Thick (2-5 m) southwest-dipping sills of biotite granite intrude quartz-mica schist. Dashed lines separate thin layers of schist from thicker granite sills. Tree at right is ~4 m tall and very old.*

GLENLYON BATHOLITH

The Glenlyon Batholith intrudes the sedimentary rocks of Cassiar Terrane along the eastern side of the map area, and is well exposed along Robert Campbell Highway and in alpine areas to the south. Three intrusive phases were recognized in the batholith. The earliest, a medium-grained biotite-hornblende granodiorite, is intruded by voluminous medium- to coarse-grained biotite ± muscovite granite, locally with phenocrysts of plagioclase or potassium feldspar. A late muscovite-quartz-plagioclase pegmatite phase is locally present. Five andesite dykes, 1-5 m wide, cut the batholith.

The batholith margins are characterized by lit-par-lit gneisses (Fig. 9). This may reflect the gross geometry of the batholith, as a sheet-like body or series of bodies that dip gently to moderately (~30°) to the southwest. Pendants of quartz-muscovite-biotite ± garnet schist are common within the intrusion, especially at topographic high points and near the batholith margin, ranging from tens to hundreds of metres across. This is interpreted as evidence that the present level of exposure is near the roof(s) of the magma chamber(s).

Whole-rock K-Ar analysis of hornfels adjacent to the batholith on the north side of the highway has yielded a metamorphic cooling age of 105 ± 4 Ma (Hunt and Roddick, 1990).

DEFORMATION AND METAMORPHISM IN TRUITT CREEK MAP AREA

The style and history of deformation and metamorphism vary across the Truitt Creek map area. Southwest of the Tummel fault zone, rocks of Yukon-Tanana Terrane have experienced a polyphase deformational history. The Snowcap complex has undergone at least one deformational event not recognized in overlying Mississippian units (Colpron et al., 2003, this volume). Contact metamorphism associated with plutons of the Telegraph and Little Salmon suites is locally preserved, although generally overprinted by subsequent regional metamorphism of all Yukon-Tanana elements. A regional dynamothermal event is recognized in, and thus post-dates emplacement of, Little Salmon volcanic and plutonic rocks. Mineral paragenesis in rocks of Yukon-Tanana Terrane indicates middle to upper greenschist facies metamorphism (chlorite- to garnet-grade). This metamorphism probably occurred prior to Early Jurassic time, as indicated by $^{40}Ar/^{39}Ar$ white mica cooling ages from samples collected along Robert Campbell Highway (Oliver, 1996).

Greenstone within the Tummel fault zone has a dominant northwest-trending S_2 schistosity that is axial planar to isoclinal folds of an earlier S_1 schistosity. A moderately to steeply east-dipping spaced crenulation cleavage is also developed in these rocks. In many places, rocks of the greenstone and chert units have a cataclastic texture (intensely fractured). Foliation in leucogabbro intrusions, defined by alignment of hornblende, is broadly parallel to S_2 schistosity. An epidote-actinolite-chlorite-plagioclase mineral assemblage indicates that these rocks have reached middle greenschist facies.

In Cassiar Terrane strata, a southwest-dipping phyllitic foliation along Robert Campbell Highway gives way to a well developed, southwest-dipping schistosity near the Glenlyon Batholith in the southeast part of the map area. Compositional layering is commonly parallel to foliation, and a moderately southwest-plunging crenulation lineation is locally developed. East of Little Salmon Lake and adjacent to the Tummel fault zone in the southeast part of the map area, pelitic and overlying carbonate strata are folded into kilometre-scale, north-northwest-trending open synclines. Also in the southeast, a northeast-trending subvertical strike-slip fault has a 1-km dextral offset.

Phyllite of the Cassiar Terrane along Robert Campbell Highway is regionally metamorphosed to chlorite grade (greenschist facies), whereas the biotite-garnet schist to the southeast, adjacent to the Glenlyon Batholith, is metamorphosed to lower amphibolite facies. The Early Cretaceous Glenlyon Batholith imposes a contact metamorphic aureole on rocks of the Cassiar Terrane.

A weak foliation of aligned phenocrysts, interpreted as a magmatic feature, is locally present in the Glenlyon Batholith. Subvertical northwest- or north-trending joints, spaced metres to tens of metres apart, are developed throughout the intrusion. Locally, joint faces are chloritized, with subhorizontal or shallowly plunging slickensides.

A NEW SULPHIDE OCCURRENCE

A new sulphide occurrence (Glad showing; Yukon MINFILE 2002, 105L 065) was uncovered during mapping of the Truitt Creek area. It consists of a vein-hosted pyrite occurrence within the Drury formation, south of the eastern end of Little Salmon Lake (Fig. 3; UTM zone 8, NAD83, 531554E, 6893223N). Assay results from two grab samples returned anomalies in Cu (1451 ppm; 425 ppm), Au (184 ppb; 177 ppb), Ag (2.8 ppm; 2.1 ppm), Co (624 ppm; 708 ppm) and Ni (844 ppm; 953 ppm). The samples were taken from a rockfall at the base of a steep cliff of highly deformed quartzite and psammitic schist. Two thin (1-2 cm) veins of pyrite were found in outcrop above the fall. Iron-oxide staining was noted on much of the talus beneath the cliff. The Glad occurrence is similar in style and in commodity to the Highway showing (Yukon MINFILE 2002, 105L 063; Colpron, 1999), in which pyrite veins less than 1 cm-thick are hosted in a black quartzite assigned to the Pelmac formation. The Glad showing is 2 km southeast along strike from the Red Knoll showing (Yukon MINFILE 2002, 105L 007) on the southeastern shore of Little Salmon Lake. The Red Knoll showing is an occurrence of disseminated pyrite hosted by the Drury formation. These sulphide occurrences occupy the footwall of the Little Salmon formation, which hosts a small massive sulphide occurrence at its base (Yukon MINFILE 2002, 105L 062; Colpron, 1999).

DISCUSSION OF NATURE, AMOUNT AND AGE OF DISPLACEMENT ACROSS THE TUMMEL FAULT ZONE

A paucity of marker units across the Tummel fault zone precludes an estimate of the nature and amount of displacement accommodated by the zone. A cataclastic texture, common in chert and greenstone, provides evidence of some brittle deformation within the Tummel fault zone. Primary mineralogies and textures are locally preserved in basalt, leucogabbro, and harzburgite, indicating a lack of penetrative strain due to faulting.

The metamorphic aureole around the Glenlyon Batholith extends across the Tummel fault zone, constraining the age of any significant displacement to pre-mid-Cretaceous. Cordierite, andalusite and garnet porphyroblasts overgrow dominant foliation (Fig. 10) and therefore cannot have been caused by earlier intrusions (such as those of the Telegraph Plutonic Suite) that share this foliation. In the southern part of the map area, no intrusions other than Glenlyon Batholith are recognized near the porphyroblastic rocks.

If this late metamorphic feature is the contact aureole of the Glenlyon Batholith, Yukon-Tanana and Cassiar terranes were juxtaposed before ~105 Ma, and little displacement on the Tummel zone can have occurred since that time. This interpretation is inconsistent with the recently proposed Saybia model (Johnston, 2001), which requires large-scale dextral displacement since late Cretaceous time.

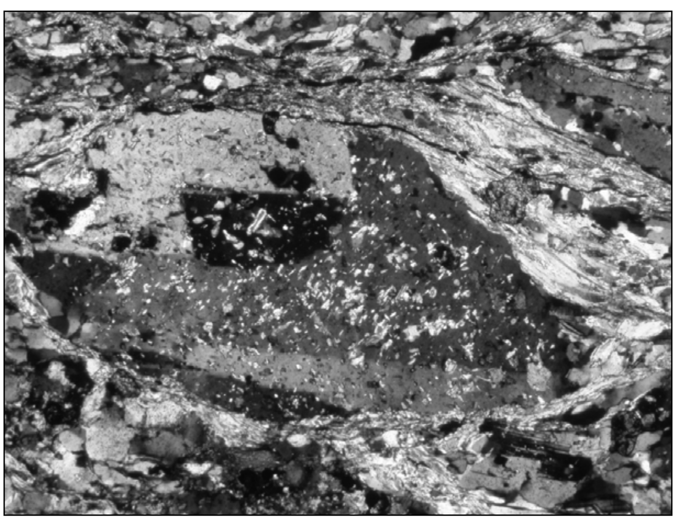


Figure 10. *Photomicrograph of cordierite porphyroblast in foliated arkosic grit of the Drury formation. Sample is from the centre of the map area, immediately west of the Tummel zone. Porphyroblast is 1.5 mm long.*

Most recent workers agree that d'Abbadie Fault in Solitary Mountain map area is a late structure that has not accommodated significant displacement (Harvey et al., 1997; de Keijzer et al., 1999). Motion on the d'Abbadie is temporally constrained by the synkinematic Last Peak pluton (98 Ma, U-Pb monazite: Harvey et al., 1997) and by ~97 Ma $^{40}Ar/^{39}Ar$ cooling dates from muscovite and biotite of the Mendocina orthogneiss, which is adjacent to the Last Peak pluton (Hansen et al. 1991; Hansen, 1992). Displacements on the order of those documented for d'Abbadie Fault (~4 km; Harvey et al., 1997) could have been accommodated by the Tummel fault zone.

SUMMARY

In Truitt Creek map area, miogeoclinal rocks of Cassiar Terrane, tentatively correlated with the Paleozoic Kechika and Askin groups, are separated from mid-late Paleozoic metavolcanic and metasedimentary rocks of Yukon-Tanana Terrane by the Tummel fault zone. The Tummel fault zone is a northwest-trending belt of metamorphosed chert, mafic and ultramafic rocks that may be correlative with the Campbell Range succession of the Finlayson Lake district.

Contact metamorphism attributed to the mid-Cretaceous Glenlyon Batholith extends across the Tummel fault zone, suggesting minimal (<5 km?) displacement since mid-Cretaceous time. Post-Late-Cretaceous large-scale translation required by recent paleomagnetic interpretations cannot have been accommodated by the Tummel fault zone.

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APPENDIX 1. GEOCHEMISTRY OF CASSIAR TERRANE AMPHIBOLITES

Analytical method: Major elements were analysed by fused disc x-ray fluorescence (XRF), and some trace elements (Ni, Co, Cr, V, Cu, Pb, Zn, As, Zr, Ga, Sr, Rb, Ba) were analysed by pressed-pellet XRF, both at the University of Western Ontario. The other trace elements were dissolved in a closed beaker, all-in-one digest using a mixed acid digestion (HF-HNO_3-perchloric) with subsequent analysis for certain trace elements (S, Sc, Mo, W, Cd, Li) by inductively coupled plasma emission spectrometry (ICP-ES), and remaining trace elements (Nb, Ta, Hf, Cs, Th, U) and rare earth elements (REE) by inductively coupled plasma mass spectrometry (ICP-MS) at the Ontario Geoscience Laboratories in Sudbury.

Sample	KG01-154	KG01-153	Method
Easting	546587	546587	
Northing	6881712	6881532	
Zone, Datum	8V, NAD83	8V, NAD83	
SiO_2	48.87	48.60	XRF
TiO_2	2.63	3.09	XRF
Al_2O_3	12.30	13.90	XRF
Fe_2O_3	14.04	15.11	XRF
MnO	0.29	0.22	XRF
MgO	4.10	4.35	XRF
CaO	9.57	8.27	XRF
K_2O	1.38	1.11	XRF
Na_2O	2.58	2.72	XRF
P_2O_5	1.22	0.71	XRF
Cr_2O_3	0.01	0.01	XRF
LOI	1.99	0.95	XRF
Total	98.99	99.04	
Nb	39.9	35	XRF
Zr	305.7	281.2	XRF
Y	58.3	50.3	XRF
Sr	133.5	308.3	XRF
Rb	52.6	48	XRF
Ba	304.5	359.3	XRF
Ga	19.1	24.9	XRF
Mn	2267.5	1616.6	XRF
Pb	5	(3)	XRF
As	(1)	(1)	XRF
Zn	166	137	XRF
Cu	23	45	XRF
Ni	215	58	XRF
Co	27	33	XRF
Cr	32	32	XRF
V	196	343	XRF

Sample	KG01-154	KG01-153	Method
Al	55980	62673	ICP-ES
Ba	338	359	ICP-ES
Be	4	N.D.	ICP-ES
Ca	67026	58692	ICP-ES
Cd	16	17	ICP-ES
Co	51	63	ICP-ES
Cr	47	43	ICP-ES
Cu	N.D.	6	ICP-ES
Fe	93789	98806	ICP-ES
K	9457	7998	ICP-ES
Li	19	45	ICP-ES
Mg	24232	25668	ICP-ES
Mn	2223	1594	ICP-ES
Mo	N.D.	N.D.	ICP-ES
Na	22605	24057	ICP-ES
Ni	48	33	ICP-ES
P	4983	2921	ICP-ES
S	491	567	ICP-ES
Sc	26	29	ICP-ES
Sr	136	291	ICP-ES
Ti	16293	20100	ICP-ES
V	178	312	ICP-ES
W	N.D.	N.D.	ICP-ES
Y	46	41	ICP-ES
Zn	220	158	ICP-ES
Ce	98.27	80.06	ICP-MS
Cs	1.65	>5.00	ICP-MS
Dy	10.86	9.46	ICP-MS
Er	5.76	5.14	ICP-MS
Eu	4.17	3.5	ICP-MS
Gd	13.19	10.78	ICP-MS
Hf	6.86	4.44	ICP-MS
Ho	2.14	1.91	ICP-MS
La	45.65	37.04	ICP-MS
Lu	0.717	0.649	ICP-MS
Nb	42.18	39.25	ICP-MS
Nd	57.82	45.64	ICP-MS
Pr	13.39	10.88	ICP-MS
Rb	56.18	52.88	ICP-MS
Sm	12.86	10.48	ICP-MS
Sr	165.03	355.5	ICP-MS
Ta	2.35	2.15	ICP-MS
Tb	1.92	1.64	ICP-MS
Th	6.95	5.09	ICP-MS
Tm	0.82	0.73	ICP-MS
U	1.68	1.33	ICP-MS
Y	57.62	51.97	ICP-MS
Yb	4.73	4.31	ICP-MS
Zr	281.54	182.67	ICP-MS

Geology of the Dezadeash Range and adjacent northern Coast Mountains (115A), southwestern Yukon: Re-examination of a terrane boundary

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Mezger. J.E., 2003. Geology of the Dezadeash Range and adjacent northern Coast Mountains (115A), southwestern Yukon: Re-examination of a terrane boundary. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 149-163.

ABSTRACT

Granodiorite of the Coast Plutonic Complex intruded metasedimentary rocks in the Dezadeash Range of the northern Coast Belt in the late Mesozoic. Graphitic staurolite–biotite schist, associated with the Kluane Metamorphic Assemblage, underlies the western Dezadeash Range, whereas cordierite–biotite gneiss, previously correlated with the Late Proterozoic – Paleozoic Nisling Assemblage, is exposed in the eastern and southern regions. A terrane boundary was placed in the central Dezadeash Range.

Recent petrographic studies reveal a southeastward increase in metamorphic grade. Prograde appearance of cordierite partly obliterated an older schistosity and caused a fabric change near the postulated terrane boundary. Furthermore, typical continental margin rocks, such as marble and quartzite, are not observed. This suggests that all metamorphic rocks in the Dezadeash Range can be correlated with the Kluane Metamorphic Assemblage, whereas Nisling Assemblage rocks occur in the Coast Mountains to the east. Therefore, the terrane boundary is located in the Dezadeash River valley, further southeast than previously thought.

RÉSUMÉ

Les granodiorites du Complexe Plutonique Côtier se sont emplacés au Mésozoïque tardif dans les roches métasédimentaires du chaînon de Dezadeash dans le nord de la Chaîne Côtière. Les schistes graphitiques à staurotide et biotite de la Série Métamorphique de Kluane se retrouvent dans la partie occidentale du chaînon de Dezadeash, alors que les parties orientale et méridionale comprennent du gneiss à cordiérite et biotite préalablement associé à la Série de Nisling d'âge Protérozoïque tardif à Paléozoïque. Une limite de terrane fut donc placée au coeur du chaînon de Dezadeash.

De nouvelles données pétrographiques montrent cependant que les conditions du métamorphisme augmentent vers le sud-est à travers le chaînon, s'exprimant par l'occurrence de la cordièrite; cette dernière recoupant une ancienne schistosité et, produisant une nouvelle fabrique cristalline à proximité de la supposée limite séparant la Série Métamorphique de Nisling de celle de Kluane. De plus, aucune roche de type marge continentale (marbre, quartzite) n'a pas été observée au sein des ces unités métamorphiques, suggérant que toutes les roches métamorphiques du Chaînon de Dezadeash se rattachent à la Série Métamorphique de Kluane. La Série de Nisling se limite donc à la partie orientale de la Chaîne Côtière et la limite du terrane se retrouve plus au sud dans la vallée de Dezadeash.

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INTRODUCTION

The Dezadeash Range is situated at a geomorphological triple junction between the Yukon Plateau, the St. Elias Mountains and northern Coast Mountains in the southwestern Yukon (Fig. 1). It is also located at a contact zone of two metamorphic belts within the Coast Belt of the northern Canadian Cordillera, an extensive graphitic mica schist belt, the Kluane Metamorphic Assemblage, to the northwest and the Nisling Assemblage to the east. Metamorphic rocks comprise graphitic plagioclase-staurolite-biotite schist in the western Dezadeash Range and cordierite-biotite gneiss in the east. Erdmer (1991) located a north-trending terrane boundary in the eastern Dezadeash Range, which is shown on current geological maps: the Tectonic Assemblage Map of the Canadian Cordillera (Wheeler and McFeely, 1991, also shown in Figure 2) and the Yukon Digital Geology map (Gordey and Makepeace, 1999). Results of recent structural, metamorphic and geochemical studies provide no evidence for a major lithological boundary in the Dezadeash Range (Mezger, 1997; Mezger et al., 2001a,b). What had been considered a terrane boundary is identified as a metamorphic mineral isograd in the high-grade gneiss terrane at the southeastern termination of the western mica schist belt, the Kluane Metamorphic Assemblage. The boundary with the Nisling Assemblage is located in the Dezadeash River valley to the east of the Dezadeash Range. The regional structural and metamorphic characteristics of the Dezadeash Range and adjacent Coast Mountains are described here, to complement more general publications that discuss the metamorphic and geochemical evolution of metamorphic rocks of the northern Coast Belt (Mezger et al., 2001a,b).

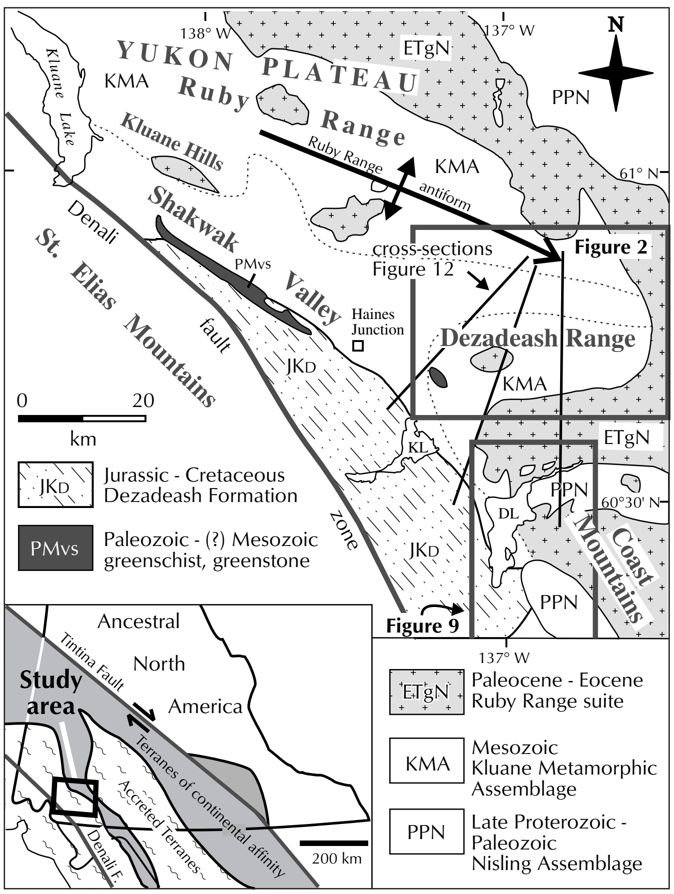


Figure 1. Tectonic setting of the southwestern Yukon with the major geological and morphological elements. The location of detailed maps and cross-sections of Figures 2, 9 and 12 are shown. Geological notation is from Dodds and Campbell (1992) and Gordey and Makepeace (1999). DL – Dezadeash Lake, KL – Kathleen Lakes

PREVIOUS GEOLOGICAL STUDIES

Metamorphic rocks east of the Denali fault zone and southwest and west of the early Tertiary plutons of the Ruby Range and the Coast Mountains are labelled 'undivided metamorphic rocks' (Wheeler and McFeely, 1991; Gordey and Makepeace, 1999). This rather meaningless name paraphrases the problems geologists had in determining the tectonic setting of a quite extensive, 150-km-long, northwest-trending belt of metamorphic rocks that form the southwestern flanks of the Ruby and the Dezadeash ranges. These metamorphic rocks are characterized by a monotonous lithology and structural orientation on a local scale, but record a strong regional metamorphic gradient. Distribution of these rocks across three map sheets (115F/G Kluane Lake, 115H Aishihik Lake, 115A Dezadeash), which were mapped over a period of 25 years, resulted in different classifications of the rocks (Kindle, 1949; Muller, 1967; Tempelman-Kluit, 1974).

In a 1912 mining report of the Kluane region McConnell (1905) first described extensive 'dark gray quartz-mica schist' of metasedimentary origin, which he named 'Kluane schists'. He already noticed the lack of limestone and quartzite that distinguishes the 'Kluane schist' from the 'Nasina series', which can be correlated with the Nisling Assemblage. The term 'Yukon Group' was introduced by Cairnes (1914) to include all metasedimentary and meta-igneous rocks along the Yukon-Alaska boundary. It was widely applied by subsequent workers in the Dezadeash (115A), Kluane Lake (115F, G) and Aishihik Lake (115H) map areas (Cockfield, 1927, 1928; Kindle, 1952; Muller, 1967), but various metasedimentary rocks were not differentiated on published geological maps. Muller (1967) subdivided schist into garnet- and staurolite-bearing quartz-biotite schist and gneiss (unit 1), and quartz-sericite schist (unit 2), and noted their high content in graphite and generally uniform lithology.

Tempelman-Kluit (1974) mapped the Aishihik Lake area (115H) and observed 'remarkably homogeneous' staurolite-, andalusite- and cordierite-bearing mica-quartz schist, which he termed 'hornfelsed schist' (PPsqr). He also noted that absence of marble makes the hornfelsed schist unit "unique in Yukon Plateau and is unlike other rocks in the Yukon Metamorphic Complex" (Tempelman-Kluit, 1974, p. 25). Erdmer (1990; 1991) came to similar conclusions after mapping selected areas in the Ruby Range, the Dezadeash Range and the Coast Mountains. He defined the 'Kluane assemblage' as graphitic mica schist with characteristic plagioclase porphyroblasts with graphite inclusions, conspicuously lacking marble, calc-silicate and quartzite units that are common in the Nisling Assemblage. The Nisling Assemblage is considered to comprise Late Proterozoic-Paleozoic continental margin rocks and correlates with the Nasina Assemblage and the Aishihik metamorphic suite (Johnston and Timmerman, 1994; Johnston et al., 1996). The contact between Kluane and Nisling assemblages was inferred to lie in the eastern Dezadeash Range, based on the absence of graphite in more heterogeneous Nisling rocks to the east (Erdmer, 1991). The terrane boundary was traced north along the Aishihik River valley. This contact was then overprinted by later metamorphism related to the early Tertiary intrusion of the Ruby Range batholith to the north (Erdmer, 1990; Erdmer and Mortensen, 1993).

A comprehensive field study of the 'Kluane schist/ assemblage' was carried out over three seasons by the author to map the extent of the Kluane metamorphic rocks. The term Kluane Metamorphic Assemblage (KMA) was introduced to include ultramafic rocks that are tectonically interleaved with the metasedimentary rocks and have experienced the same deformation (Mezger, 1995, 1997, 2000). In general, the KMA is a homogeneous 12-km-thick metapelitic sequence, ranging in metamorphic grade from greenschist facies along the Kluane Lake shore to the amphibolite-granulite facies transition zone in the eastern Dezadeash Range. Lower grade rocks are mylonitic L-S tectonites with a monoclinic symmetry indicating top-to-the-west sense of shear (Mezger and Creaser, 1996). In rocks of higher metamorphic grade, shear sense indicators are obliterated by contact metamorphism related to the Ruby Range batholith emplacement. Along the metamorphic gradient the rocks change their appearance, which caused previous workers to view the high-grade gneiss as a different unit. Inclusion of schist and gneiss in one assemblage was confirmed by neodymium isotope studies, which show that they are derived from a uniform protolith, distinct from that of other metamorphic assemblages, such as the Aishihik metamorphic suite (Mezger et al., 2001b). Table 1 lists lithologies of the KMA and the Nisling Assemblage.

THE DEZADEASH RANGE

The Dezadeash Range is triangular-shaped with sides 35-40 km long, separated from adjacent mountain ranges by the Dezadeash River in the north and southeast, and the Shakwak Valley in the southwest. The northern Dezadeash Range, dominated by metasedimentary rocks and two intrusive granodioritic stocks, has a rugged topography and rises up to 1200 m above the valley (Fig. 2). In contrast, the southern part of the range, predominantly underlain by massive granodiorite, is lower and has a smoother topography (Fig. 3). Easy direct access into the Dezadeash Range is only possible from the Haines Road at the southwestern end, halfway between Kathleen Lakes and Dezadeash Lake. An apparently non-maintained — at the time of fieldwork in 1995 — dirt road leads onto the southwestern ridges from where the central and eastern Dezadeash Range can also be reached. The northwestern Dezadeash Range is best accessed by helicopter.

STRUCTURAL CHARACTER OF THE NORTHERN DEZADEASH RANGE

Graphitic garnet-staurolite-biotite-plagioclase schist of the northwestern Dezadeash Range possesses a well developed spaced schistosity defined by platy alignment of biotite flakes. Undulating foliation surfaces are common, but well developed folding is not observed in every outcrop. Folds are asymmetrical open to closed, shallowly inclined or recumbent, with amplitudes and wavelengths in decimetre- to metre-range (Fig. 4). Fold axes trend sub-parallel to the general southeastern strike of the schistosity, which dips moderately to steeply (50-80°) towards northeast or southwest. This indicates the

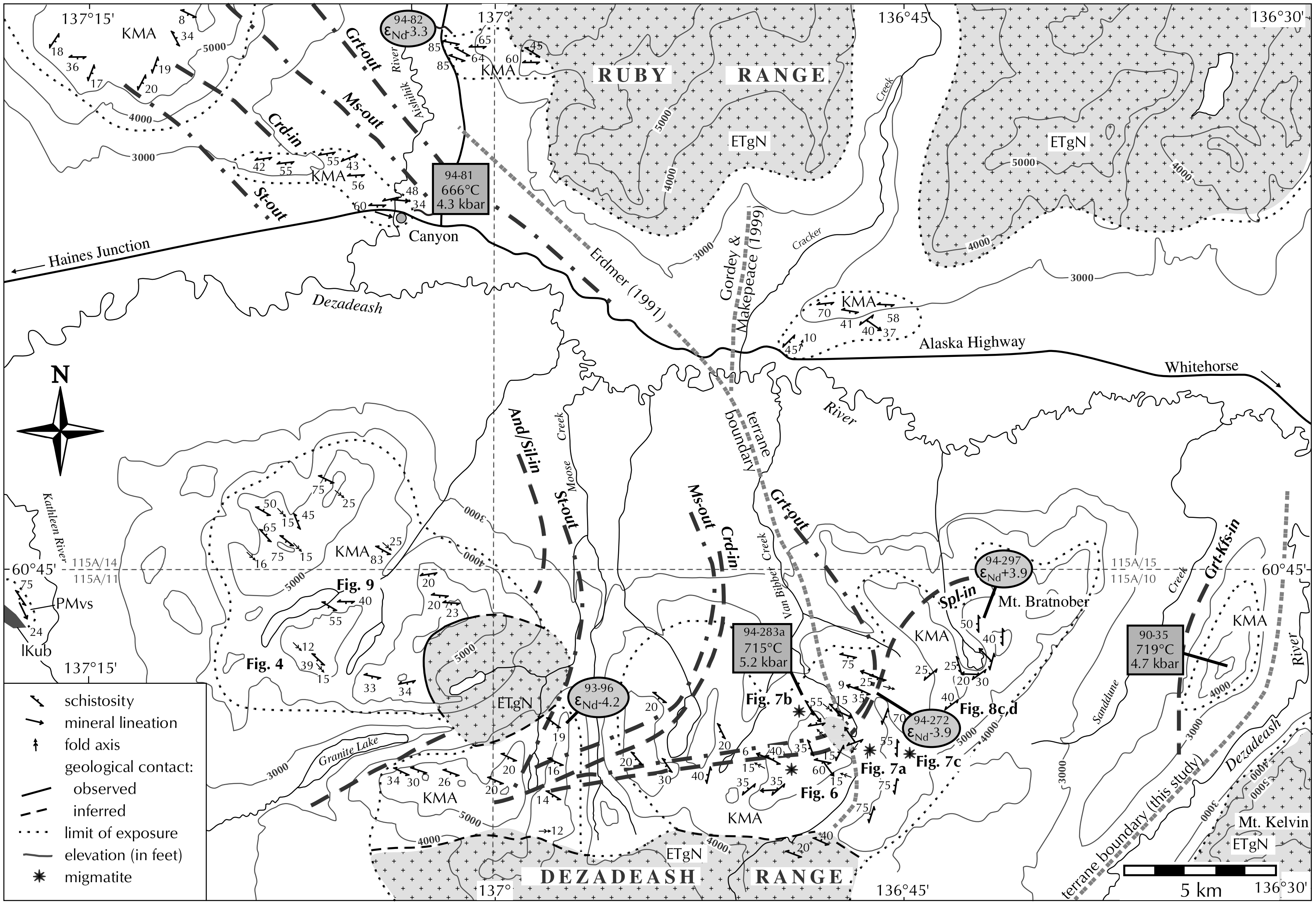


Figure 2. *Geological map of the northern Dezadeash Range and the southeastern Ruby Range, displaying mineral isograds, P-T estimates and neodymium data (shaded boxes and ellipses) of Mezger et al. (2001a,b). Mineral abbreviations are listed in Table 1. KMA-Nisling terrane boundaries proposed by Erdmer (1991), Gordey and Makepeace (1999), and this study are shown. Additional structural data are from Erdmer (1991). Geological signatures (legend) are the same as in Figure 1. 'lKub' denotes late Early Cretaceous pyroxenite (Dodds and Campbell, 1992). Locations of following figures are shown: 4, 6, 7a-c, 8c,d, 9. Figure covers parts of 1:50 000 map areas Mount Bratnober (115A/10), Kathleen Lakes (115A/11), Canyon (115A/14) and Cracker Creek (115A/15).*

Table 1. *Comparision of Kluane Metamorphic and Nisling assemblages lithology.*

Kluane Metamorphic Assemblage	Nisling Assemblage[1]
Ruby Range	
graphitic (Ep)-Chl-Ms-Pl-Qtz schist	
graphitic Grt-St-(And)-Bt-Pl-Qtz schist	
Sil-Crd-Pl-Bt-Qtz gneiss	
olivine serpentinite	
minor interfoliated actinolite hornfels	
Dezadeash Range	**Coast Mountains east of Dezadeash Lake**
graphitic Grt-St-(And)-Bt-Pl-Qtz schist	Spl-Crd-Ky-Bt-Qtz schist
(Spl)-Sil-Crd-Pl-Bt-Qtz gneiss	Ky-Grt-Pl-Bt-Qtz schist
Spl-Kfs-Crd gneiss	Sil-Grt-Pl-Bt-Qtz schist
Spl-Kfs-Grt-Crd-Bt-Qtz gneiss	Sil-Spl-Crd-Grt-Bt-Qtz gneiss
	Grt-Pl amphibolite
	Diopside calc-silicate
	Marble
Mt. Bratnober only	
Orthoamphibole-Bt-Pl-Qtz gneiss	

1: Additional information is from Erdmer (1989; 1990).

And: andalusite; Bt: biotite; Chl: chlorite; Crd: cordierite; Ep: epidote; Grt: garnet; Kfs: potassium-feldspar; Ky: kyanite; Ms: muscovite; Pl: plagioclase; Qtz: quartz; Sil: sillimanite; Spl: spinel; St: staurolite.

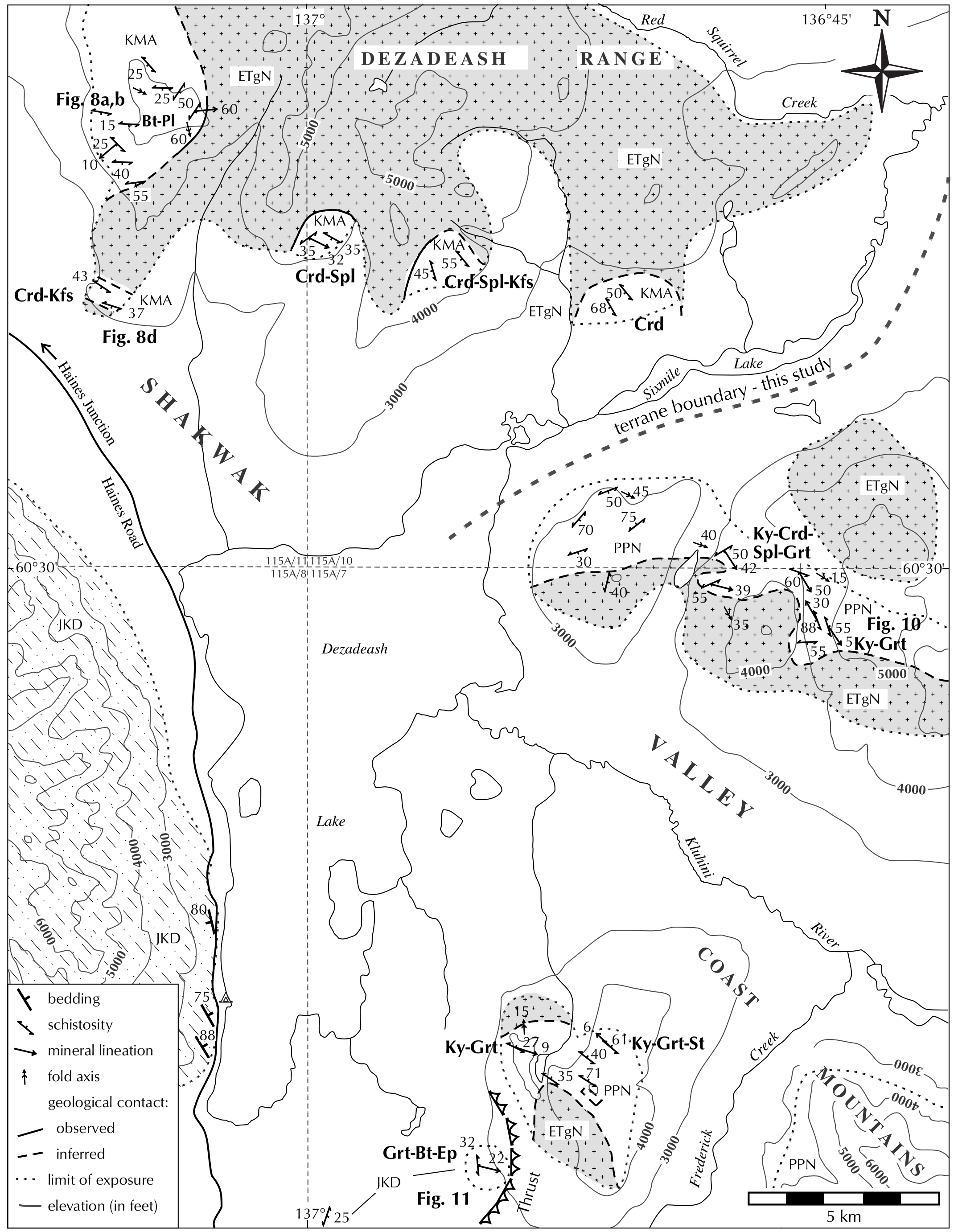


Figure 3. *Geological map of the southern Dezadeash Range and the Dezadeash Lake area. Legend as in Figure 1. Minerals on the map list only the characteristic metamorphic phases; their abbreviations are listed in Table 1. Detailed geological maps of areas adjacent to the south and east were published by Lowey (2000) and Erdmer (1990), respectively. Locations of following figures are shown: 8a,b, 10, 11. Figure covers parts of 1:25 000 map areas Mush Lake (115A/6), Kluhini River (115A/7), Mount Bratnober (115A/10) and Kathleen Lakes (115A/11).*

existence of several southeast-trending and southwest-verging syn- and antiforms with wavelengths of several hundred metres to a few kilometres (Fig. 2). The lack of marker horizons and discontinuous exposure prevent further distinction. The strike of schistosity is similar to that of east-striking biotite-cordierite gneiss exposed 8 km to the north, at the southern limb of the Ruby Range antiform (Figs. 1,2,5). It remains unclear if the structural sequence is continuous or disrupted by an east-striking fault located in the Dezadeash River valley.

Steeply southwest-dipping hornblende-chlorite schist is exposed near Kathleen River, in the Shakwak valley 5 km to the west. Originally mapped as 'Yukon Group' by Kindle (1952), these rocks can be correlated with chlorite schist of the PMvs unit that underlies the Kluane Ranges west of Haines Junction (Dodds and Campbell, 1992). Immediately to the west, serpentinized pyroxenite (lKub) was drilled for asbestos on the REX claim (Yukon MINFILE, 2001, 115A 032).

Figure 4. *Recumbent, similar fold in staurolite-biotite schist of the western Dezadeash Range. Fold axis plunges to southeast. Length of rock hammer is 30 cm.*

The orientation of schistosity in the Dezadeash Range gradually becomes moderately (15-35°) south-dipping near the vicinity of the massive granodiorite stock of the Moose Creek valley (Fig. 2). The granodiorite is exposed on both sides of the valley and structurally underlies the schist. Over the next 10 km towards the east, the schistosity retains moderate dip angles, but its dip direction gradually changes to the southwest. The character of the rocks changes from schist to gneiss. Isoclinal folds and small-scale shear zones are indicative of higher strain deformation than in the western range (Fig. 6).

A small granodiorite stock cross-cutting the cordierite gneiss is exposed at the southwestern slope of an unnamed lake in the Van Bibber Creek valley (Fig. 2). Dip direction and angle of the cordierite gneiss vary strongly in the vicinity of the granodiorite, and it displays shallow dips close to the contact. Mineral lineation, which is commonly observed in the gneiss, and axes of isoclinal folds show scattering of plunge directions. The character of the contact varies. Intruded granodiorite can display intrusion-parallel foliation discordant with schistosity of the cordierite gneiss float, which contains leucosome veins perpendicular to schistosity (Fig. 7a). These fabrics can be interpreted as an early stage of migmatization. At another locality the gneiss shows schlieren and stromatic textures characteristic of migmatization (Fig. 7b). An older more mafic plutonic rock, possibly an amphibolite or diorite, forms boudinaged layers within granodiorite sills cross-cutting the cordierite gneiss (Fig. 7a). Nearby, massive coarse-grained granitic rocks intrude fine-grained amphibolite (Fig. 7c).

The eastern ridges of the Dezadeash Range are underlain by moderately to steeply northwest-dipping cordierite gneiss. Metre-thick sills and dykes of granodioritic composition cross-cut the gneiss. Erdmer (1991) described several phases of cross-cutting granite pegmatite and aplite. West of Mt. Bratnober, an orthoamphibole-biotite-plagioclase-quartz schist of unknown thickness crops out. It has a well developed schistosity which is oriented parallel to nearby cordierite gneiss. The main granodiorite, cropping out at the southwestern end of the ridge, displays a northeast-dipping foliation near the intrusive contact (Fig. 2). This indicates that the granodiorite underlies the cordierite gneiss to the north.

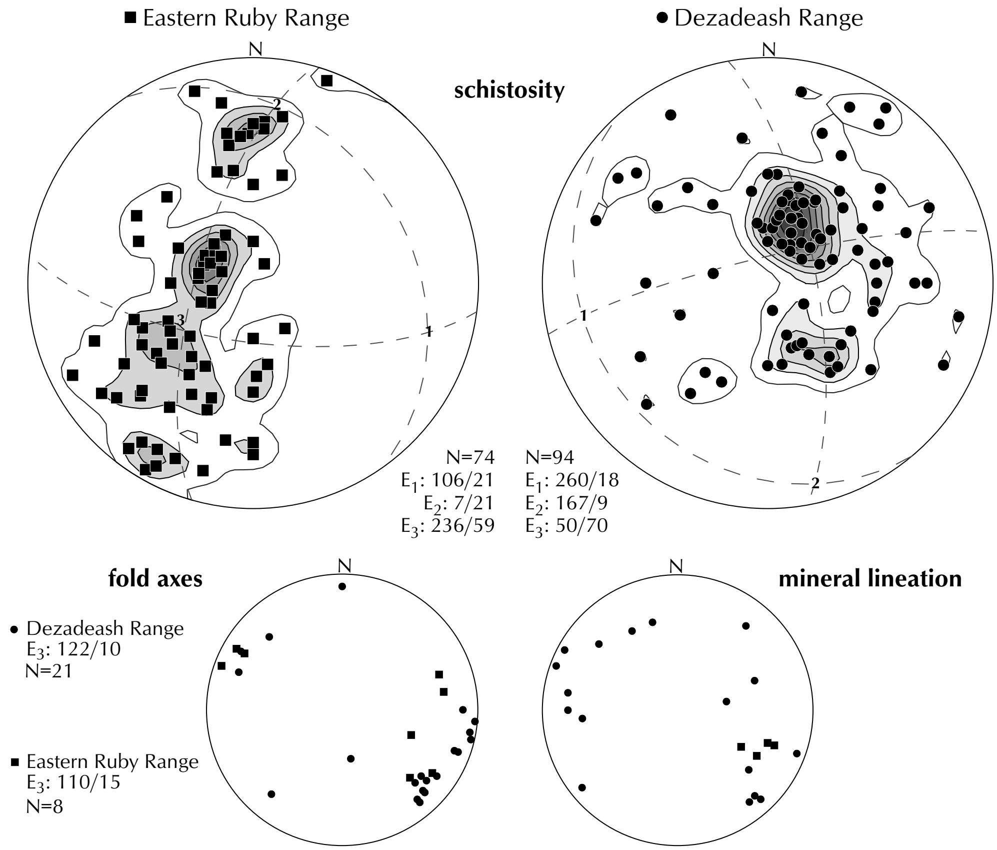


Figure 5. *Equal area stereographic lower hemisphere projection of structural data of the Kluane Metamorphic Assemblage in the Dezadeash Range and the southeastern Ruby Range. Smoothed Gaussian contouring with intervals of 2 sigma. 'E' denotes eigenvectors.*

In comparison with the Ruby Range, where poles to schistosity form a girdle with a shallow east-plunging fold axis, the foliation is more widely scattered in the Dezadeash Range (Fig. 5). The scattering of foliation and lineation can be attributed to the occurrence of granodiorite intrusions, which postdate fabric development and deflect them during emplacement. Similar deviation of structural fabrics around intrusions can be observed in the Ruby Range (e.g., Garnet Creek, Killermun Lake; Mezger, 1997). In the Dezadeash Range, shallowing of foliation has been observed around the Moose Creek stock in the west, and especially in the contact zone of the small Van Bibber Creek granodiorite. Other small-scale perturbations may be related to doming of plutons, which are not exposed at the surface. Several cross-cutting metre-sized granodiorite sills and dykes may indicate the presence of unexposed plutons.

METAMORPHIC CHARACTER OF THE NORTHERN DEZADEASH RANGE

The metamorphic grade in the northern Dezadeash Range increases from west to east, and to the contact with the granodiorite in the southeast. The northwestern ridges are underlain by a graphitic garnet-staurolite-biotite-quartz schist with plagioclase porphyroblasts that are characteristic throughout the Kluane Metamorphic Assemblage (similar to Fig. 8a,b). Muscovite and chlorite are minor phases. Garnets in the so-called staurolite zone

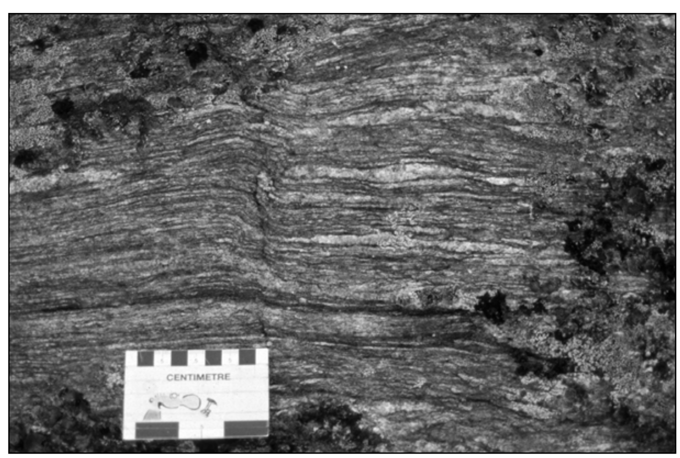
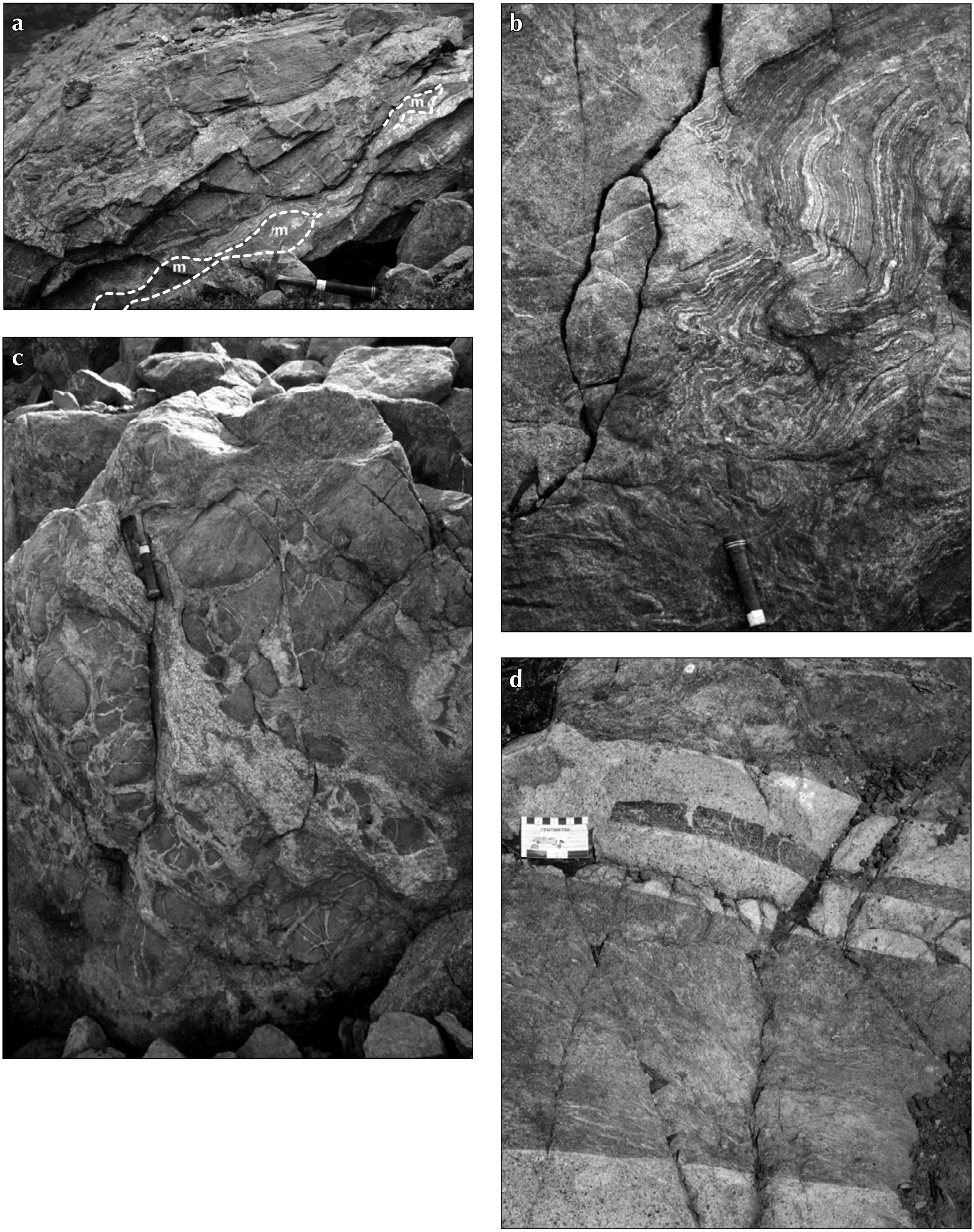


Figure 6. *Lichen-framed coarse-grained cordierite gneiss of the eastern Dezadeash Range, characterized by discontinuous, centimetre-thick, lens-shaped quartz layers and poorly defined cleavage domains. A small vertical shear zone is developed in the centre. Scale bar is in centimetres.*


a
m
m
m
b
c
d

show strong compositional zoning, with increasing almandine (iron-rich end member) component (60-72%) and decreasing grossular (calcium-rich end member) component (25-8%) from core to rim, indicative of heating during decompression (Mezger, 1997; Mezger et al., 2001a). Garnet rims show signs of corrosion and replacement by staurolite (Fig. 9). Geothermobarometric calculations of these samples produce errors too large to provide reliable pressure and temperature estimates (Mezger, 1997). East of Granite Lake, andalusite and fibrolitic sillimanite are first observed, and slightly further east, staurolite and chlorite disappear completely (Fig. 2). Primary muscovite decreases in abundance from 5 vol.% to less than 1 vol.%. From these observations the following reaction can be inferred:

(1) Ms + Chl + Qtz + St = And/Sil + Bt + H_2O

The major textural change occurs with the appearance of cordierite. Cordierite forms colourless, anhedral porphyroblasts up to 4 mm in size that can be distinguished from plagioclase by yellow alteration rims composed of pinite, a fine-grained white mica. Cordierite can make up as much as 20 vol.% of the rock. Potassium feldspar makes its first prograde appearance, but its distinction is difficult and generally only possible with an electron microprobe. A notable decrease in the biotite, sillimanite and garnet abundance, and the final disappearance of muscovite, can be observed. Cordierite mantling garnet, potassium-feldspar and cordierite in contact with biotite, and embayed biotite grain boundaries are textural indicators for the following reactions (Mezger et al., 2001a):

(2) Bt + Sil + Qtz = Crd + Kfs + L

(3) Grt + Sil + Qtz = Crd

(4) Ms + Qtz = Kfs + Sil + L

Rocks within the cordierite zone that do not contain cordierite, because of unfavourable whole rock geochemistry, i.e., insufficient magnesium, commonly have abundant fibrolitic sillimanite (up to 20 vol.%). Garnets are rare in the cordierite zone and differ from those of the staurolite zone above: they show very little zoning, and have high almandine (80) and low grossular (<5) contents (Mezger, 1997). Mg-numbers for cordierite range from 50-60%. The transition from staurolite to cordierite zone does not affect plagioclase composition: grains are unzoned and have oligoclase-andesine composition (An27-30). A sample south of the Van Bibber Creek granodiorite (94-283a) yielded P-T estimates of 715°C and 5.2 kbar. (For detailed information on mineral composition and thermobarometry see Mezger et al. (2001a)). Randomly growing new biotite (reaction 1) and the prograde appearance of cordierite, which partly replaces biotite (reaction 2), obliterate the distinct schistosity of the staurolite zone rocks. Minute graphite inclusions are not observed, due to dissolution and either escaped through metamorphic fluids or precipitation at grain boundaries. Thus the rock attains the appearance of a dark-brown-weathering gneiss (Figs. 6, 8c). Migmatization (L), inferred from reactions (2) and (4), can be observed in several outcrops on the ridges west and south of the Van Bibber Creek intrusion (Fig. 7b).

Cordierite porphyroblasts have inclusions of small (10-20 μm) green cubes or worms of hercynite, a Zn-rich spinel. It is commonly associated with inclusions of fibrolite (Fig. 8d) and garnet in cordierite, suggesting the reaction (Mezger et al., 2001a):

(5) Sil + Grt = Crd + Spl

Garnet is conspicuously absent in the eastern ridge of the Dezadeash Range, being consumed by reactions (3) and (5). Inclusion-free, subhedral second generation garnet is observed on the isolated ridge between Sanddune Creek and Dezadeash River, immediately west of the granodiorite massif, according to reaction (Mezger et al., 2001a):

(6) Bt + Sil + Pl + Qtz = Grt + Crd + Kfs + L

The highest grade assemblage of the Kluane Metamorphic Assemblage consists of garnet, biotite, K-feldspar,

Figure 7 *(previous page). Nature of the gneiss-granodiorite contact.* ***(a)*** *At the southern margin of the Van Bibber Creek plug, the granodiorite-cordierite gneiss interface is discrete. Centimetre-thick leucosomes cut the gneiss perpendicular to schistosity. Flow foliation is developed in granodiorite between gneiss floats. A boudinaged dioritic layer (m) can be observed in the lower part of the outcrop.* ***(b)*** *Massive granodiorite in contact with migmatitic gneiss at the northern contact of the Van Bibber Creek plug.* ***(c)*** *Granitic pegmatite cross-cutting massive amphibolite? near (a).* ***(d)*** *Massive granodiorite in sharp contact with cordierite-K-feldspar gneiss at the foot of the southwestern Dezadeash Range. Outcrop along mining road, 2 km east of the Haines Road.*

plagioclase, sillimanite, and hercynite as inclusions in cordierite and quartz. It marks the transition from the upper amphibolite to the lower granulite facies (Bucher and Frey, 1994). Calculated temperature and pressure are 717°C at 4.7 kbar (sample 90-35; Mezger et al., 2001a).

Traced on a map, the mineral isograds show a convergence and deflection to the south, where the higher grade cordierite-spinel-bearing assemblages parallel the contact with the southern granodiorite (Fig. 2). Widening of the isograds towards the north suggests that a heat source, the postulated intrusions that are also responsible for deflection of the schistosity, is located below the surface. The observed mineral assemblages and inferred mineral reactions are the same as those observed in the Ruby Range, where they outline a 5-km-thick contact aureole related to the intrusion of the Ruby Range batholith in the Paleocene/Eocene (Erdmer and Mortensen, 1993; Mezger et al., 2001a). In the Dezadeash Range and the eastern Ruby Range, the isograds cross-cut the foliation, indicating that formation of the antiform predated the intrusion (Fig. 2).

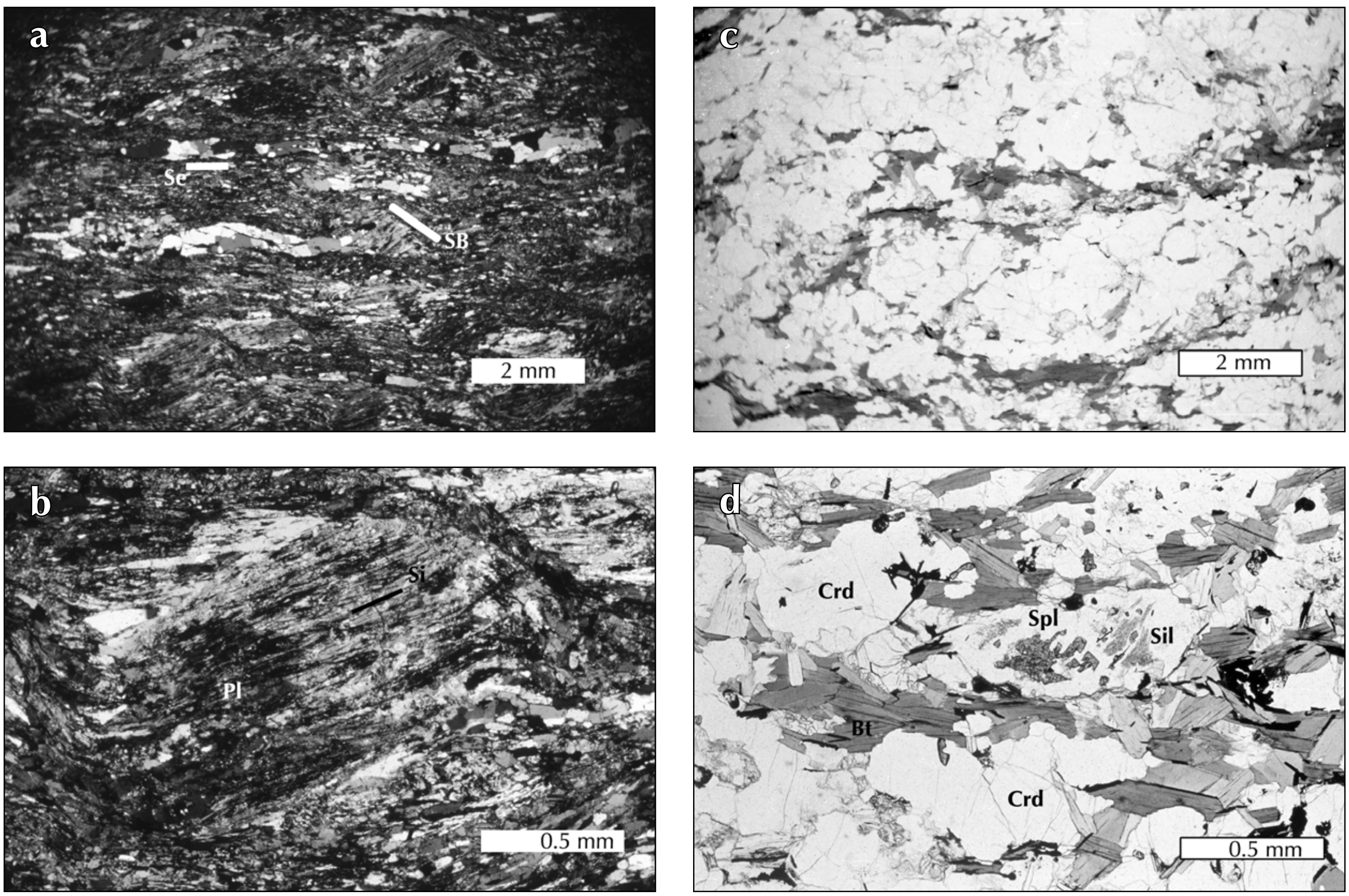


Figure 8. *Photomicrographs illustrating the textural differences between low-grade plagioclase-biotite-quartz schist (a, b) of the western Dezadeash Range and high-grade biotite-cordierite gneiss (c, d) of the eastern part. Both are shown at the same scale for comparison.* ***(a)*** *Fine-grained, well foliated schist with discontinuous layers of coarse quartz. Pervasive graphite dust results in the dark appearance of the schist. Shear bands (SB) are developed around plagioclase porphyroblasts.* ***(b)*** *Enlargement of the lower left corner of (a) showing graphite inclusion trails in plagioclase that preserve an older schistosity (Si) and are at an angle with the external main foliation (Se), indicating relative counterclockwise rotation.* ***(c)*** *Post-kinematic biotite and cordierite are larger and grow randomly. The rock has a gneissic appearance. Graphite has disappeared or has precipitated in large opaque concentrates at grain boundaries. Small green cubes of hercynite (Zn-spinel) nucleate in cordierite porphyroblasts* ***(d)****. Note that the photographs of (a) and (b) are taken with crossed polarized light, enhancing the darker appearance of the sample, in contrast to (c) and (d) which were taken with plane polarized light. Mineral abbreviations are the same as in Table 1.*

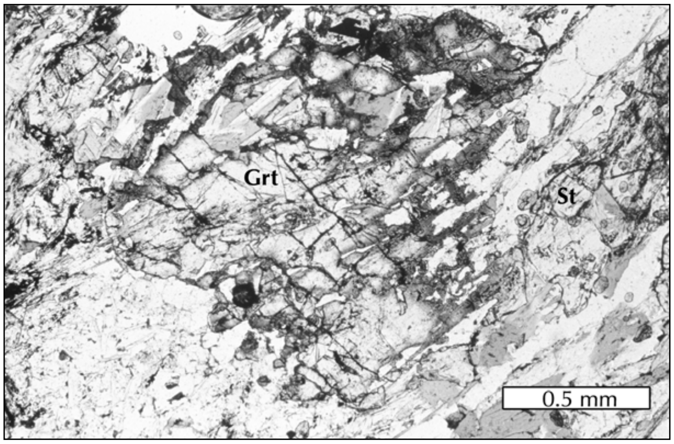


Figure 9. *Photomicrograph of a garnet porphyroblast of a typical staurolite-garnet-biotite-quartz schist from the western Dezadeash Range with strongly corroded rim, partly replaced by staurolite. Inclusions of graphite dust give the garnet a dirty appearance. Plane-polarized light. Mineral abbreviations are the same as in Table 1.*

GEOLOGY OF THE SOUTHERN DEZADEASH RANGE

The southern Dezadeash Range differs from the northern part in that it is mostly underlain by massive, equigranular biotite-hornblende granodiorite. Metamorphic rocks only crop out on a western ridge and in small isolated areas along the southern slopes of four southward-extending ridges, at elevations below 1500 m (Fig. 3). At the western ridge, dark bluish grey graphitic biotite-plagioclase-quartz schist occurs with characteristic graphite inclusions in plagioclase porphyroblasts (Figs. 8a,b). Muscovite is only a minor constituent. Schistosity and mineral lineation are well developed. The schist is very similar to those underlying the northwestern Dezadeash Range. The foliation varies from steeply southeasterly dipping to moderately south-dipping. The mineral lineation trends approximately easterly. East-southeasterly plunging, west-verging open folds are common, as well as small crenulation folds with a similar plunge direction. Isoclinal folds were observed in some outcrops. The contact with the overlying granodiorite is sharp.

The metamorphic rocks that crop out on the southern slope are brownish weathering, equigranular, fine-grained (<0.5 mm) cordierite-biotite-plagioclase-quartz gneisses. Hercynite was observed in the cordierite of some samples. Potassium-feldspar was determined with the aid of an electron microprobe. A gneissic foliation is well developed, dipping generally to the southwest, at angles of 35-68°. Mineral lineations are not common. The contact with the granodiorite is intrusive in nature, and generally fabric-parallel (Fig. 7d). The granodiorite itself is not foliated. Metre-sized granodiorite sills within the gneiss close to the contact have been observed. These rocks are very similar to the cordierite zone rocks of the northeastern Dezadeash Range, and were assigned to the Nisling Assemblage by Erdmer (1991).

GEOLOGY OF THE COAST MOUNTAINS EAST OF DEZADEASH LAKE

The hills south of the Dezadeash River and Sixmile Lake zone are underlain by an east-southeast-trending 2-km-wide belt of graphitic garnet-kyanite-biotite-quartz schist. This schist differs from the metamorphic rocks in the Dezadeash Range in that it includes kyanite, and garnet grains are not corroded (Fig. 10). The schist dips moderately to steeply south, forming a metasedimentary septum within massive medium-grained granodiorite of the Coast Mountains, which crop out north and south of the kyanite-biotite schist belt. Near the contact with the schist, a contact-parallel foliation is developed in the granodiorite. Mineral lineation in the schist is well developed and trends southeasterly. A further 8-10 km east, biotite-sillimanite-garnet schist is interlayered with calc-silicate rock and biotite amphibolite, and forms a close southeast-plunging regional antiform. Erdmer (1989; 1990) assigned these rocks to the Nisling Assemblage and correlated them to assemblages found near Kusawa Lake to the southeast.

Kyanite-garnet schist forms a 2-km-wide southeast-striking belt on an isolated hill between Dezadeash Lake and Frederick Creek, southwest of the Shakwak Valley (Fig. 3). Schistosity dips moderately to steeply to the northwest, with a subhorizontal southeast-trending mineral lineation. Spectacular centimetre-sized garnets and kyanite can be found along the main eastern ridge. The schist is bounded by massive granodiorite. Granodiorite occurring as sills within the schist possess a foliation parallel to that of the schist. At the southeastern foot of that hill, a fine-grained, graphitic garnet-biotite-epidote schist with strong top-to-the-west shear-sense indicators dips eastwards underneath the kyanite schist (Fig. 11). It is interpreted as metamorphosed Dezadeash Formation (Mezger, 1997). The contact is inferred to be a thrust, perhaps the northern continuation and termination of the Tatshenshini shear zone, which is linked to the Coast shear zone in the south, and was supposed to be active from 75 to 55 Ma (Lowey, 2000).

DISCUSSION

A terrane boundary between the Kluane Metamorphic and Nisling assemblages was inferred to be located on a ridge south of the Van Bibber Creek granodiorite stock (Fig. 2). Erdmer (1991) originally traced the boundary northwest into the Ruby Range where it crosses the Aishihik River 3 km north of the Aishihik Road junction, to include metamorphic rocks east of Aishihik River to the Nisling Assemblage. On the digital Yukon Geology map, the terrane boundary continues straight north following Cracker Creek (Gordey and Makepeace, 1999). The reason for proposing a terrane boundary was the apparent lithological heterogeneity of rocks in the eastern Dezadeash Range: among others, the absence of graphite. The contact was thought to be a sharp and foliation-parallel fault, welded by metamorphism (Erdmer, 1991).

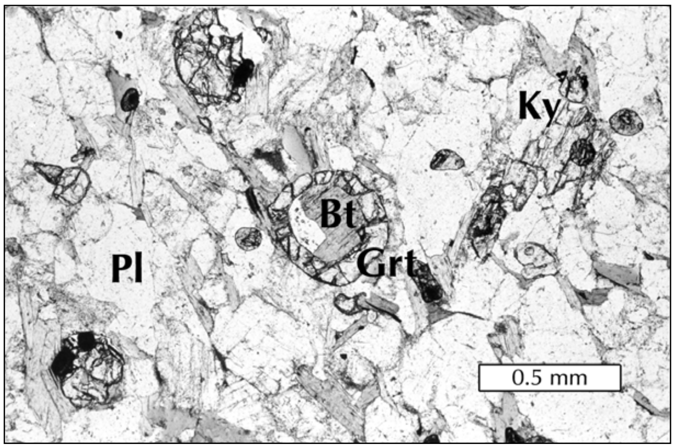


Figure 10. *Photomicrograph of kyanite-garnet-plagioclase schist of the Nisling Assemblage east of Dezadeash Lake with distinct atoll garnets. Plane polarized light. Mineral abbreviations are the same as in Table 1.*

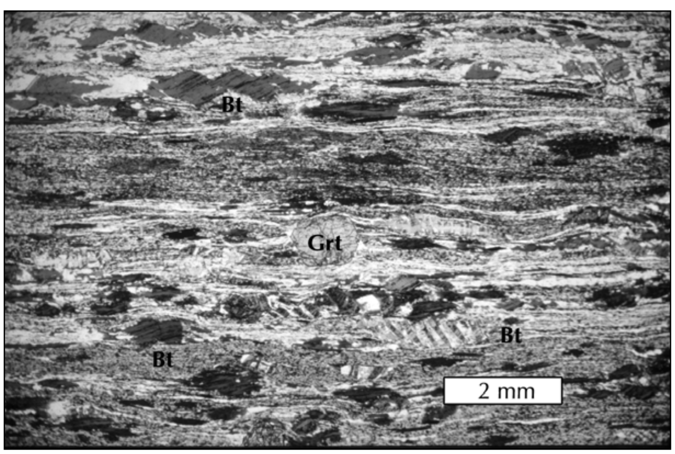


Figure 11. *Photomicrograph of graphitic garnet-biotite-epidote schist from the foot of the Coast Mountains south of Dezadeash Lake. Biotite porphyroblasts display curved graphite inclusion trails and domino structures that indicate top-to-the-left sense of shear. The schist, which has a well developed mineral lineation, structurally underlies kyanite-garnet Nisling Assemblage schist to the east and is assigned to the Dezadeash Formation (Mezger, 1997). Mineral abbreviations are the same as in Table 1.*

As discussed above, the postulated boundary lies within the cordierite zone, close to the spinel-in and garnet-out isograd. Petrographic observations suggest a prograde metamorphism related to intrusion of the granodiorite resulted in changes of rock fabric and mineral assemblages. Continental margin-derived metamorphic rocks, e.g., marble, calc-silicate rock and quartzite, are not observed in the Dezadeash Range. Neodymium isotope studies and whole rock geochemistry have shown that samples of the Kluane Metamorphic Assemblage (KMA) in the Dezadeash Range and the southern Ruby Range outside the postulated terrane boundary have signatures (∈Nd -3.3 to -3.9) within the range of the KMA to the west. These values suggest that the sedimentary protolith derived from mixing juvenile with evolved sources. The orthoamphibole gneiss west of Mt. Bratnober has an ∈Nd-value (+3.9) similar to island arc volcanic rocks, and is interpreted to be metamorphosed volcanoclastic sediment. Samples of the Aishihik metamorphic suite near Aishihik Lake, correlated with the Nisling Assemblage, have ∈Nd values of -29 to -20, characteristic of an ancient cratonic source (Mezger et al., 2001b).

The amphibolite layers intruded by granodiorite and boudinaged at the contact with cordierite gneiss in the Van Bibber Creek stock (Figs. 7a,b) are observed elsewhere at the margin of the Ruby Range batholith. Leucocratic granodiorite and granitic pegmatite intruded foliated tonalite and quartz diorite at the western shore of Talbot Arm of Kluane Lake (Mezger, 2000). Similar dioritic rocks were reported by Johnston (1993) from the northern margin of the Ruby Range batholith near Aishihik Lake, and yielded crystallization ages of 90-70 Ma, pre-dating the Paleocene/Eocene emplacement age of the main granodiorite body of the Ruby Range batholith (Erdmer and Mortensen, 1993). Mafic plutonic rocks are interpreted as the magmatic precursor of the Coast Plutonic Complex and form the 'Great Tonalite Sill' (Ingram and Hutton, 1994).

The metamorphic rocks east and southeast of the Dezadeash Range are distinct from KMA schist and gneiss by their garnet-kyanite assemblage, which indicates higher pressures during prograde metamorphism than in the KMA, where andalusite replaces staurolite. This suggests that the boundary between KMA and Nisling Assemblage, between back-arc basin- and continental margin-derived metasedimentary rocks, is located in and obscured by the northeast-trending valley of the Sixmile Lake and Dezadeash River. Mezger (1997) suggested that it is a post-intrusive reverse fault.

The contrast of high-grade gneiss in the southwestern Dezadeash Range with unmetamorphosed shale of the Dezadeash Formation at Kathleen Lakes, does not support Eisbacher's hypothesis that the KMA is metamorphosed Dezadeash Formation (Eisbacher, 1976). This is confirmed by neodymium isotope studies (Mezger et al., 2001b). The present juxtaposition of the KMA with the Dezadeash Formation and the greenschist (PMvs) is the result of reactivation of a Paleocene or older northeast-dipping thrust, along which the KMA was underplated by the Dezadeash Formation and exhumed, into a steeply southwest-dipping reverse fault (Mezger, 1997). This process of uplift is presently continuing, evident in the steep front of the Kluane Ranges (Lowe et al., 1993).

Three north- to northeast-trending cross-sections through the western, central and eastern Dezadeash Range show the correlation of structural style of the KMA with the presence of granodiorite intrusion (Fig. 12). In the northwestern Dezadeash Range, where the KMA schist is undisturbed by plutons, the schist is at its lowest grade and its structural style is similar to that in the Ruby Range. In the central and eastern Dezadeash Range, metamorphic rocks are underlain, and in part overlain, by the granodiorite of the Coast Plutonic Complex. Deflection of foliation near granodiorite stocks exposed at lower structural levels suggests that interleaving of plutonic and metamorphic rocks is primary and not tectonic in origin. The widely spaced mineral isograds in the eastern Dezadeash Range indicate that plutonic rocks are present underneath the surface, and possibly connect with the Ruby Range batholith north of the Alaska Highway. In the southern Dezadeash Range, where

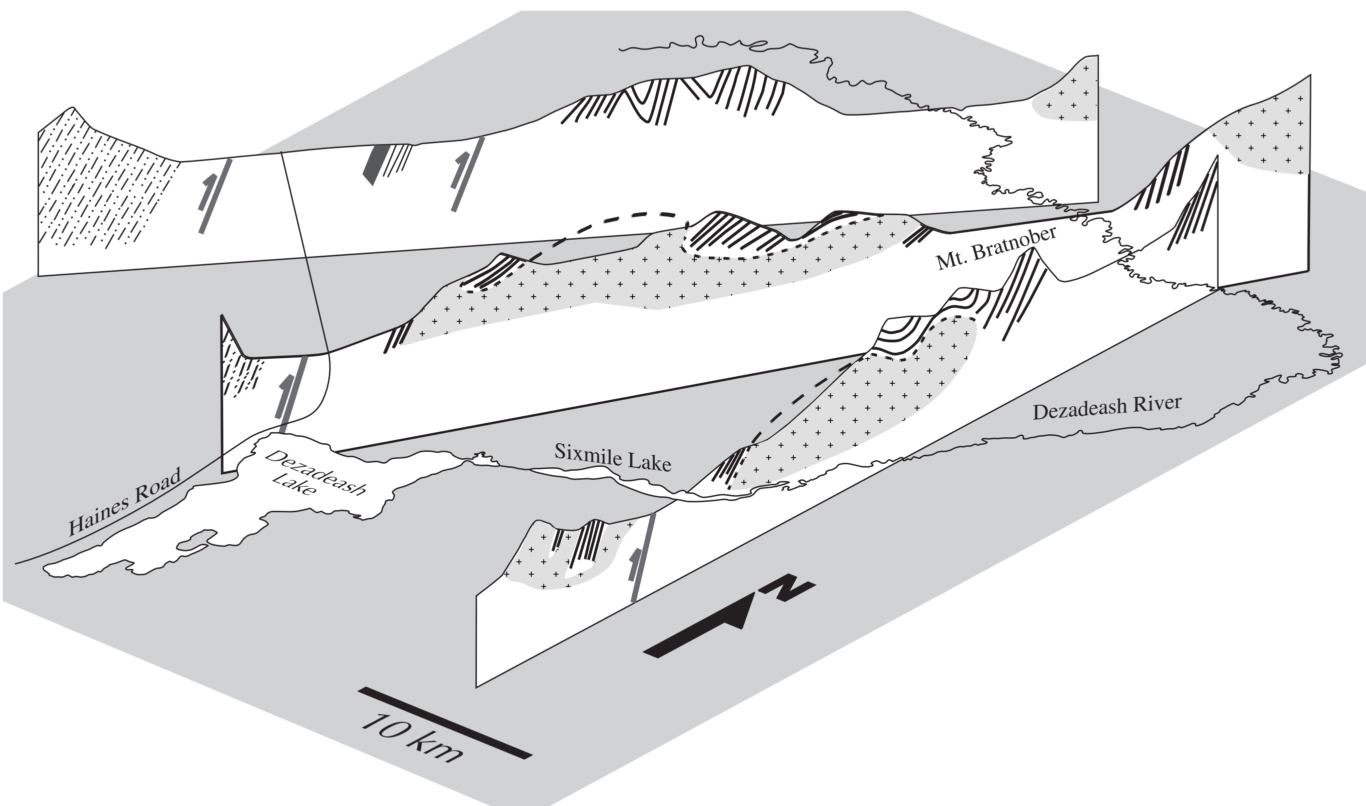


Figure 12. *Three-dimensional arrangement of schematic cross-sections through the western, central and eastern Dezadeash Range. Elevation is approximately exaggerated twice. Location of cross-sections and legend are shown in Figure 1.*

deeper erosion has exposed the granodiorite core, the cordierite gneiss occurrences are reduced to small relict roof pendants. In contrast to the Ruby Range, in the Kluane Lake region, where the KMA constitutes a 12-km-thick sequence of mica-quartz schist, they form relatively thin discontinuous high-grade gneiss sheets in the eastern and southern Dezadeash Range.

CONCLUSIONS

Plutonic rocks of the Ruby Range batholith and the Coast Plutonic Complex underlie most parts of the central, southern and eastern Dezadeash Range, and are overlain by metamorphic rocks of the Kluane Metamorphic Assemblage (KMA). Intrusion of the granodiorite resulted in disturbance of the structural orientation, with local deviation of foliation, and in thermal overprinting of the previously regionally metamorphosed mylonitic schist. Mapped mineral isograds show a change of metamorphic grade from staurolite-zone amphibolite facies to the second garnet isograd, the transition between amphibolite and granulite facies. The prograde appearance of cordierite changed the rock fabric from a mylonitic L-S tectonite to coarse-grained gneiss. New biotite and cordierite overgrew and obliterated the mylonitic fabric. This transition, which can be followed into the Ruby Range to the northwest, was considered to be a terrane boundary between the KMA and the Nisling Assemblage, of cratonic North American affinity, to the east (Erdmer, 1991; Wheeler and McFeely, 1991; Gordey and Makepeace, 1999). The data presented in this study show there is no evidence for a terrane boundary within the Dezadeash Range. The eastern and southern Dezadeash Range is underlain by high-grade gneiss of the KMA. Rocks of the Nisling Assemblage occur to the southeast of the Dezadeash Range, and are characterized by a different metamorphic evolution than the KMA in the Dezadeash Range.

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Geological and U-Pb age constraints on base and precious metal vein systems in the Mount Nansen area, eastern Dawson Range, Yukon

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ABSTRACT

Epithermal vein and porphyry-related gold-silver deposits in the Mount Nansen area are mainly hosted in Paleozoic Yukon-Tanana Terrane metasedimentary rocks and Early Jurassic Big Creek Batholith intrusive rocks. Mineralization is spatially, and probably temporally, related to a northwest-trending belt of mid-Cretaceous hypabyssal felsic intrusions and dykes along the Mount Nansen Trend. The proximal relationship between the veins and mid-Cretaceous intrusive rocks suggests that mineralization may be genetically related to felsic magmatism. The Dickson stock yields a U-Pb zircon age of 108.3 ± 0.7 Ma, and proximal dykes in the Flex, Dickson, Brown-McDade and Weber zones give ages of 107.9 ± 0.9 Ma to 109.0 ± 0.7 Ma, similar to the age of the Mount Nansen Group volcanic rocks. Granodiorite that hosts the Dickson deposit gives a U-Pb titanite age of 191.5 ± 2.9 Ma, and is likely part of the Big Creek Batholith. Previous studies indicated two periods of mineralization in the Dawson Range: mid-Cretaceous and Late Cretaceous. Dating indicates that Mount Nansen mineralization is associated with the mid-Cretaceous emplacement of the high-level felsic intrusions.

RÉSUMÉ

Les gisements d'or-argent associés à des roches porphyriques et à des filons épithermaux dans la région du mont Nansen sont surtout logés dans des roches métasédimentaires paléozoïques du terrane de Yukon-Tanana et dans des roches intrusives du Batholite de Big Creek du Jurassique précoce. La minéralisation est associée, sur le plan spatial et probablement temporel, à une zone d'intrusions et de dykes felsiques hypabyssaux du Crétacé moyen à direction nord-ouest parallèle à la direction de mont Nansen. Le lien proximal entre les filons et les roches intrusives du Crétacé moyen pourrait indiquer une relation génétique avec un magmatisme felsique. La datation par la méthode U-Pb sur zircon donne un âge de 108,3 ± 0,7 Ma pour le stock de Dickson et un âge entre 107,9 ± 0,9 Ma et 109,0 ± 0,7 Ma pour les dykes proximaux des zones de Flex, Dickson, Brown-McDade et Weber. Cette datation est semblable à celle des roches volcaniques du Groupe du mont Nansen. La granodiorite dans laquelle est encaissé le gisement de Dickson donne par la méthode U-Pb sur titanite un âge de 191,5 ± 2,9 Ma; elle fait probablement partie du Batholite de Big Creek. Des études antérieures indiquaient deux périodes de minéralisation dans le chaînon Dawson : Crétacé moyen et Crétacé tardif. La datation indique que la minéralisation du mont Nansen est associée à la mise en place au Crétacé moyen d'intrusions felsiques de haut niveau.

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INTRODUCTION

The Mount Nansen area, in the eastern Dawson Range mineral belt of west-central Yukon (Fig. 1), hosts approximately 30 mineral occurrences within a 15-km-long, northwest-trending corridor known as the Mount Nansen trend (Fig. 2). Within this trend, mineralization consists of copper-molybdenum ± gold porphyries and epithermal gold-silver veins, with fewer skarns and breccias, as well as placer gold occurrences that together comprise the Mount Nansen district (Hart and Langdon, 1998). At the district's southeasterly end, five precious-metal-enriched veins comprise the Mount Nansen gold deposit: Brown-McDade, Webber, Heustis, Flex and Dickson (Fig. 2). Mineralization throughout the district has a spatial association with hypabyssal felsic porphyry stocks and dykes that intrude Paleozoic Yukon-Tanana Terrane metamorphic rocks and Mesozoic granitic rocks (Hart and Langdon, 1998). In particular, mineralized veins that comprise the Mount Nansen gold deposit are proximal to a central quartz-feldspar porphyry stock (informally termed the Dickson stock), and quartz-feldspar porphyry dykes occupy the same structures as the mineralized veins.

Most mineral deposits throughout the Dawson Range are generally considered to be associated with hydrothermal activity related to Late Cretaceous Carmacks Group magmatism (Smuk, 1999; Selby and Creaser, 2001). However, the presence of mid-Cretaceous volcanic rocks in eastern Dawson Range and Eocene magmatic rocks in western Dawson Range, indicates that other magmatic phases may be responsible for mineralization. In this study, the authors have dated five intrusive rocks in the Mount Nansen area using U-Pb methods in order to constrain aspects of the local geology and the possible age(s) of mineralization in the Mount Nansen veins.

LOCATION

The area is located ~160 km north of Whitehorse and ~42 km west of Carmacks, at latitude 62°05'N and longitude 137°08'W, on NTS map sheet 115I/13. The Mount Nansen mine is accessible via the 63-km Mount Nansen Road from Carmacks (Fig. 1). The Mount Nansen area is one of the oldest precious metal camps in the Yukon, with the discovery of placer gold on Nansen Creek in 1899, and the staking of the first lode claims in the area in 1910. The district has had a long and episodic history of exploration and mining, with most efforts focussed on the Brown-McDade, Heustis and Webber gold-silver veins, and the Cyprus copper-molybdenum porphyry.

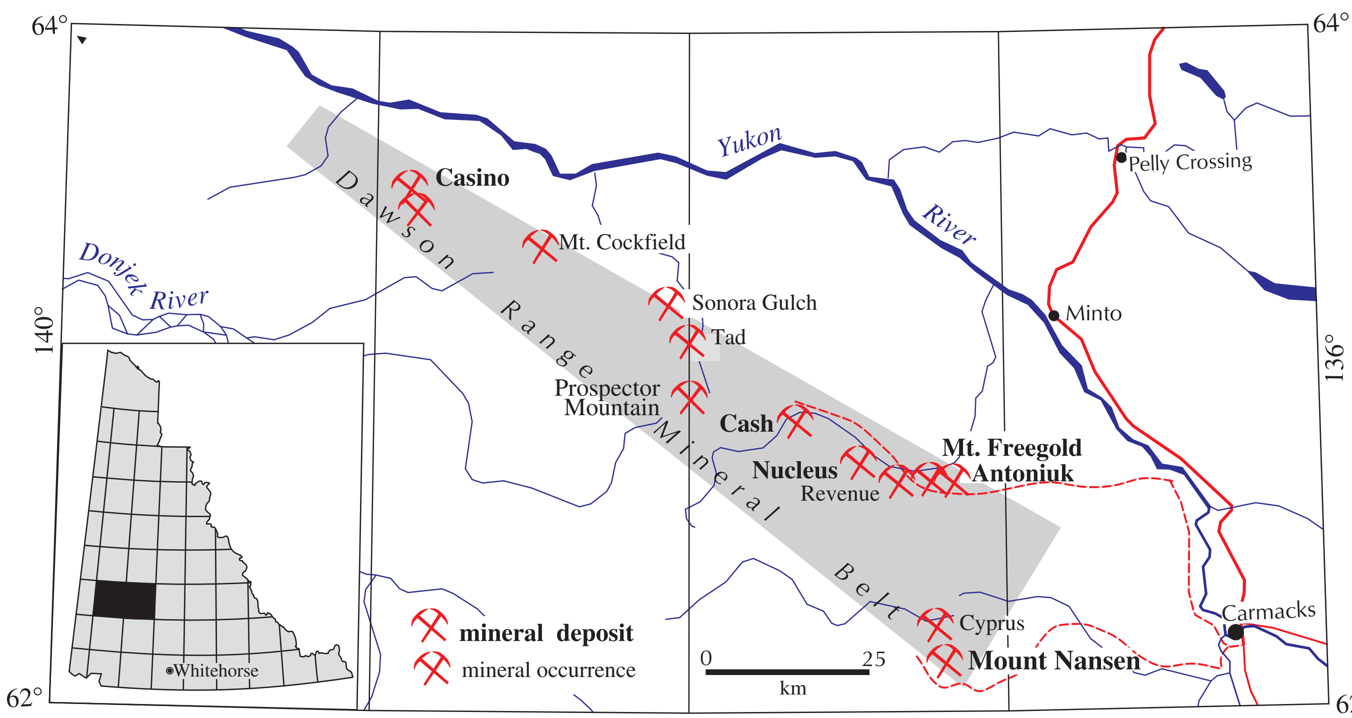


Figure 1. *Regional setting of the Mount Nansen district within Dawson Range mineral belt.*

HISTORY

Prior to recent mining operations (from November, 1996 to March, 1999), a combined resource of approximately 1 million tonnes of 7.4 g/t Au and 148 g/t Ag was calculated for these deposits (BYG Press Release, 1995), and included both open pit and underground resources. Approximately 450 000 tonnes was considered oxide ore. Approximately 140 000 tonnes of oxide ore from the Brown-McDade open pit and Webber and Brown-McDade stockpiles were processed in the late 1990s and yielded approximately 34,000 oz Au (1.1 million g) and 131,000 oz Ag (4.1 million g; Stroshein, 1999). Considerable placer mining activity also occurs in the region (LeBarge, 1995).

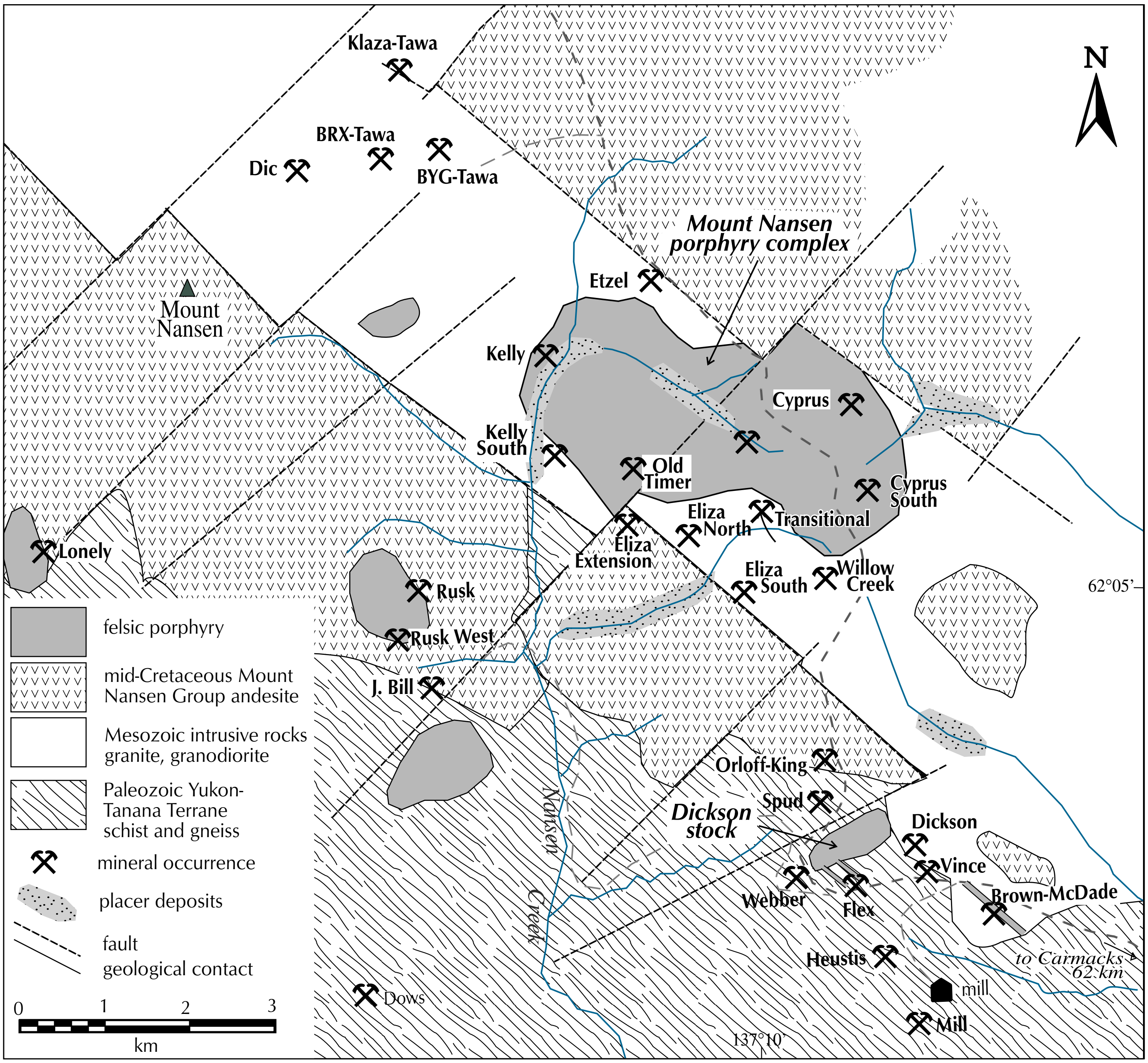


Figure 2. *Generalized geology of the Mount Nansen district. The undivided granitic rocks include coarse-grained representatives of the Early Jurassic Big Creek and Granite Mountain batholiths, and the medium-grained Dawson Range Batholith. Modified from Hart and Langdon (1998).*

REGIONAL GEOLOGY

The regional geology of the Mount Nansen area has been described by Cairnes (1916), Bostock (1934, 1936) and Tempelman-Kluit (1984). Cairnes (1916) carried out reconnaissance geological mapping and first defined a 12 x 15 km area that he called the Nansen district. The most recent study of the area's regional geology (Carlson, 1987) describes the Nansen camp in detail. Studies focussing on the mineralization of the area include Lamb (1947), Saager and Bianconi (1971), Dickinson (1972), and Sawyer and Dickinson (1976). More recently Hart and Langdon (1998) provided an overview of the district, Anderson and Stroshein (1998) described the mineralization of the Flex zone, and Stroshein (1999) summarized the mineralization of the Brown-McDade deposit.

The eastern Dawson Range lies beyond the limits of the McConnell and Reid glaciations: valley bottoms in the area are deeply buried by alluvium related to at least two earlier pre-Reid glaciations, but the upland surfaces are not affected (Bostock, 1966; Laberge, 1995). Discontinuous permafrost is present in the area, and surface weathering extends to depths of up to 75 m below ground surface. Mineralized zones are commonly at least partially oxidized, as sulphide minerals are replaced by limonite and other secondary minerals. Bedrock exposure is extremely limited in the study area (<2%) — hence much of the regional geological mapping is based on felsenmeer rather than outcrop. The most resistant rock units, including the Mount Nansen Group volcanic rocks and coeval felsic stocks and dykes, typically form substantial outcrops (Carlson, 1987). Bulldozer trenching, and stripping of some of the mineralized zones provide much-improved local exposure.

GEOLOGY OF THE MOUNT NANSEN AREA

Most of the Dawson Range is within the Yukon-Tanana Terrane, which is composed of Devonian and older meta-igneous and metasedimentary rocks (Templeman-Kluit, 1984; Carlson, 1987). In the Mount Nansen area, the metamorphic rocks are dominated by chlorite schist and felsic orthogneiss, with lesser, quartz-rich metasedimentary rocks and amphibolite. Foliation within the metamorphic rocks typically strikes northeasterly and dips steeply northwest. The metamorphic rocks are intruded by several plutonic suites. The Early Jurassic suite includes Big Creek Batholith, which is notable for its coarse grain-size, megacrystic alkali feldspars, and its variable, but generally quartz-poor, compositions such as quartz syenite. Quartz-rich, alkali feldspar megacrystic plutonic rocks, such as granite, that outcrop in the area are also considered to be Early Jurassic, but are more similar to the Granite Mountain Batholith. The Jurassic plutonic rocks are only locally, weakly foliated. Medium-grained, biotite-hornblende granodiorite of the mid-Cretaceous Dawson Range Batholith is also present in the area.

A thick succession of dominantly andesitic flows, tuffs and breccias form the mid-Cretaceous Mount Nansen Group volcanic rocks (Fig. 2; Templeman-Kluit, 1984; Carlson, 1987). They are resistant to weathering and form most of the higher peaks in the vicinity. These volcanic rocks are interpreted to represent the erosional remnants of caldera complexes (Hart and Langdon, 1998). Associated quartz-feldspar-phyric stocks, plugs, dykes and sills typically consist of 1- to 3-mm-diameter altered feldspar and/or quartz phenocrysts in an aphanitic to fine-grained, buff-weathering, felsic groundmass. Dykes range from 10 cm to 12 m in width, averaging about 1.5 m, and cut all other rock units in the immediate Mount Nansen mine area. These hypabyssal felsic porphyry dykes are considered to be the intrusive equivalents of the Mount Nansen Group volcanic rocks. These high-level felsic intrusions are significant because they host, or are proximal to, both the porphyry copper mineralization and precious metal veins.

The main geological feature in the Mount Nansen mine area is a quartz-feldspar rhyolite porphyry stock informally named the Dickson stock. It is the second largest of at least six distinct bodies of felsic porphyry, and is located adjacent to or near a fault with a strike length of about 7 km (Fig. 2). Emanating from the Dickson stock are several quartz-feldspar porphyry dykes that intrude both the metamorphic rocks and the hornblende-biotite granodiorite of the Big Creek plutonic suite in the northeast part of the study area (Fig. 3).

The Late Cretaceous (~78-65 Ma) Carmacks Group volcanic rocks are mostly north and east of the Mount Nansen area (Templeman-Kluit, 1984, Carlson, 1987). They consist of flat-lying basaltic, and lesser andesitic flows, felsic pyroclastic rocks and associated felsic domes and plugs, as well as basaltic dykes.

Hart and Langdon (1998) examined the structural history of the Mount Nansen area and emphasized three main structural orientations. The Mount Nansen trend is a 2 x 15 km northwest-trending corridor controlled by bounding faults that form an uplifted block of basement rocks within the Mount Nansen volcanic rocks. These and other parallel faults define the regional structural trend at 130° to 150°. These faults bound wide (20-500 m) zones that host porphyry dykes and mineralized quartz veins. Both normal and right-lateral displacements are observed on these structures. Slickensides on veins and dykes suggest that mineralization occurred after normal movement on the faults, but before the strike-slip movement. A secondary structural trend averaging 020° is typified by locally developed joint sets, but there is a general absence of associated shearing. These structures are thought to be second-order oblique extension fractures related to the northwest-trending strike-slip movement. The second-order structures host narrow mineralized quartz veins and porphyry dykes. The third structural trend recognized in the Mount Nansen area comprises faults, fractures and joints that trend between 050° and 080°. These faults are recognizable on air photographs and geophysical magnetic surveys, and have also been observed in trenches in some areas. Most notably, they occur in the Flex zone where they have dominantly sinistral offsets (Anderson and Stroshein, 1998)

MINERALIZATION IN THE MOUNT NANSEN DISTRICT

The most significant porphyry-style deposit in the Mount Nansen area is the Cyprus porphyry. It consists of a low-grade copper-molybdenum occurrence with local supergene gold enrichments (Sawyer and Dickinson, 1976). Gold-silver veins and breccias occur throughout the Mount Nansen trend and are particularly evident adjacent, and peripheral, to the region's numerous quartz-feldspar porphyry bodies and dykes (Dickenson, 1972; Hart and Langdon, 1998).

The Mount Nansen deposits consist of five main mineralized zones within a 1 km radius — the Brown-McDade, Weber, Heustis, Flex and Dickson. Mineralization within the zones consists mainly of brittle fault- and shear-hosted sulphide-mineral-rich quartz veins with associated bleached clay-rich alteration zones that range from a few centimetres to up to 5 m wide. The vein systems range from narrow, relatively simple veins (e.g., Heustis) to complex anastomosing systems (e.g., Brown-McDade). In zones such as the Flex (Anderson and Stroshein, 1998), narrow precious metal-bearing sulphide mineral-rich veins occur along anastomosing, steeply dipping, northwest-trending faults and are best developed within metamorphic wall rocks, although they occur in all rock types.

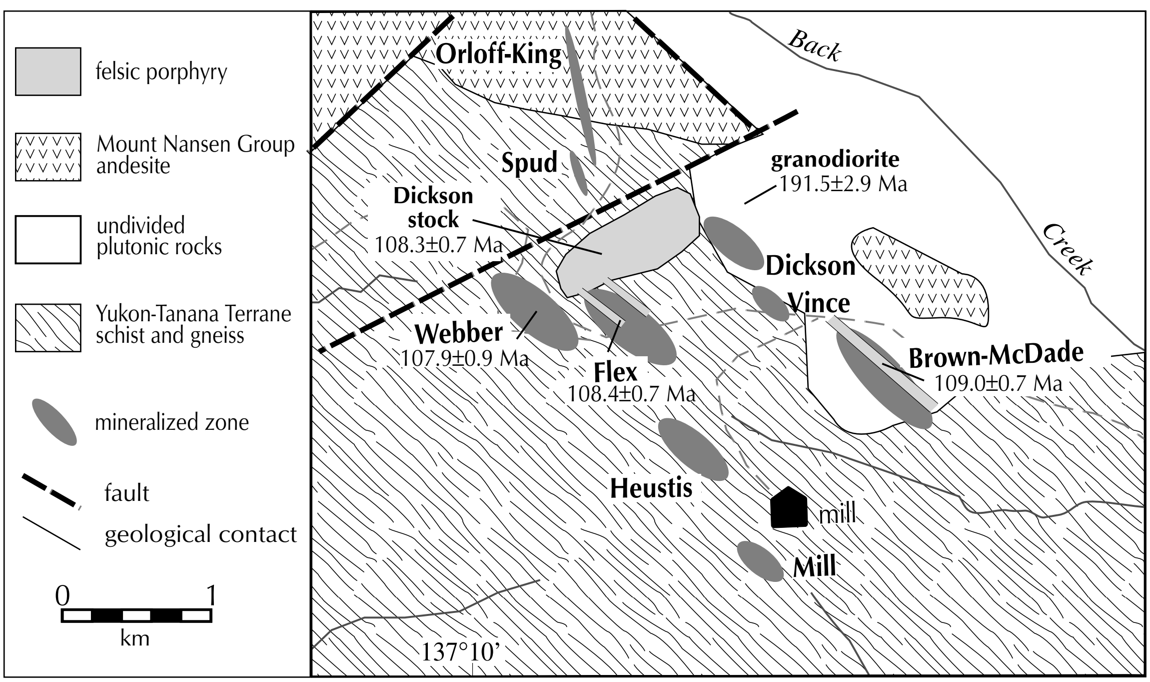


Figure 3. *Detailed geology of the Mount Nansen deposits and locations of age dates reported in the text.*

Complex vein and breccia zones such as the Brown-McDade (Stroshein, 1999) share many characteristics with the narrow veins, but mineralization and alteration is more widely distributed. There is also a stronger spatial association with feldspar porphyry dykes that are hosted in the faults. These zones are considerably wider due to an abundance of either parallel, or intersecting structures that generate highly fractured and altered zones; they are up to 50 m wide and largely developed within the quartz-feldspar porphyry. Some mineralized veins locally change character into a brecciated zone, and then into a porphyry dyke, either along strike or down-dip. Webber zone veins also occur within felsic dykes.

Quartz in veins throughout the area is typically finely crystalline to chalcedonic, and dark grey to bluish due to sparsely disseminated, fine-grained sulphide minerals. Sulphide minerals include abundant pyrite and arsenopyrite with lesser galena, sphalerite, stibnite, andorite (Pb-Ag sulphantimonide) and chalcopyrite (mineralogy from unpublished company reports, BYG Natural Resources Inc.). Supergene minerals in addition to limonite and geothite include scorodite and cerussite; plumbojarosite, stibiconite and cervantite have also been reported. Precious metal values (>3.5 g/t Au and >35 g/t Ag) are confined to quartz-sulphide mineral-rich zones, and values drop off rapidly to less than 0.7 g/t Au and 17 g/t Ag in the surrounding altered wallrock. Wallrocks adjacent to the veins are typically bleached with intense phyllic and kaolinitic alteration envelopes.

GEOCHRONOLOGY

U-Pb dating of zircon and titanite was carried out to establish the crystallization ages of the Dickson stock and three related porphyry dykes. The dykes are spatially associated with vein mineralization in that they occupy the same fault structures and are locally cut by mineralized veins. The felsic dykes were nowhere

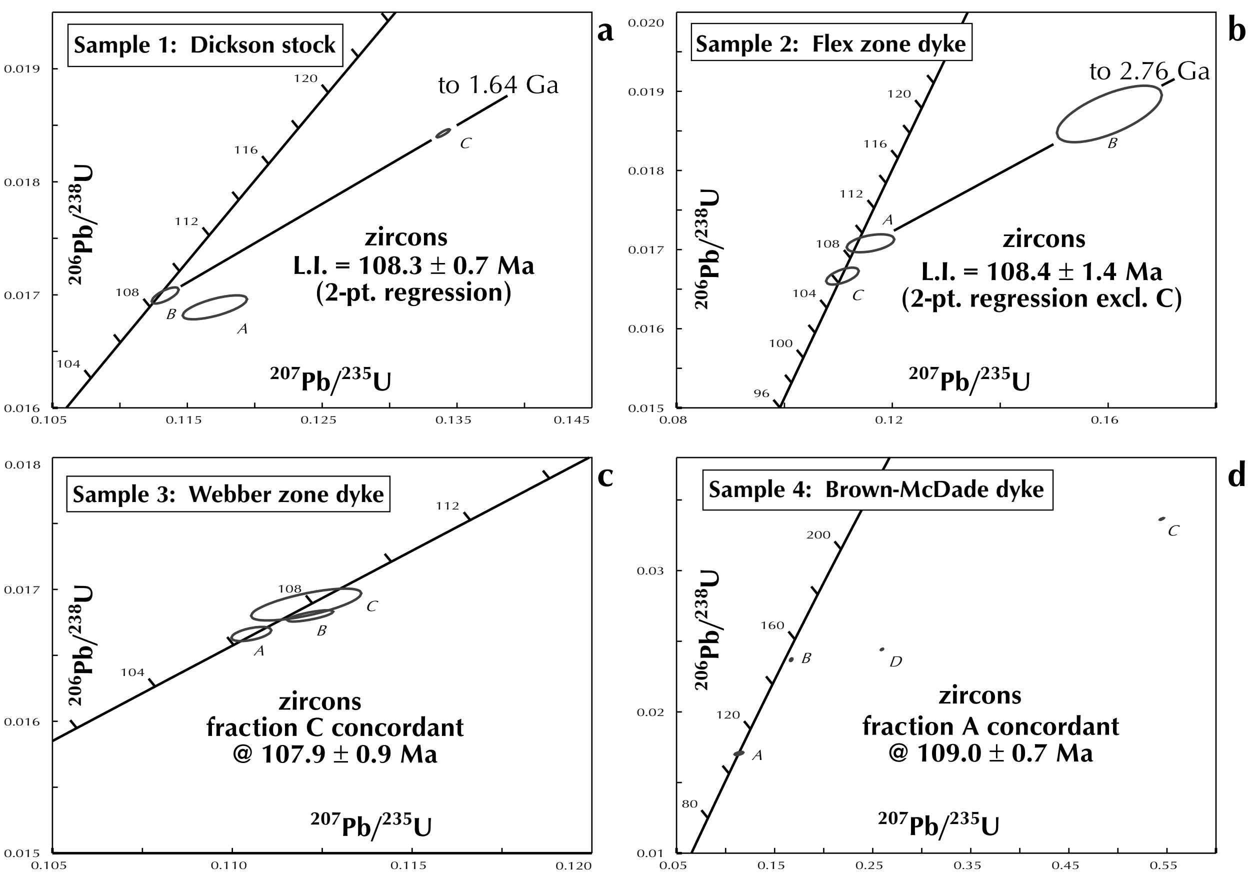
Table 1. *U-Pb analytical data.*

Sample description[1]	Wt (mg)	U content (ppm)	Pb[2] content (ppm)	$^{206}Pb/^{204}Pb$ (meas.)[3]	total common Pb (pg)	% ^{208}Pb[2]	$^{206}Pb/^{238}U$[4] (± % 1σ)	$^{207}Pb/^{235}U$[4] (± % 1σ)	$^{207}Pb/^{206}Pb$[4] (± % 1σ)	$^{206}Pb/^{238}U$ age (Ma; ± % 2σ)	$^{207}Pb/^{206}Pb$ age (Ma; ± % 2σ)
Sample 1 (97VIK-47: Dickson stock)											
A: N2,+105,a	0.061	164	3.0	205	57	17.4	0.01689(0.31)	0.1170(1.02)	0.05026(0.84)	108.0(0.7)	207.0(39.0)
B: N2,+105,a	0.055	151	2.9	899	10	20.2	0.01699(0.21)	0.1134(0.44)	0.04838(0.33)	108.6(0.5)	117.8(15.4)
C: N2,+105,a	0.099	322	7.0	2958	13	22.9	0.01843(0.10)	0.1340(0.18)	0.05272(0.11)	117.7(0.2)	316.9(5.0)
Sample 2 (97VIK-33: Flex zone porphyry)											
A: N2,+105,a	0.067	176	3.7	416	31	25.9	0.01708(0.33)	0.1160(1.91)	0.04924(1.78)	109.2(0.7)	159.1(83.2)
B: N2,+105,a	0.055	193	4.4	56	329	53.3	0.01872(0.95)	0.1602(3.04)	0.06210(2.50)	119.5(2.3)	677.4(107.0)
C: N2,+105,a	0.047	94	2.3	220	23	37.9	0.01667(0.32)	0.1108(1.37)	0.04820(1.21)	106.5(0.7)	109.1(57.0)
Sample 3 (97VIK-41: Webber zone porphyry)											
A: N2,+105,a	0.068	153	2.8	2608	4	18.0	0.01666(0.16)	0.1105(0.25)	0.04811(0.22)	106.5(0.3)	104.8(10.2)
B: N2,+105,a	0.056	209	4.5	1086	12	29.0	0.01680(0.13)	0.1122(0.28)	0.04843(0.21)	107.4(0.3)	120.1(9.7)
C: N2,+105,a	0.023	174	3.9	975	4	31.6	0.01688(0.36)	0.1120(0.66)	0.04809(0.47)	107.9(0.8)	103.8(22.1)
Sample 4 (97VIK-50: Brown-McDade zone porphyry)											
A: N2,+134,a	0.035	33	0.6	117	12	16.4	0.01706(0.33)	0.1136(1.94)	0.04830(1.76)	109.0(0.7)	114.0(83.5)
B: N2,+134,a	0.052	154	3.8	1353	9	14.2	0.02370(0.18)	0.1669(0.38)	0.05108(0.31)	151.0(0.5)	244.3(14.4)
C: N2,+134,a	0.070	176	7.8	1546	17	27.0	0.03366(0.09)	0.5447(0.18)	0.11738(0.11)	213.4(0.4)	1916.7(3.8)
D: N2,+134,a	0.087	192	6.3	1172	22	30.4	0.02442(0.09)	0.2595(0.22)	0.07705(0.15)	155.5(0.3)	1122.5(5.9)
Sample 5 (97VIK-48: biotite-hornblende granodiorite)											
A: N2,+105,a	0.091	358	11.5	14960	4	9.8	0.03201(0.09)	0.2223(0.16)	0.05036(0.08)	203.1(0.4)	211.6(3.8)
B: N2,+105,a	0.072	264	8.6	10640	4	10.4	0.03239(0.25)	0.2248(0.27)	0.05034(0.16)	205.5(1.0)	210.8(7.3)
C: N2,+105,a	0.046	220	7.7	15090	1	10.7	0.03447(0.11)	0.2427(0.17)	0.05106(0.10)	218.5(0.5)	243.7(4.4)
T1: titanite,u	1.36	111	4.5	94	3750	32.3	0.03014(0.72)	0.2071(2.55)	0.04984(2.12)	191.4(2.7)	187.4(98.8)
T2: titanite,u	0.78	118	4.7	102	2090	30.4	0.03023(0.65)	0.2103(1.24)	0.05045(1.85)	192.0(2.4)	215.9(85.7)

[1] *N2=non-magnetic 2 degrees side slope on Frantz isodynamic magnetic separator; grain size given in microns; a = abraded; u = unabraded.*
[2] *radiogenic Pb; corrected for blank, initial common Pb, and spike*
[3] *corrected for spike and fractionation*
[4] *corrected for blank Pb and U, and common Pb*

observed cutting mineralized veins. A sample of granodiorite that hosts mineralization in the Dickson zone was also dated. Zircons were recovered from 10-15 kg samples of the Dickson stock and porphyritic dykes from the Flex, Webber and Brown-McDade zones. The zircons are very similar in appearance, comprising clear, equant to stubby prismatic, euhedral grains with rare to abundant colourless bubble-, rod- and tube-shaped inclusions. All zircon fractions were subjected to strong air abrasion prior to dissolution in order to minimize the effects of post-crystallization Pb-loss. Analytical work was done in the UBC Geochronology Laboratory, using techniques as described by Mortensen et al. (1995). Analytical data are reported in Table 1 and are plotted on conventional U-Pb concordia plots in Figure 4. Relatively high contents of common Pb were measured in many of the zircon fractions; this likely results from common Pb contained within the abundant inclusions.

Three fractions of the coarsest, least magnetic zircon recovered from the Dickson stock sample (Sample 1) were analysed. Fraction B is nearly concordant at 108.3 ± 0.7 Ma (Fig. 4a), which is the best estimate for the



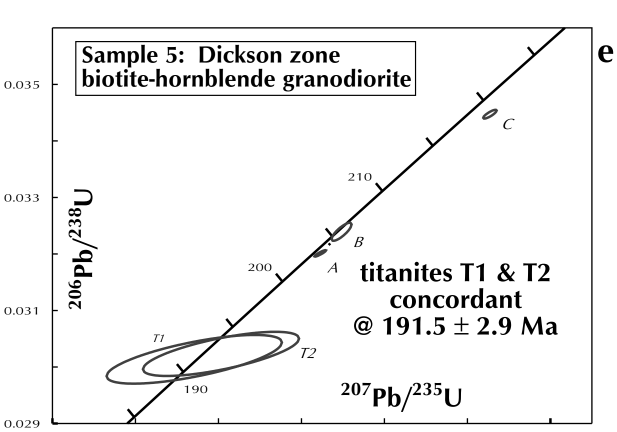


Figure 4. *Concordia plots of age dates reported for rocks from the Mount Nansen deposits:* ***(a)*** *Dickson stock,* ***(b)*** *Flex zone dyke,* ***(c)*** *Webber zone dyke,* ***(d)*** *Brown-McDade dyke,* ***(e)*** *Dickson zone biotite-hornblende granodiorite. L.I. – lower intercept.*

crystallization age of the sample. The other two fractions yield considerably older $^{207}Pb/^{206}Pb$ ages, suggesting the presence of an older, inherited zircon component. A regression through fractions B and C gives a calculated upper intercept age of 1.64 Ga, which is interpreted as an average age for the inherited zircon component. Fraction A falls below this line, suggesting that this analysis reflects Pb-loss effects that were not completely removed by the strong abrasion.

A sample was collected from a quartz-feldspar porphyry dyke from a freshly stripped area at the south end of the Flex zone (Sample 2). This phase is within the same structure and adjacent to well mineralized veins and was interpreted to be a mineralizing dyke related to the Dickson stock. Three strongly abraded zircon fractions were analysed (Fig. 4b). A two-point regression through fractions A and B gives a lower intercept of 108.4 ± 1.4 Ma, which is interpreted as the crystallization age of the sample. The upper intercept is 2.76 Ga, which indicates the presence of a Late Archean inherited zircon component in this sample. Fraction C is concordant but gives a slightly younger $^{206}Pb/^{238}U$ age of 106.5 Ma. Zircons in this fraction were finer than in fractions A and B, and it is thought that the younger age reflects minor post-crystallization Pb-loss.

Three zircon fractions from a quartz-feldspar porphyry dyke sample from a trench cutting the Webber zone (Sample 3) all yield concordant or nearly concordant analyses between 106 and 108 Ma (Fig. 4c). Fraction C yields the oldest $^{206}Pb/^{238}U$ age of 107.9 ± 0.9 Ma, which is interpreted as the crystallization age of the sample.

A quartz-feldspar porphyry dyke that is crosscut by mineralization in the Brown-McDade zone was sampled from drill core (Sample 4). Four zircon fractions were analysed (Fig. 4d). Fraction A is concordant with a $^{206}Pb/^{238}U$ age of 109.0 ± 0.7 Ma, which gives the crystallization age of the sample. The other three fractions are all discordant, with considerably older $^{207}Pb/^{206}Pb$ ages; however the data do not define a linear array. This scatter is interpreted to reflect the presence of older, inherited zircon components of more than one age, possibly compounded by post-crystallization Pb-loss effects that were not completely removed by abrasion.

Medium-grained, equigranular, biotite-hornblende granodiorite was sampled in freshly stripped exposures in the Dickson Zone northeast of the Dickson stock (Sample 5). Zircons from the sample form clear, stubby to elongate, euhedral prisms with no visible zoning or cores. Three fractions of the best quality, inclusion-free grains were analysed following strong abrasion. The analyses are all slightly discordant, falling below concordia between ~203 and 220 Ma (Fig. 4e). Two unabraded fractions of coarse, high-quality titanite from the sample were also analysed, and yielded overlapping concordant analyses with a total range of $^{206}Pb/^{238}U$ ages of 191.5 ± 2.9 Ma. The titanite ages are interpreted to give the crystallization age of the sample, whereas the slightly older zircon analyses appear to indicate the presence of a component of slightly older inherited zircon.

DISCUSSION AND CONCLUSIONS

Field relationships and age-dating results from deposits in Mount Nansen mine area indicate that the main magmatic event associated with mineralization, specifically the emplacement of the Dickson stock and intrusion of related porphyry dykes, occurred at ~ 108 ± 1 Ma. These dates suggest that mineralization and associated hydrothermal activity may have also occurred at this time. Previous age determinations for samples related to mineralization in the Mount Nansen mine area have given conflicting results. Hydrothermal adularia from the Huestis zone yielded a K-Ar age of 122.9 ± 1.9 Ma (Hunt and Roddick, 1987). This is an unexpected age and likely results from excess Ar contained with the adularia. A whole rock Ar-Ar date from an altered rhyolite dyke in the Brown-McDade zone yielded a date of 77 ± 1 Ma (M.E. Villeneuve, pers. comm., 1997). The significance of this single date is uncertain, but may be interpreted to result from partial resetting due to thermal or hydrothermal overprinting associated with Carmacks Group magmatism at ~ 70 Ma. Such resetting is widespread in the central Yukon (Hart, 1995). Further afield within the Mount Nansen trend, molybdenite associated with potassic alteration in the Cyprus porphyry deposit yielded a Re-Os date of 71.1 ± 0.3 Ma (Selby and Creaser, 2001) that is similar to a K-Ar biotite age of 70.5 ± 2.2 Ma (Stevens et al., 1982) for quartz-feldspar porphyry from the Rusk showing. Similarly, three whole rock K-Ar analyses on feldspar-porphyry bodies yielded dates between 70 and 61 Ma (Hunt and Roddick, 1991). Unlike the Ar-Ar and K-Ar dates, which may be reset, the Re-Os date is unlikely to have been reset and therefore indicates that mineralization in the Cyprus porphyry complex is Late Cretaceous.

These data indicate that hypabyssal intrusions and associated mineralization within the Mount Nansen area are likely of two generations — Late Cretaceous (Cyprus intrusion) and mid-Cretaceous (Dickson stocks and dykes). The aforementioned and other geochronological and metallogenic studies (i.e., Carlson, 1987; Smuk et al., 1997; Smuk, 1999) emphasized a single, Late Cretaceous mineralizing event for the Dawson Range that was associated with Carmacks Group volcanism. Although the Late Cretaceous magmatic-hydrothermal event is responsible for the bulk of Dawson Range mineralization (i.e., Casino, Cash), it also is likely that it may have disturbed or reset Ar isotopic systematics in older rocks throughout the district such that the Late Cretaceous mineralizing event may be over-represented.

New U-Pb zircon and titanite age data reported here help constrain the nature and timing of magmatism in the Mount Nansen area. The data show that high-level felsic intrusions that are spatially and possibly genetically associated with base and precious metal-rich veins in the area are part of the mid-Cretacous Dawson Range Batholith. These results provide additional evidence for a mineralizing event in the eastern Dawson Range that is considerably older than the Late Cretaceous mineralization age indicated by previous studies. This reinforces the regional prospectivity of the hypabyssal phases of the mid-Cretaceous intrusions within the Dawson Range mineral belt. The Early Jurassic U-Pb titanite age reported here for the biotite-hornblende granodiorite body in the northeast portion of the study area supports a correlation of this body with either the Big Creek or Granite Mountain batholith.

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Nature and origin of copper-gold mineralization at the Minto and Williams Creek deposits, west-central Yukon: Preliminary investigations

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ABSTRACT

A new research project was begun in 2002, aimed at better understanding the nature and origin of copper-gold mineralization and its main host rocks at the Minto and Williams Creek (Carmacks Copper) deposits in west-central Yukon. This will also help to further constrain exploration models both on a property and a regional scale. Field work in 2002 confirmed that the main host rocks for both deposits are variably deformed plutonic rocks (diorite and quartz diorite at Williams Creek and mainly granodiorite at Minto). Mineralization formed prior to the ductile deformation that has affected these units. Mineralized granodioritic gneiss from Minto and apparently post-mineralization quartz diorite at Williams Creek yield U-Pb ages of ~194 Ma and ~191 Ma, respectively; thus the mineralization appears to have formed at essentially the same time as the host intrusions. Reconnaissance Pb- and S-isotope analyses of sulphide minerals from both deposits also indicate a likely magmatic source for the mineralization.

RÉSUMÉ

Un nouveau projet de recherche entrepris en 2002 visait à mieux comprendre la nature et l'origine de la minéralisation de Cu-Au et des principales roches encaissantes aux gisements de Minto et de Williams Creek (Carmacks Copper) dans le centre-ouest du Yukon. Il permettra d'affiner les modèles d'exploration tant à l'échelle d'une propriété qu'à l'échelle régionale. Les travaux exécutés sur le terrain en 2002 confirment que les principales roches encaissantes des deux gisements sont des roches plutoniques inégalement déformées (diorite et diorite quartzique au gisement de Williams Creek et surtout granodiorite au gisement de Minto). La minéralisation est antérieure à la déformation ductile de ces unités. Le gneiss granodioritique minéralisé de Minto et la diorite quartzique apparemment postérieure à la minéralisation des gisements de Williams Creek donnent par la méthode U-Pb des âges respectifs de ~194 Ma et de ~191 Ma; la minéralisation semble donc synchrone des intrusions encaissantes. Des analyses de reconnaissance des isotopes Pb et S dans les sulfures des deux gisements indiquent également une minéralisation d'origine probablement magmatique.

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INTRODUCTION

The Minto deposit in west-central Yukon (Yukon MINFILE 2002, 115I 021 and 022), located 240 km northwest of Whitehorse and owned by Minto Exploration Ltd., was discovered in 1971 and contains approximately 9 million tonnes with an average grade of 1.73% Cu, 0.48 g/t Au and 7.5 g/t Ag. The Williams Creek (Carmacks Copper) deposit (Yukon MINFILE 2002, 115I 008), located approximately 50 km to the southeast of the Minto deposit and owned by Western Copper Holdings Ltd., contains published reserves of approximately 15.5 million tonnes at 1.01% Cu. The Minto and Williams Creek deposits lie within a northwest-trending belt that includes numerous other copper (± gold) occurrences, some of which have been drilled (e.g., the Stu occurrence; Yukon MINFILE 2002, 115I 011). The Minto-Williams Creek area is unglaciated and has subdued topography, hence exposure is generally poor, and underlying rock units have been affected by deep surface weathering and oxidation by meteoric waters. Resolving original lithological contact relations in the vicinity of the deposits themselves depends largely on examination of drill core. The geology outside of the immediate deposit areas is poorly understood.

Although both the Minto and Williams Creek deposits are now at a pre-production stage of development, there is still no consensus regarding the nature or origin of mineralization in the deposits. Previous workers have assigned them to various different deposit types, including metamorphosed volcanogenic massive sulphide deposits, metamorphosed redbed Cu deposits and deformed Cu-Au porphyries (e.g., Pearson, 1977; Sinclair, 1977; Pearson and Clark, 1979). Any future exploration for similar Cu-Au mineralization in the region is greatly hampered by the lack of a descriptive model for the deposits, which is a basic requirement for developing genetic or exploration models for this style of mineralization.

The purpose of the current project is to gain a better understanding of the nature, age and origin of the main host rock units and copper-gold mineralization at the Minto and Williams Creek deposits. This information can then be used as a basis for developing an exploration model for similar mineralization elsewhere in the region. In this paper, the authors present some of the initial results of the study and describe the work that is presently underway and planned for the 2003 field season.

PREVIOUS WORK

Sinclair (1977) carried out six weeks of geological mapping in the vicinity of the Minto deposit and its surroundings, as well as reconnaissance level geochemical studies of intrusive rocks in the area. Pearson (1977; see also Pearson and Clark, 1979) completed a Master of Science thesis focused on the Minto deposit, which included petrographic, mineralogical and geochemical studies, as well as a limited amount of sulphur isotope work on the sulphide minerals. A 1:250 000-scale geological map of the Carmacks map sheet was published by Tempelman-Kluit (1984). In addition, the geology of the Minto and Williams Creek deposits is described in numerous unpublished mineral assessment reports prepared by various company geologists. A low-level magnetic and gamma ray survey was flown over the entire Minto-Williams Creek area by the Geological Survey of Canada and the Yukon Geology Program in 2001 (Shives et al., 2002). No geological interpretation of this new geophysical data set has yet been prepared.

REGIONAL SETTING

The Minto-Williams Creek area is underlain by three main lithological assemblages. Intermediate to felsic intrusive and meta-intrusive rocks of the early Mesozoic Granite Mountain Batholith underlie much of the area and are interpreted to be intrusive into the Yukon-Tanana Terrane (Fig. 1; Gordey and Makepeace, 1999). The batholithic rocks are in fault and/or intrusive relation with an unnamed package of altered mafic volcanic rocks to the northeast, and are unconformably overlain by sedimentary rocks and volcanic flows of the Late Cretaceous Tantalus Formation and Late Cretaceous Carmacks Group, respectively. Mineralization at Minto and Williams Creek is hosted by intrusive rocks assigned to the Granite Mountain Batholith, and/or deformed and metamorphosed rafts and pendants contained within the batholith. Regional structure is poorly understood because outcrop is very sparse (<1%) and the area is unglaciated and deeply weathered. In addition, there is a lack of detailed geological mapping in this area. However some significant steep faults have been recognized in the area (e.g., the DEF fault at Minto; see later discussion).

INITIAL RESULTS

Initial investigations of the Minto and Williams Creek deposits were carried out between July 30 and August 12, 2002. The following were examined and sampled: surface exposures of the Minto Main Zone; host rocks for the mineralization exposed in new cuts in the vicinity of the camp and along the access road at Minto; and core from several Minto and Williams Creek drill holes. This work included examining contact relationships, and sampling various rock units for petrographic, geochemical and geochronological studies. In addition, magnetic susceptibility measurements were taken on representative samples of the main lithological units to help constrain interpretations of ground and airborne magnetic surveys.

Preparation of standard and polished thin sections for petrographic study is underway, and a representative suite of deformed and undeformed intrusive rocks at both deposits has been submitted for whole rock geochemical analysis. In addition, slabs of almost all samples were cut and stained for K-feldspar in order to characterize the different rock types in the area and begin preparation of a digital 'atlas' of igneous rock textures and compositions in the Minto and Williams Creek areas. Samples are also being prepared for U-Pb and Ar-Ar dating studies of the main host rock units and various alteration assemblages, and common Pb analysis of sulphide minerals and host rocks. Results of work thus far are summarized in the following sections.

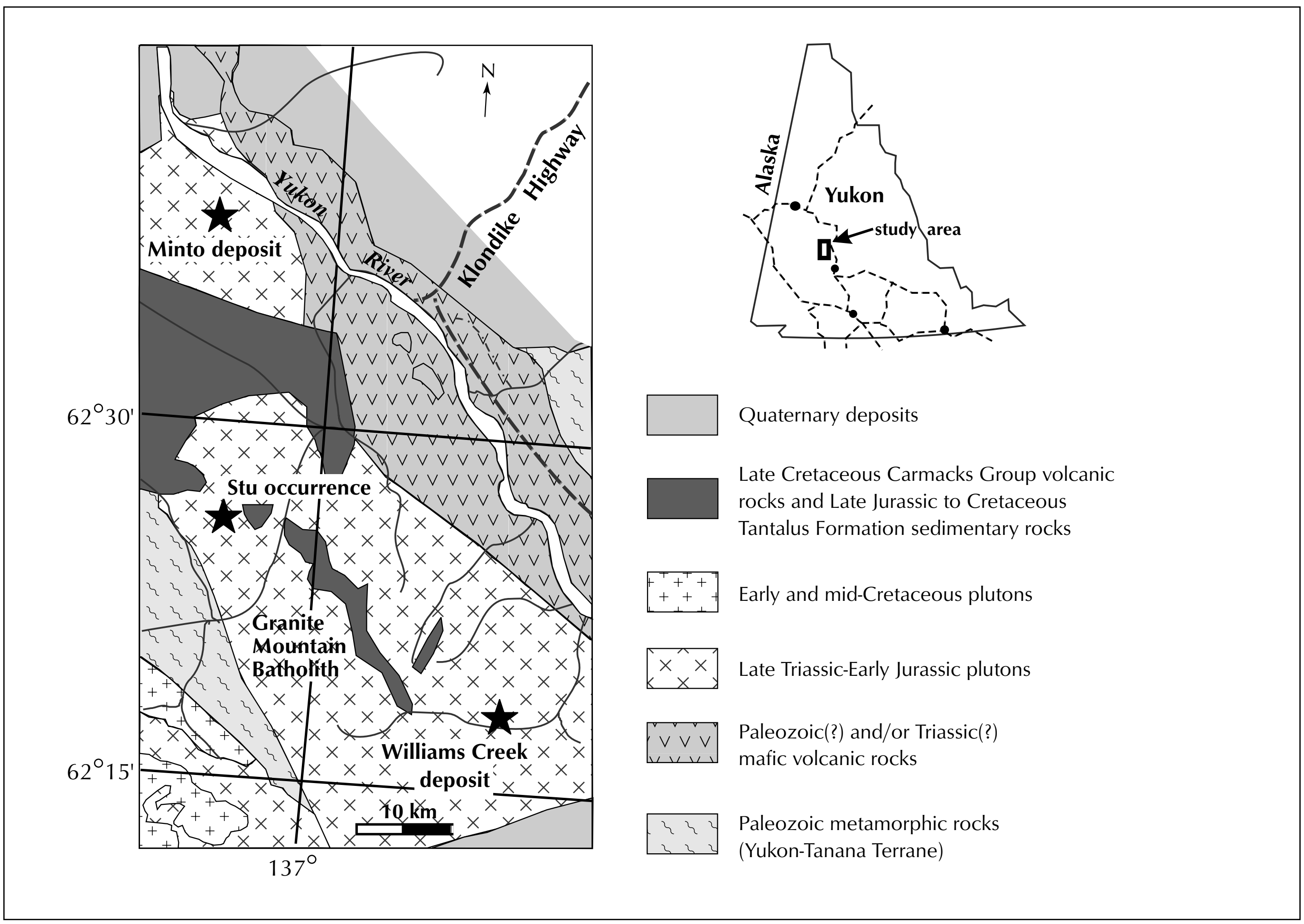

Figure 1. *Map showing the location and regional geological setting of the Minto and Williams Creek deposits and the Stu occurrence (Yukon MINFILE 2001, 115I 011; simplified from Gordey and Makepeace, 1999).*

LITHOLOGICAL ASSEMBLAGES IN THE MINTO-WILLIAMS CREEK AREA

A preliminary lithological breakdown of the main rock units was done based on field observations and modal analysis. Sample modes were calculated using digital image analysis methods on stained slabs, as described by Duncan (1999). Calculated modes for a range of intrusive and meta-intrusive rock units from Minto and Williams Creek are shown on an IUGS ternary diagram in Figure 2.

INTRUSIVE ROCKS

Ten distinct intrusive phases have been identified in the Minto and Williams Creek area based on preliminary work:

1. Fine-grained granitic orthogneiss (at Williams Creek only; possibly Paleozoic in age).
2. Massive K-feldspar-phyric granodiorite of the Granite Mountain Batholith.
3. Massive to moderately foliated porphyritic diorite/quartz diorite of the Granite Mountain Batholith.

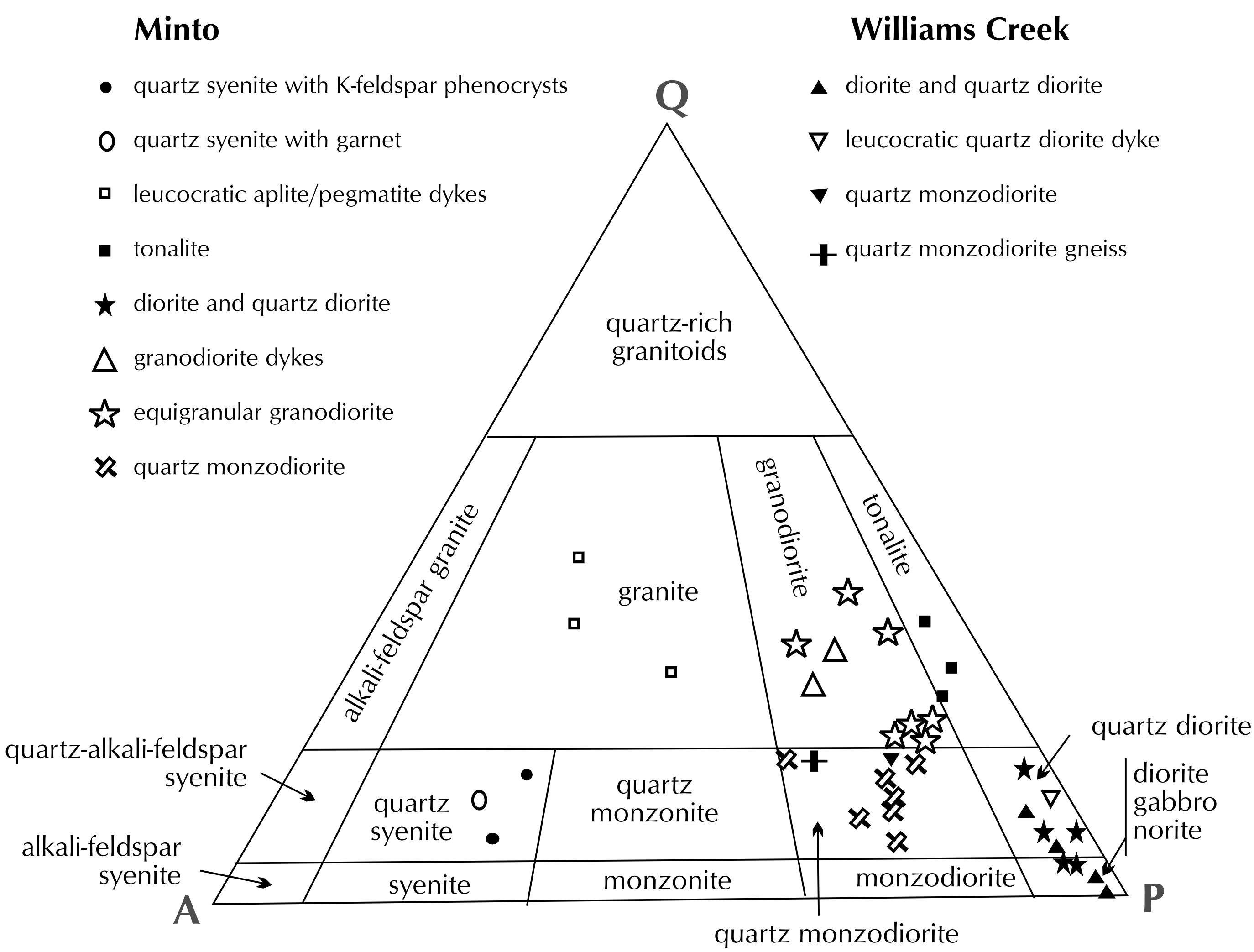

Figure 2. Calculated modes of quartz-alkali feldspar-plagioclase (QAP) for a range of representative intrusive and meta-intrusive rock units from the Minto and Williams Creek area.

4. Massive quartz-phyric granodiorite of the Granite Mountain Batholith.
5. Biotite-rich gneiss and quartzofeldspathic gneiss (main ore hosts at Minto).
6. Massive to moderately foliated diorite and quartz diorite (main ore host at Williams Creek).
7. Pink granitic pegmatite/aplite dykes.
8. Foliated, fine-grained, grey, biotite aplite dykes.
9. Equigranular biotite-quartz monzonite dykes.
10. Late mafic dykes (aphyric or hornblende-phyric).

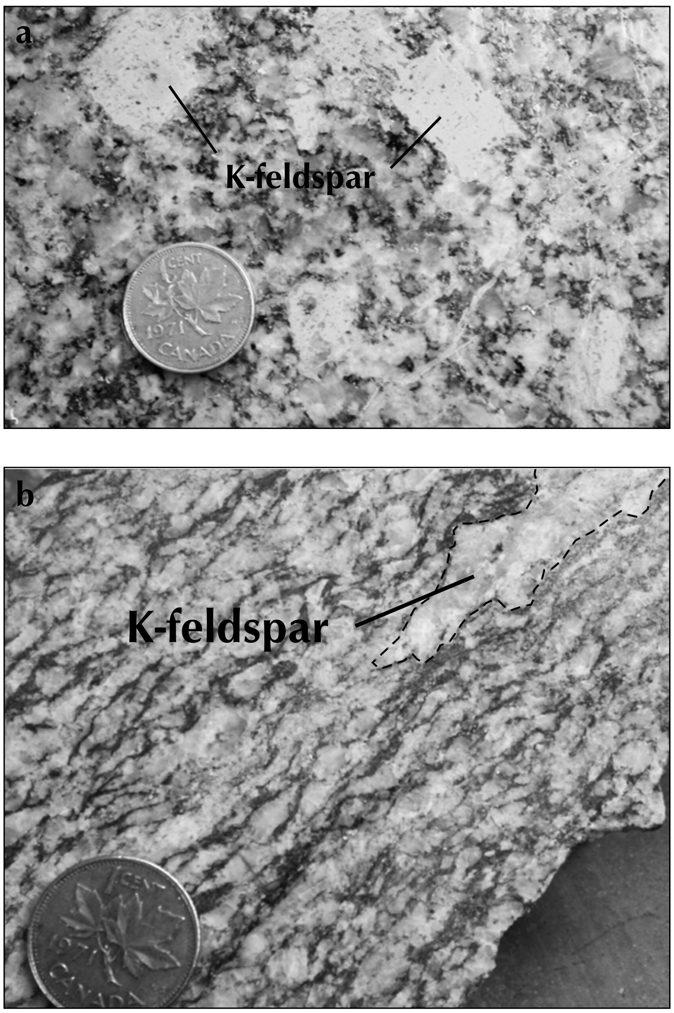

***Figure 3.** Representative igneous rock units from Minto: **(a)** typical massive, K-feldspar-phyric hornblende-biotite granodiorite (phase 2) of the Granite Mountain Batholith; **(b)** strongly foliated and weakly mineralized biotite granodiorite meta-intrusive rock with broken and strung-out K-feldspar phenocryst (phase 5).*

Parts of phase 5 contain deformed and strung out pink K-feldspar augen, and are clearly a ductilely deformed equivalent of phase 2 (Fig. 3a,b). Phase 6 is also seen to pass gradationally into phase 3.

OTHER ROCK UNITS

Two other main rock units are recognized in the area:

1. 'Siliceous ore' at Minto and rarely at Williams Creek — the typically thinly banded structure seen in numerous intercepts of 'siliceous ore' in drill core, together with the quartz- (and magnetite-) rich composition, suggests derivation from a very different protolith than the 'quartzofeldspathic or biotite gneiss ore'. The quartz-rich bands could have been derived from siliceous layers in a thinly bedded supracrustal sequence or may be completely transposed quartz veins.
2. Fine-grained 'amphibolite' at Williams Creek — this unit is likely derived from a supracrustal rock unit, most likely an intermediate or mafic volcanic rock or a sedimentary rock derived from a volcanic source of this composition. The presence of banded 'siliceous ore' interlayered with the amphibolite in the Williams Creek core may support the sedimentary origin suggested above for this unit.

GEOCHRONOLOGY AND GEOCHEMISTRY OF INTRUSIVE ROCK UNITS

Only limited age information is available thus far for intrusive and meta-intrusive rocks from the Minto-Williams Creek area. However, two preliminary U-Pb dates shed critical light on the age of the deposits. A sample of mineralized, strongly foliated granodiorite from Minto contains a single population of igneous zircons that give an age of 194 ± 1 Ma (J.K. Mortensen, unpublished data, 2002). This is interpreted as the crystallization age for the intrusive host rock, and provides a maximum age limit for the mineralization at Minto. A sample of massive, porphyritic quartz diorite of the Granite Mountain Batholith at Williams Creek that is interpreted to post-date mineralization gives a U-Pb zircon age of approximately 192 Ma and a U-Pb titanite age of 191 ±1 Ma (J.K. Mortensen, unpublished data, 2002). These data provide a minimum age bracket for the mineralization at Williams Creek.

A detailed geochemical study of the intrusive and meta-intrusive rocks in the Minto-Williams Creek area is currently underway. A very limited amount of data from the study area indicate that the rocks are geochemically very similar to other Late Triassic and Early Jurassic intrusive rocks throughout the Yukon-Tanana Terrane in Yukon and eastern Alaska as described by Mortensen et al. (2000). This intrusive suite is generally metaluminous and sub-alkaline to slightly alkaline in composition. Concentrations of immobile trace, high field strength and rare earth elements are most consistent with generation in a continental magmatic arc.

STRUCTURAL GEOLOGY

The structural evolution of the Minto and Williams Creek areas, and the nature and origin of the foliation(s) within the various rock units, will be critical for understanding the genesis of the two deposits. Alignment of K-feldspar phenocrysts in the porphyritic granodiorite of the Granite Mountain Batholith is ascribed to magmatic flow and it is likely that some alignment of mafic minerals and mineral aggregates, and potentially the formation of mafic schlieren observed locally within the batholith, may have also occurred during emplacement of early phases of intrusion. However, these K-feldspar phenocrysts (and their host rocks) have themselves been involved in subsequent ductile deformation that coincided with, or post-dated, introduction of the sulphide minerals. Therefore at least two distinct phases of foliation development can be demonstrated. Feldspar phenocrysts (mainly plagioclase) in the main phase of porphyritic diorite and quartz diorite at Williams Creek are typically strongly recrystallized in both the massive and foliated phases. It is unclear what the nature, origin and timing of this recrystallization is; this will be resolved in part by petrographic studies.

Post-mineralization deformation includes brittle faults with several orientations, including the east-trending DEF fault which forms the northern boundary of the Main Zone at Minto. These young brittle faults have facilitated relatively deep circulation of surface waters and oxidation of the hypogene sulphide minerals and their host rocks, including the pervasive hematization noted throughout parts of the Minto deposit. This oxidation has made it possible to economically recover copper from the Williams Creek deposits by heap leach methods. In addition, substantial block rotation has occurred, at least locally. This is evidenced by the tilting of younger sedimentary units (probably Late Jurassic to Cretaceous Tantalus Formation), south of the Main Zone at Minto, by up to 60° (bedding/core angles as low as 30° in vertical drill hole 99-01). Such late fault block rotation may in part account for the anomalously shallow dips of the dominant foliation in gneissic host rocks in the Minto Main Zone.

MINERALIZATION

Results of the 2002 field work confirm that the main host rocks for both deposits are variably deformed plutonic rocks. Mineralization at Minto is hosted mainly within foliated biotite and quartzofeldspathic orthogneiss (‘quartzofeldspathic ore’), with a lesser amount of mineralization contained within a banded, relatively quartz-rich rock (‘siliceous ore’). The ‘ore zones’ are enclosed by massive to very weakly foliated granodiorite of the Granite Mountain Batholith. The main host rock for mineralization at the Williams Creek deposit is foliated intrusive rock of dioritic to quartz dioritic composition. As with Minto, the ‘ore zones’ at Williams Creek and their metamorphosed host rocks are enclosed by massive quartz diorite and granodiorite of the Granite Mountain Batholith. At both deposits, chalcopyrite, bornite and lesser pyrite are disseminated and occur as stringers. Mineralization occurred prior to the ductile deformation that has affected the host units. ‘Siliceous ore’ may represent either mineralized and deformed quartz-rich sedimentary wall rocks to the intrusions or possibly strongly transposed sulphide-bearing quartz vein sets.

Although most sulphide mineralization at Minto and Williams Creek was clearly emplaced early and was ductilely deformed along with its host rocks, trace amounts of chalcopyrite and bornite are also present within post-tectonic pegmatites and aplites, particularly within the ore zones but also in a few cases outside of the main mineralized intersections. This is currently interpreted to represent local, late remobilization of the sulphide minerals. Thin aplite, pegmatite and quartz veins within ‘quartzofeldspathic ore’ are commonly deformed into complex ptygmatic folds, and some of these veins also contain sulphide minerals.

Pyrrhotite is disseminated throughout significant sections of the fine-grained, garnetiferous amphibolite and schist in Williams Creek, and may be syngenetic (volcanogenic?) in origin. No base metals are known to be associated with the disseminated pyrrhotite. Pyrite is also locally associated with late mafic dykes, which may be feeders to overlying Late Cretaceous Carmacks Group volcanic rocks.

ALTERATION

A detailed petrographic study of alteration assemblages at Minto and Williams Creek is currently underway. The following observations are based mainly on examination of drill core. Biotite in massive intrusive phases is at least, in part, primary igneous in origin; however there may be secondary biotite replacing primary hornblende in some of the altered but undeformed phases. Biotite in the strongly foliated gneissic zones was recrystallized along with the sulphide minerals, and therefore, primary textural information relating to its origin is not preserved. However it appears likely that both primary igneous biotite and a substantial component of hydrothermal (hypogene) biotite were originally present in the rocks; and both phases of biotite were completely recrystallized during the ductile deformation.

Relatively coarse-grained sericite is only rarely developed as an alteration phase at Minto. It has been observed first as an alteration envelope around a late epidote-filled vein that cut non-porphyritic, massive granodiorite; and secondly as a narrow envelope surrounding a late aplite and pegmatite dyke. Fine-grained sericite alteration may be more extensive in the deposit; this will be determined by petrographic studies.

Hematite commonly replaces magnetite, stains feldspars along late fractures and fills late fractures. It is commonly accompanied by bleaching of the wall rocks, and appears to be entirely late in the alteration history, and is likely completely unrelated to the mineralizing process. Bleaching, accompanied by minor hematization, produces a rock that many previous workers have incorrectly called a syenite. Epidote is commonly associated with hematite on late fractures but also occurs as an earlier, disseminated style of alteration, commonly associated with mafic minerals.

Chlorite is widespread throughout the Minto and Williams Creek areas. Some chlorite is clearly associated with late faults and breccia zones. It is unclear at this point whether any of the chlorite is related to the mineralizing process or simply represents a post-mineral retrograde recrystallization of the metamorphic mineral assemblages. Clay alteration, mainly of feldspars, was noted in numerous drill intersections. Some clay minerals are spatially associated with late faults and fractures, but other early, syn-mineral clay alteration cannot be ruled out.

DISCUSSION

Sulphide mineralization at Minto and Williams Creek occurs mainly as blebs or is disseminated within moderately to strongly deformed intrusive rocks. The mineralization must be younger than the host rocks (dated at 194 Ma at Minto); however the sulphides clearly pre-date most if not all of the ductile strain fabric recorded by the host rocks. The mineralization is older than the apparently post-mineral Granite Mountain Batholith (dated at ~192 Ma at Williams Creek). The mineralization is therefore temporally very closely tied to the host rocks. In addition, lead isotopic analyses of sulphide minerals and igneous feldspars from Minto and Williams Creek by J.K. Mortensen (unpublished data), and sulphur isotopic studies by Pearson (1977) indicate magmatic sources, which suggest a possible genetic link between mineralization and the host intrusive and meta-intrusive rocks.

The protolith(s) for some of the minor 'ore' hosts remains uncertain. Fine-grained, locally garnetiferous amphibolite at Williams Creek and banded, quartz-rich 'siliceous ore' at Minto (and rarely at Williams Creek) are likely supracrustal rocks of the Yukon-Tanana Terrane. Alternatively the 'siliceous ore' could represent zones of dense quartz (+ sulphide mineral) veins that have been completely tectonically transposed.

Multiple generations of post-mineral dyke emplacement, brittle fault offsets and associated alteration obscure hypogene alteration assemblages, and textures that may be directly related to mineralization at Minto and Williams Creek. At this point, the only alteration that can be strongly argued to be directly related to the mineralization is introduction of secondary biotite into some of the biotite-rich, deformed plutonic ore hosts. Additional work will be required to better understand the alteration zonation and history in the study area.

FUTURE WORK

Numerous lines of investigation are currently underway or are planned for the 2003 field season, including

- Detailed petrographic studies of ore and host rocks
- U-Pb dating of all phases of host rocks and younger dykes
- Ar-Ar dating of alteration mineral assemblages to constrain the cooling and uplift history of the area
- Geochemical studies of all intrusive and meta-intrusive phases
- Additional Pb and S isotopic studies of the mineralization and its host rocks
- Relogging and sampling of selected drill holes from Minto, Williams Creek and other occurrences elsewhere in the Carmacks Copper Belt
- Structural studies of the Minto and Williams Creek area.

ACKNOWLEDGEMENTS

We thank Lutz Klingman and Minto Exploration Ltd. for access to the Minto property, drill core and proprietary company reports, and for logistical support during our field work in 2002. We also thank Jim Proc (Minto Exploration Ltd.) and Tom Simpson (ASARCO Inc.) for assistance and valuable discussions in the field. Christa Sluggett provided cheerful and enthusiastic assistance in the field and during long hours at the core library. The project is funded by a grant from the Yukon Geology Program and a National Science and Engineering Research Council (NSERC) grant to J.K. Mortensen. The manuscript benefited from a critical review by Dick Tosdal.

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Cirque forms and alpine glaciation during the Pleistocene, west-central Yukon[1]

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Nelson, F.E.N. and Jackson, L.E., Jr., 2003. Cirque forms and alpine glaciation during the Pleistocene, west-central Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 183-198.

ABSTRACT

Uplands in west-central Yukon supported alpine ice centres during the pre-Reid glaciations (Early Pleistocene). Subdued cirque forms are thought to be glacial cirques that have undergone degradation by nivation. The paleo-equilibrium line altitude (ELA) dropped as low as 1054 ± 96 m in the Crag Mountain upland (CMU). A pre-Reid age for the CMU cirques is based upon the presence of an Early-Middle Pleistocene paleosol in a moraine feature. Cirques in the Ogilvie Mountains provide proxy ELAs for the Reid (mean 1391 ± 132 m) and McConnell (mean 1488 ± 103 m) glaciations. Cirque glaciers did not form in CMU and most of Dawson Range during these later glaciations due to a decrease in precipitation. It is suggested that the progressive marginality of cirque glaciation through the Middle and Late Pleistocene may be related to the progressive enlargement of precipitation-diverting continental ice sheets east of the Cordillera.

RÉSUMÉ

Les hautes terres dans le centre ouest du Yukon ont été le siège de centres glaciaires alpins durant les glaciations pré-Reid (Pléistocène précoce). Les formes quasi-circulaires estompées seraient des cirques glaciaires ayant subi une dégradation par nivation. L'ancienne altitude de la ligne d'équilibre a chuté à 1054 ± 96 m dans les hautes terres du mont Crag. L'attribution d'un âge pré-Reid aux cirques des hautes terres du mont Crag est basée sur la présence d'un paléosol du Pléistocène précoce-moyen dans une forme morainique. Les cirques dans les monts Ogilvie fournissent des altitudes de la ligne d'équilibre pour les glaciations Reid (valeur moyenne de 1391 ± 132 m) et McConnell (valeur moyenne de 1488 ± 103 m). Aucun glacier de cirque ne s'est formé dans les hautes terres du mont Crag et dans la grande partie du chaînon Dawson au cours de ces glaciations tardives à cause d'une diminution des précipitations. Le caractère marginal progressif des glaciers de cirque pendant le Pléistocène moyen et tardif pourrait être attribuable à l'agrandissement progressif des calottes glaciaires continentales dû à un déplacement des précipitations à l'est de la Cordillère.

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INTRODUCTION

The surficial geology of a large area of west-central Yukon (Stewart River 1:250 000 map area (115N and 115O) and adjacent areas) is currently being mapped as part of the Geological Survey of Canada's Ancient Pacific Margin NATMAP project. Defining the limits of past glacial ice cover is a key component in this endeavour. Bostock (1966) established limits of past regional glaciations. These pertain to areas covered by past Cordilleran ice sheets. However, recent investigation of cirque-like features and glacial landforms in the Sixtymile River basin (Lowey, 2000), mapping of degraded cirques in the Dawson Range (Jackson, 2000), and mapping of landforms and glacial erratics in the Yukon-Tanana Upland of adjacent Alaska (Weber, 1986) have suggested that cirque, valley or small ice cap glaciation may have existed earlier in the Pleistocene at elevations common within uplands of the Stewart River map area.

There are significant problems inherent in gaining more of an understanding of these past local ice centres: most of the deposits of these alpine glaciers have been eroded away or buried, and the cirques from which the glaciers originated have been eroded to suggestive but equivocal bowl-shape alpine landforms.

This paper presents an inquiry into these cirque-like features. It deals with the following questions:

1) Are these bowl-like alpine features really degraded glacial cirques?

2) Do middle or Early Pleistocene glacial deposits related to the purported cirques exist?

3) What is the geographic distribution of these cirque-like features?

4) What do their geographic distributions indicate about climatic factors during these old glaciations and how did they differ from more recent glaciations?

To address these questions, the occurrences of these cirque-like forms were mapped and their distributions and morphometry compiled. A literature review was carried out to investigate the climatic controls determining the occurrence of cirques and similar landforms. Deposits that were suspected as originating from alpine valley glaciers were also investigated.

SETTING

West-central Yukon lies within the Yukon Plateau (Mathews, 1986), a region of accordant summits and broad intervening valley systems. The age of this formerly uplifted surface is uncertain, but probably dates to the Early Tertiary. Elevations of summits generally decrease westward from the Pelly Mountains (elevations up to 2190 m) and southward from the Ogilvie Mountains (elevations up to 2050 m). Relief from mountain summit to valley floors ranges up to 1130 m. Glaciation has caused the most notable differences in the morphology of uplands and drainage patterns. Recently glaciated uplands such as the Pelly and Ogilvie mountains are marked by alpine glacial landforms such as horns, arêtes and cirques. Valley systems are commonly anastomosed due to widening and deepening of pre-existing fluvial drainage by valley glaciers.

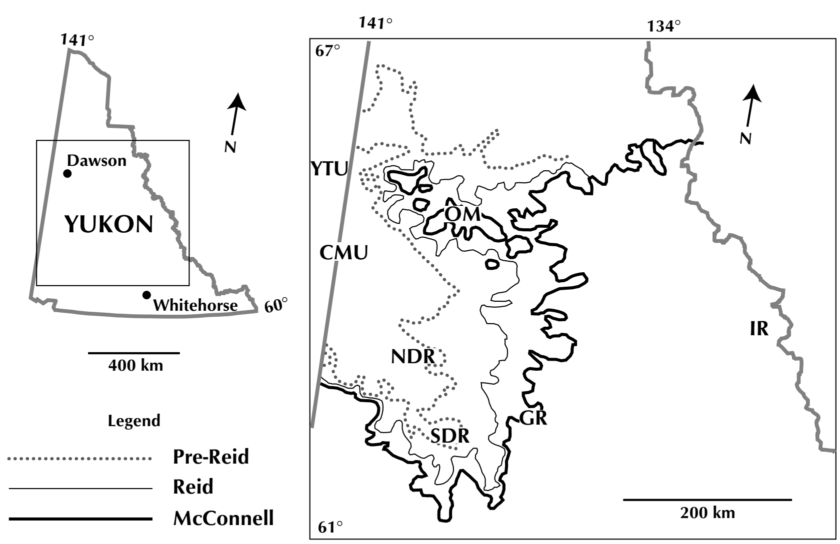


Figure 1. *Map showing study areas and generalized Cordilleran glaciation limits, central Yukon Territory (modified from Duk-Rodkin, 1999).*
YTU – Yukon-Tanana Upland (Alaska)
OM – Ogilvie Mountains
CMU – Crag Mountain upland
NDR – northern Dawson Range
SDR – southern Dawson Range
GR – Glenlyon Range
IR – Itsi Range

In contrast, areas such as the Klondike Plateau have been described as "gentle undulations rising here and there along converging ridges to culminate in...dome-like eminences or groups of relatively smooth-sloped mountains" (Bostock, 1948, p. 62). Valley systems reflect their fluvial origin, and anastomosing valley systems occur only along the limits of regional glaciation. The cirque-like features, which are the subject of this paper, occur along the dome eminences and the sides of the higher ridges.

Bostock (1966) recognized four glaciations during which an ice sheet formed over eastern and southern Yukon and advanced west and north: the Nansen, Klaza, Reid and McConnell. Each of these glaciations was less extensive than its predecessor (Fig. 1). Hughes et al. (1969) grouped Nansen and Klaza glaciations into the pre-Reid glaciations due to the difficulty in correlating the scattered occurrences of sediments left behind by these glaciations that pre-date the last geomagnetic reversal (*ca.* 0.78 Ma), and may date to *ca.* 2.5 Ma (Froese et al., 2000). The pre-Reid grouping will be used in this paper.

The present climate of the Yukon Plateau is sub-Arctic continental with low relative humidity, and precipitation modified by orographic and rain shadow effects (Wahl et al., 1987). The highest mean annual precipitation, up to 3500 mm, occurs over the presently glacierized Coast Mountains (CM) and Saint Elias Mountains (SEM) (Fig. 2). The Pelly (PM) and Selwyn (SM) mountains form an interior wet belt with precipitation up to 700 mm. The Stewart River map area and adjacent parts of west-central Yukon are particularly arid due to their position in the rain shadow of CM/SEM, with annual mean total precipitation ranging from 300 to 500 mm.

GLACIAL CIRQUES AND SIMILAR FEATURES

A cirque is a topographic hollow, open downstream but bounded upstream by the crest of a steep slope (headwall), which is arcuate in plan around a more gently sloping floor. It is glacial if "the floor has been affected by glacial erosion while part of the headwall has developed subaerially, and a drainage divide was located sufficiently close to the top of the headwall for little or none of the ice that fashioned the cirque to have flowed in from the outside" (Evans and Cox, 1974, p. 151). Glaciers require cold temperatures and sufficient effective precipitation for snow accumulation to exceed ablation (Benn and Evans, 1998). Glaciers erode cirques once the surface gradient of the ice initiates rotational flow (Evans, 1999). Cirque altitudes and aspects provide a "long-term integration of the morphological effect of glacial climate" (Evans, 1977,

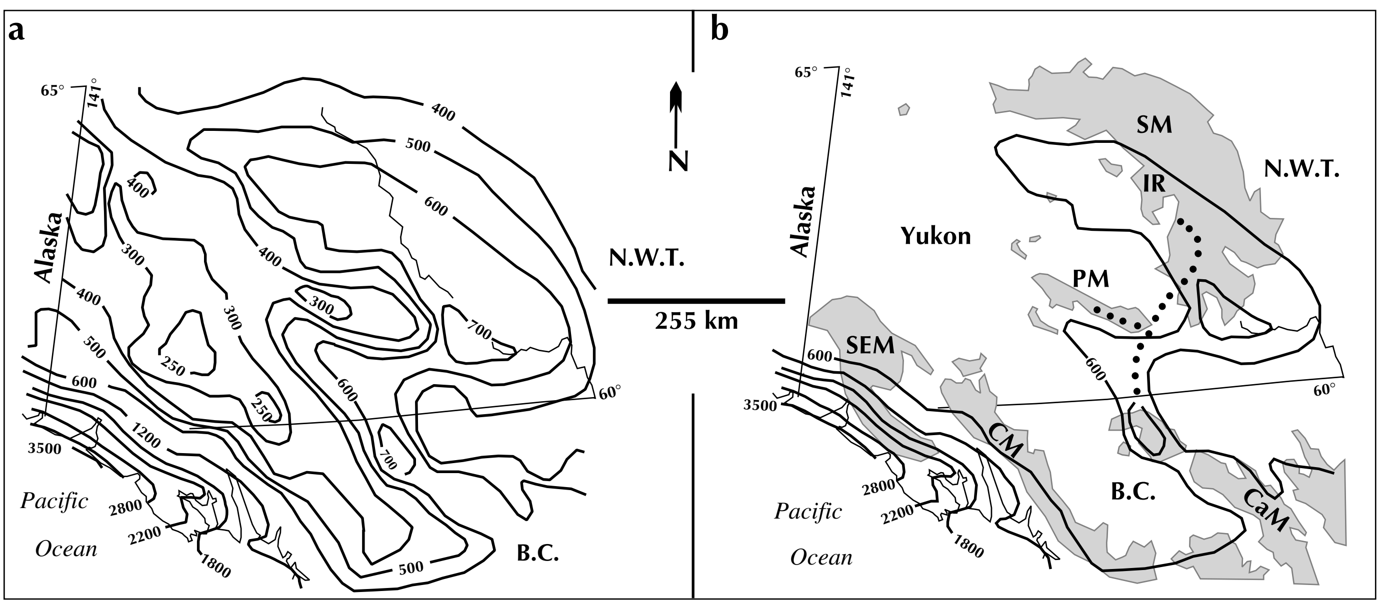


Figure 2. (a) *Isohyet map (mean annual precipitation, mm) of southern Yukon and northern British Columbia;* ***(b)*** *> 600 mm isohyets and areas containing summits with elevations >1900 m (shaded). The generalized ice divide (dotted line) from which the Selwyn and Cassiar lobes advanced into the Yukon River basin (figure after Jackson et al., 1991, his Figure 2; climatic data from Wahl et al., 1987). SM – Selwyn Mountains; IR – Itsi Range; PM – Pelly Mountains; SEM – Saint Elias Mountains; CM – Coast Mountains; CaM – Cassiar Mountains*

p. 151). Where and when climate conditions are marginal for the existence of cirque glaciers, they occur in deep, wide cirques with a narrow pass, or col, upwind (Graf, 1976). This implies that cirque glacier formation is encouraged and perpetuated by pre-existing cirque forms.

A nivation hollow or nivation cirque, as this landform is also called, shares the cirque form; however, it shows evidence of the suite of processes known as nivation taking place under snowpatches, rather than glacial erosion. Nivation processes include freeze-thaw cycles and abrasion by material embedded in mobile snow pack, intensification of chemical weathering through insulation and moisture, and mechanical transport through solifluction and meltwater flow (Thorn, 1988; Christiansen, 1998). The rate of degradation in a snow-covered nivation hollow in the Colorado Rockies has been measured at 0.0074 mm/yr (Thorn, 1976). Definitive criteria for the purely morphometric discrimination between glacial cirques and nivation hollows are absent from the literature. Nivation features, although usually smaller than glacial features, cannot be differentiated by size alone (Evans and Cox, 1974). Large nivation hollows have been studied in northern Quebec (Henderson, 1956), Sweden (Rudberg, 1984; Rapp, 1984; Rapp et al., 1986), Denmark (Christiansen, 1996) and northeast Greenland (Christiansen, 1998). The only definitive way to discriminate between these landforms and glacial cirques, particularly when cirques have been degraded by erosion and periglacial activity, is by demonstrating past flow of glacial ice from cirques into adjacent valleys.

METHODS

Lowey (2000) presented evidence suggesting the existence of degraded cirques, and morainal and related features in the upland south of Sixtymile River (Fig. 3). This upland will be referred to as Crag Mountain upland after one of the few named peaks in that area. The sites discussed by Lowey (2000) were visited during the course of surficial geology mapping in 2001 in order to further investigate the genesis and the age of the glacial features. In the office, cirques and cirque-like landforms between latitudes 62 and 65 degrees North and longitudes 136 and 141 degrees West were inventoried and their morphometric parameters measured. This geographic area includes the broad physiographic regions of the Yukon Plateau and the Ogilvie Mountains. Included in this area are unequivocal glacial cirques from the Late Pleistocene glaciations. Cirques and cirque-like features were compiled from existing surficial geology maps and new air photo interpretation.

FIELD INVESTIGATION OF VALLEY GLACIATION IN UPLANDS BEYOND THE LIMIT OF REGIONAL GLACIATION

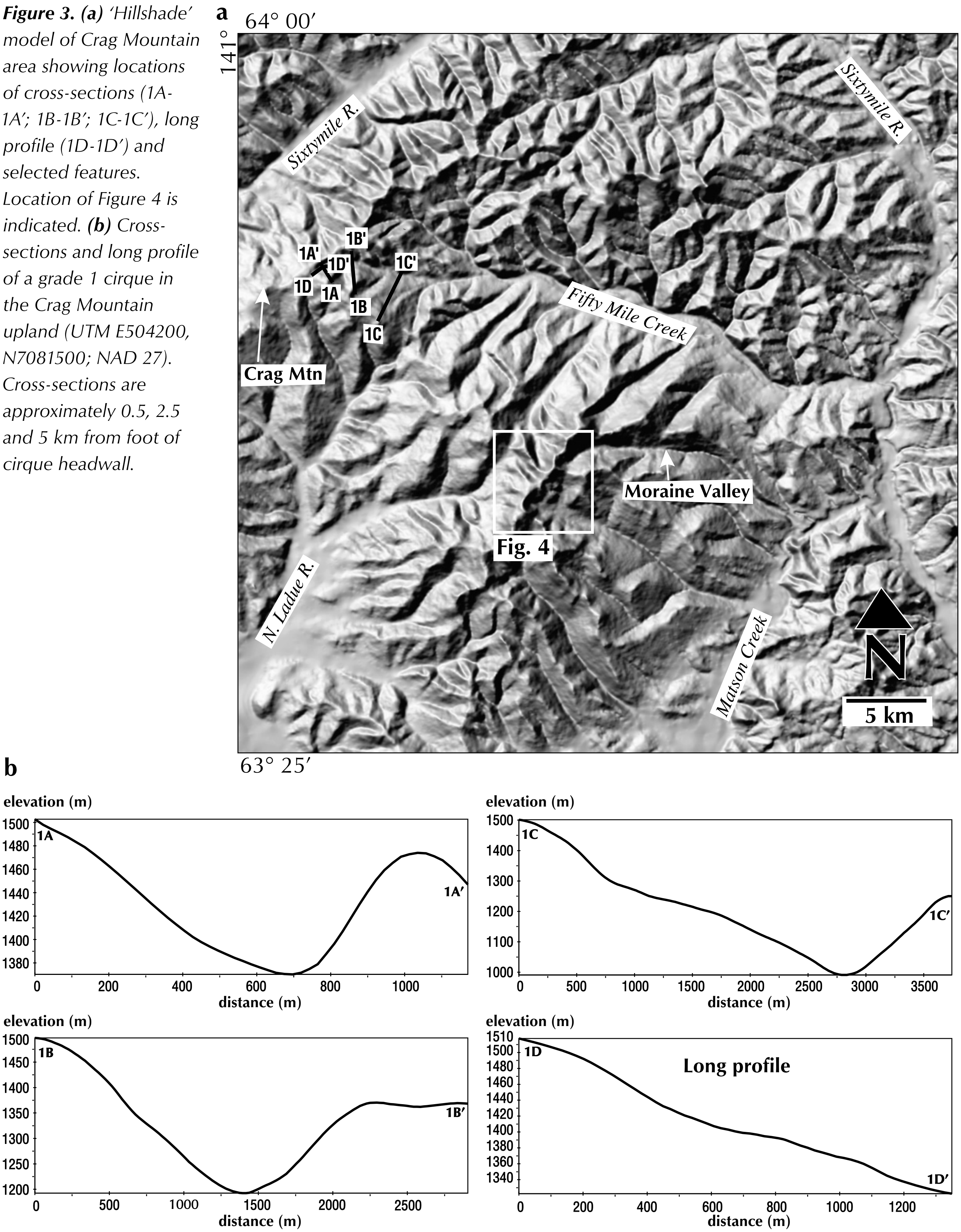
Lowey (2000) noted several features indicative of the past presence of valley glaciers in valleys descending from the Crag Mountain upland: arête-like ridges, U-shaped valleys, truncated spurs, flights of terraces (upper Fifty Mile Creek) and morainal features that lie across valleys. A valley south of Fifty Mile Creek is notable in this regard and will be referred to as Moraine Valley (Fig. 3). Other similar features were noted on air photos and visited in the field. Suspected morainal features were traversed and pits were dug in them in order to determine the depth and type of soils and degree of weathering as an indication of their age. In the lab, a succession of topographic cross-sections was constructed across valleys descending the Crag Mountain upland to compare cross-valley shape changes with distance in a down-valley direction. This was done in order to look for changes indicative of the transition between formerly glaciated upper reaches of valleys and unglaciated lower reaches.

MORPHOMETRIC AND STATISTICAL METHODS

Morphometric characteristics for cirque and cirque-like landforms are measured on 1:50 000-scale NTS maps, with the exception of cirques on sheets 105L/7, L/8, L/1 and 115I/5, which are measured off of 1:100 000-scale base maps assembled from the respective 1:50 000 sheets (Ward and Jackson, 1993; Jackson, 1997). A total of 331 cirque forms were studied in five regions: Crag Mountain upland (115N/15,16,10,9), northern Dawson Range (115J/15,10,9,8), southern Dawson Range (115I/5,6, 4,3), Glenlyon Range (105L/7,8,1) and Ogilvie Mountains (116A/12,11,10,9). The established cirques and cirque-like landforms were divided into four grades based on quality of form, with grade 1 forms closest to the ideal cirque form of Evans and Cox (1974) and grade 4 being still recognizable but different from the ideal (Fig. 4). This is similar to the methodology used by Lowey (2000); however, in this study, subdued cirque forms are grouped within grade 4 rather than a grade 5 (marginal, with cirque status and origin doubtful).

Developing criteria for differentiating between cirques of different ages is problematic because of the many variables involved. Vernon and Hughes (1966) separated glacial features in the Ogilvie Mountains into two classes,

Figure 3. ***(a)*** *'Hillshade' model of Crag Mountain area showing locations of cross-sections (1A-1A'; 1B-1B'; 1C-1C'), long profile (1D-1D') and selected features. Location of Figure 4 is indicated.* ***(b)*** *Cross-sections and long profile of a grade 1 cirque in the Crag Mountain upland (UTM E504200, N7081500; NAD 27). Cross-sections are approximately 0.5, 2.5 and 5 km from foot of cirque headwall.*



"glaciated in the last glaciation" and "not affected by last glaciation," on the basis of qualitative geomorphic criteria (rounded arêtes and gully-dissected cirque walls interpreted as older). However, stages of weathering found within cirque forms may be explained by differing rates of erosion within different rock lithologies. Jackson et al. (1996) found this to be the case in the Alberta Foothills and Rocky Mountain Front Ranges.

Cirque-floor altitudes represent a maximum value for the ELA (paleo-equilibrium line) of cirque glaciers and must be used with caution (Meierding, 1982; Benn and Evans, 1998); however, as a relative measure they are thought to be useful. Cirques of all aspects are included in the altitudinal frequency distributions. Descriptive statistics for cirque-floor elevations only include cirque forms facing north, as any calculation involving cirque elevation is biased by including cirques of greatly different orientation (Evans, 1977). Skewness measures the degree of symmetry in a frequency distribution. Kurtosis measures flatness or peakedness of a data set. In order to estimate the amount of depression of snowline during past glaciations relative to the present (Holocene) interglacial periods, the present equilibrium line altitude (ELA) was inferred from glaciers in the Itsi Range ice fields along the Yukon/Northwest Territories border in the Selwyn Mountains (Fig. 1). The ELA was approximated by

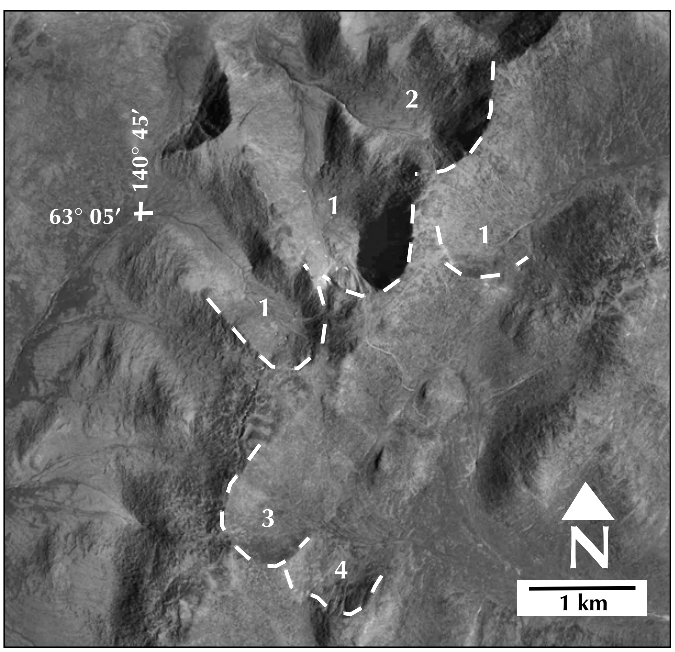


Figure 4. *Detail of air photo showing cirques of varying quality (grade) in Crag Mountain upland. Grade 1 cirques are closest to the ideal cirque form and grade 4 cirques are poorly developed. 1, 2, 3, 4=grade. NAPL A27660-66.*

an accumulation-area ratio of 0.65 (Meierding, 1982). The 'ice field' layer of the digital topographic map (105J/16) was imported into AutoCAD and the ELA was interpolated from contour lines.

Ninety-five percent confidence intervals for the mean cirque-floor elevations of cirques and cirque-like features were calculated using VassarStats: Website for statistical computation (R. Lowry, 2002, *http://faculty.vassar.edu/lowryVassarStats.html*). A 95% confidence interval for the mean is calculated by adding and subtracting 1.96 standard errors of the mean. Confidence intervals are used to compare the cirque-floor elevations of high-quality (grade 1 or 2) cirques to those of low-quality (grade 3 or 4) cirque forms. Confidence intervals are viewed as a strong replacement for hypothesis testing (Johnson, 1999).

Cumulative vector diagrams (Evans, 1977) determine the mean orientation of cirques in each geographic area studied. These diagrams depict the resultant vector, the only valid mean for directional data (Curray, 1956). Each individual vector in these diagrams is the sum of the number of cirques within one of sixteen 22.5° divisions of the compass. Evans (1977) suggested that vector strength could be interpreted as the degree of asymmetry of cirque orientation (Table 1). Asymmetry represents the preference to 'best' aspect for glacier formation, and therefore, cirque formation. Evans (1977) found that as snowline falls, the effect of aspect, and therefore asymmetry, is reduced, forming a 'law of decreasing glacial asymmetry with increasing glacier cover.' Cumulative vector diagrams for all regions except the Itsi Range and the Ogilvie Mountains, where cirques could be related to moraines from succeeding glaciations, include cirque aspects from multiple glaciations. Therefore, results must be regarded as composite. Nevertheless, because alpine glaciation may not have occurred in a particular region during every glaciation, the results are thought to be meaningful.

Table 1. *Suggested interpretation of vector strength (after Evans, 1977).*

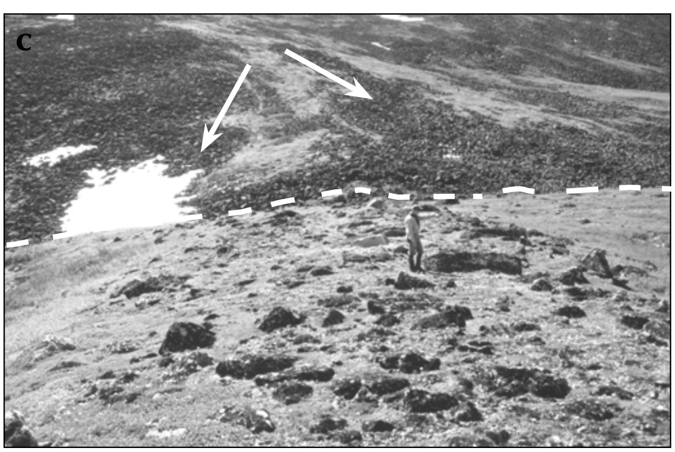
Vector strength (L)	Degree of asymmetry
>80%	extremely asymmetric
60-80%	strongly asymmetric
40-60%	markedly asymmetric
20-40%	weakly asymmetric
<20%	symmetric

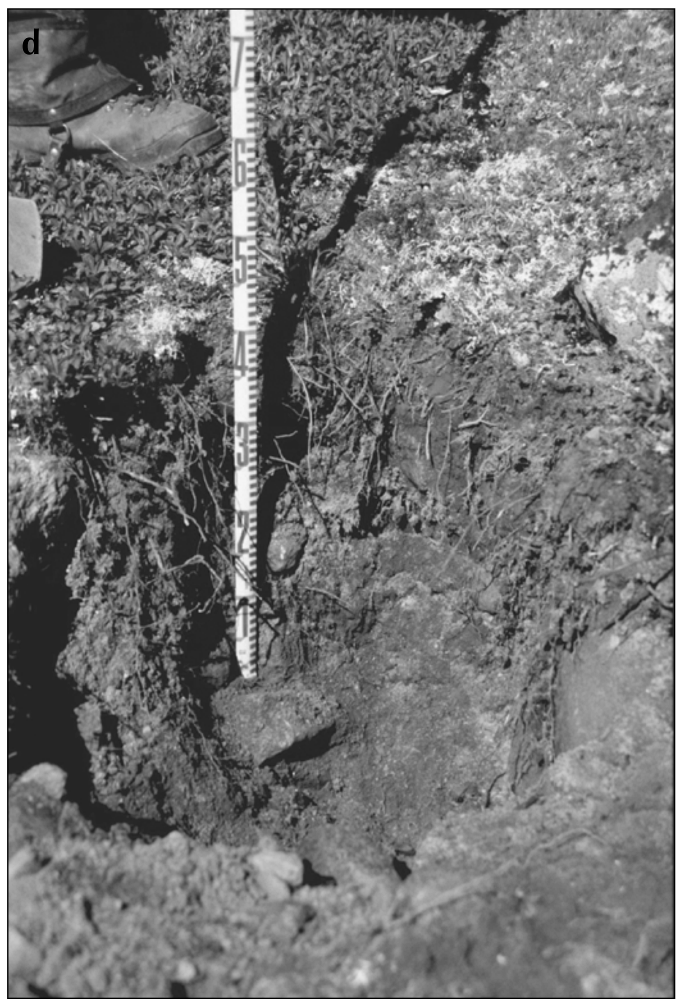
RESULTS

FIELD EVIDENCE OF FORMER VALLEY GLACIERS

Crag Mountain upland yields the best evidence for past valley glaciation in areas beyond the limit of regional glaciation (Bostock, 1966; Duk-Rodkin, 1999), corroborating the conclusions of Lowey (2000) for the Crag Mountain area and those of Weber (1986) for Yukon-Tanana Upland in Alaska. Evidence includes U-shaped valleys (Fig. 5a) and truncated spurs in valleys that originate from cirque-like landforms along divides above 1300 m, as well as corroboration of the glacial origin morainal feature in Moraine Valley. U-shape valleys locally transform into V-shaped valleys downstream. This suggests a former glacial limit similar to canyon transformations seen in valleys at the limits of valley

Figure 5. *Glacial features in and around Crag Mountain upland.* ***(a)*** *View of U-shaped valley of Borden Creek. View is to the northwest with summit of the Crag Mountain upland in the background.* ***(b)*** *View looking down valley at three bouldery ridges: distance from X to X′ is 200 m.* ***(c)*** *Looking along morainal ridge in the area of x' toward the slope to the south. Toe of a large rock glacier (dashed line) is seen advancing onto the moraine (flow direction of rock glacier indicated by arrows).* ***(d)*** *Soil pit containing red fossil soil with ventifacts and clasts with clay skins.*





glaciers in unglaciated regions such as the Merced River valley below Yosemite Valley, California (Matthes 1930, his Fig. 4). In other valleys, such as those of Borden, Sven and Pine creeks, the U-shape form persists to the valley of Sixtymile River (Fig. 5a). Unfortunately, a complete lack of exposures and of distinctive erratic rock types prevents the discrimination of glacial deposits in these areas.

Deposits at Moraine Valley

The moraine-like feature in Moraine Valley consists of a complex of elongate boulder ridges transverse to the long axis of the valley (Fig. 5b,c). The largest is 200 m long, 65 m wide with local relief of up to 23 m between the crest and the down-valley side. It is studded with large angular boulders of granitoid plutonic and gneissic lithologies. Although the soil directly underlying the surface is an incipient one (Regosol), excavation of 30-cm-deep pits between boulders on the down valley side of the largest ridge encountered remnants of a fossil soil having Munsell colours in the 7.5 yr 3/4 range (brown), buried ventifacts (wind-sculpted stones), and clay skins (argillans) on stones (Fig. 5d). These are all characteristic of the Wounded Moose paleosol which is developed in the deposits of the Early Pleistocene pre-Reid glaciations (Tarnocai et al., 1985; Smith et al., 1986; Tarnocai 1987, 1990; Tarnocai and Schweger, 1991). The burial of pods of this soil attests to intense cryoturbation following the formation of the soil. The effects of a periglacial climate are further indicated by complexes of rock glaciers which cover the adjacent north-facing slopes and are overrunning the southern margins of these bouldery ridges. The narrow, elongate form of these features precludes a nonglacial origin either as a rock avalanche or as the toe of an inactive rock glacier, (the former forms a hummocky carpet of bouldery debris across a valley, whereas the latter remains as a lobate or spatulate tongue of bouldery debris). Morainal features similar to the ridges in question occur in the headwaters of the Kananaskis River in the Canadian Rocky Mountains, Alberta (Jackson, 1987, p. 19). They originated as a rockfall onto the surface of a retreating valley glacier. The rockfall debris was transported to the terminus and concentrated as transverse ridges and heaps of boulders with reliefs comparable to those in Moraine Valley. The angular, bouldery texture of these ridges has allowed their survival as landforms. Other glacial landforms and deposits that existed in the area presumably have been buried or removed by erosion.

In order for a valley glacier to have deposited these bouldery ridges, it would have had to advance 1.5 km from the cirque at the head of the valley. This is a minimum figure for the length of the former valley glacier. U-shape cross-sections in adjacent valleys persist more than 8 km. Although no detailed calculations were done, it appears that there is a direct relationship between the linear persistance of valley U-shape cross-section and the total area of degraded cirques.

CIRQUE MORPHOMETRY AND CIRQUE-FLOOR ALTITUDES

In west-central Yukon, fresh and degraded cirque forms range from the classic semi-circular armchair-like forms to valley heads with bowl-shaped curvature. North-facing

Table 2. *Descriptive statistics for cirque-floor elevations in five regions of west-central Yukon. Only north-facing cirques are considered.*

Region	Altitude (m)			Standard deviation	Skewness	Kurtosis
	Minimum	Maximum	Mean			
Itsi Range ice fields	1780	2100	1929	84	0.04	-0.08
Ogilvie Mountains						
not active during last glaciation	1036	1646	1391	132	-0.77	0.41
active during last glaciation	1219	1707	1488	103	-0.65	1.05
Glenlyon Range	1402	2012	1667	122	0.67	1.68
Dawson Range						
northern	1189	1676	1433	125	-0.10	-0.42
southern	1128	1515	1451	117	-0.83	0.62
Crag Mountain upland						
minor mode	853	1189	1054	96	-0.76	-0.04
major mode	1219	1515	1346	92	0.10	-0.80

cirque-floor altitudes range from 853 to 2012 m above sea level. Altitudinal frequency distributions for the regional groups are presented in Figure 6. Ninety-five percent confidence intervals comparing the means of high-quality and low-quality cirque forms are presented in Figure 7. Descriptive statistics for cirque-floor elevations are presented in Table 2. Backwall height ranges from 30 to 518 m. Cirque-form width ranges from 91 to 2300 m, and length ranges from 100 to 2700 m. The mean values for a range of characteristics are summarized in Table 3. Most cirque forms are drained by first-order streams and have an outward sloping bottom, with little or no overdeepening. Cumulative vector diagrams depict the mean aspect and degree of asymmetry for each region (Fig. 8).

Itsi Range of the Selwyn Mountains and contemporary ELA

The Selwyn lobe of the Cordilleran Ice Sheet (McConnell Glaciation) originated from an ice-divide in the Selwyn Mountains and pressed into west-central Yukon (Campbell, 1967; Jackson et al., 1991). Ice fields present today in the Itsi Range are thought to be analogous to glacier cover present in Selwyn Mountains during the Reid/McConnell interglacial period (Jackson et al., 1991).

The Itsi Range supports 21 ice fields, with a total area of 18 386 569 m^2 (data from 1976-77 air photos). The mean ice field ELA is 1929 ± 84 m (Table 2) and provides an estimate of the contemporary ELA within the interior of Yukon. It can be used to evaluate the depression of the ELA during past glaciations. The average ice field has a headwall aspect of 28° west of north, and the aspect distribution is weakly asymmetric (Fig. 8). South-facing ice fields have higher ELAs due to the enhanced insolation received by that orientation.

Ogilvie Mountains

The Ogilvie Mountains (OM) have the least complicated glacial history of the formerly glacierized areas inventoried. During the McConnell and Reid glaciations, cirques fed valley glaciers, which in turn locally fed piedmont lobes in adjacent lowlands. Confluence of Ogilvie Mountain glaciers with a lobe of a Cordilleran Ice Sheet that occupied Tintina Trench occurred during the pre-Reid glaciations (Duk-Rodkin, 1999).

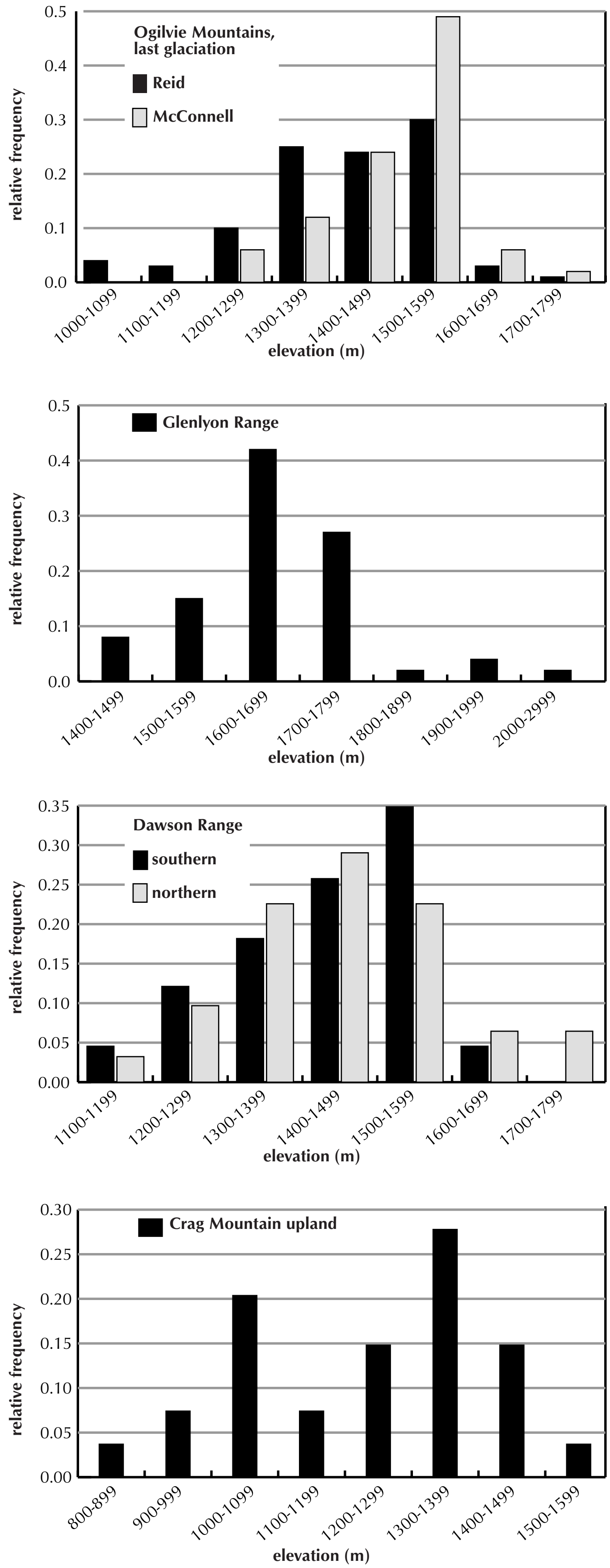


Figure 6. *Relative frequency distributions of cirque-floor elevation (m).*

Table 3. *Mean cirque-form values for various morphometric parameters.*

Area (proposed glaciation(s))[1]	Generalized geology[2]	N	Grade[3]	Altitude[4] (m)	Height[5] (m)	Width[6] (m)	Length[7] (m)	Length: Height Ratio	Length: Width Ratio
Crag Mountain upland (pre-Reid/Reid)	metamorphic/ volcanic	54	3	1232	152	797	985	7.7	1.3
Dawson Range (pre-Reid/Reid)	metamorphic/ volcanic/plutonic								
northern		31	2	1456	168	787	932	6.6	1.2
southern		66	3	1439	135	747	603	4.9	1.8
Glenlyon Range (Reid/McConnell)	plutonic	52	1	1665	214	636	791	4.2	1.7
Ogilvie Mountains									
(McConnell)	sedimentary	49	2	1487	322	732	780	2.5	1.1
(Reid)	sedimentary	79	2	1417	273	718	723	2.8	1.1
All		**331**	**2**	**1449**	**214**	**736**	**802**	**4.8**	**1.4**

[1]Ages from Lowey, 2000; Jackson, 2000; Ward and Jackson, 2000; Vernon and Hughes, 1966.

[2]Summarized from Gordey and Makepeace, 1999.

[3]Follows classification of Evans and Cox, 1995 as used in Lowey, 2000.

[4]Altitude measured as most obvious break in slope denoted by contour lines (to nearest 50 ft (15 m), 100 ft (30 m)contour interval), essentially, the altitude of the cirque-floor, converted to metres (/3.2810).

[5]Height measured from top of headwall to break in slope denoted by contour lines (to nearest 50 ft (15 m)).

[6]Width measured at widest extent of break in slope denoted by contour lines (to nearest 15 m).

[7]Length measured from apex of obvious break in slope denoted by contour lines to where sidewalls abruptly end or drop in altitude (to nearest 15 m).

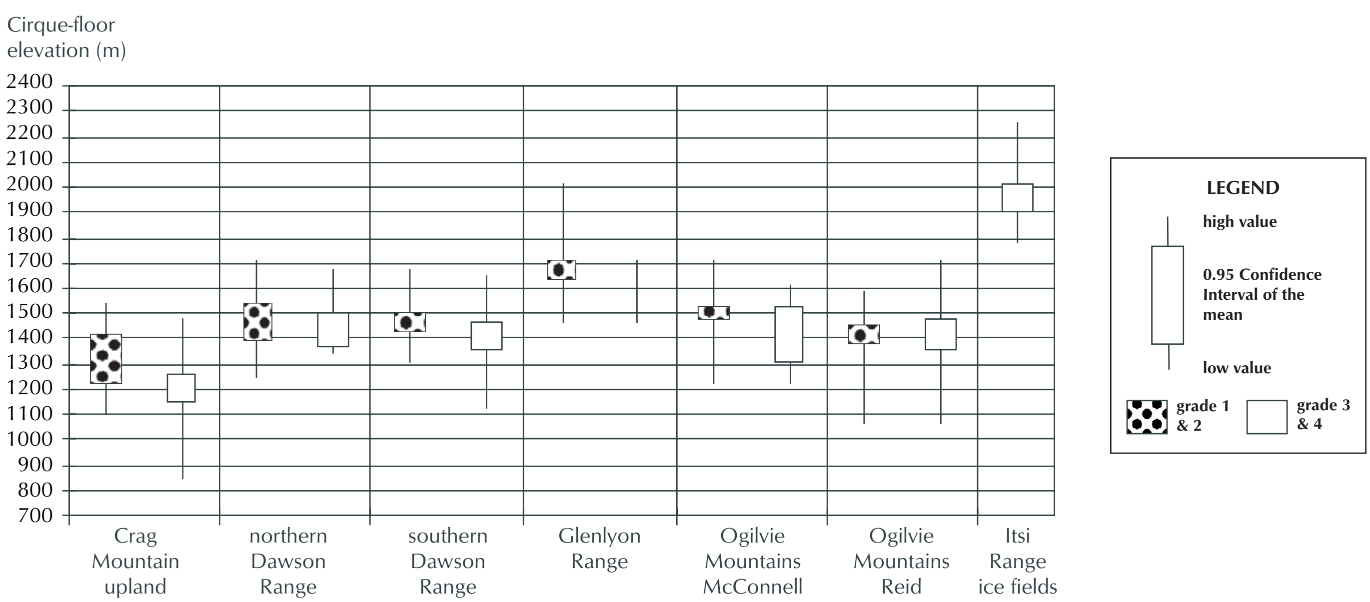


Figure 7. *The 0.95 confidence intervals (CI) for the mean cirque-floor elevation with high and low outliers. The Itsi Range ice fields represent the CI for an interglacial equilibrium line altitude (ELA).*

Inventoried OM cirques comprise a subset of those mapped by Vernon and Hughes (1966). The means of cirque-floor elevations for the two age populations of cirques identified by them, i.e., active during the last glaciation and not active during last glaciation, are 1488 ± 103 m and 1391 ± 132 m, respectively (Table 2). We will refer to the former population as 'McConnell' and the latter as 'Reid.' Both are related to moraine systems. Such moraines are generally lacking elsewhere in areas glaciated only during pre-Reid glaciation. The 'McConnell' altitudinal frequency distribution is leptokurtic: cirque-floor elevations predominantly fall within the 1400-1499 m range. The cirque-floor elevations, of both of Vernon and Hughes' cirque groupings are 440-540 m lower than the contemporary ELA in the Itsi Mountains (1930 ± 84 m). If only the mean cirque-floor elevations for the grade 1 and 2 cirques are compared, 'McConnell' cirques occur at a mean elevation approximately 100 m higher than 'Reid' cirques. The mean cirque-floor elevation for high-quality (grade 1 or 2) 'Reid' cirques is between 1381 and 1452 m whereas for the 'McConnell' cirques it is between 1474 and 1531 m (0.95 confidence interval) (Fig. 7). This is consistent with the view of increasing marginality, as demonstrated by a rise of ELA, with decreasing age between the Reid and McConnell glaciations. Furthermore, 29% of the 'Reid' cirques are

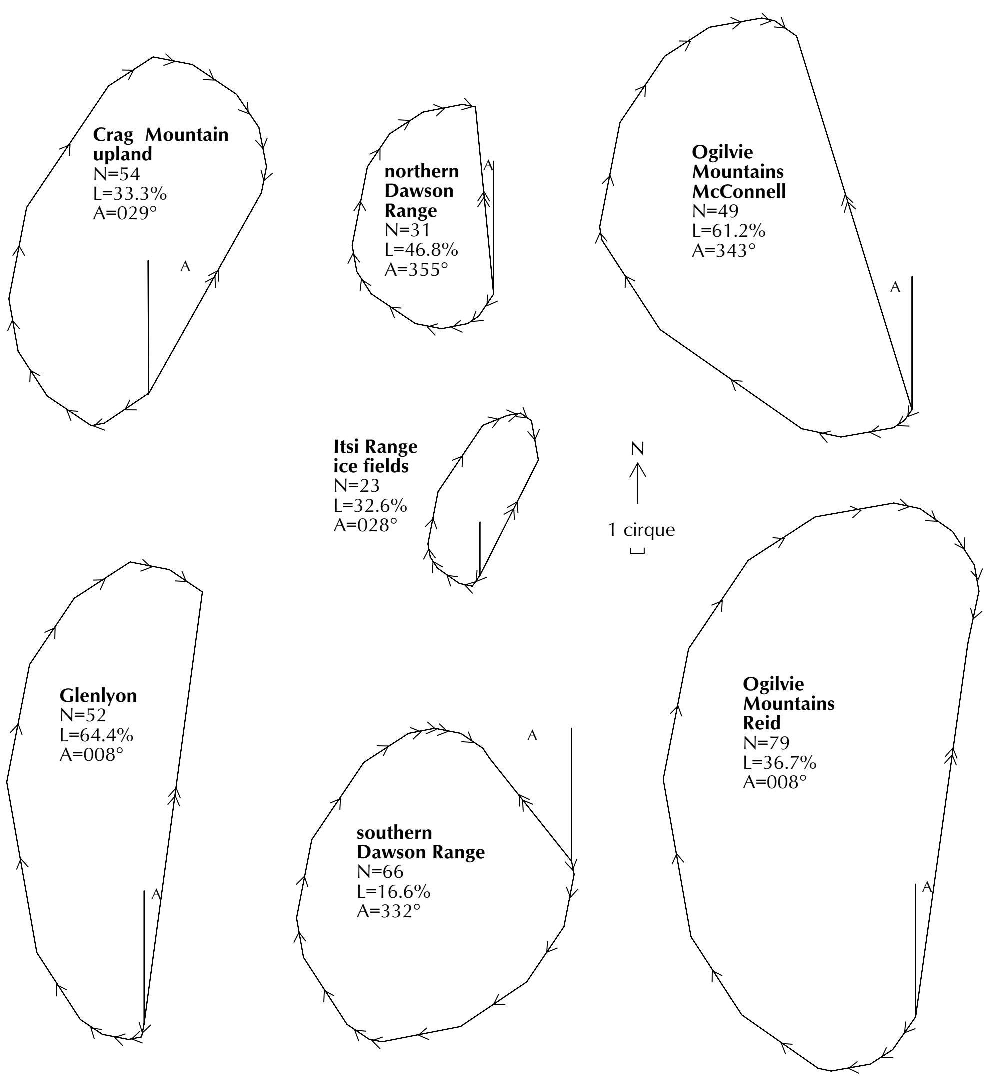


Figure 8. *Cumulative vector diagrams showing cirque aspects. Each leg is proportional to the number of cirques within one of 16 aspects. The resultant vector (double arrow) joins the first and last legs and represents the mean vector angle (A), or mean aspect, in degrees. Vector strength (L) is the length of the resultant vector expressed as a percentage of the total length of individual vectors. N= total number of cirques.*

grade 3 or 4 whereas only 18% of 'McConnell' distribution is grade 3 or 4. Assuming degradation of form over time, this difference may represent the longer period of degradation since the Reid Glaciation (300 to 200 ka B.P., Huscroft et al. 2001; Westgate et al. 2001) as opposed to time since McConnell Glaciation (<26 ka to *ca.* 12 ka B.P., Jackson and Harington, 1991; Ward, 1989). The lower limit of 'Reid' cirques likely reflects the altitude at which adjacent valley glaciers 'trimmed' or otherwise limited the extent of cirque formation and preservation.

Cirque aspect also provides evidence of a change in the character of alpine glacierization between the Reid and McConnell glaciations (Fig. 8). The 'Reid' aspect distribution is weakly asymmetric, with a greater number of southern hemisphere aspects (29%) than the strongly asymmetric 'McConnell' cirque forms (18%). This supports the view that the earlier glaciation was stronger than the later one, either because of lower mean summer temperatures or greater precipitation.

Glenlyon Range

Unlike the Ogilvie Mountains, one or more Cordilleran ice sheets overrode the Glenlyon Range (GR) during pre-Reid glaciations. During Reid and McConnell glaciations, GR was a nunatak within the Cordilleran Ice Sheet and cirques supplied little or no ice to the ice sheet (Ward and Jackson, 1992).

Cirque glaciation was marginal in GR during Reid and McConnell glaciations: distribution of cirque aspect is highly asymmetrical to the north (Fig. 8). Furthermore, cirque-floor elevations (mean 1667 ± 122 m) indicate that the ELA was about 276 m and 180 m higher than that present in Ogilvie Mountains (OM) during Reid and McConnell glaciations, respectively, and about 260 m lower than the contemporary ELA in the Itsi Range (Table 2). This is consistent with the view of Ward and Jackson (1992) that localized high aridity existed in GR at the climax of the McConnell Glaciation relative to divide areas of the Cordilleran Ice Sheet to the east in Pelly Mountains. The quality of cirque form is high: grade 1 and 2 cirques comprise 92% of the population. The apparent explanation for the lack of degraded (grade 3 and 4) cirques at lower elevation in GR is its history as a nunatak: trim-lines of the surrounding Reid and McConnell ice sheets defined the lower limit of cirque formation.

Dawson Range

The Dawson Range was beyond the limit of the last Cordilleran Ice Sheet. However, glaciers flowed through valleys of the eastern parts of Dawson Range during pre-Reid glaciations and pressed against the western and southern margins of the range during the Reid Glaciation (Jackson, 2000). Duk-Rodkin (1999) mapped cirques on scattered upland surfaces as being pre-Reid. These upland surfaces are surrounded by unglaciated terrain. Bostock (1936) noted that the valley heads resemble cirques formed by Early Pleistocene ice. High-grade cirques are found only on Apex Mountain, in the highest part of the Dawson Range, where one cirque contains a small lake held in by morainal debris and solid rock. Bostock (1936) believed this cirque developed during the last glaciation. Its 1585 m elevation falls within the elevation range of 'McConnell' cirques in OM, corroborating Bostock's age estimate. Two cirques on Apex Mountain were removed from the descriptive statistics (Table 2) due to their apparent youth.

Cirque-floor elevations in the northern Dawson Range (NDR) and southern Dawson Range (SDR) (mean 1433 ± 125 m and 1451 ± 117 m, respectively) indicate that the ELA was about 40-60 m higher than that present in Ogilvie Mountains (OM) during the Reid Glaciation, 40-55 m lower than that present in OM during the McConnell Glaciation and about 480-496 m lower than the contemporary interglacial ELA in the Itsi Range (Table 2). High-quality NDR cirque forms have a mean cirque-floor altitude of 1397 to 1544 m, while low-quality cirque forms have a mean altitude of 1371 to 1503 m (0.95 confidence interval) (Fig. 7).

NDR is markedly asymmetric with respect to aspect (marginal glaciation), with the average cirque facing 355°. The aspect distribution in the SDR is symmetric, indicating little preference for aspect (robust glaciation) (Fig. 8). The striking difference in vector strengths suggests that SDR experienced a lower snowline than NDR during pre-Reid glaciations.

Crag Mountain upland

Crag Mountain upland (CMU) is most distant from the limits of past ice sheets of all the upland areas investigated. The bimodality of the altitudinal frequency distribution suggests two separate populations of cirque forms (Fig. 6). The major mode includes the cirque forms noted by Lowey (2000) in the Fifty Mile Creek basin, as well as forms from the larger CMU region. Lowey (2000) correlates the high quality CMU forms with the Eagle glaciation of Alaska and the Reid glaciation in the Yukon. These cirque forms are at a mean elevation of 1346 ± 92 m and have a length:width ratio of 1.3. The minor, lower elevation mode (mean 1054 ± 96 m) represents the 'cirque problematica' of CMU. These cirque-like forms are similar to stream-head bowl-shaped depressions in areas covered by glaciers during the Charley River Glaciation in the Yukon-Tanana Upland (F. Weber, pers. comm., 2000). The minor, low-quality mode forms in CMU have an average length:width ratio of 1.0, being on average 631 m wide and 690 m long. The average quality is grade 3, with all but two being grade 3 or 4. If they are Early Pleistocene cirques, their mean elevation of 1054 ± 96 m indicates that the ELA was about 337 m lower than that present in Ogilvie Mountains during Reid Glaciation and about 875 m lower than the contemporary interglacial ELA in the Itsi Range (Table 2). Crag Mountain upland as a whole exhibits a northeastward resultant and weak asymmetry (Fig. 8), indicating that it has experienced alpine glaciation during the Early Pleistocene.

DISCUSSION

The overlap between 0.95 confidence intervals of high- and low-grade cirques indicates that the low-grade cirques are likely part of the same population, although perhaps older and degraded (Fig. 7). Exceptions to this are the poor-quality low-outliers of Crag Mountain upland, the 'cirque problematica,' which are at a significantly lower altitudinal level, although their distribution is not so drastically different as to preclude a glacial origin. They could be glacial cirques dating to the Early Pleistocene and highly degraded by nivation. Since younger glaciations were less extensive than older glaciations, cirques at lower altitudinal levels would have experienced more degradation from periglacial processes compared to higher cirques. According to Evans (1999), "drastic changes in the spatial pattern of climate would be needed if cirque glaciers were not to grow while ice cover expanded greatly elsewhere" (p. 33). Evans suggests a hypothesis of time-transgressive cirque glaciation whereby as higher mountains become covered by ice caps, previously unaffected lower mountains may undergo cirque glaciation. This would lead to more altitudinal variation and higher complexity of cirque aspects (Evans, 1999).

The 0.95 confidence intervals of mean cirque-floor elevation indicate that the ELAs throughout west-central Yukon Territory fell approximately the same amount during each glaciation, as all intervals tend to overlap. This likely indicates a similarity of summer temperatures throughout the region during glaciations. The fact that glaciers formed in the Ogilvie Mountains during the Reid and McConnell glaciations, but not at comparable altitudes in the Dawson Range and Crag Mountain upland, indicates that moisture availability was the controlling factor in the extent of alpine glaciation. Burn (1994) suggests that the greater extent of ice sheets in central Yukon during pre-Reid glaciations is attributable to the St. Elias Mountains being substantially lower during the Late Pliocene/Early Pleistocene, thus decreasing their rain-shadow effect. This explanation could presumably be applied to the extent of cirque glaciation as well.

However, recent work in the interior of North America since Burn (1994) leads us to propose another possible explanation for a progressive decrease in moisture reaching the Yukon interior. Pleistocene ice sheets influenced atmospheric circulation, either through associated high-pressure systems deflecting storm tracks and reducing precipitation, or by acting as precipitation traps (Porter, 1964). Barendregt and Irving (1998) presented evidence that continental ice sheets became progressively larger through the late Cenozoic in North America. This culminated with the Late Wisconsinan Laurentide Ice Sheet; it had the greatest extent of all ice sheets in Western North America (Duk-Rodkin et al., 1996; Jackson et al., 1999). The progressive decrease in the extent of Cordilleran ice sheets in Yukon and increase in the marginality of cirque glaciation in uplands west of these ice sheets through time from pre-Reid to McConnell glaciations may be linked to the progressive increase in the size of continental ice sheets east of the Cordillera. The high-pressure systems associated with successively larger continental ice sheets may have been progressively more effective in steering storm tracks away from west-central Yukon during glacial periods. This would account for the progressively limited ice sheet and cirque glaciation in west-central Yukon throughout the late Cenozoic.

IMPLICATIONS FOR PLACER GEOLOGY

Cycles of aggradation and degradation in stream systems can be caused by the growth and disappearance of alpine ice centres in upland areas (Vandenburghe, 1993). Lowey (2000) suggested that glaciation may have been a control in placer formation along streams draining Crag Mountain upland (CMU). With the exception of the upper Sixtymile River basin and Matson Creek, the streams draining CMU are unexplored or are just starting to be explored for placer gold (e.g., Fifty Mile Creek). The work reported in this paper suggests that other areas of the Stewart River map area (115 N and O) with extensive elevations in excess of 1200 m likely supported cirque glaciers or small ice caps during the Early Pleistocene. Consequently, deposition of placer gravels, and reworking and concentration of gold placers in those areas, may have had a glaciofluvial component. The South Klondike Placer District (e.g., Thistle, Kirkman and Barker creeks) has extensive upland areas exceeding 1200 m. This possibility of past cirque glaciation should be kept in mind during the exploitation and interpretation of placers gravels in these areas.

CONCLUSIONS

Cirque-like landforms in Dawson Range and Crag Mountain upland are glacial in origin, although some are highly degraded by periglacial processes. Alpine glaciation in west-central Yukon was time-transgressive, whereby some cirques were active during early glaciations but inactive during subsequent glacials. Glacial deposits associated with valley glaciers that originated in cirques of the Crag Mountain upland have soils developed on them, suggesting that the last ice advance occurred during the Early Pleistocene pre-Reid glaciations; the paleo-ELA of high-quality cirques is between 1217 and 1417 m (0.95 confidence interval). A relative decrease in moisture reaching west-central Yukon during the Reid and McConnell glaciations, as compared to pre-Reid glaciations, resulted in the cessation of cirque glaciation in Crag Mountain upland and most of the Dawson Range. The authors suggest that the progressive marginality of cirque glaciation and progressive decrease in the extent of ice sheets in west-central Yukon through the late Cenozoic may be related to the progressive enlargement of continental ice sheets east of the Cordillera during the same interval of geologic time. High-pressure systems associated with the continental ice sheet may have diverted storm tracks away from west-central Yukon.

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Geology and U-Pb zircon geochronology of upper Dorsey assemblage near the TBMB claims, upper Swift River area, southern Yukon

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ABSTRACT

Meta-sandstone, siltstone and phyllite, with marble and intermediate-to-felsic tuffaceous horizons, host the Munson (TBMB) and Mod zinc-lead occurrences, about 7 km southwest of the Dan and Crescent properties. These host rocks are part of the Late Devonian Dorsey assemblage. Complexities resulting from isoclinal folding and faulting inhibit direct correlation of strata from one ridge exposure to another. The strata are overlain by dark meta-siltstone of the mid-Mississippian Swift River succession. Although faulted, the lack of a strong lithologic contrast between the units suggests only minor dislocation.

Pre-Jurassic and Cretaceous granites and a diorite sill intrude the Dorsey rocks. Chloritic tuffaceous layers host showings of pyrrhotite, chalcopyrite and sphalerite; carbonate pods contain sphalerite + galena ± pyrrhotite; and quartz-feldspar meta-tuff layers are pyritic.

U-Pb zircon age results for leucosome from a nearby exposure of lower Dorsey rocks indicate an approximate crystallization age of 373 Ma, and about 358 Ma for a granitic dyke in the upper Dorsey assemblage, bracketing the age of deposition of this Yukon-Tanana Terrane assemblage.

RÉSUMÉ

Le grès, le siltstone et le phyllade métamorphisés, avec marbre et horizons tufacés intermédiaires à felsiques, contiennent les indices (Zn-Pb) de Munson (TBMB) et de Mod à environ 7 km au sud-ouest des indices de Dan et de Crescent. Ces roches encaissantes font parties de la série de Dorsey du Dévonien tardif. La complexité due à un plissement isoclinal et à une fracturation empêche d'établir une corrélation directe d'une crête exposée à l'autre. Ces strates sont recouvertent par le siltstone métamorphisé foncé de la succession de Swift River du Mississippien moyen. Même si ce contact semble être une faille, l'absence d'un contraste nettement lithologique entre les unités font supposer une dislocation mineure.

Des granites et un filon-couche de diorite préjurassiques et crétacés injectent les roches de Dorsey. Les couches tufacées chloritiques logent des indices de pyrrhotite, de chalcopyrite et de sphalérite; les masses carbonatés contiennent sphalérite + galène ± pyrrhotite; et les couches de tuf métamorphisé à quartz-feldspath sont pyriteuses.

Les résultats de datations U-Pb sur le zircon d'un mobilisat migmatitique provenant de la partie inférieure de la série de Dorsey indique un âge de cristallisation approximatif de 373 Ma, et d'environ 358 Ma pour un filon granitique dans la partie supérieure de la série de Dorsey. Ces âges délimitent la période de déposition de cette série du terrane de Yukon-Tanana.

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INTRODUCTION

Yukon-Tanana Terrane is a composite of continentally derived strata overlain by volcanic arc successions and intruded by granitic rocks of characteristic Mississippian age. Most areas are polydeformed, and only recently have several Late Paleozoic stratigraphic successions been differentiated as a result of new mapping and isotopic dates. Better understanding of these rocks (e.g., Nelson et al., 2000) and new maps of their distribution can focus exploration for stratabound mineral deposits to favourable stratigraphy (including correlative units separated by faulting and at different metamorphic grade).

The southern prong of the Yukon-Tanana Terrane extends south of the Yukon-BC border near the hamlet of Swift River. There it broadly comprises three tectono-stratigraphic units. These are Neoproterozoic (?) to Paleozoic pericratonic terranes (namely Big Salmon Complex and Ram Creek assemblage); late Paleozoic arc and basin successions (Klinkit and Swift River groups); and sheared, highly metamorphosed Mississippian to Permian? units (Dorsey assemblage; see Fig. 1). In the Dorsey assemblage (Stevens and Harms, 1996; Roots et al., 2000) are several occurrences of felsic schist (e.g., Nelson, 1997, 2000), the age of which (Roots and Heaman, 2001) is similar to felsic rocks that host significant volcanogenic massive sulphide occurrences in Yukon-Tanana Terrane near Finlayson Lake (e.g., Murphy, 1998).

This paper describes the stratigraphic setting of the felsic tuffaceous rocks of Dorsey assemblage where they are best exposed near stratiform Zn-Pb occurrences that include Crescent (Atom) and Dan (Yukon MINFILE 2001, 105B 026 and 027; Bremner and Liverton, 1991a,b; D'el-Rey Silva, et al., 2001a). Although these and nearby showings are clearly skarn-related, the felsic rocks are more abundant than previously recognized, and abundant pyrite is associated with them. Furthermore, previous cursory examination of these rocks has led to the suggestion that they may be a structurally emplaced slice of a younger unit, such as Klinkit Group (Roots et al., 2000) or Ram Creek assemblage (D'el-Rey Silva et al., 2001b). The work described here refutes these earlier notions.

The regional mapping project for which this study is a part included geochronology research in order to place constraints on the probable oldest and youngest age of sedimentation. The appendix describes further attempts to isotopically date the Dorsey assemblage.

REGIONAL TECTONIC FRAMEWORK

Rocks of the Yukon-Tanana Terrane were deformed in pre-Mississippian and mid-Permian time (Mortensen, 1992; Murphy and Piercey, 1999), then pushed north- and eastward over the miogeoclinal sedimentary apron of ancestral North America (e.g., Snyder et al., 2002), beginning in Middle Jurassic time. The Yukon-Tanana Terrane is therefore a relatively thin carapace of strongly deformed, dismembered and admixed stratigraphic sequences or assemblages (see Colpron and the Yukon-Tanana Working Group, 2001 for assemblage summary), and their continuity is further offset by major transcurrent faults, such as Tintina (Fig. 1).

In southern Yukon, Yukon-Tanana Terrane includes the Dorsey assemblage and overlapping Swift River group. Near the head of Swift River in southern Yukon and also near the head of the Cottonwood River in northern British Columbia, the Dorsey assemblage can be divided into a lower part that contains abundant sill-like bodies of metabasite, and an upper part, which does not. The lower part consists of amphibolite and garnet amphibolite interlayered (interbedded?) with metatuffs, fine-grained quartzite, biotite-muscovite + graphite schist, quartzofeldspathic schist (metamorphosed chert, argillite and orthoquartzite, respectively), and marble. The upper part consists of thinly layered impure quartzite with biotite-muscovite partings (meta-argillite); thin bedded limestone and calc-silicate rock; dark grey meta-chert; and interlayered chlorite + muscovite + garnet schist and quartz-muscovite schist that represent intermediate to felsic tuff protoliths (J. Nelson, pers. comm., 2001). A quartz-eye metarhyolite from the upper Dorsey assemblage near Munson Lake yielded a U-Pb age of 355 ± 2.7 Ma (Late Devonian; Roots and Heaman, 2001).

The Swift River group exhibits two depositional themes: hemipelagic, deep-water sedimentation resulting in thick successions of dark-coloured chert and argillite; and sporadic siliciclastic influx, represented by quartzite/phyllite sequences near its base, and local units of quartz wacke, grit, argillite and phyllite, particularly near its top (J. Nelson, pers. comm., 2001). This succession is unconformably overlain by the Screw Creek Limestone of late Mississippian to early Pennsylvanian age.

In the Swift River area these units are also thermally metamorphosed by diorite of probable Jurassic age and the Cretaceous Seagull Batholith.

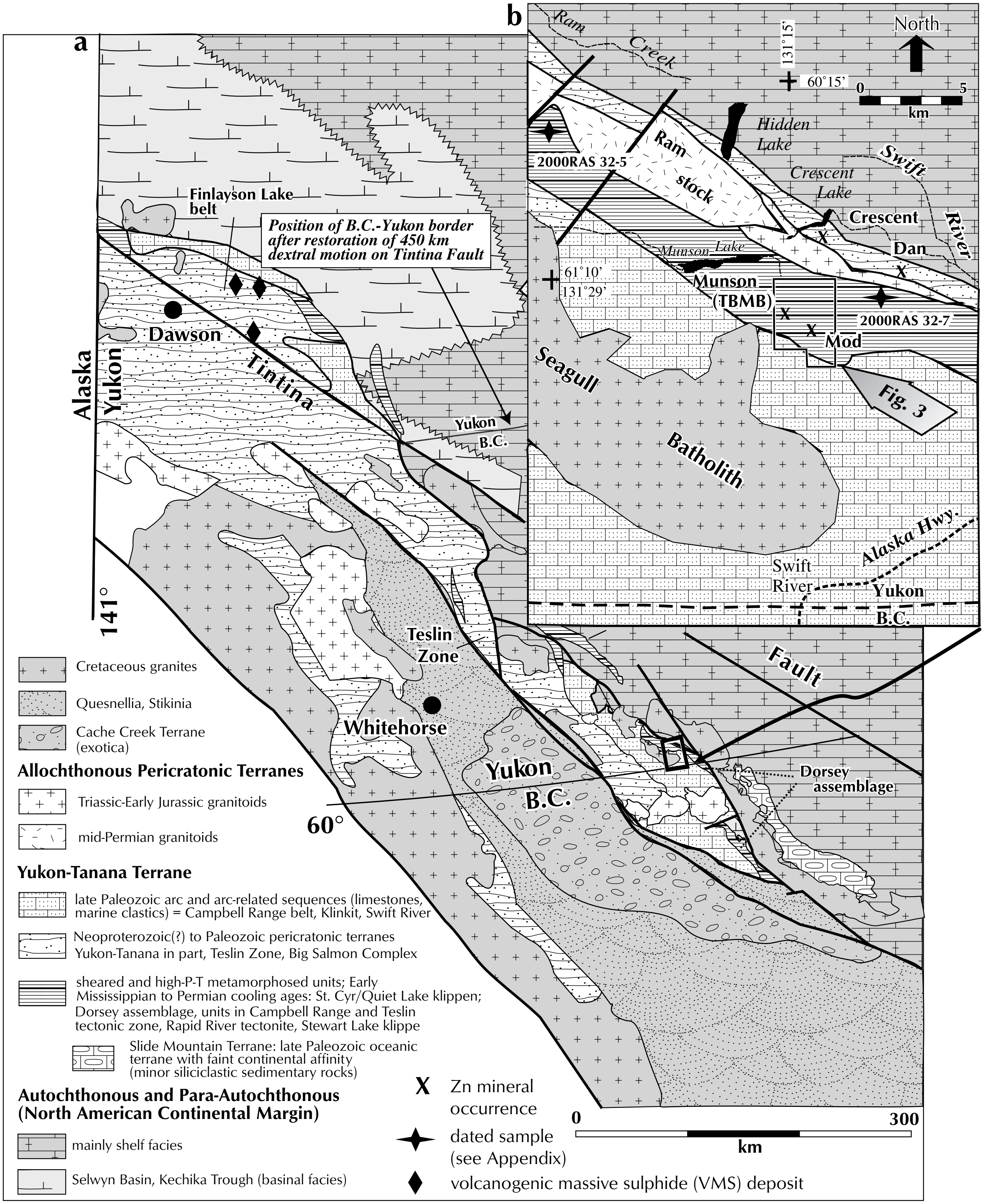

***Figure 1. (a)** Tectonic elements in Yukon-Tanana Terrane of southern Yukon and northern British Columbia (modified from Nelson et al., 2000). **(b)** Distribution of main geological units, and location of the principal Zn occurrences, isotopically dated igneous samples (see Appendix), and the study area (Fig. 3).*

GEOLOGY OF THE TBMB AREA

ACCESS AND PREVIOUS WORK

The current study area lies 15 km north of the hamlet of Swift River, Yukon. It is accessed by 4-wheel drive vehicle on an upgraded bulldozer track that extends 7 km south and west from a former exploration camp (for the Dan-Crescent mineralization) at the end of a 37-km-long gravel road leaving the Alaska Highway at km 1162. It is an area of steep-sided mountain ridges (Fig. 2) separated by alpine valleys.

Showings of magnetite and pyrrhotite with sphalerite and galena were discovered in 1946 by prospectors working for Hudson Bay Mining and Smelting Company, Limited. Now known as Bom, Munson (TBMB) and Mod occurrences (Yukon MINFILE 2001, 105B 028, 029 and 031), they were drilled in 1947 and 1969, and have been periodically restaked and trenched since.

Poole et al. (1960) included this area in a broad map unit (Dorsey Group) during reconnaissance mapping; the rocks were later subdivided by Abbott (1981), and named the Dorsey and Swift River assemblages based on assumed provenance and differing metamorphic grade by Stevens and Harms (1996, 2000). The current study extends the structural study of the TBMB occurrence by D'el-Rey Silva et al. (2001b) to adjacent ridges and provides a more regional perspective.

PRESENT WORK

Ridges surrounding the TBMB occurrence provide excellent exposure of layered rocks (hereafter referred to as the 'TBMB succession') and their contact with overlying Swift River strata.

Foot-traverses by Liverton and Roots covered all ridges and most prominent outcrops in the area (Fig. 3; features mentioned in the text are located by UTM coordinates, based upon NAD 83, Zone 9 grid system). The first two authors also measured two transects of continuous across-strike exposure on adjacent ridge crests (referred to as 'TBMB' and 'East' ridges), using a 60-m tape to survey the lithologic variety of the layered rocks. As a result of deformation strata thickness is not primary,

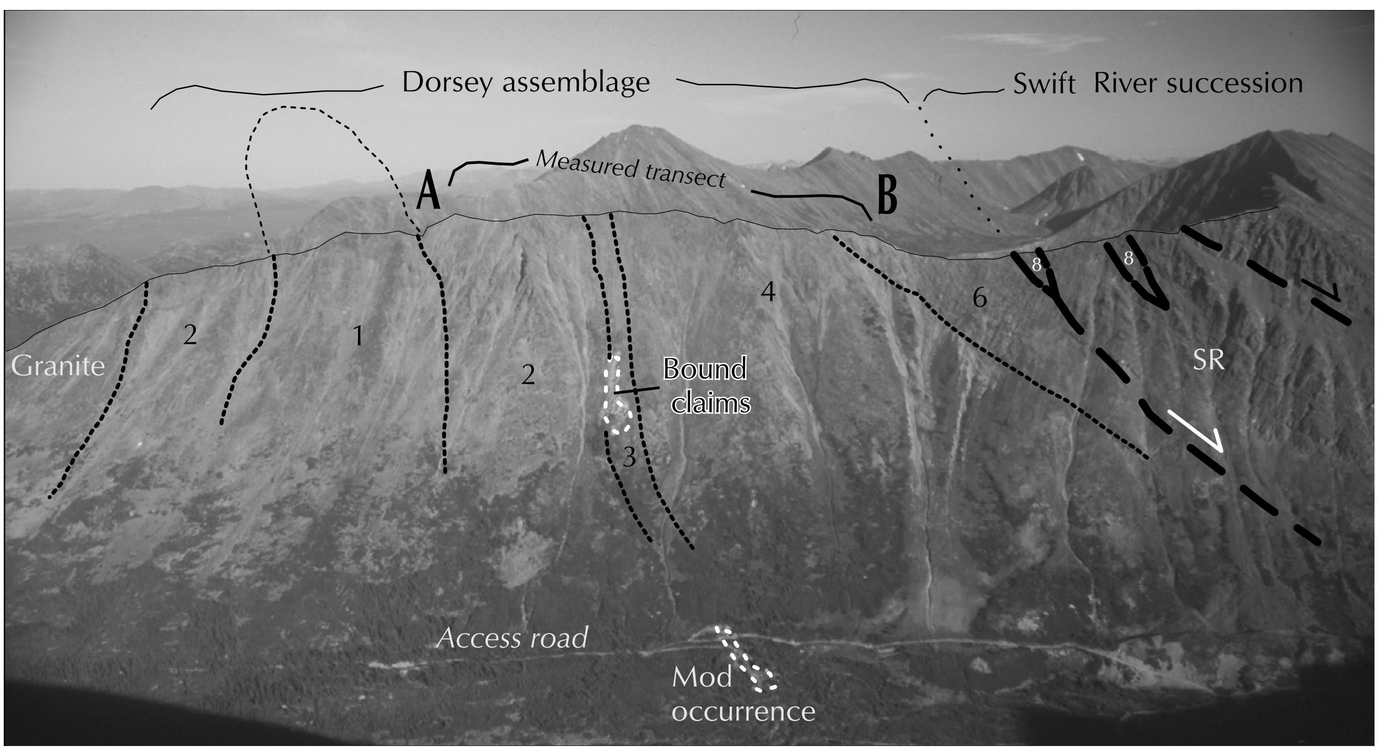

Figure 2. *Looking southeast at the profile of East ridge (field of view: 2 km) indicating units described in text and in the legend of Figure 3.*

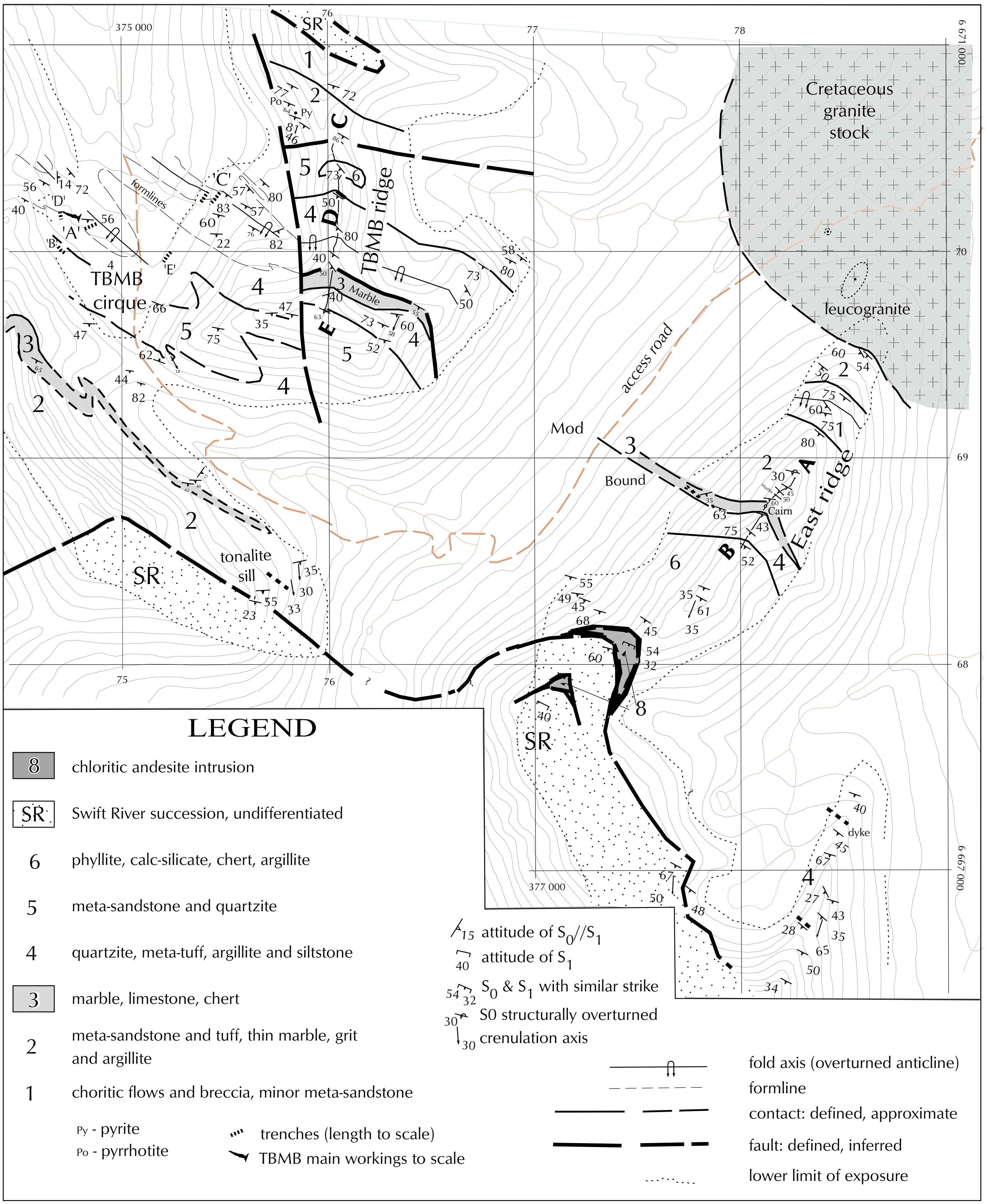

Figure 3. *Sketch geological map of the study area surrounding the TBMB mineral occurrence.*

geological contacts are transposed parallel to tectonic foliation, and this foliation obliterates primary depositional textures. Six numbered lithological units are described here.

Unit 1: Mafic flows and breccias.

The structurally lowest unit (north end of the generally south-dipping succession) consists of dark green to grey, massive or thickly layered, amphibole-chlorite ± quartz-biotite schist, interlayered with brown meta-sandstone. The only primary volcanic structures are calcite clots in one layer, which may originally have been amygdules. Most layers contain hornblende crystals retrograded to chlorite. At the north end of East ridge, decimetre-scale brown psammite and gritty layers with chloritic matrix interspersed with mafic layers indicate that the latter were probably extrusive flows and breccias.

Unit 2: Mixed meta-volcanic and sedimentary rocks

Metre-scale layering is plainly observed from a distance in this light brown to greenish weathering unit but these contacts are difficult to discern in outcrop. The lower part (unit 2a) is dominated by meta-sandstone, meta-siltstone and thin black argillite layers, with at least two horizons of quartz-feldspar schist. The upper part (unit 2b) includes grey and brown meta-sandstone with laminated chlorite schist (probably mafic meta-tuff), thin layers of grey quartzite and beds of limestone up to 2 m thick.

Thin sections of the schist reveal isolated euhedral quartz and feldspar phenocrysts, some exhibiting embayments. The authors therefore conclude that the schist was a felsic meta-tuff.

Unit 3: Carbonate and bedded meta-chert

Marble, limestone and minor dolostone form a prominent white band 30-50 m wide, extending eastward from TBMB ridge. Its base is not exposed (the argillite is sheared immediately below, suggesting a fault) and most of the band is coarse-grained white marble. The upper third of the unit is thin- to medium-bedded limestone in which vague columnar structures are locally discerned.

This marble contains no evidence of multiple tight folds, and the previous interpretation by D'el-Rey Silva et al. (2001b) of its thickness resulting from folding of a thin limestone bed mapped in the TBMB cirque to the west, is rejected.

The limestone band described above ends abruptly west of TBMB ridge (Fig. 4). Another band of white carbonate is exposed on the ridge 1 km to the southwest. These two outcrops are interpreted as the same unit, separated by a north-northwest trending, steeply east-dipping fault. The

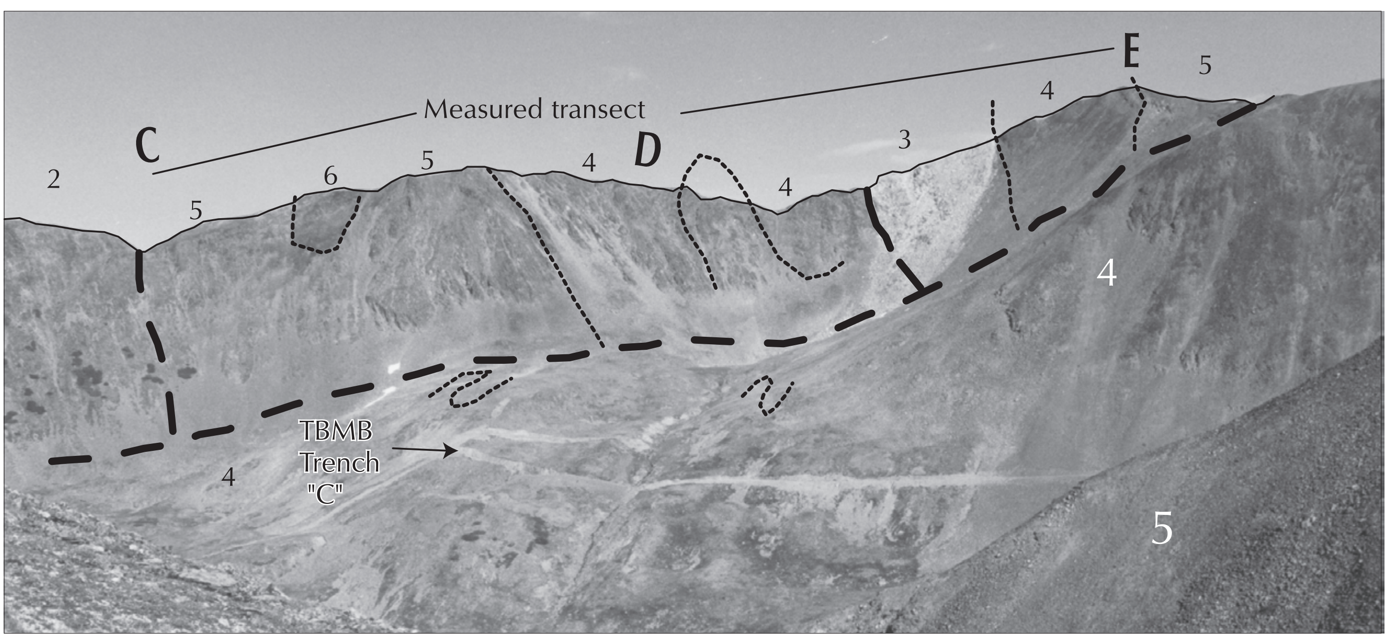

Figure 4. *Looking eastward at profile of mid-section of TBMB ridge, indicating units and structures described in the text and in the legend of Figure 3. The measured transect is 760 m long.*

existence of this fault is indicated by a shallow ditch on the spur south of TBMB ridge (UTM 375890E, 6669885N), which is an abrupt lithologic break between greenish psammite (unit 4) and grey phyllite/quartzite (unit 5).

The prominent white carbonate band is not present on the crest of East ridge, but is exposed midway down the western slope (the 'Bound' showing, Figs. 2, 3). Following the tectonic layering to the ridge crest suggests the white limestone undergoes a transition to light brown-weathering, medium-bedded chert, which comprises a 30-m section of the ridge crest, including the cairn on the highest point. This could be a lateral facies transition, or the chert may have replaced part of the carbonate through diagenesis, regional or contact metamorphism — exposure is insufficient to determine.

Unit 4: Quartzite, felsic meta-tuff and fine-grained metasedimentary rocks

Grey-white quartzite, metre-thick beds of coarse quartz-feldspar augen schist, thin beds of green and purple meta-chert, dark grey argillite and meta-siltstone comprise an upper mixed unit in the TBMB succession. On East ridge the quartzite has maroon (hematitic) stains parallel to foliation. At the south end of TBMB ridge quartzite and carbonaceous metasiltstone enclose a quartz-feldspar schist layer at least 10 m thick, as well as a 2-m thick grey marble and thinner calc-silicate layers.

Unit 5: Meta-sandstone and quartzite

This unit, dominated by brown siliclastic layers without argillite, tuff or carbonate interbeds, underlies the southwest spur of the TBMB ridge, and is also identified at the north end of the same transect. Some metre-thick layers of white-weathering medium-bedded meta-chert are present, and in the west where deformation is slightly less pervasive, intraclasts near the top allow determination of upright bedding. In other places ptygmatic folding and quartz boudinage indicate the futility of applying such observations to large areas.

Unit 6: Calc-silicate rock and phyllite

The uppermost unit of the TBMB succession is defined from its exposure on East ridge, directly beneath the dark cliffs of Swift River strata. The long saddle contains only sparse outcrops of grey phyllite, with lesser green-yellow calc-silicate rock and dark argillite. North of the transect on TBMB ridge, a knob of pyritic black argillite is correlated with this unit. This unit is present beyond this area: it was described below the Swift River strata, 7 km east of the TBMB (see Roots et al., 2000).

Swift River Group

Dark-weathering siltstone and argillite borders the study area on the south (Fig. 3) and these rocks extend southward around the Seagull Batholith. These strata are less deformed and metamorphosed than the underlying TBMB succession and are regionally described by Nelson (2001). Although this extensive unit has not been directly dated, it predates late Mississippian-early Pennsylvanian limestone, and appears to be younger than mid-Mississippian, since it lacks the ca. ~340 Ma intrusions ubiquitous in Yukon-Tanana Terrane.

At the south end of the East ridge the lowest Swift River rocks are dark grey siliceous and phyllitic argillite. Centimetre-thick sandy intervals exhibit size grading and cross-stratification, indicating upright beds. Higher in the succession are layers of fine-grained brown quartzite several metres thick. On the ridge southwest of TBMB cirque, the lowest rock of Swift River Group is jet-black argillite with sandy intervals.

Unit 8

On East ridge, at the base of the Swift River Group, and also as a fault-bounded outcrop about 50 m stratigraphically above the base, is a black, dense, slightly magnetic, fine-grained andesite with slickensides. No features were found to indicate whether this rock was intrusive or a flow. The sheared zones are probably related to the competency contrast between the Dorsey and Swift River rocks during Jurassic deformation. The unfoliated nature of the andesite suggests its Jurassic or Cretaceous age.

Intrusive rocks

A sub-circular granitic stock underlies the northeast corner of the study area (Fig. 3), but other intrusions are too small to show on the map.

Pink to grey, medium-grained, unfoliated granite is exposed at the north end of East ridge and in a stream canyon below the access road. Although undated, its mineralogy and geochemistry (Liverton, 1992) indicate it is a satellite plug of the Seagull Batholith (mid-Cretaceous; nearest exposure is 5.5 km south). Granitic dykes within Swift River rocks on East ridge (e.g., at UTM 375572E, 6685593N) are likely apophyses of this intrusion.

A foliated tonalite sill near the southwest edge of the study area (at UTM 75858E, 6668510N) and a larger plug north of the area on TBMB ridge (close to the Verley (STQ) showing; Yukon MINFILE 2001, 105B 078) have similar texture and mineralogy to the meta-plutonic rock that yielded a Late Devonian (358 Ma) U-Pb zircon date (see Appendix).

Dark green, fine-grained andesite dykes less than a metre wide crosscut the TBMB succession on both East and TBMB ridges. Their age is unknown but in composition they resemble the andesite within the Swift River strata (unit 8).

STRUCTURE

The TBMB succession exhibits a strong planar tectonic fabric. Rootless near-isoclinal fold hinges are common in thinly banded rocks. Regional metamorphism is upper-chlorite to lower-amphibolite grade with garnet and secondary hornblende developed in rocks of appropriate composition. The S_1 layering dips moderately to steeply southwest, and lineations measured on prismatic secondary minerals and minor fold axes plunge south.

Isoclinal, metre-wavelength F_1 folds are refolded by more open, mountain-scale F_2 folds that are overturned to the northeast (D’el-Rey Silva et al., 2001b). Several outcrops (e.g., around UTM 375600E, 6670200N) exhibit mesoscopic chevron folds with inter-limb angles of ~25-30° (Fig. 5), which is considerably less than the ‘lock-up’ angle for brittle deformation. Such folding suggests the presence of high-strain zones within the F_2 structures, likely within the axes of these folds. F_2 axial traces plunge south and major antiforms were deduced from repetition of tectono-stratigraphic units.

D’el-Rey Silva et al. (2001b) measured minor structures in the TBMB cirque and extrapolated the derived antiforms eastward. The transect along the TBMB Ridge shows that the thick marble there is not the result of tight isoclinal folds of the thinner carbonate layers mapped around the TBMB cirque — it is a separate carbonate unit with contrasting lithological units above and below. Furthermore on East ridge the lack of repetitive stratigraphy suggests that the large antiform proposed in D’el-Rey Silva et al. (2001b) does not exist. Instead the authors of the current study infer the structural style to be cascading northerly verging folds with attenuated limbs similar to those described by D’el-Rey Silva et al. (2001b) in the TBMB cirque.

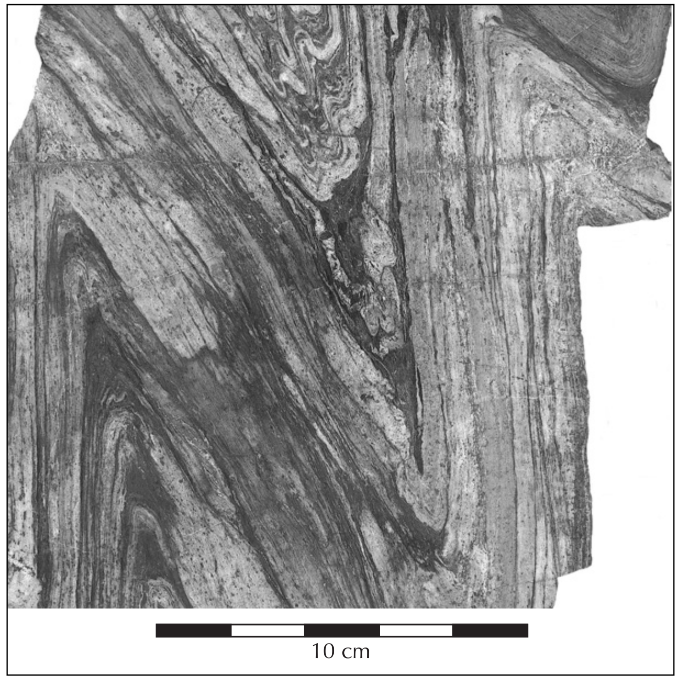

Figure 5. *Sawn slab of green-grey meta-siltstone collected from talus of unit 4, about 500 m southeast of the TBMB trench ‘C’. Light-coloured minerals are quartz, feldspar and ?diopside; dark patches contain hornblende and magnetite.*

MINERALIZATION

Regionally the TBMB, Mod occurrences and Bound showing are aligned with the northwest-trending foliation, however each has distinctive mineralogy:

(i) At the Bound showing, sphalerite and euhedral magnetite replace portions of a marble lens;

(ii) At the Mod (Bom) occurrence, bands of massive pyrrhotite, sphalerite and galena up to 15 cm thick lie within chlorite and amphibole-rich layers of Unit 2;

(iii) The highest economic grade showing, of the TBMB is at trench ‘A’ where coarse-grained sphalerite and galena are abundant along the irregular contact of a massive white marble and siliceous metasedimentary rocks (unit 4). In places, chlorite and actinolite form veins and stringers within the marble.

(iv) Sphalerite occurs in mafic rocks in the antiform core exposed at trench ‘C’, and pyrrhotite and chalcopyrite are disseminated in mafic layers in trench ‘E’.

(v) Disseminated pyrrhotite and sphalerite occur in chloritic metavolcanic rocks (unit 1) immediately north of the TBMB ridge transect.

DISCUSSION

1. CORRELATION AND PALEO-ENVIRONMENT OF UPPER DORSEY ASSEMBLAGE

The authors conclude that the TBMB succession is part of the Dorsey assemblage, despite its lower state of strain and greater lithological variety when compared to other Dorsey exposures. It is of higher metamorphic grade than Ram Creek assemblage to the north, and contains felsic metavolcanic rock, a lithology notably absent in the Klinkit Group. Furthermore, felsic tuff and foliated granitic intrusions along strike with the TBMB succession are older (ca. 357 Ma (upper Devonian); Roots and Heaman, 2001; sample 32-7 in appendix) than Ram Creek assemblage (mid-Mississippian: 349 ± 1.1 Ma felsic volcanic unit 1 km west of Hidden Lake, U-Pb zircon date by J.K. Mortensen, pers. comm., 2002; and a ca. 342 Ma intrusion, Roots and Heaman, 2001). All Klinkit Group ages are late Mississippian or younger.

The TBMB succession, however, has greater lithologic variety and preserved layering than most exposures of the Dorsey assemblage. Only one other locality, about 24 km southeast of the hamlet of Swift River, is known. That 200-m thick exposure is described by Nelson (2001, p. 62): "above the highest grits, a thin and highly variable upper Dorsey assemblage — garnetiferous and magnetite-bearing green biotite-sericite-chlorite schist, quartzite, amphibolite, black phyllite and quartz-sericite schist — passes into monotonous black chert and phyllite/argillite of the lower Swift River..." These metaclastic sedimentary rocks likely correlate with the TBMB succession.

The TBMB succession appears to represent distal products of bi-modal volcanism — pyroclastic flows or settling from the water column — interbedded with quartz sandstone, siltstone, mudstone and chert. The thin limestone and chert beds suggest a deep-water depositional environment. A possible tectonic setting for the TBMB succession would be the sedimentary apron at the base of a seamount or volcanic island. The variety of source material and alternation of sediment types suggest deposition as a deep-sea fan below a submarine canyon from a rapidly eroding source area. The lack of large clasts and presence of fine sediment suggest a position near the limit of the fan. Alternation of sediment types is well documented surrounding volcanic arc islands in Indonesia (e.g., Mitchell and Reading, 1971).

2. THE CONTACT BETWEEN THE DORSEY AND SWIFT RIVER ROCKS

This boundary between the Dorsey and Swift River rocks is visible on the west side of East ridge (Fig. 2), but is difficult to observe at close range among the low cliffs. It was not specifically studied, but the authors present several observations.

i) The Dorsey layering is generally more steeply dipping than the Swift River strata on East ridge. On the ridge crest the contact is a metre-thick band of strongly cleaved rock at the top of relatively incompetent unit 6, overlain by 10 m of andesite (unit 8; considered intrusive) overlain by argillite.

ii) On the ridge southwest of TBMB, gently south-dipping Swift River black argillite directly overlies steeply foliated calc-silicate and psammitic rocks, which the authors interpret as an overturned limb of unit 2.

iii) Toward its top the Dorsey assemblage becomes finer grained and increasingly carbonaceous, suggesting waning volcanism and erosion of the Dorsey arc. There is no great lithologic distinction between these and overlying Swift River strata, which was deposited in a basin without volcanic input. Regionally the authors have determined that these units are in correct stratigraphic sequence: a major thrust fault bringing older over younger is not present here.

Regionally the contact between these two units is a fault wherever it is exposed. South of the hamlet of Swift River, Nelson (2001) noted that the contact was sheared and the shear bands and minor faults dip more steeply than the overall foliation. A top-to-the southwest, normal shear sense was determined from thin section by Nelson (2001) and is locally found in outcrop (M. de Keijzer, pers. comm., 1999). Near the TBMB, the contact is sheared but no small-scale indicators reveal the primary sense of motion. Nevertheless, the planar nature of the shear — slicing across the tightly folded underlying TBMB succession — clearly indicates these units came in contact relatively late in the tectonic history. It is possible that Swift River strata were detached during regional uplift resulting from Jurassic or Cretaceous intrusions. The down-to-the-southwest slip (noted by Roots et al., 2000 and Nelson, 2001) is in the range of hundreds of metres, rather than kilometres, displacement.

3. ZN-PB-CU-AG METALLOGENY

The two 'trends' of zinc-dominated sulphide mineralization (Dan-Crescent, and Munson-Mod; Fig. 1) differ in metamorphic grade but not in style.

In the northern trend, trenches at the Dan occurrence exhibit discordant massive sphalerite and pyrrhotite with garnet and/or pyroxene and retrograde actinolite-chlorite adjacent to marble; and immediately south in the same area, pyrrhotite ± chalcopyrite occur in acid to intermediate tuffs. At the 'Lucy' prospect, 1050 m to the west-northwest along the regional trend, concordant pyrrhotite-chalcopyrite is present in finely banded actinolite-chlorite rock, adjacent to coarse euhedral magnetite. Finely laminated actinolite-chlorite with fine-grained red sphalerite is present ~50 m north (on the opposite side of the marble horizon intersected in drilling). Further west-northwest along the regional trend, the 'Gossan Hill' showing consists of massive sphalerite and discordant coarse magnetite; and the Atom occurrence consists of coarse massive sphalerite associated with ferroactinolite and hedenbergite. This northern trend, therefore, shows many features of contact metasomatic mineralization (Bremner and Liverton, 1991a,b).

The southern 'trend' of TBMB-Mod-Bound also shows mineralogy consistent with skarn origin. The Mod occurrence consists of pyrrhotite and sphalerite in mafic tuffaceous rocks; while the Bound and TBMB showings lie at the contact of carbonate with chlorite/amphibolite rock, similar to the Dan occurrence. Galena and pyrrhotite collected from three of these occurrences were analysed for lead isotopes and clearly demonstrate broadly mid-Triassic to mid-Jurassic model ages (Mortensen and Gabites, 2002). The 400-m-thick diorite and gabbro sill of inferred Jurassic age that lies between the Dan and TBMB occurrences is the most likely cause of the mineralization.

With the exception of disseminated pyrrhotite and sphalerite north of the TBMB ridge transect, no new indications of mineralization were discovered during this study.

CONCLUSIONS

i) The southern trend of Zn-Pb occurrences lie within rocks of Dorsey assemblage, in contrast to Ram Creek assemblage, which hosts the northern trend.

ii) Abundant felsic and mafic volcanic rocks are present in uppermost Dorsey assemblage.

iii) Dorsey assemblage is overlain by Swift River succession, but the fault is probably a relatively late feature (Jurassic or Cretaceous)

ACKNOWLEDGEMENTS

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APPENDIX
U-PB ZIRCON DATES FROM IGNEOUS ROCKS IN DORSEY ASSEMBLAGE

Determination of the age of the oldest and youngest rocks in polydeformed assemblage is a fundamental step in their tectonic reconstruction. The Dorsey assemblage is considered among the oldest elements of the Yukon-Tanana Terrane in southern Yukon. A felsic tuff from upper Dorsey assemblage is 355.6 ± 2.7 Ma in the Swift River area (Roots and Heaman, 2001); and a 355 Ma intrusion into lowest Dorsey assemblage in the Cottonwood River area (R. Friedman, pers. comm., 1999; in Nelson, 2000), further indicates the Late Devonian / Early Mississippian age of this unit. The samples reported here were attempts to discover if some Dorsey strata (e.g., the TBMB succession) are younger than this, and to find out whether significantly older rocks were present in lower Dorsey assemblage. Locations of the two samples (one east, the other west, of the TBMB area) are shown on Figure 1. Although the samples contained only poor quality zircon and did not yield tightly constrained dates, they confirm the age of Dorsey assemblage.

SAMPLE 2000RAS 32-5 - LEUCOSOME

High-pressure and -temperature mineral assemblages in the lower Dorsey assemblage were recognized by Stevens (1996) 23 km northwest (along regional trend) of the TBMB area. There the floor of a north-facing cirque, presumed to have been vacated by ice in the last century, spectacularly exposes quartz + biotite + feldspar + muscovite + horneblende ± garnet + actinolite schist and gneiss. Dispersed through these dark, migmatitic rocks are cream-coloured quartz-feldspar boudins, veins and rootless fold hinges. One of the largest of these anastomosing leucosome veinlets was sampled in hopes of finding isotopically dateable minerals.

Table 1. Description and location information for igneous samples in Table 2.

Zircon fraction	Description*	Location data
2000RAS 32-5: Leucosome of high-grade lower Dorsey Assemblage		
1	21 zircon crystals; equant, transparent with inclusions, non-magnetic	Yellow-white feldspathic melt segregation (1 m wide), west side of central gully at front of upper level of north-facing cirque at 5100′ elevation, 7 km northwest of outlet of Munson Lake; UTM: 366500E, 6679250N (NAD 27) in northwest 105 B/3 map area.
2	52 zircon crystals; slim prisms with 4-6:1 length:width, colourless, transparent, non-magnetic	
2000RAS 32-7: Meta-tonalite dyke in upper Dorsey Assemblage		
1	Single large prismatic zircon crystal; 2:1 length:width, colourless, nearly transparent; no chemistry	Foliated intrusion, 4 m x 100 m exposure on north slope of large hill at 5125′; 6.25 km southeast of outlet of Crescent Lake; UTM: 380900E, 6669091N (NAD 27) in east-central 105 B/3 map area.
2	11 poor zircon; prism fragments with 1:1 length:width, brown, transparent, magnetic, 1° tilt	
*Note: 1° is the angle of tilt of the Fanz isodynamic separator.		

This sample contained a moderate amount of tan to colourless, generally poor-quality zircon. The zircon population is complex with abundant crystals displaying visible core/overgrowth relationships. The majority of the zircon crystals are small resorbed tan prisms (<60 microns) with thin colourless tips, abundant fractures and associated turbidity (alteration?). A small proportion of colourless subhedral to euhedral prisms with no visible evidence of cores, fractures or alteration, were also recovered. The first two multi-grain fractions from this sample consisted of (#1) 21 equant colourless best quality grains and (#2) 52 narrow long colourless prismatic grains (Table 1). Crystals with visible cores were avoided during grain selection.

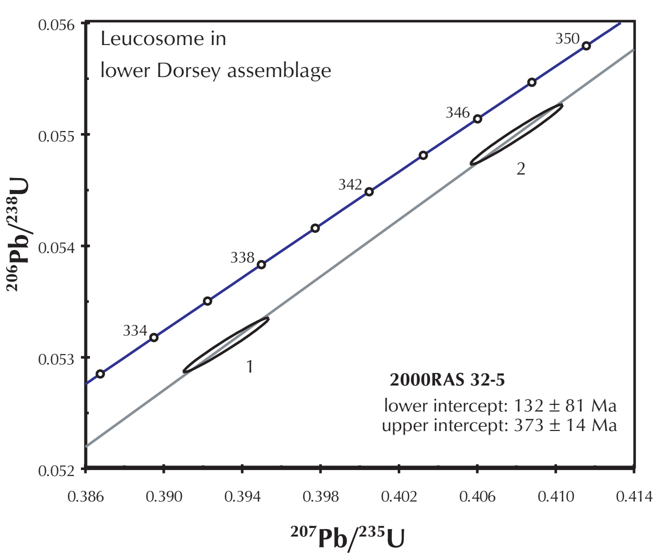

Figure 6. Concordia plot with 2-sigma error estimates for two zircon fractions of Dorsey leucosome.

The U-Pb results for these two multi-grain zircon fractions are listed in Table 2 and displayed in the concordia diagram (Fig. 6). Both fractions had similar chemistry with moderate uranium content (558-586 ppm) and slightly low Th/U (0.16-0.18). Although the analyses are slightly discordant, they have similar $^{207}Pb/^{206}Pb$ ages of 358.1 and 362.6 Ma, hinting at a Devonian crystallization age. A reference line constructed to pass through these two analyses yields an upper intercept age of 373 ± 14 Ma, which is interpreted as an approximate estimate for the crystallization age of this gneiss.

Discussion

The leucosome is presumed to be siliceous partial melt released during peak metamorphism (estimated 609-732°C and 7.7 to 14.1 kbar from mineral assemblages in nearby siliceous rock; Stevens, 1996) from the intermediate-to-mafic refractory parent. The 373 Ma date confirms conviction that the migmatitic rocks are older than the upper Dorsey assemblage of metasedimentary origin.

SAMPLE 2000RAS 32-7 – META-TONALITE DYKE

This strongly foliated plutonic rock intrudes psammite and garnet-bearing schist correlated with the TBMB succession in upper Dorsey assemblage. It outcrops over a 4-m-wide and about 100-m-long area on a north-facing slope,

Table 2. *Uranium-lead analytical data for igneous samples in Dorsey assemblage.*

Zircon fraction	Weight (µg)	U (ppm)	Th (ppm)	Pb (ppm)	Th/U	TCPb (pg)	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	% Disc
2000RAS 32-5														
1	16	585.6	90.7	29.9	0.16	8	3859	0.05311 ± 10	0.3932 ± 9	0.05369 ± 5	333.6 ± 0.6	336.7 ± 0.6	358.1 ± 2.1	7.0
2	35	558.3	100.5	30.0	0.18	23	2969	0.05500 ± 11	0.4080 ± 10	0.05380 ± 5	345.2 ± 0.7	347.4 ± 0.7	362.6 ± 2.2	4.9
2000RAS 32-7														
1	4	110	52	27	0.48	10	624	0.21589 ± 44	2.6864 ± 83	0.09025 ± 20	1260.1 ± 2.3	1324.7 ± 2.3	1430.8 ± 4.1	13.1
2	10	1155	204	56	0.18	7	4878	0.04991 ± 10	0.3694 ± 8	0.05368 ± 5	314.0 ± 0.6	319.2 ± 0.6	357.5 ± 1.9	12.5

about 300 m south of the previously dated felsic tuff (sample 99RAS 31-1; Roots and Heaman, 2001). In two outcrops the compositional boundary between tonalite and schist obliquely crosscuts the strong tectonic layering, indicating the intrusive relationship.

The rock is medium grained, with about 25% clear quartz prominent among the white feldspar and oriented hornblende. Primary minerals are entirely recrystallized.

A moderate zircon yield was recovered from the crushed and separated sample. The majority of zircon crystals are light tan and generally of poor quality with numerous fractures and turbid zones. Most are small (<80 microns) and dominantly resorbed subhedral prisms. A large number of grains display visible core/overgrowth relationships with the more obvious examples having turbid brown cores. A smaller number of the zircon crystals are colourless, transparent subhedral to euhedral prisms (generally 3:1 length:width ratios), and a very small proportion of tiny slender needles were also recovered.

Two zircon fractions were selected from this sample (Table 1) and U-Pb results are presented in Table 2. Fraction #1 was a large resorbed single grain interpreted to be a xenocryst, and it has a Mesoproterozoic $^{207}Pb/^{206}Pb$ age of 1431 Ma. Fraction #2, consisting of 11 light brown prisms and fragments, had a much higher uranium content (1155 ppm), lower Th/U (0.18) and a much younger $^{207}Pb/^{206}Pb$ age of 358 Ma. Because one fraction is a xenocryst, portrayal on a concordia diagram is not meaningful. The light brown prisms selected for fraction #2 are interpreted to be primary igneous crystals and, taking into consideration the slight discordance (12.5%), the best estimate for the minimum emplacement age is 358 Ma.

Discussion

The best estimate for the age of the orthogneiss is very close to that of the more precisely dated felsic tuff nearby. If the actual date is younger by a few million years, it would suggest that the sedimentary succession underwent rapid burial and was cannibalized by rising granitic magma in the roots of the volcanic arc.

The xenocryst date of 1.4 Ga coincides with a minor fraction of detrital zircon ages from Dorsey grits — only one of the twenty grains analysed by Ross and Harms (1998) was similar. The Dorsey sedimentary rocks are considered continentally derived, based upon the preponderance of zircons whose ultimate source was the western Canadian Shield (1.7-2.0, and 2.5-3.3 Ga;) and those ca. 1.4 Ga were considered to reflect local source areas (Ross and Parrish, 1991). The supposition of a local source is reinforced by the presence of this xenocryst, presumably gleaned from underlying crystalline rock, in intrusions of the Dorsey assemblage.

Preliminary geology of the southern Semenof Hills, central Yukon (105E/1,7,8)

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ABSTRACT

The volcano-sedimentary rocks of the Semenof block of central Yukon have not been closely studied in the past. Recent bedrock mapping in the southern Semenof Hills highlights the presence of possibly two exceptionally well preserved, undeformed and unmetamorphosed volcano-sedimentary sequences of Late Paleozoic age. The main sequence is composed, from bottom to top, of (1) 2- to 3-km-thick thinly bedded fragmental volcanic rocks interbedded with few limy intervals, (2) thick massive plagioclase- and clinopyroxene-phyric basaltic lava flows with clastic intervals, and (3) a 1- to 3-km-thick volcanic conglomerate. The other sequence, of lesser extent, consists of (1) a thin quartz-porphyritic felsic volcanic unit, less than 50 m thick, (2) 2- to 3-km of massive to pillowed fine-grained basaltic lavas, and (3) 100 m of fossiliferous Upper Carboniferous limestone. These two sequences sit in faulted contact on ~2 km of a deformed clastic sequence of unknown affinity.

RÉSUMÉ

Les roches volcano-sedimentaires du bloc de Semenof dans le centre du Yukon ont été sous-étudiées dans le passé. Une cartographie récente dans la partie sud des Semenof Hills vient tout juste de mettre au grand jour la présence potentielle de deux séquences volcano-sédimentaires d'âge Paléozoïque tardif non déformées et non métamorphisées. La séquence principale est composée, de la base au sommet, de (1) 2 à 3 km de roches volcaniques fragmentaires finement litées présentant quelques intervalles calcareux, (2) d'épaisses coulées de laves basaltiques porphyriques massives à phénocrystaux de clinopyroxènes et plagioclases présentant des intervalles clastiques et de (3) 1 à 3 km de conglomerat volcanique. La seconde séquence, de moindre importance, consiste en (1) une mince unité volcanique felsique porphyrique à phénocrystaux de quartz, (2) 2 à 3 km de laves basaltiques massives à coussinées finement grenues et (3) 100 m de calcaires fossilifères du Carbonifère supérieur. Ces deux séquences reposent en contact de faille sur environ 2 km d'une séquence clastique déformée d'affinité inconnue.

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INTRODUCTION

This report presents preliminary results from 1:50 000 scale bedrock mapping of the southern Semenof Hills (105E/1,7 and 8) in summer of 2002. Located approximately 60 km northeast of Whitehorse, the Semenof Hills form a band of north-trending rounded hills, between the Teslin and Big Salmon rivers in the Laberge map area (105E; Fig. 1). These hills extend for more than 100 km north to Little Salmon Lake, in Glenlyon map area (105 L; Fig. 1).

The Semenof Hills were previously mapped in the late 1970s-early 1980s at a scale of 1:250 000 by Tempelman-Kluit (1984). Tempelman-Kluit's work identified a sequence of Late Paleozoic volcano-sedimentary rocks, the Semenof block (Fig. 1), that lies between the Yukon-Tanana Terrane to the east and Stikine Terrane to the west. Two informal formations were recognized, the lower Boswell formation, mainly sedimentary rocks, and the upper Semenof formation, mainly volcanic rocks (Monger et al., 1991). The Boswell formation was about 1100 m and consisted of laterally interfingering units of slate, phyllite, chert, greenstone and limestone. Conodonts and fusulinids indicated an Early to mid-Pennsylvanian age (Monger et al., 1991). The Semenof formation was possibly 800 m thick, and consisted of massive mafic rocks mainly without structure, but in places showing faint pillow outlines, amygdules and layers of basaltic tuff. Augite phenocrysts were noted to be present locally. A carbonate lens in the formation contained fusilinids of Late Moscovian age (Monger et al., 1991).

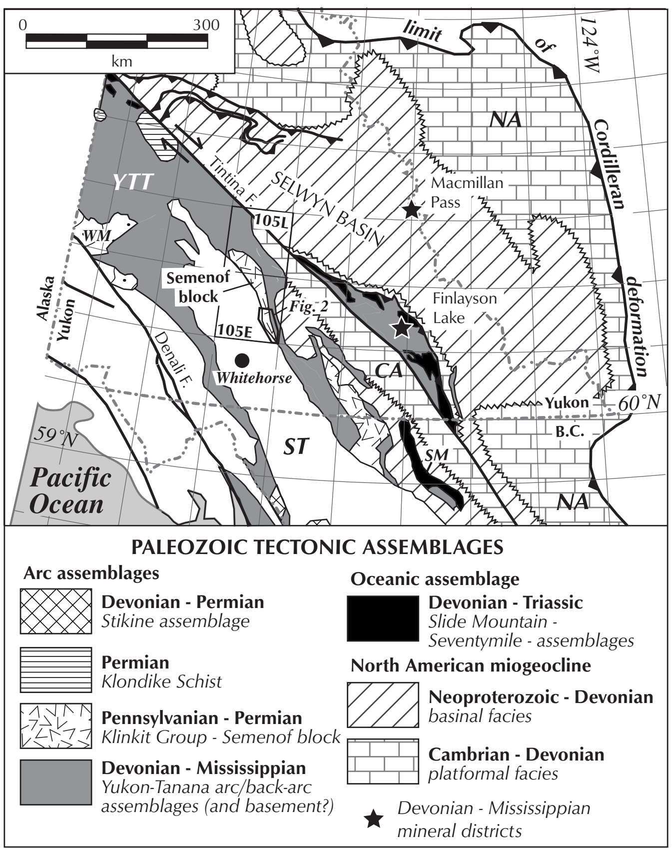


***Figure 1**. Location map of Late Paleozoic volcano-sedimentary rocks of the Semenof block, central Yukon, with respect to the distribution of other Paleozoic tectonic assemblages of the northern Canadian Cordillera (modified from Wheeler and McFeely, 1991). NA – Ancient North America, ST – Stikine Terrane, YTT – Yukon-Tanana Terrane, SM – Slide Mountain Terrane, WM – Windy-McKinley Terrane.*

To date, no detailed work has been done on those rocks and informal units of Tempelman-Kluit (1984) have yet to be defined. As a result, the stratigraphy and tectonic affinity of the Semenof block remain enigmatic. It has previously been assigned to the Slide Mountain Terrane (Monger et al., 1991), then to Quesnel Terrane (Gordey and Makepeace, 2000), and its relationship to the Yukon-Tanana Terrane is not clear (Colpron and Yukon-Tanana Working Group, 2001).

Bedrock mapping in summer of 2002 focused on the southern part of the Semenof Hills, from east of Livingstone, on Mason Landing ridge, southward to Mount Peters and Moose and Boswell mountains (Fig. 2). These areas provide good alpine exposures, which offer the opportunity to study these rocks in detail. Stratigraphic, geochemical, biostratigraphic and geochronological studies will characterize this volcano-sedimentary sequence, as part of a PhD project at Dalhousie University, Halifax. The goal is to clarify its relationship to other known Late Paleozoic volcano-sedimentary sequences of the northern Canadian Cordillera, like the Little Salmon and Little Kalzas successions (Colpron, 2001; Colpron and Reinecke, 2000; Colpron, 1999) of central Yukon, the Klinkit Group (R.-L. Simard, work in progress, 2002) of northern British Columbia and southern Yukon, and the Lay Range Assemblage (Ferri, 1997) of central northern British Columbia.

STRATIGRAPHY

The general stratigraphy of the southern Semenof Hills shows thick continuous subvertical to steeply dipping volcanic and sedimentary units trending southeast (Fig. 2).

The sedimentary rocks in the eastern part of the study area, along the South Big Salmon River, consist of limestone and clastic units. The main ridges, mainly above tree-line, expose two distinct volcanic packages intercalated with minor sedimentary units. The western part of the hills was not mapped during this field season, but will be the focus of the 2003 field season.

The volcanic and sedimentary rocks of the area are generally undeformed and unmetamorphosed. Local brittle deformation zones as well as epidote veins are observed in places. Pristine primary textures are preserved in most of the exposures, and top indicators, mostly to the southwest, were observed throughout the sequence. Stratigraphic units are described below and presented in four sections from east to west (Figs. 2,3). This stratigraphy is preliminary, assumes undisturbed upright stratigraphic sequences, and may be revised after further field, biostratigraphic, geochemical and geochronological studies are completed.

CLASTIC UNITS

Unit A

The lowermost unit of the stratigraphy in the Boswell and Moose mountains area, unit A, consists predominantly of greenish-beige, well bedded subarkosic to arkosic sandstone beds (Figs. 2,3). These sandstones typically occur in 5- to 15-cm-thick beds and have ~15% rounded quartz grains from 0.5 to 3 mm in diameter (Fig. 4). These clastic beds are interbedded with minor chloritic schist beds. Toward the top, scattered limestone lenses are observed. Unlike the other units of the southern Semenof Hills, unit A shows a well developed foliation dipping steeply to the south-southwest and gentle folding of the bedding.

In the upper 200 metres of unit A, the increasing intensity of the foliation and the presence of abundant quartz veins as well as an oxidized zone in the last metres suggest a faulted contact with the overlying limestone.

Unit B

Unit B is found on the west side of the Boswell and Moose mountains. It consists mainly of grey conglomeratic litharenite with minor argillaceous beds and conglomeratic intervals (Figs. 2,3). The conglomeratic litharenite beds consist of non-sorted medium- to coarse-grained sandstone with 10-30% granules containing mainly angular black argillite fragments, and quartz and feldspar grains. A few metres of clast-supported, non-sorted polymictic conglomerate with mainly angular black argillaceous clasts up to 15 cm in diameter are observed in this unit and characterize its base. About 15 m of finely bedded to massive black argillite occur in the upper part of unit B.

Unit C

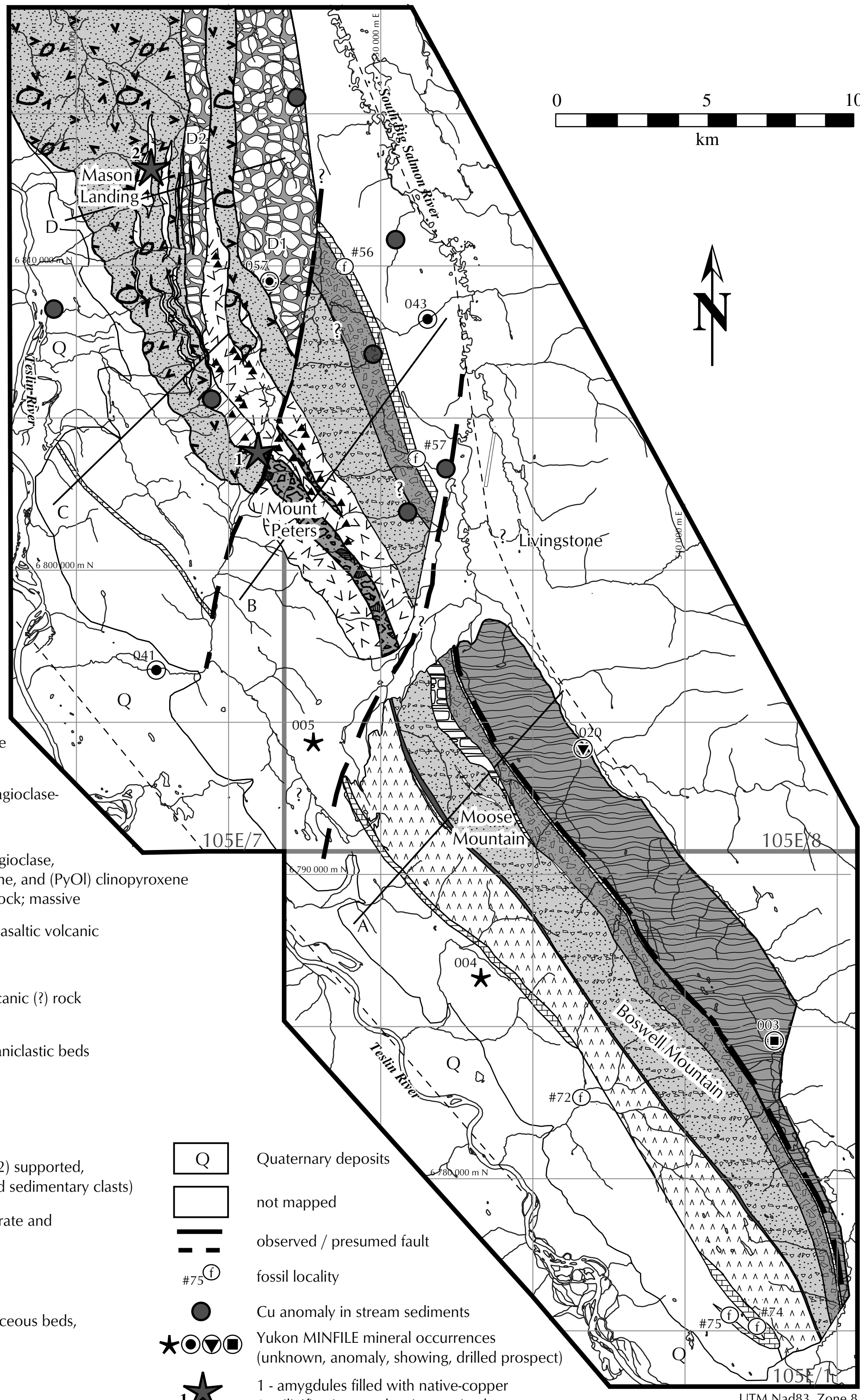
Unit C is found in the Mount Peters area as thick intervals in the massive volcanic rocks. It is mainly composed of massive, dark polymictic conglomerate and litharenite beds. The westernmost exposures consist predominantly of massive, non-sorted, granule- to pebble-polymictic conglomerate containing subrounded black and dark green chert, angular black argillite, angular limestone, coral, and subrounded clinopyroxene-plagioclase porphyritic volcanic fragments. Minor conglomeratic litharenite intervals are found in the southern part of this unit. The eastern exposures are mainly composed of litharenite beds with minor argillaceous and conglomeratic litharenite intervals. This finer facies of unit C is richer in volcanic fragments and lacks limy clasts. South of Mount Peters, graded beds indicate that the top of the section is toward the southwest.

The transition between conglomeratic rocks of unit C and the surrounding volcanic facies is marked by the gradual increase in amount and size of the volcanic components.

Unit D

Unit D is found in the Mason Landing area. It consists of massive polymictic conglomerate. Two main facies are observed. The easternmost facies (D1; Figs. 2,3) is characterized by red and green, massive, matrix-supported, non-sorted, polymictic pebble conglomerate showing various subangular porphyritic volcanic clasts and subrounded fine-grained sedimentary clasts. Clast sizes are commonly between 2 mm and 2 cm in diameter, with a maximum diameter of 12 cm. Several clasts have centimetre-sized oxidation rims. The westernmost facies (D2; Figs. 2,3) consists of brownish, massive, clast-supported, non-sorted, polymictic pebble- to cobble-conglomerate containing both porphyritic volcanic and fine-grained sedimentary clasts (Fig. 5). This coarser facies is very extensive and can be followed for several kilometres along strike, forming the resistant crest of Manson Landing.

Figure 2. *Preliminary geological map of southern Semenof Hills (105E/1,7-8). Map shows transects A-D, from which the stratigraphic sections in Figure 3 were created. Fossil localities from Tempelman-Kluit, 1984 and Poulton et al., 1999. Numbers 003, 004, 005, 020, 041, 043 and 057, and symbols refer to mineral occurrences in 105E (Yukon MINFILE 2002). Location of copper anomaly in stream sediments from Hornbrook and Friske (1989).*



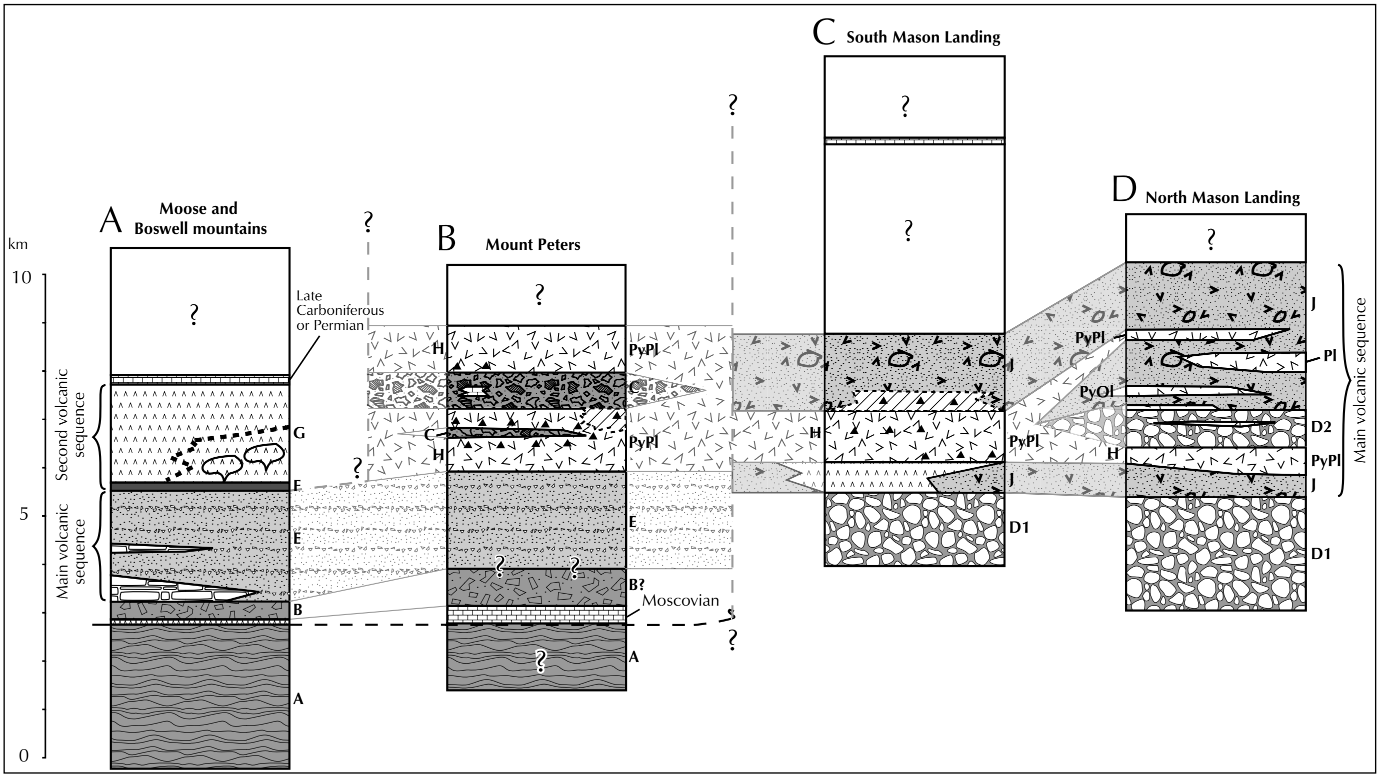


Figure 3. *Correlative stratigraphic sections of southern Semenof Hills (105E/1,7-8). Shaded patterns in between columns used to show possible correlative units in the main volcanic sequence. Legend is same as for Figure 2.*

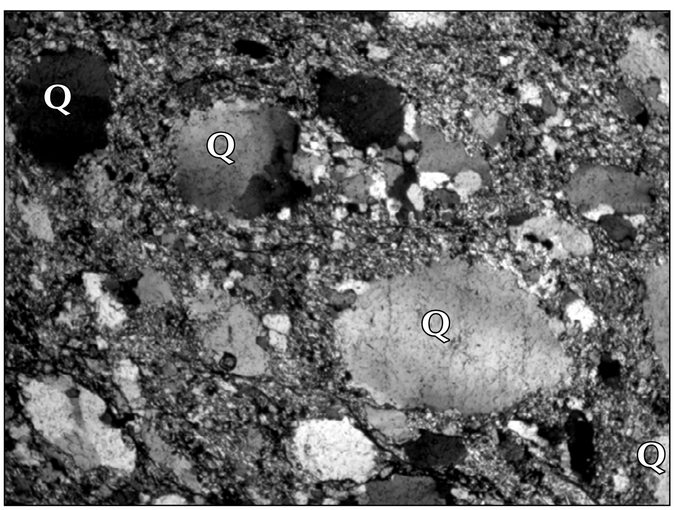


Figure 4. *Subarkose of unit A. Note the roundness of the big quartz grains (Q). Microphotograph 2.3 mm across.*

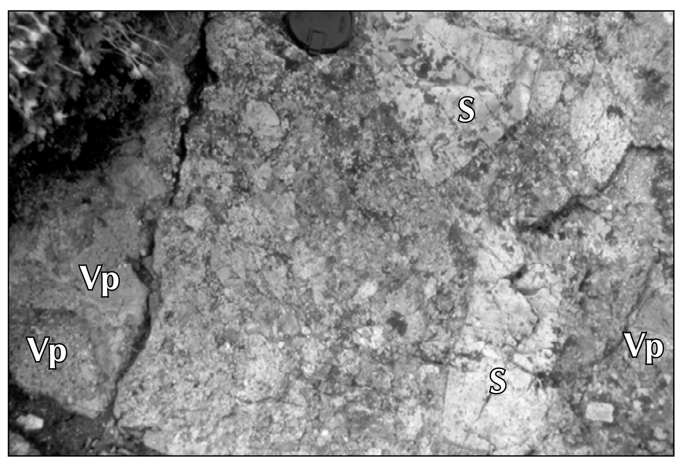


Figure 5. *Massive, clast-supported, non-sorted, polymictic pebble- to cobble-conglomerate D2 of Mason Landing showing rounded porphyritic volcanic (Vp) and angular fine-grained sedimentary (S) clasts. Lens cap, 55 mm across.*

LIMESTONE UNITS

Boswell and Moose mountains

The lowermost limestone unit in the Boswell and Moose mountain area, to the east, is a grey, massive, highly recrystallized ~30-m-thick limestone. It shows metre-width stratification characterized by thin intervals of pinkish muscovite schist. Quartz veins and quartz boudins are common, especially in its lower part. The base of this limestone is faulted against the deformed clastic unit A.

In the north, several important limestone conglomerate lenses are found at the base of, and within, a volcaniclastic succession. They consist predominantly of clast-supported, limestone-pebble to -boulder conglomerate with less than 20% of angular chert and mafic volcanic fragments (Fig. 6). Crinoids and chain coral were observed in some limestone clasts.

The uppermost limestone unit, to the west, is a buff-weathered, light grey massive limestone containing abundant crinoid fragments. Poorly preserved brachiopods from this unit yielded Late Carboniferous to Permian ages (Tempelman-Kluit, 1984; fossil localities #72, 74, 75; Poulton et al., 1999).

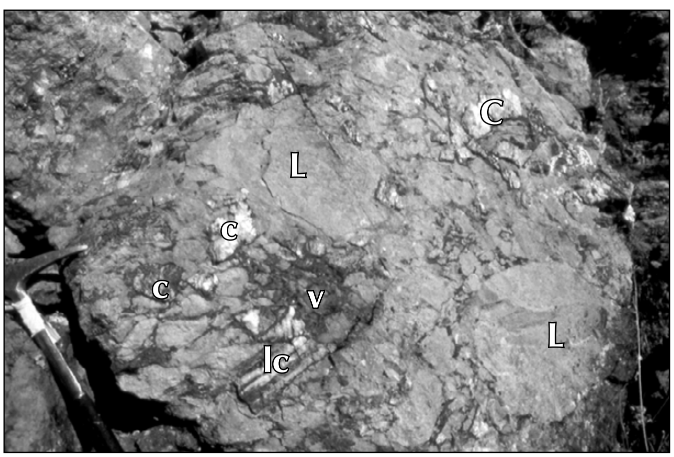


Figure 6. *Limestone conglomerate on top of Moose Mountain. Note the presence of angular laminated chert (lc), white chert (c), and dark mafic volcanic (v) clasts mixed with the rounded limestone (L) clasts. Hammer for scale.*

Mount Peters

E.W. Bamber (in Tempelman-Kluit, 1984) describes the basal limestone of the Mount Peters succession as light grey grainstone and packstone, which contains lower Moscovian (Pennsylvanian) fusulinids (Tempelman-Kluit, 1984; fossil localities #56, 57; Poulton et al., 1999). This limestone may be laterally equivalent with the lower limestone unit on Boswell and Moose mountains (Figs. 2,3).

A pod of 30 x 40 m of massive, light grey, fetid, crinoid-rich limestone is present in the clastic rocks of unit C (Fig. 3).

VOLCANIC UNITS

Unit E – (volcaniclastic unit)

Unit E covers the main ridges of Boswell and Moose mountains and the easternmost side of Mount Peters (Figs. 2,3). It consists of a 1500- to 3000-m-thick succession of thinly bedded crystal- and lithic- tuffaceous mudstone and sandstone with minor conglomeratic intervals. The tuffaceous beds are mainly composed of rounded clinopyroxene- and/or plagioclase-phyric volcanic fragments up to 7 mm in diameter, and of euhedral plagioclase and clinopyroxene crystals. Thinly bedded tuffaceous 'sand-silt couplet' beds (Fig. 7) and graded beds are common in this unit, suggesting a resedimented origin, such as turbidite sequence.

Figure 7. *Thinly bedded tuffaceous 'sand-silt couplet' beds in the volcaniclastic unit E. Lens cap, 55 mm across.*

Unit F – (felsic volcanic unit)

Unit F consists of a ~30-m-thick pinkish-beige massive quartz-phyric felsic volcanic rock. Unit F occurs only above the volcaniclastic unit E of Boswell and Moose mountains (Figs. 2,3).

Unit G – (mafic volcanic unit)

Unit G underlies most of the west side of Boswell and Moose mountains (Figs. 2,3). It consists of ~2 km of dark green, massive, fine-grained basaltic volcanic rock. It is locally plagioclase-phyric and vesicular. Pillow structures were observed in basalt on the west side of Moose Mountain (Fig. 8).

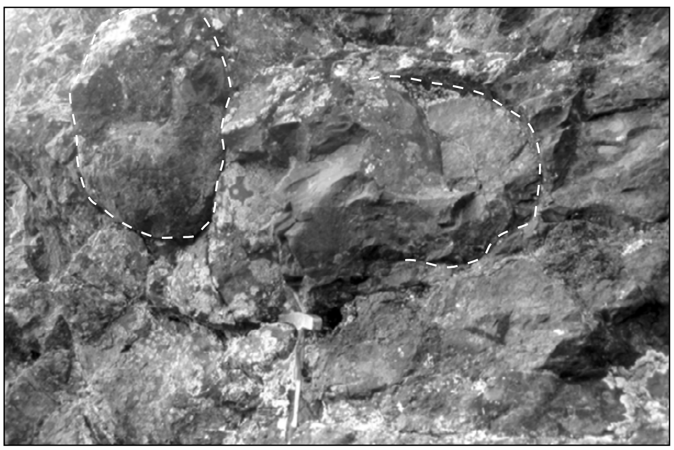


Figure 8. *Pillowed basaltic lava flow of unit G, west of Moose Mountain. Hammer for scale.*

Unit H – (porphyritic mafic volcanic unit)

Unit H consists of green to greyish, massive, plagioclase- and clinopyroxene-phyric basalt. It forms the crest of Mount Peters and the southern part of the Mason Landing ridge (Figs. 2,3). Euhedral plagioclase and clinopyroxene crystals (up to 7 mm and 4 mm in diameter, respectively) are set in a glassy matrix characterizing this unit. Unit H can be locally amygdaloidal.

Unit H is commonly brecciated, showing angular fragments of porphyritic material in a matrix of smaller fragments, and plagioclase and clinopyroxene crystals (Fig. 9). This brecciated facies is mainly localized along the margin of this unit. On the west side of Mount Peters and Mason Landing, at the head of St-Germain Creek, the upper part of unit H is red-purple and shows millimetre-size amygdules filled with native copper.

To the north, on Mason Landing ridge, the crystal nature and composition of unit H is more variable. Plagioclase-phyric, clinopyroxene- and plagioclase-phyric, and clinopyroxene- (and olivine-) phyric massive and brecciated facies are present (Figs. 2,3). They are locally oxidized (reddish in colour), and show large silicification patches (a few metres wide, Fig. 10) indicating the presence of hydrothermal fluid circulation.

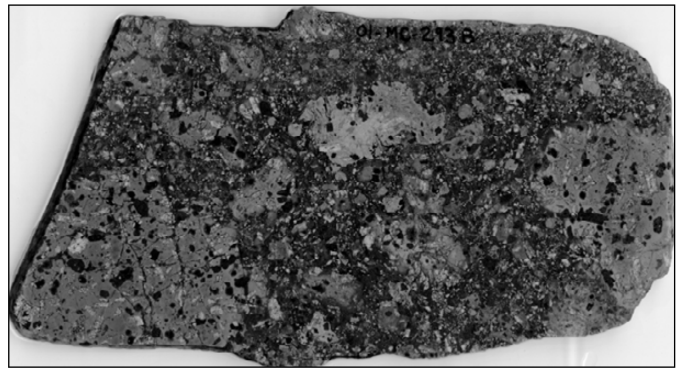


Figure 9. *Slab of vesicular brecciated clinopyroxene- and plagioclase-phyric volcanic rock of unit H from Mount Peters. Note the angularity of the fragments. Slab is 12 cm across.*

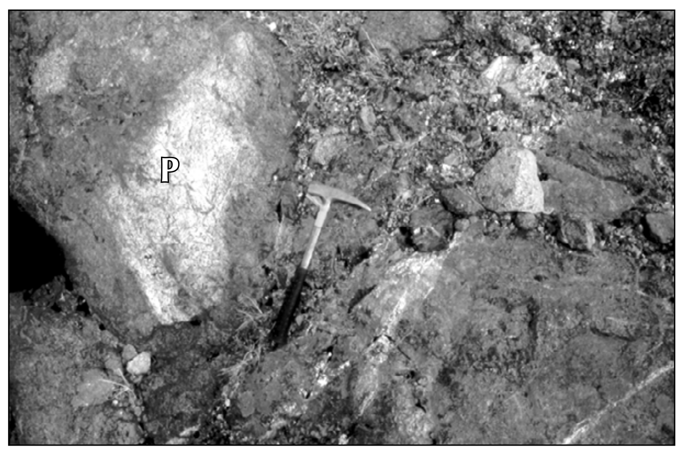


Figure 10. *Silicification patches (P) in massive volcanic lava of unit H, west of Mason Landing. Hammer for scale.*

Unit J – (volcanic conglomerate)

The massive volcanic flows of unit H are interbedded to the north with unit J, a massive, clast-supported, non-sorted, pebble to boulder conglomerate (Figs. 2,3,11). This conglomerate is composed of exclusively volcanic clasts. Although they are all volcanic in nature, they are very variable in composition and texture. The larger clasts are typically rounded and porphyritic. Smaller fragments in the matrix of the conglomerate are composed of angular, porphyritic and highly vesicular fragments, as well as crystals of clinopyroxene and plagioclase.

Figure 11. *Volcanic pebble to cobble conglomerate, west of Mason Landing. Hammer for scale.*

REGIONAL CORRELATION

Figure 3 shows the regional correlation of the different units of the southern Semenof Hills.

Two volcanic sequences can be observed throughout the study area. The main sequence (Fig. 3) is composed of basal fragmental volcanic rocks (Units E, J) overlain by massive porphyritic lava flows (Unit H) and more fragmental volcanic rocks (Unit J). This sequence is exposed throughout the study area (Figs. 2,3). Notable lateral changes in unit thickness and grain size likely reflect facies changes and/or faulting in a volcanic environment.

The second volcanic sequence (Fig. 3) is restricted to the Boswell and Moose mountains area (Fig. 2,3). It comprises the felsic rocks of unit F and massive basalt flows (unit G). The relationship between rocks of unit G and those of the main volcanic sequence to the north is still unclear (Fig. 3). Late Carboniferous or Permian limestone is found just above unit G to the south (Figs. 2,3).

Finally, these volcanic sequences sit unconformably on the clastic units B and D, themselves sitting on Moscovian limestone.

The rocks of the Boswell/Moose mountains and Mount Peters areas are virtually undeformed, suggesting that the deformed clastic rocks of unit A to the east (Figs. 2,3) are not part of the same volcano-sedimentary sequence that characterizes most of the southern Semenof Hills.

ECONOMIC POTENTIAL

The current project highlighted the presence of amygdules filled with native copper in the oxidized facies of unit H at the head of St-Germain Creek, just north of Mount Peters (Fig. 2), and the presence of silicification patches in massive volcanic rocks of unit H ~15 km to the north on the east side of Mason Landing (Figs. 2,10). This suggests the presence of an active copper-bearing hydrothermal system in these rocks at one point. In the same area, copper anomalies are also reported in the stream sediments (Fig. 2; Hornbrook and Friske, 1989).

Seven Yukon MINFILE (2002) occurrences are also present in the mapping area, but were not visited. These are mainly copper and gold occurrences (Yukon MINFILE 2002; this reference is used for the occurrences listed in this section). Just east of Boswell Mountain, occurrence 105E 003, named Mink, Beaver and Loon through time, contains copper mineralization with gold in steeply dipping poorly defined silicified zones in chlorite-sericite-quartz schist and cherty quartzite (unit A; Fig. 2). East of Boswell Mountain, occurrence 105E 004, named Bee, reports rumors of magnetite and pyrrhotite with minor chalcopyrite in limestone and argillite. East of Moose Mountain, 105E 005, named Napua, shows an unmineralized pyritic gossan at the contact of limestone and argillite with mafic volcanic rock. West of Moose Mountain, occurrence 105E 020, named Sylvia, presents galena, sphalerite and chalcopyrite occurring in quartz veins in a shear zone between quartzite and volcanic rocks. On both sides of Mount Peters, occurrences 105E 041 and 105E 043, named Enof and Germ, were staked on gold geochemical anomalies between clastic and mafic volcanic rocks, and on mafic volcanic rocks, respectively. Finally, occurrence 105E 057, named Milner, reports an isolated outcrop of coal in a poorly exposed area east of Mason Landing in unit D1 (Fig. 2).

CONCLUSION

New regional mapping in the southern Semenof Hills identified possibly two very well preserved volcanic sequences sitting on clastic rocks. This undeformed volcano-sedimentary rock package is in faulted contact with a more deformed clastic unit to the east (unit A).

The volcanic sequences probably represent part of the Semenof formation of Tempelman-Kluit (1984). However, the sedimentary rocks of the Boswell formation are not recognized in the area.

Occurrences of volcanic rocks and their association with evidence for a copper-bearing hydrothermal system suggest good potential for mineral exploration in the area.

ACKNOWLEDGEMENTS

Thanks goes to Maurice Colpron for pointing out the existence of such great rocks and for great discussions on Yukon geology. Thanks also goes to Delmar, Doug and Jennifer from Capital Helicopter (Whitehorse) for great flying, and support in the cloudy days. Finally, thanks goes to 'Mother Nature' for not deforming, for once, Late Paleozoic Cordilleran volcanic rocks!

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Geology and mineral occurrences of the Quartet Lakes map area (NTS 106E/1), Wernecke and Mackenzie mountains, Yukon

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ABSTRACT

The Quartet Lakes map area is underlain by rocks that range in age from Early Proterozoic to early Paleozoic. Stratified rocks include, from oldest to youngest, the Lower Proterozoic Fairchild Lake and Quartet groups (Wernecke Supergroup), the Middle to Late Proterozoic Tsezotene Formation, Katherine Group, and Little Dal Formation (Mackenzie Mountains Supergroup), and the Cambrian Slats Creek Formation. Five igneous units are recognized, including the Early Proterozoic Bonnet Plume River Intrusions, the Middle Proterozoic Bear River dykes, the Late Proterozoic Tsezotene Sills, Late Proterozoic to Cambrian lamprophyre, and Late Proterozoic to early Paleozoic diorite. Older rocks (Wernecke Supergroup, Wernecke Breccia and Bonnet Plume River Intrusions) were thrust northward over the Mackenzie Mountains Supergroup along a portion of the Knorr Fault. This part of the fault may be a restraining bend in an otherwise dextral strike-slip system. Copper-gold-uranium mineral occurrences in the area include disseminated and vein mineralization associated with zones of Wernecke Breccia.

RÉSUMÉ

La zone cartographique de Quartet Lakes repose sur des roches dont l'âge varie du Protérozoïque précoce au Paléozoïque précoce. Les roches stratifiées sont composées, des plus anciennes aux plus récentes, des groupes de Fairchild Lake et de Quartet (Supergroupe de Wernecke) du Protérozoique inférieur, de la Formation de Tsezotene, du Groupe de Katherine, de la Formation de Little Dal du Protérozoïque moyen à tardif (Supergroupe de Mackenzie Mountains) et de la Formation de Slats Creek du Cambrien. On distingue cinq unités ignées : les intrusions de Bonnet Plume River du Protérozoïque précoce, les dykes de Bear River du Protérozoïque moyen, les filons-couches de Tsezotene du Protérozoïque tardif, un lamprophyre du Protérozoïque tardif au Cambrien et une diorite du Protérozoïque tardif au Paléozoïque précoce. Les roches plus anciennes (Supergroupe de Wernecke, Brèche de Wernecke et intrusions de Bonnet Plume River) chevauchent vers le nord le Supergroupe de Mackenzie Mountains le long de la faille de Knorr. Cette partie de la faille de Knorr pourrait constituer une courbure restrictive dans un système de décrochement autrement dextre. Les indices minéraux de Cu-Au-U dans la région sont des filons ainsi que des minéraux disséminés de Cu-Au-U associées à des zones de la Brèche de Wernecke.

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INTRODUCTION

Geological mapping and research was undertaken in the summer of 2002 in the northern Wernecke and Mackenzie mountains (NTS map area 106E/1), located approximately 180 km north-northeast of Mayo and herein called the study area (Fig. 1). The region is rugged and remote, with mountain peaks typically elevated 1000 m above valley bottoms. Vegetation ranges from mixed coniferous and deciduous forest at lower elevations to lichen and bare rock on the mountaintops. The map area is drained by the Bonnet Plume River, which flows northward as part of the Arctic watershed (Fig. 2). The area is most easily accessed by helicopter but fixed-wing aircraft on floats can land on the Quartet Lakes and some reaches of the Bonnet Plume River. Fixed-wing aircraft on wheels can land on the 'copper point' airstrip approximately 1 km south of the map area in the northeastern corner of map area 106D/16. An unmaintained track called the Wind River trail, and related routes, lead into the study area. They are most useful as snowmobile trails in the winter after the rivers and wet ground in the region have frozen.

This study is a rejuvenation of the Wernecke Mountains Project initiated in 1992 by the first author and the Canada/Yukon Geoscience Office. Field work was carried out in map areas 106D/16, 106C/13 and 106C/14 from 1992-1995 (Fig. 1). Supplemental field and laboratory studies based from Simon Fraser University continued until 1998. A comprehensive report with three 1:50 000-scale maps was published subsequently (Thorkelson, 2000). The current program included regional mapping of map area 106E/1 by Thorkelson and Laughton, and detailed investigations of breccia-hosted mineral occurrences by Hunt and Baker. Products from the current study include this report and a companion 1:50 000-scale map (Thorkelson et al., 2002). The new findings will contribute to the PhD study of Hunt at James Cook University in Australia, and the MSc thesis of Laughton at Simon Fraser University in British Columbia.

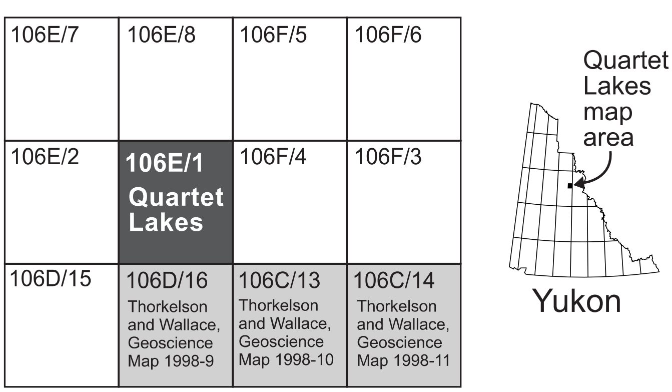


Figure 1. *Location of study area in context of previously released 1:50 000-scale maps.*

In this report, frequent reference is made to mineral occurrences as defined in Yukon MINFILE 2002 and reproduced in the legend of Figure 2. Note that where a mineral occurrence is identified on the map of Figure 2 or mentioned in the text of the report, the occurrence number has been abbreviated, for simplicity, to show only the last three digits (e.g., 029).

PREVIOUS WORK

Geological investigations in the map area have largely revolved around mineral exploration, and several mineral assessment reports detailing this activity are available from the Indian and Northern Affairs Canada library in Whitehorse. Maps from government agencies include a 1:250 000-scale map of 106E (Norris, 1981) and a 1:100 000-scale map covering the southern part of 106E/1 and nearby areas (Bell, 1986a). Hunt et al. (2002) mapped a small area in the southeastern corner of the map area. Reports and articles containing regional overviews include those by Delaney (1981), Norris (1997), Norris and Dyke (1997), and Thorkelson (2000). Papers focusing on specific aspects of the geology in and near the study area are cited where appropriate in the following text.

GEOLOGICAL FRAMEWORK

As outlined in Norris (1997) and Thorkelson (2000), rocks of the northern Wernecke Mountains range in age from Early Proterozoic to Paleozoic (Fig. 3). Most of the rocks are clastic and carbonate sedimentary strata that were deposited in basinal to platformal environments along the western shores of ancestral North America. These strata host hydrothermal breccias, dykes, sills and small stocks. Events of deformation involving contraction, transcurrent displacement and extension affected the region. The first major deformational event was the Early Proterozoic Racklan orogeny (Fig. 3), which produced southeasterly directed folds, foliations, crenulations and kinks. The last major event was the Laramide orogeny, which involved north- to northwest-directed folding and thrusting in Late Cretaceous to Paleocene time.

In the study area, the rocks consist of two main sedimentary successions crosscut by numerous small igneous intrusions and zones of hydrothermal breccia. The older succession is the Lower Proterozoic Wernecke Supergroup (Delaney, 1981), and the younger is the Middle to Upper Proterozoic Mackenzie Mountains Supergroup (Atiken et al., 1982). The Wernecke Supergroup has greater potential to host mineral occurrences because it has a greater abundance of mineral occurrences, particularly ones with iron oxide-copper-gold affinity. These successions are separated by the Knorr Fault, a strand of the Richardson Fault array (Fig. 2, 4; Norris, 1984).

Rocks that form the basement to the successions in the Wernecke Mountains are not exposed (Fig. 3). However, they are likely to be as old, or older than, the Early Proterozoic Wopmay orogeny and Fort Simpson magmatic belt (ca. 1.84-1.9 Ga) in the Northwest Territories. Conceivably, part of the lithospheric infrastructure beneath the Wernecke Mountains and neighbouring regions could be Archean (>2.5 Ga).

STRATIGRAPHY

WERNECKE SUPERGROUP

The Wernecke Supergroup is the oldest sedimentary succession exposed in the Wernecke Mountains (and probably all of western North America). It consists of three groups with an aggregate thickness of approximately 13 km (Delaney, 1981; Thorkelson, 2000). In the study area, only the lowest unit, Fairchild Lake Group, and the middle unit, Quartet Group, are exposed southwest of the Knorr Fault (Fig. 2, 3). The highest unit, Gillespie Lake Group, is exposed 3 km to the south of the map area.

In the study area, the Fairchild Lake Group consists mainly of weakly to moderately metamorphosed grey- to brown-weathering siltstone, shale, very fine-grained sandstone, and brown-, grey- and white-weathering dolostone. Following Thorkelson (2000), the succession is divided into two main parts, simply named the 'lower' and 'upper' Fairchild Lake Group (more detailed divisions were provided by Delaney, 1981, but are not followed in this report). The lower part consists mainly of siltstone, fine-grained sandstone and shale, with minor dolostone, and their metamorphosed equivalents. The upper Fairchild Lake Group consists mainly of siltstone, shale and dolostone. A prominent 10-m-thick white marker unit of dolostone lies near the top of the group where it grades into the Quartet Group (Delaney, 1981). The Fairchild Lake succession in the study area is at least 1 km thick.

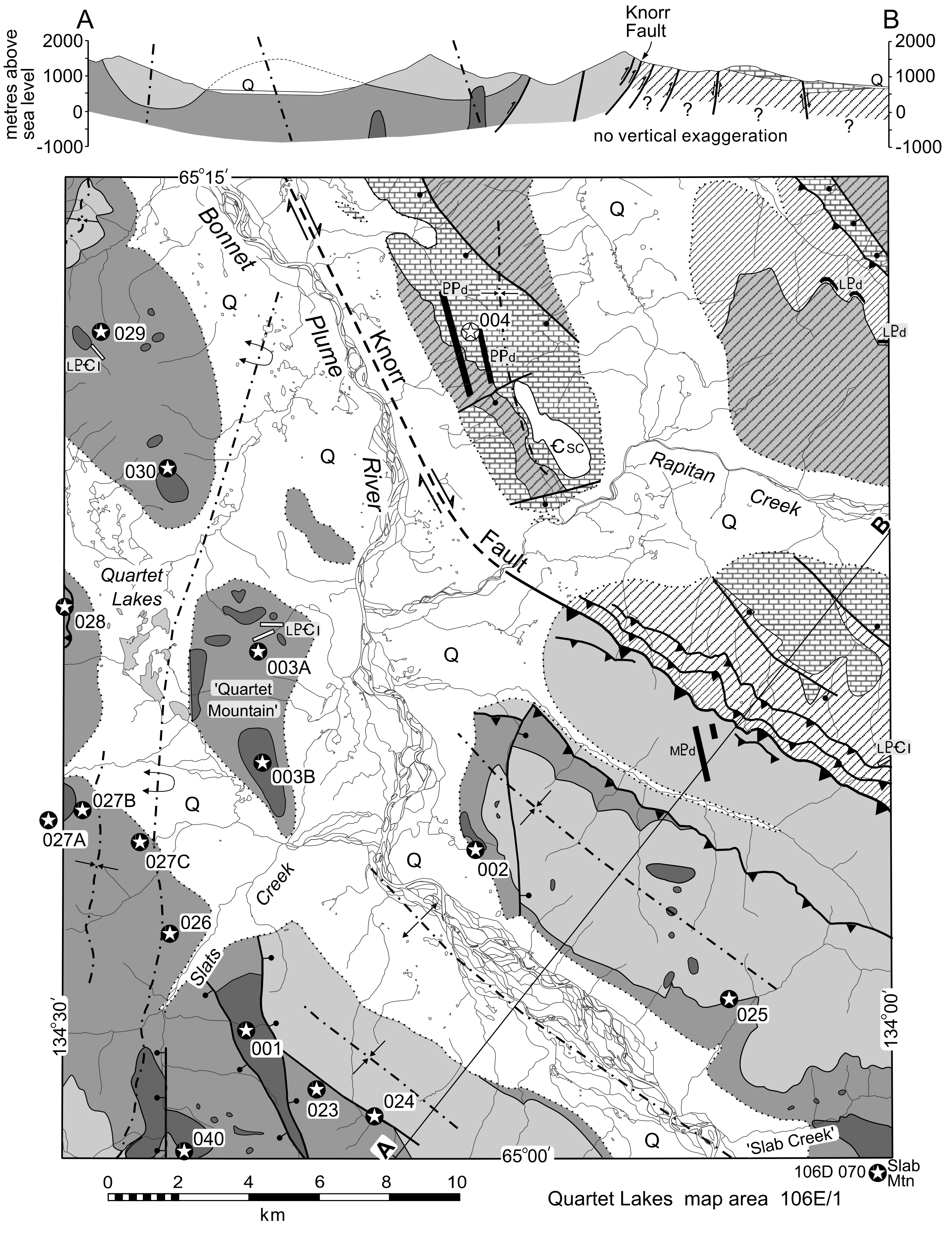
In most places, the Fairchild Lake Group rocks display slaty cleavage, and locally host porphyroblasts of chloritoid or, less commonly, garnet (Fig. 5). Sedimentary features such as plane- and ripple-laminations and syneresis cracks are typically preserved. In other localities, the rocks have undergone greater strain and mineral growth, and have been metamorphosed to bluish-grey-weathering chlorite- and muscovite-rich phyllite, and fine-grained chlorite-muscovite-quartz schist, which also hosts choritoid or garnet porphyroblasts (Fig. 6). In addition to being schistose, these rocks are commonly crenulated and kink-banded. Brideau et al. (2002) described the metamorphic grade of the schist as lower greenschist, with peak temperatures near 550°C.

The Quartet Group grades from black-weathering shale and siltstone at its base, where it conformably overlies the upper Fairchild Lake Group, to more siliceous rocks including quartz-rich siltstone with interbedded fine- to medium-grained white-weathering quartzite up to 12 m thick (Fig. 7). Although the most siliceous rocks are not foliated, most Quartet Group rocks display slaty cleavage. The most fine-grained Quartet rocks are typically cleaved, crenulated and locally kink-banded, and host tiny (<0.5 mm) porphyroblasts of chloritoid. The preserved thickness of the Quartet Group in the study area, based on the cross-section in Figure 2, is approximately 1.5 km. The top of the succession is not preserved in the study area.

MACKENZIE MOUNTAINS SUPERGROUP

Northeast of the Knorr Fault, strata of the Mackenzie Mountains Supergroup are exposed. Lithologically, these strata range from dolostone to siltstone and quartz arenite, similar to protoliths of the Wernecke Supergroup but generally devoid of cleavage. The three main units of the Mackenzie Mountains Supergroup, the Tsezotene Formation (lowest), the Katherine Group, and the Little Dal Formation (highest), are all present in the study area. At some locations, these units were identified with confidence, following the descriptions of Aitken et al. (1982). However, distinguishing the Tsezotene Formation from the Katherine Group in fault panels near the Knorr Fault was difficult, and the two units in that area have been grouped together (Fig. 2).

The Tsezotene Formation consists mainly of brown-, grey- and purple-weathering siltstone, shale and wacke; buff-,


A
B
Knorr
Fault
metres above
sea level
2000
1000
0
-1000
Q
?
no vertical exaggeration
65°15′
Bonnet
Plume
River
Knorr
Fault
Q
029
030
028
Quartet
Lakes
003A
'Quartet
Mountain'
003B
027B
027A
027C
026
Creek
Slats
001
023
024
040
004
Csc
Rapitan
Creek
002
025
'Slab Creek'
65°00′
134°30′
134°00′
106D 070
Slab
Mtn
0
2
4
6
8
10
km
Quartet Lakes map area 106E/1

STRATIFIED ROCKS

QUATERNARY

Q — alluvium, colluvium and glacial deposits

MIDDLE CAMBRIAN (?)

SLATS CREEK FORMATION (?)

Csc — grey-weathering dolostone and purple-weathering mudstone interlayered with carbonate-rich conglomerate and olistostrome; brown-weathering, thin- to medium-bedded, plane- to cross-bedded, coarse sandstone and chert-rich granule conglomerate in carbonate matrix

MIDDLE TO UPPER PROTEROZOIC

MACKENZIE MOUNTAINS SUPERGROUP

LITTLE DAL FORMATION: grey- to yellow-weathering, medium- to thick-bedded micritic dolostone; minor black mudrock

KATHERINE GROUP: grey- to white- and pinkish-white-weathering, fine- to medium-grained quartz arenite; black-, brown- and purple-weathering siltstone and wacke, locally micaceous, mudcracked and ripple-marked; minor dolostone

TSEZOTENE FORMATION: black- to brown-weathering siltstone and wacke, commonly micaceous, mudcracked and ripple-marked; brown- to orange- and grey-weathering, medium- to very thick-bedded dolostone; black-, grey- and maroon-weathering mudrock; minor grey- to white- and pinkish-white-weathering, plane-bedded quartz arenite

TSEZOTENE FORMATION and/or *KATHERINE GROUP*

LOWER PROTEROZOIC

WERNECKE SUPERGROUP

QUARTET GROUP: black-weathering shale; grey-weathering, thin- to medium-bedded, finely laminated to cross-laminated siltstone; light-grey-weathering, thick-bedded, fine- to medium-grained quartz arenite.

FAIRCHILD LAKE GROUP, undivided (includes upper and lower successions)
Upper Fairchild Lake Group: black-weathering shale, silstone and dolomitic siltstone, locally crenulated and kink-banded; orange-, brown-, grey-, and white-weathering dolostone
Lower Fairchild Lake Group: black- to grey-weathering, thin- to medium-bedded, siltstone, shale, and slate, commonly laminated; brown-weathering, thin-bedded silty dolostone; bluish- to greenish-grey-weathering phyllite and fine-grained muscovite-chlorite-quartz schist, commonly hosting chloritoid porphyroblasts, crenulations and kink bands

stratigraphic contact

contact with Quaternary sediments

fault: strike-slip, reverse, normal, inferred

fold trace: syncline, anticline, overturned anticline

A — B line of cross-section

INTRUSIVE ROCKS

LATE PROTEROZOIC TO EARLY PALEOZOIC

PPd — dark-green-weathering, fine- to medium-grained diorite dykes crosscutting Little Dal Formation and Katherine Group; dykes locally host veins of epidote, calcite, hematite and malachite

LATE PROTEROZOIC TO CAMBRIAN

LPCl — *QUARTET LAKES LAMPROPHYRE:* brown-weathering, aphyric to phlogopite-phyric dykes crosscutting Wernecke and Mackenzie Mountains supergroups, and locally hosting abundant xenoliths

LATE PROTEROZOIC

LPd — *TSEZOTENE SILLS*: dark-green-weathering, fine- to medium-grained diorite within Tsezotene Formation; locally, diorite is plagioclase-phyric and hosts veins of calcite, quartz and pyrite

MIDDLE PROTEROZOIC

MPd — *BEAR RIVER DYKES*: dark-green-weathering, fine- to medium-grained diorite crosscuting Quartet Group; locally, diorite hosts veins of epidote, quartz, calcite, pyrite, chalcopyrite and hematite

WERNECKE BRECCIA

grey-weathering, or mottled red-, pink-, brown- and grey-weathering hematitic breccia containing clasts of Wernecke Supergroup and, locally, megaclasts of the Early Proterozoic Bonnet Plume River Intrusions (greenish-grey-weathering, fine-to medium-grained diorite locally hosting disseminations and veinlets of hematite or magnetite, and chalcopyrite). Includes metasomatized country rock of the Wernecke Supergroup. Breccia crosscuts foliations, crenulations and kink bands in the Fairchild Lake Group and locally hosts enrichments of Cu (as chalcopyrite), Au, U, Co and Mo (as molybdenite). Tentatively includes rusty-weathering pyritic breccia with matrix of vein quartz.

MINERAL OCCURRENCES
Yukon MINFILE 2002

Wernecke Breccia
Cu and/or U (+/- Co, Au, Mo, Ba, Ag)

106 E/001	✪	Otis	drilled prospect
106 E/002	✪	Irene	drilled prospect
106 E/003	✪	Quartet	showings
106 E/023	✪	Radio	prospect
106 E/024	✪	Break	prospect
106 E/025	✪	Mountaineer	showing
106 E/026	✪	Helikian	prospect
106 E/027	✪	Five	prospect
106 E/028	✪	Rapitan	showing
106 E/029	✪	Ikona	showing
106 E/030	✪	Bell	showing
106 E/040	✪	Eaton	showing

Unknown affinity
Zn, Pb

106 E/004	☆	Farion	showing

Figure 2. *Geological map (facing page) and legend (this page) of study area, simplified from Thorkelson et al. (2002). Mineral occurrences are taken from Yukon MINFILE 2002 except for locality 003B which was identified by the authors and has been proposed as an addition to future versions of Yukon MINFILE.*

orange-, and grey-weathering dolostone; and minor grey- to white-weathering quartz arenite. The siltstone and sandstone are commonly ripple-marked and mud-cracked, and locally contain abundant detrital muscovite. The dolostone is generally micritic, is commonly crosscut by veins of red-weathering dolomite spar, and locally hosts nodules of red- and white-weathering dolomite cored by granular to sparry quartz crystals. In the study area, the Tsezotene succession is at least 1.2 km thick.

The overlying Katherine Group is distinguished from the Tsezotene by its greater abundance of sandstone, particularly grey- to white-weathering and locally pink-weathering quartz arenite. In many places, the arenite contains grains of pyrite that have partly or completely altered to limonite, leaving a spotty and locally rusty appearance in an otherwise 'pure' quartz sandstone. Although the Katherine Group is generally coarser grained than the Tsezotene, it contains some layers of carbonate and thick successions of siltstone, including muscovite-rich varieties. For example, on a peak 2 km west of the

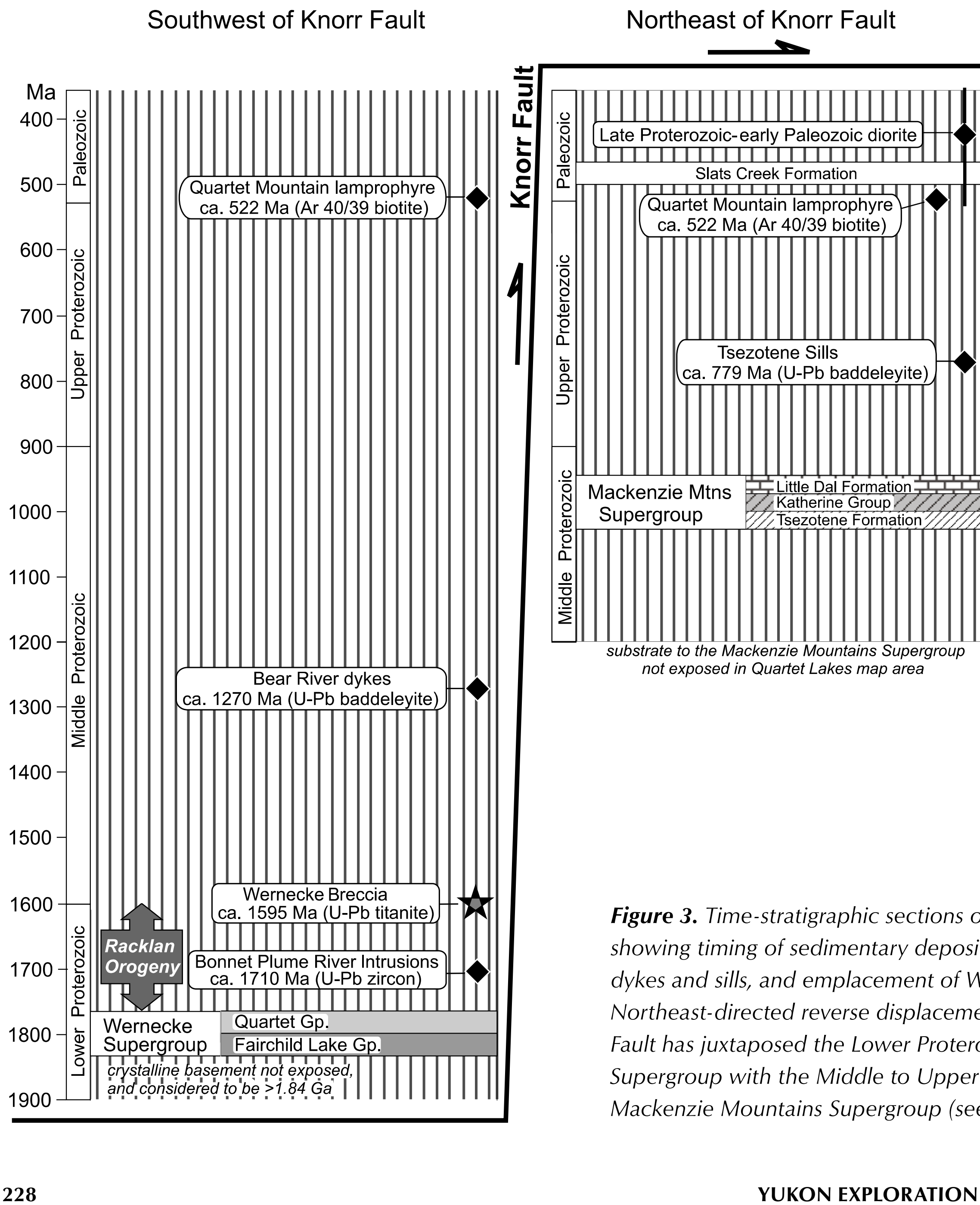


Figure 3. *Time-stratigraphic sections of the study area showing timing of sedimentary deposition, intrusion of dykes and sills, and emplacement of Wernecke Breccia. Northeast-directed reverse displacement along the Knorr Fault has juxtaposed the Lower Proterozoic Wernecke Supergroup with the Middle to Upper Proterozoic Mackenzie Mountains Supergroup (see Figs. 2, 4).*

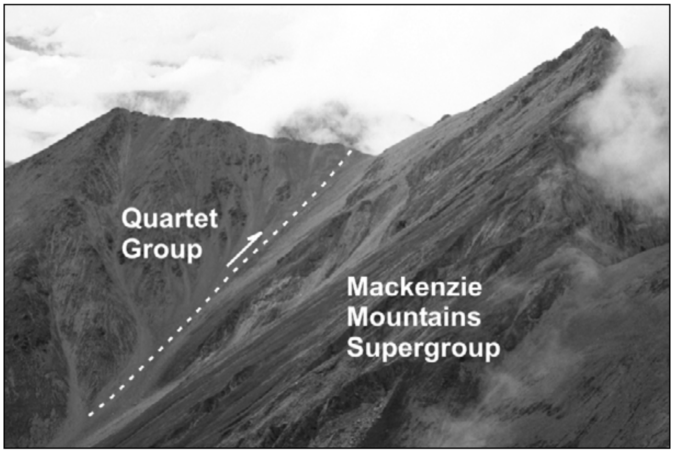


Figure 4. *Knorr reverse fault separating Quartet Group (hanging wall) from Mackenzie Mountains Supergroup. View to west. Width of area is approximately 500 m.*

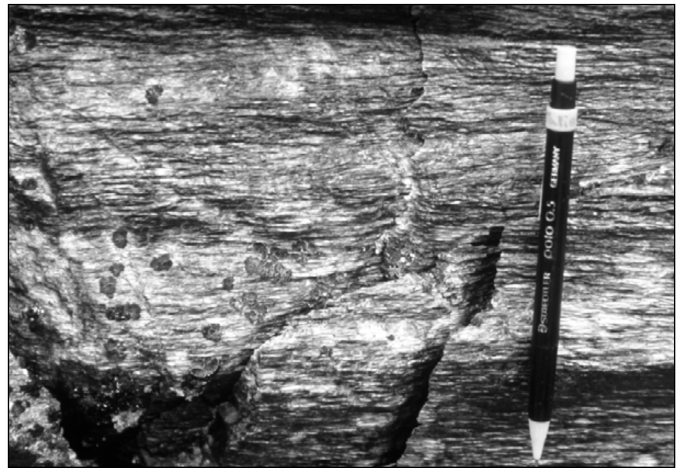


Figure 6. *Crenulated, fine-grained chloritoid-muscovite-chlorite-quartz schist of the lower Fairchild Lake Group, between Ikona (029) and Bell mineral occurrences (030).*

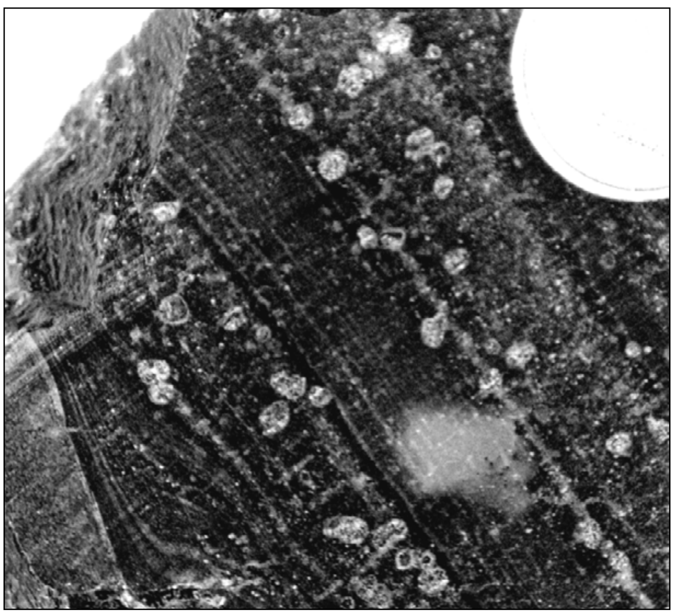


Figure 5. *Garnet porphyroblasts in metamorphosed Fairchild Lake Group siltstone with relict plane- and cross-laminations, near the Irene mineral occurrence (002). Width of rock is 6 cm.*

Figure 7. *Gently dipping succession of Quartet Group siltstone and fine-grained sandstone, 3 km north-northeast of Mountaineer mineral occurrence (025). Thickness of strata in photograph is approximately 900 m. View to the north.*

eastern map boundary and 3 km north of Rapitan Creek, a thick (150 m) succession of micaceous, purple-weathering siltstone is interbedded with more siliceous strata. In the study area, the Katherine Group is at least 800 m thick.

The Little Dal Formation, which conformably overlies the Katherine Group, is well exposed in the study area. The unit consists of grey- to yellow-weathering grey micritic dolostone interbedded with subordinate black-weathering shale. More coarsely grained varieties of dolostone, as described by Aitken et al. (1982), were not observed. The thickness of the Little Dal in the study area ranges up to 500 m.

Taken together, the Tsezotene-Katherine strata are lithologically and stratigraphically similar to the Hematite Creek Group (formerly units D-F of the Pinguicula Group), located 40 km east-southeast of the study area (Thorkelson, 2000). They apparently belong to the same regional sedimentary succession, ca. 1 Ga, and are derived, in part, from the Grenville orogen (Rainbird et al., 1997; Thorkelson, 2000).

SLATS CREEK FORMATION (?)

A succession of varied sedimentary strata, approximately 250 m thick, is exposed on the top of a mountain approximately 7.5 km northeast of the confluence of Rapitan Creek and the Bonnet Plume River. These strata overlie the Little Dal Formation above a gentle angular unconformity (10-20°). Norris (1981) suggested a correlation between these strata and the Knorr Ranges succession, whereas Norris (1984) included the strata in the Rapitan Group. However, it is suggested here that the succession is better correlated with the lithologically similar Middle Cambrian Slats Creek Formation as described by Norris (1981). A lower succession of interbedded brown-, grey- and maroon-weathering dolostone, dolostone conglomerate and dolostone diamictite (interpreted as olistostrome), and an upper succession of brown- to purple-weathering siliciclastic sandstone and granule conglomerate set in a carbonate matrix is recognized. The granule conglomerate contains abundant clasts of chert. The contact between the lower and upper successions is gradational.

IGNEOUS ROCKS

INTRODUCTION

Several generations of magmatism from Early Proterozoic to early Paleozoic have affected the study area through the emplacement of numerous dykes and sills. All of the igneous units are low in volume relative to their sedimentary host rocks; however, greater volumes of correlative plutonic rock may exist at depth.

BONNET PLUME RIVER INTRUSIONS

The Bonnet Plume River Intrusions (Thorkelson et al., 2001a) exist almost entirely as megaclasts in Wernecke Breccia (Fig. 9; Wernecke Breccia is discussed below) and rarely occur as dykes and small stocks within the Wernecke Supergroup. In the study area, the intrusions consist of fine- to medium-grained diorite which has been variably altered, veined and metasomatized. Samples from elsewhere in the Wernecke Mountains have been dated at 1.71 Ga, which provides a minimum age for the Wernecke Supergroup. The intrusions may be correlative with the Slab volcanics, which also occur as megaclasts in Wernecke Breccia, 500 m south of the southeastern corner of the study area (Laughton et al., 2002). The Bonnet Plume River Intrusions have compositions indicative of a rift origin and imply extension of Yukon crust in the Early Proterozoic.

BEAR RIVER DYKES

Two mafic dykes located approximately 1 km south of the Knorr Fault are tentatively regarded as Middle Proterozoic Bear River dykes (an alternative and equally plausible possibility is that they belong to the unnamed Late Proterozoic to early Paleozoic diorite dykes, described below). In the study area, the larger and better-studied of the two dykes is up to 15 m wide, extends for nearly 2 km, and dips to the west at approximately 60°. Its composition ranges from aphanitic greenstone to fine-grained diorite, and it hosts veins of quartz, calcite, epidote, pyrite, chalcopyrite, malachite and hematite. The dyke and veins are similar to those at a Bear River dyke locality 5 km south of the study area (Schwab and Thorkelson, 2001). The Bear River dykes have been dated at 1.27 Ga by the U-Pb method on baddeleyite (Thorkelson, 2000). They are scattered throughout much of the northern Wernecke Mountains and appear to be a westerly manifestation of the Mackenzie dyke swarm (Schwab and Thorkelson, 2001).

TSEZOTENE SILLS

Four exposures of diorite are regarded as Late Proterozoic Tsezotene Sills, which are common in the Mackenzie Mountains to the north and west of the study area (Aitken et al., 1982). In the study area, the sills were emplaced near the top of the Tsezotene Formation. In the Northwest Territories, Tsezotene Sills have been dated at ca. 779 Ma by the U-Pb method on baddeleyite (Heaman et al., 1992). Regionally, they are regarded as an early expression of Windermere-aged rifting and continental break-up.

QUARTET MOUNTAIN LAMPROPHYRE

Numerous lamprophyre dykes, herein collectively termed the Quartet Mountain lamprophyre, crosscut the Wernecke and Mackenzie Mountains supergroups in the study area. The dykes are particularly common on 'Quartet Mountain' (informal name), near the original Quartet mineral occurrence (003A; Fig. 2) but also crop out near the Ikona occurrence (029; Fig. 2). One lamprophyre that crosscuts the Mackenzie Mountains Supergroup at the eastern edge of the study area hosts altered xenoliths of apparent crustal and mantle provenance. Only a few lamprophyre dykes were seen in outcrop, but many more exist, as indicated by the local abundance of lamprophyre blocks in talus cones. The intrusions are brown-weathering, mafic, and host phenocrysts of phlogopite and clinopyroxene. Laznicka and Gaboury (1988) also reported perovskite phenocrysts in lamprophyre from Quartet Mountain, but this finding has not been verified. The most reliable age of lamprophyre emplacement in the region was provided by an $^{40}Ar/^{39}Ar$ biotite determination of ca. 522 Ma from a locality approximately 12.5 km south-southwest of the study area (this age determination was incorrectly assigned to the Slab volcanics by Thorkelson, 2000). Slightly older K-Ar biotite ages of ca. 613 Ma and ca. 552 Ma from lamprophyres north of the study area were reported by Delaney (1981). Taken together, these ages indicate a Late Proterozoic to Cambrian age of magmatism. The cause and significance of the Quartet Lakes lamprophyre is unknown.

LATE PROTEROZOIC TO EARLY PALEOZOIC DIORITE

Two large north-striking dykes up to 3 km long and 18 m wide crosscut the Katherine Group near the Farion mineral occurrence, east of the Bonnet Plume River. The longer, more westerly dyke was studied in greater detail. It dips approximately 70° to the west and is composed of chlorite-altered fine-grained diorite with aphanitic chilled margins. It is cut by epidote-quartz veins and thin veinlets composed of grey-weathering calcite, specular hematite and malachite. A K-Ar whole-rock age of ca. 398 Ma was reported by Norris (1981), and we suggest that this is the minimum age of the dyke. Its maximum age is that of the Katherine Group, approximately 1 Ga (Rainbird et al., 1997).

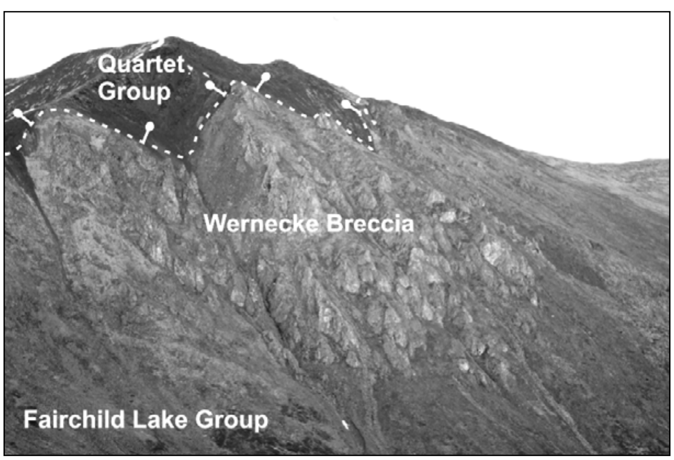


Figure 8. *Normal fault separating Quartet Group from Fairchild Lake Group and zone of castellate-weathering Wernecke Breccia and related metasomatically altered siltstone near the Otis mineral occurrence (001). View to southeast. Width of area is approximately 1 km.*

WERNECKE BRECCIA

Zones of hydrothermally generated breccia, collectively termed Wernecke Breccia, are present in the study area (Fig. 8). The breccias are regionally extensive, host numerous mineral occurrences and have been targets for mineral exploration for decades (Bell, 1986b; Thorkelson et al., 2002; Hunt et al., 2002). The breccias are

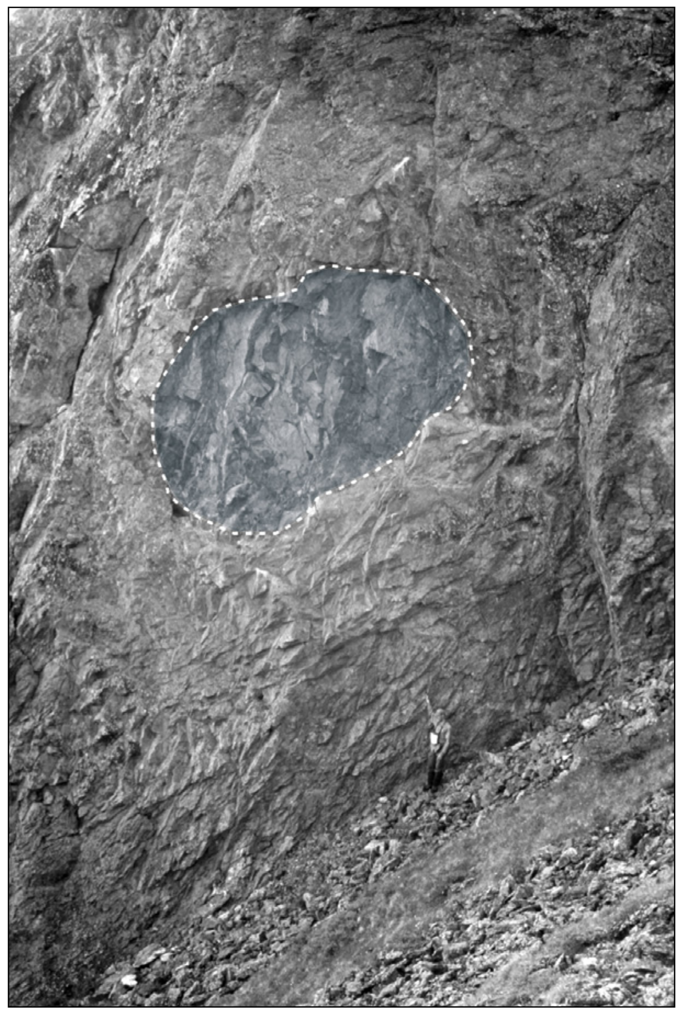


Figure 9. *Megaclast of diorite (approximately 6 x 9 m), outlined by white dashed line, on cliff face of Wernecke Breccia near newly recorded showing of the Quartet mineral occurrence (003B).*

Figure 10. *Weathered surface of Wernecke Breccia showing clasts of metasomatically altered siltstone in hydrothermally precipitated matrix, near newly recorded showing of the Quartet mineral occurrence (003B).*

characterized by clasts of metasomatized siltstone in a hydrothermally precipitated matrix containing abundant specular hematite (Fig. 10). All breccia zones host clasts of granule- to cobble-size, but some also contain megaclasts ranging from small boulders to blocks tens of metres wide, or larger. Locally, clasts and megaclasts of the Bonnet Plume River Intrusions are also present in breccia zones (Fig. 9). At 'Slab Mountain' (informal name), 500 m south of the study area, a 250-m-wide megaclast of the Slab volcanics lies within a megaclast-rich breccia (Laughton et al., 2002).

The oldest published date on Wernecke Breccia, ca. 1.60 Ga, was obtained from U-Pb analysis of titanite from breccia at Slab Mountain (Thorkelson et al., 2001b), and is presently regarded as the time when most of the brecciation occurred. Younger ages (Archer et al., 1986; Parrish and Bell, 1987) probably reflect either open-system behaviour of radioisotopes or younger pulses of hydrothermal fluids (cf. Schwab and Thorkelson, 2001).

STRUCTURE

Several events of structural deformation have affected the rocks in the study area. The ages of these events range from Early Proterozoic to early Tertiary. Brideau et al. (2002) examined the Fairchild Lake Group and Wernecke Breccia in the southeast corner of the study area (Fig. 2) and nearby parts of neighbouring map areas, and concluded that the first three deformational events in the region produced (1) a foliation in the Wernecke Supergroup (ranging from slaty cleavage to schistosity); (2) crenulations and a localized crenulation cleavage; and (3) kink bands. The regions of greater foliation development and metamorphic mineral growth (Fig. 6) appear to represent zones of greater strain and recrystallization, commonly in the cores or overturned parts of tight folds. Wernecke Breccia crosscut these structural features at 1.60 Ga, a relation that constrains the age of foliation, crenulation and kink-banding to Early Proterozoic. Collectively, these structures are regarded as manifestations of Racklan orogeny (Brideau et al., 2002).

Macroscopic folds are also likely to have developed during Racklan orogeny, and the most likely folds of Racklan age are north-trending structures in the western part of the study area. The most prominent of these folds is an east-verging overturned anticlinorium whose main hinge extends northward from near the Eaton mineral occurrence (040) along the west side of Quartet Mountain toward the Knorr Fault (Fig. 2). Regions of strong foliation and overturned beds exposed on Quartet Mountain and to the northeast near the Ikona mineral occurrence (029) are interpreted as products of minor folding associated with this anticlinorium. An east-verging syncline to the west of this anticlinorium, and another syncline in the northwestern corner of the study area, share the same structural trend and likely formed synchronously. Other folds of probable Racklan age include overturned anticline-syncline pairs in the Quartet Group, south and east of the Break mineral occurrence (024). Post-Racklan faulting and folding in the region is likely to have affected the geometry and orientation of the Racklan folds, and may be largely responsible for their tight, overturned structural style.

Development of Wernecke Breccia by repeated explosions of hydrothermal solutions (Thorkelson et al., 2001b; Hunt et al., 2002) produced localized but widespread shattering of the Wernecke Supergroup. Some steep faults with apparently normal displacements are spatially associated with zones of Wernecke Breccia (near the Otis mineral occurrence (001), for example), and may be broadly coeval with the brecciation.

Folding and faulting of post-Wernecke Breccia age have affected much of the study area. The most prominent features produced by these events are large-wavelength, west-northwest-trending folds and reverse faults in the Wernecke and Mackenzie Mountains supergroups. Three main folds are present, centred by a large south-verging anticline that trends along the Bonnet Plume River valley. This anticline extends for 25 km to the east-southeast into map area 106C/13 where it progressively tightens and becomes overturned (Thorkelson, 2000). In the study area, this anticline and its pair of flanking synclines appear to be related to, or are affected by, a set of north-northeast verging reverse faults. The Knorr Fault is the main fault in this set (Fig. 2). Reverse motion along the Knorr Fault has brought the Quartet Group alongside the Mackenzie Mountains Supergroup (Fig. 4). The immediate footwall of this fault consists of mylonitic carbonate breccia, locally tens of metres thick, which developed through fault-brecciation and shearing of bedded dolostone of the Tsezotene Formation. According to Norris (1984), the western end of the Knorr Fault curves toward the north and merges with the Richardson Fault array where it accommodates dextral strike-slip displacement (Fig. 2). In that framework, the part of the Knorr Fault exposed in the study area may be viewed as a restraining bend in an overall dextral transcurrent system. All of these folds and faults probably occurred during the Cretaceous to Tertiary Laramide orogeny and subsequent dextral transpression (Norris, 1997).

Another set of five folds is present in the Mackenzie Mountains Supergroup and Slats Creek Formation near the Farion mineral occurrence (004). The folds are tightly spaced, and for clarity, only one of the fold traces is identified in Figure 2; all are shown in Thorkelson et al. (2002). These structures trend at a moderate angle to the other post-brecciation folds, and the relation between these sets is uncertain. They could have been generated at different times under separate regimes or they could have developed at the same time, a possibility which is supported by the curvature in the Knorr Fault and the large anticline-syncline structures to the south. This curvature is most evident in the large anticline that lies in the Bonnet Plume River valley, south of the Irene (002) and Mountaineer (025) mineral occurrences. In map area 106C/13, to the southeast, the trend of this fold is nearly west, but it progressively curves northwestward as it extends into the study area. The same sense of curvature (concave to the northeast) is present in the folds near the Farion mineral occurrence (004), and this similarity may be evidence of structural continuity.

MINERAL OCCURRENCES

INTRODUCTION

All mineral occurrences in the area, except the Farion, occur southwest of the Knorr Fault and are classified in Yukon MINFILE 2002 as Wernecke Breccia-type. Mineral enrichments at these occurrences include copper in the form of chalcopyrite and malachite; uranium as uraninite, brannerite and pitchblende; thorium as thorite; molybdenum as molybdenite; and native gold. These enrichments occur in three general styles. Firstly, they occur as intrinsic parts of breccia bodies, as disseminated minerals, veinlets, or pods (e.g., the Irene occurrence, 002). Secondly, they occur within country rock or megaclasts as disseminated minerals, veinlets or pods (e.g., the Quartet occurrence, 003). Thirdly, they occur mainly in veins near or within zones of Wernecke Breccia (e.g., the Eaton occurrence, 040; the Ikona occurrence, 029; and the Five occurrence, 027A).

Some vein occurrences in the area may have been generated by hydrothermal activity during emplacement of nearby zones of Wernecke Breccia, whereas others may be younger (or older) features which developed from unrelated events of fracturing and fluid flow. This complexity raises a challenge for exploration geologists who wish to understand the origin of vein mineralization in regions affected by Wernecke Breccia. Geological and geochronological investigations may be useful in determining which vein occurrences are truly related to Wernecke Breccia, and which, if any, should be reclassified.

NEW SHOWING OF QUARTET OCCURRENCE

A new showing was identified by the authors on the southern part of Quartet Mountain, and is herein regarded as part of the Quartet mineral occurrence. The new showing will be assigned occurrence number 106E 003B in future editions of Yukon MINFILE; the original Quartet occurrence will be changed from 003 to 003A (Fig. 2). The new showing is located at the intersection of the following UTM grid coordinates (NAD 83): Zone 8; 529133 east; 7219734 north. The showing consists of abundant clots of chalcopyrite in highly metasomatized and veined Fairchild Lake Group siltstone in outcrop and an adjacent talus field. Cursory investigations of the area suggest that this exposure is a megaclast of country rock engulfed by a zone of dark-grey-weathering, grey Wernecke Breccia approximately 2.5 km long and 1 km wide. The surrounding breccia

(Fig. 10), which hosts several blocks of Bonnet Plume River diorite (Fig. 9), is generally rich in specular hematite but barren of chalcopyrite. Near a megaclast of diorite 400 m to the north of the showing, the breccia is mottled red and grey and hosts octahedral grains of magnetite up to 2 cm long.

The new showing is an example of how country rock and megaclasts are, in some instances, more enriched in copper than the host breccia. The change in breccia colour and iron oxide mineralogy in proximity to the diorite suggests that the igneous rock locally affected the geochemical character of the mineralizing fluids. These findings, which build upon those of Thorkelson (2000), highlight the importance of considering the distribution and type of clasts and wallrock when prospecting for Wernecke Breccia-type deposits.

'SLAB CREEK' AREA

The 'Slab Creek' area, in the southeast corner of the study area, is underlain by Fairchild Lake Group fine-grained sedimentary rocks, their schistose equivalents, and Wernecke Breccia (Hunt et al., 2002). Wernecke Breccia in this area has been divided into two units, known informally as Type 1 and Type 2, based on crosscutting relationships (ibid.). Type 1 Wernecke Breccia is limited in extent and consists of grey sedimentary clasts and locally abundant fragments of massive magnetite, in a matrix of carbonate mineral(s) and magnetite. Type 2 Wernecke Breccia cuts Type 1 and is made up of dominantly sedimentary clasts in a matrix that is itself fragmental. Type 2 breccia also contains rare clasts of fragmental matrix (Fig. 11), indicating that more than one phase of Type 2 brecciation occurred. Detailed information on this area is available in Brookes et al. (2002) and Brookes (2002).

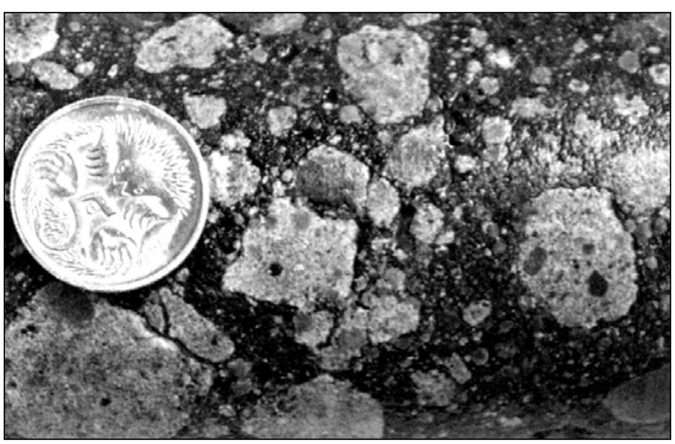


Figure 11. *Core sample of rebrecciated Wernecke Breccia (light grey) from the Irene mineral occurrence (002). Clasts of Wernecke Breccia are hosted in a dark, hydrothermally precipitated matrix.*

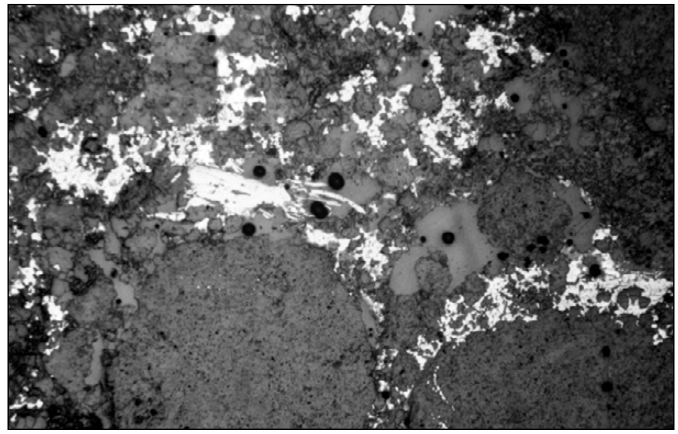


Figure 12. *Reflected-light photomicrograph of chalcopyrite (bright) within matrix to metasomatized siltstone clasts in Wernecke Breccia 5 km southeast of the Mountaineer mineral occurrence (025). Width of rock surface is 5.6 mm.*

Mineralization occurs in two zones about 500 m apart on the south side of Slab Creek, and may be regarded as part of the Slab mineral occurrence to the south, 106D 070 (Yukon MINFILE 2002). In these zones, iron oxide-copper-gold mineralization, dominantly hematite-magnetite-chalcopyrite (with minor molybdenum and uranium), is associated with breccia and occurs in five styles: (1) disseminated in quartz-carbonate veins cutting metasomatized sedimentary rocks proximal to the breccia bodies; (2) as up to 10-cm-thick, pyrite-chalcopyrite veins that cut Type 1 breccia; (3) as rare sulphide clasts in Type 2 breccia; (4) disseminated locally in the matrix and/or forming the matrix of Type 2 breccia (Fig. 12); and (5) as rare sulphide veinlets that crosscut Type 2 breccia.

Table 1. *Significant drill intercepts in the Slab Creek area. Information is from Vance et al. (1995, unpublished company report), Owerko (1995, unpublished company report), and Montgomery (1998, unpublished company report).*

DDH number	Length of intersection (m)	Cu %	Au (ppb)
SB95-5	13.8	0.42	150
SB95-6	9.7	0.57	110
SB95-8	12.7	0.03	410
SB97-9	213.05	0.175	36

Crosscutting relationships indicate that sulphide mineral deposition likely occurred after the emplacement of Type 1 breccia and continued until after the emplacement of Type 2 breccia (ibid.).

Diamond drilling in Slab Creek intersected mineralization associated with Wernecke Breccia in both zones, and significant results from this drilling are shown in Table 1. Slab Creek is approximately 1 km northwest of Slab Mountain which has a potential of 20 million short tons (18 million tonnes) grading 0.35% Cu and 0.17 g/t Au (with small zones of 0.1% MoS_2) based on three diamond drill hole penetrations and surface sampling (Vance et al., 1995, unpublished company report).

IRENE MINERAL OCCURRENCE

Introduction

At the Irene mineral occurrence (002; Fig. 2), iron oxide-copper-gold mineralization and minor uranium and cobalt enrichments are associated with Wernecke Breccia (Jones and Stammers, 1995, unpublished company report). Two regions of breccia are present: a lower one at the base of the mountainside at least 100 m thick, between 600 and 750 m elevation; and an upper, discontinuous one, 1-20 m thick, at approximately 1300 m elevation. The upper breccia zone is truncated by a thrust fault (Bell, 1986a; Thorkelson et al., 2002). Descriptions of the breccias and the mineral enrichments they host, based on observations of outcrops and polished sections, are summarized below.

Lower breccia

The lower breccia weathers tan to brown and hosts white- to cream-weathering clasts. It is hosted by phyllite and siltstone of the Fairchild Lake Group. The breccia is clast- to matrix-supported with a dominantly fine-grained, hard, white, pink or pale grey matrix. Locally the matrix consists of coarse-grained quartz and albite (locally with crystal faces – indicating open space filling) and lesser carbonate, magnetite, hematite, biotite, chlorite, muscovite, and minor pyrite and chalcopyrite and accessory apatite. Locally, disseminated fine-grained specular hematite and abundant pyrite porphyroblasts up to 3 cm across occur in the matrix.

Clasts in the lower breccia are dominantly sub-angular (rarely angular) to sub-rounded, fine-grained, purple-, grey- or white-laminated siltstone from 0.2 cm-2 m across (average 0.5-10 cm). Other clast types include sub-rounded sulphide + carbonate, 1-12 cm across (Fig. 13); rounded sulphide about 5 cm across; fine-grained

Figure 13. *Sulphide clast (black) in Wernecke Breccia, Irene mineral occurrence (002).*

carbonate; chloritic phyllite; and diorite clasts up to 12 x 10 m across which occur only locally. They are strongly chloritized, moderately magnetic and are cut by fractures coated with hematite. The diorite clasts are commonly crackle-brecciated on the margins by feldspar-quartz veins. The breccia also contains rare clasts of earlier breccia that are made up of fine-grained siltstone clasts in a medium-grained matrix of albite + quartz + muscovite + carbonate + minor disseminated hematite + accessory apatite. Rare 1-4 cm clasts of massive fine-grained specular hematite are also present in the breccia.

Contacts between siltstone and breccia vary from sharp to gradational. Where gradational, the siltstone varies from being completely replaced by feldspar-quartz alteration, to being crackle-brecciated, to containing feldspar-quartz veins with increasing distance from the breccia body.

Copper mineralization in the lower breccia occurs as

- rare rounded sulphide-carbonate and sulphide clasts up to 12 cm across in the breccia (Fig. 13);
- disseminated minerals in feldspar-quartz-pyrite-chalcopyrite veinlets within siltstone clasts in the breccia and replacement layers in siltstone clasts;
- chalcopyrite blebs in the carbonate matrix of the breccia; locally, chalcopyrite-pyrite forms the breccia matrix;
- sulphide blebs approximately 5 cm across in carbonate-chlorite-muscovite-pyrite-chalcopyrite-hematite ± magnetite veins and alteration that crosscut the breccia;

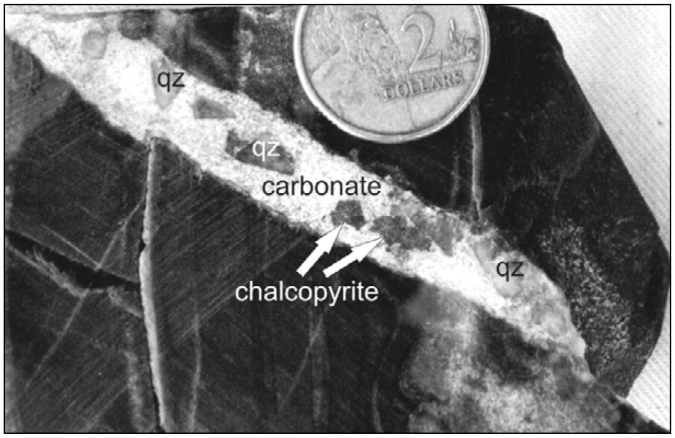


Figure 14. *Carbonate-quartz vein hosting chalcopyrite grains, Irene mineral occurrence (002); qz = quartz.*

- disseminated minerals in quartz-hematite-pyrite-chalcopyrite veins that cut Fairchild Lake Group siltstone and Wernecke Breccia;
- small blebs in coarsely crystalline carbonate ± chalcopyrite veins that cut Wernecke Supergroup sedimentary rocks and Wernecke Breccia;
- blebs and disseminated minerals in quartz–muscovite-hematite-chalcopyrite veins that cut Fairchild Lake Group siltstone. Quartz and muscovite crystals in these veins are up to 1 cm long and 0.5 cm across (Fig. 14);
- small blebs and disseminated minerals in feldspar-quartz-chalcopyrite veinlets that parallel and crosscut calcareous layers (layers are 5 to 20 cm thick) in siltstone, and as small blebs in the calcareous layers adjacent to the veins.

Massive chalcopyrite mineralization is exposed in a trench about 45 m above the valley floor. Samples of drill core from this location returned average grades of 3.6% Cu over 3.1 m in a fault zone, and 0.23 % Cu over 64.9 m in breccia (Yukon MINFILE, 2002). Other drill results in this area indicate there are large zones of low-grade copper-gold mineralization; samples from the best intersection returned results of 0.32 g/t Au and 0.42% Cu over 73 m (Jones and Stammers, 1995, unpublished company report).

Upper breccia

The upper breccia occurs as small discontinuous outcrops hosted in the Quartet Group, near the top of the ridge. Overall, the breccia weathers cream to light brown with local iron staining. Outcrops have a pitted appearance due to weathered-out clasts. The breccia is matrix-supported with a matrix of carbonate ± magnetite ± hematite ± quartz ± chlorite ± pyrite ± chalcopyrite. Clasts are dominantly composed of sub-rounded, laminated, brown, rusty-weathering carbonate 1 to 3 cm across. The remaining clasts (about 50%) are sub-rounded, <1 to 3 cm across and composed of fine-grained, light grey laminated siltstone/phyllite; fine-grained white clasts; fine-grained beige clasts; and fine-grained dark grey slate. Some of the siltstone/phyllite clasts have bleached alteration rims. Locally the breccia is crosscut by magnetite veinlets, carbonate-magnetite-chlorite veins, quartz veins and chlorite-biotite veins.

The breccia is in sharp contact with surrounding siltstone and locally crosscuts layering. White quartz veinlets cut the siltstone for up to 30 cm from the margin of the breccia. The siltstone is bleached for up to 10 cm from the breccia. Slate in contact with the breccia has round, black spots. In the upper breccia body pyrite-chalcopyrite mineralization occurs as a narrow vein, and as blebs and disseminated within the breccia matrix.

EATON MINERAL OCCURRENCE

The Eaton mineral occurrence (040) is located in a large region of Wernecke Breccia which spans the Slats Creek valley near the southwestern corner of the map area (Fig. 2). The Fairchild Lake and Quartet groups, and bodies of Bonnet Plume River diorite, host the breccia. Two distinctive types of mineral enrichments are present. One consists largely of chalcopyrite and uranium enrichments, which are typical of many Wernecke Breccia-hosted occurrences. The other consists of visible gold within quartz veins, which may be related to Wernecke Breccia formation or may represent an unrelated event of fluid flow and metallogenesis.

Breccia zone

Breccia near the Eaton occurrence, on the east side of Slats Creek, weathers dark green to brown (locally pink to red) and varies from clast- to matrix-supported. Clasts are sub-angular (rarely angular) to sub-rounded (rarely rounded) and made up dominantly of grey, maroon, pink and red fine-grained sediments, and banded to laminated siltstone. Clasts average about 5 cm across but larger clasts, up to 1 x 3 m, occur locally. Rare clasts of fine-grained brown-weathering carbonate up to 5 cm across occur locally. The breccia matrix is itself fragmental and is made up of micro-breccia with a carbonate matrix and fine-grained sedimentary clasts. Locally, there is abundant

Table 2. *Select anomalous results from surface sampling at the Eaton mineral occurrence (Montgomery and Stammers, 1995, unpublished company report; Montgomery, 1995, unpublished company report).*

Type	Au (ppb)	Cu	Co (ppm)	Sampled material
1.3 m chip	780	1.46%	43	mineralized potassium and silica metasomatized sedimentary rocks
8.4 m chip	45	4380 ppm	107	weakly mineralized breccia and metasomatized sedimentary rocks
2.0 m chip	1380	9650 ppm	63	mineralized potassium and silica metasomatized sedimentary rocks
select grab	140	1.66%	39	mineralized potassium and silica metasomatized sedimentary rocks
select grab	95	3.90%	253	malachite-stained contact between dolomitic shale and breccia

patchy fine-grained disseminated specular hematite in the matrix (Fig. 15).

Locally, breccia is fine-grained with sub-rounded to sub-angular fine-grained grey and pink sedimentary clasts <1 cm across. The matrix is dominantly made of carbonate and specular hematite. The breccia is generally non-magnetic and non-calcareous. Locally it is strongly chlorite- or sericite-altered, but is more typically stained pink to red, probably due to potassium feldspar and/or hematite alteration. The breccia is cut by brown-weathering carbonate-quartz ± chalcopyrite ± hematite veins up to 3 cm wide; some of these are tension veins.

In general, Wernecke Breccia in this area appears to occur as numerous narrow bands (that pinch out along strike), up to 1.5 m thick, emplaced parallel to layering in the sedimentary rocks. Locally, the breccia occurs in zones 20 to 80 cm wide that cut across siltstone and are roughly parallel to prominent jointing in the sediments. Contacts between siltstone and breccia vary from sharp to gradational (crackle-brecciated). Locally there is a strong fabric in the breccia and some clasts are elongate parallel to the fabric.

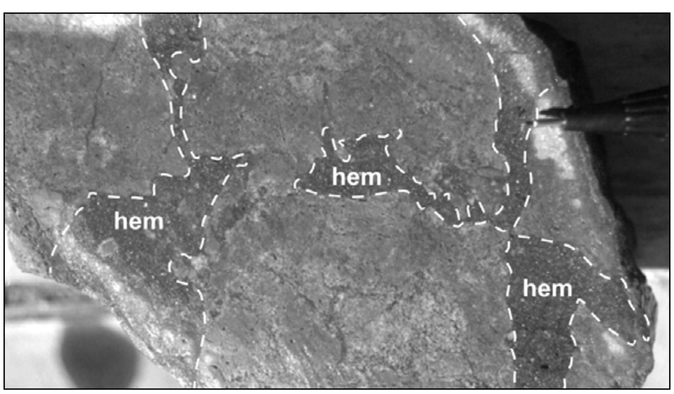


Figure 15. *Polished slab of Wernecke Breccia from near the Eaton mineral occurrence (040), featuring metasomatized siltstone clasts in matrix of massive specular hematite (labelled 'hem'). Width of surface is 7.5 cm.*

Mineralization

Iron oxide-copper ± gold ± cobalt mineralization is associated with Wernecke Breccia, metasomatically altered sedimentary rocks and diorite at the Eaton occurrence. A selection of results from this style of mineralization is shown in Tables 2 and 3.

The mineralization is widely distributed and generally low-grade with sporadic high-grade occurrences (Montgomery, 1995, unpublished company report). In general, it is dominated by chalcopyrite that occurs as disseminated fine- to coarse-grained patches and in veins and fractures. Pyrite occurs locally. Cobaltite and bornite occur rarely. Pods of massive specular hematite up to 2 x 3 m are also associated with the breccia zones. They contain rare euhedral pyrite approximately 1 mm across, and rare tiny blue specks tentatively identified as bornite. A 2- to 4-m-wide vein of massive medium-grained magnetite + very coarse-grained specular hematite + carbonate + quartz extends for at least 50 m within brecciated phyllite of the Fairchild Lake Group.

Table 3. *Select results from analysis of diamond drill core from the Eaton mineral occurrence (Montgomery, 1995, unpublished company report).*

Width (m)	Cu (ppm)	Au (ppb)
29.5	1080	spot highs to 310
7.5	2093	
5.75	1270	< 20
1.8	8	875

Gold-quartz veins

Gold-rich, brannerite-bearing, quartz-vein material containing up to 10% gold by volume is present in a float train. Lower grade samples typically returned results of 686-10 285 g/t Au (Yukon MINFILE, 2002). The source of this material has not been found.

FARION MINERAL OCCURRENCE

According to Yukon MINFILE 2002 and our investigations, the Farion occurrence (004) is a showing of sphalerite, galena and marcasite near a fault and a Late Proterozoic to early Paleozoic dyke. No additional mineralization in this region was found in the course of mapping.

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Age of the gold-bearing White Channel Gravel, Klondike district, Yukon

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Westgate, J.A., Sandhu, A.S., Preece, S.J. and Froese, D.G., 2003. Age of the gold-bearing White Channel Gravel, Klondike district, Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 241-250.

ABSTRACT

Four new glass-fission-track age determinations on three distal tephra beds, together with published magnetostratigraphic and $^{40}Ar/^{39}Ar$ age data, securely place a Late Pliocene age (2.6-3.3 Ma) on the upper White Channel Gravel in the Klondike district of the Yukon. No tephra beds have been found in the lower White Channel Gravel, so its age is only loosely constrained by paleomagnetism and paleobotany, which suggest a post-Miocene and pre-Late Pliocene age.

RÉSUMÉ

Quatre nouvelles datations par la méthode des traces de fission dans le verre de trois couches de téphra distales ainsi que des datations magnétostratigraphiques et $^{40}Ar/^{39}Ar$ publiées permettent de conférer un âge du Pliocène tardif (2,6-3,3 Ma) au gravier supérieur de White Channel dans le district de Klondike au Yukon. Aucune couche de téphra n'a été localisée dans le gravier inférieur de White Channel. C'est pourquoi son âge n'est basé que sur des données paléomagnétiques et paléobotaniques qui le font remonter à une période postérieure au Miocène et antérieure au Pliocène tardif.

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INTRODUCTION

Much of the placer gold in the Klondike district of the Yukon has been recovered from the White Channel Gravel, a quartz-rich fluvial deposit, commonly preserved as high-level terraces along valleys that radiate from the King Solomon Dome in that part of the Klondike uplands framed by the Klondike and Indian rivers, and Dominion Creek (Figs. 1, 2; McConnell, 1905, 1907; Lowey, 1998). McConnell (1907) thought the White Channel Gravel was probably of Pliocene age, and subsequent studies have supported this view. Tempelman-Kluit (1980) envisaged a Late Miocene erosional surface of low relief and elevation, uplifted and dissected by rejuvenated streams. The White Channel Gravel is thought to have been deposited during the early phase of this uplift, probably during the Pliocene. Morison (1987) interpreted the presence of *Corylus* sp. as evidence of a Pliocene age. Further support comes from the work of Kunk (1995), who obtained hornblende $^{40}Ar/^{39}Ar$ age estimates of 2.64 to 3.01 Ma on Quartz Creek tephra in the upper White Channel Gravel at Quartz Creek (Figs. 1, 3). A zircon-fission-track age determination of 0.80 (± 0.40 Ma) on the same tephra is clearly too young given the physiographic and stratigraphic setting of the White Channel Gravel (Morison et al., 1998). Paleomagnetic and stratigraphic information likewise suggested to Froese et al. (2000) that deposition of the White Channel Gravel spanned the Pliocene.

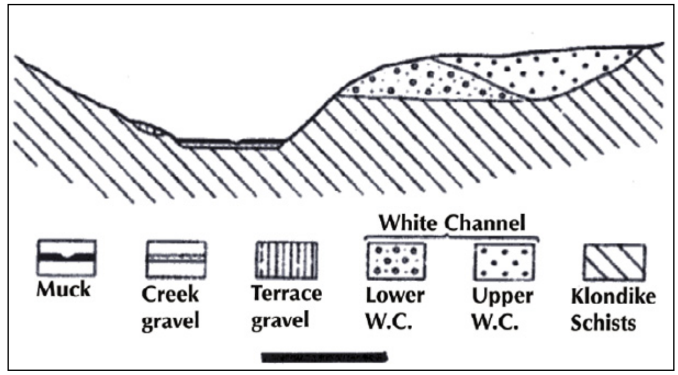


Figure 2. *Generalized geological section across Hunker Creek showing the upper and lower units of the White Channel Gravel and its physiographic setting (modified after Froese et al., 2000). Scale bar represents 100 m.*

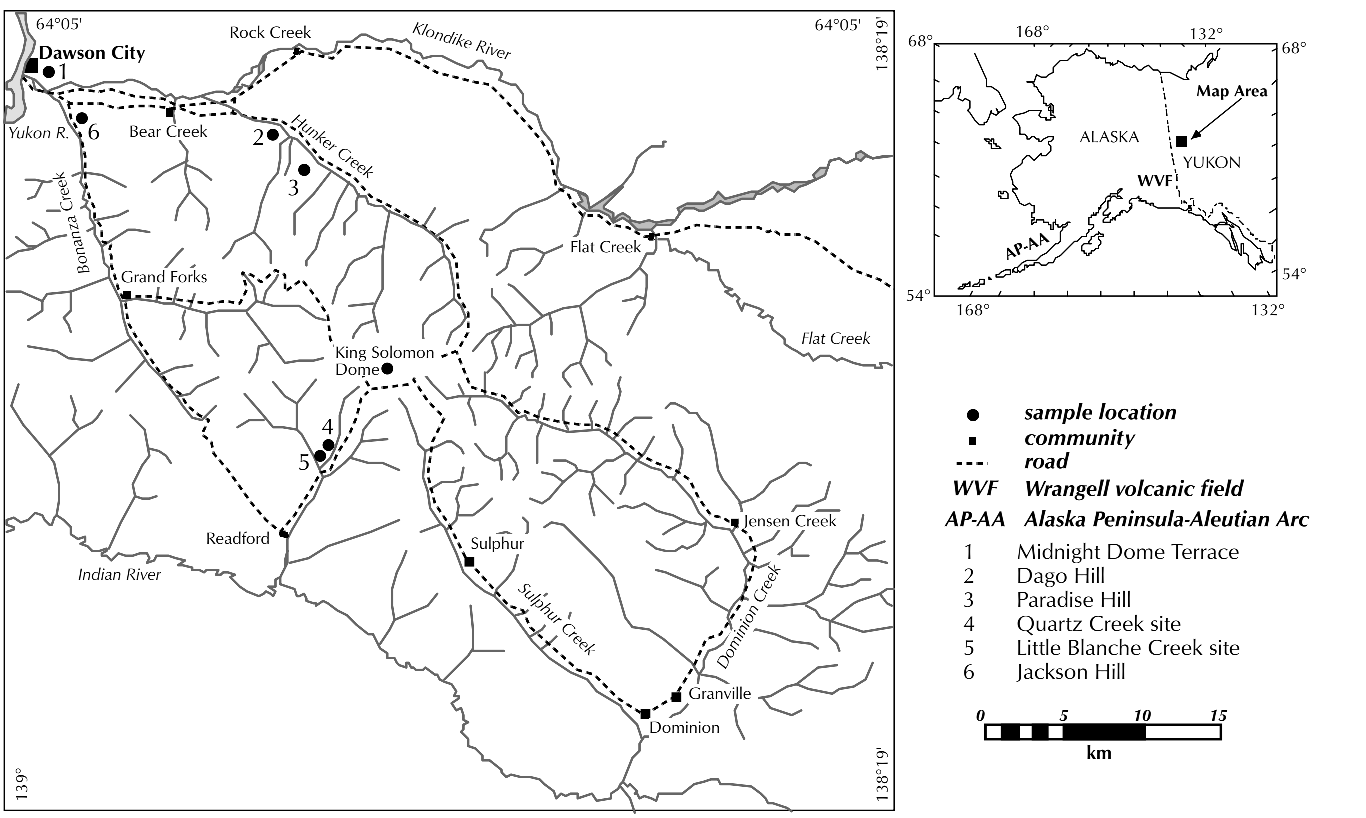


Figure 1. *The Klondike district of the Yukon showing locations of sites where sediments are exposed that provide information on the age of the White Channel Gravel. Inset map shows source regions (WVF and AP-AA) of volcanoes that contributed tephra to the Klondike region during the late Cenozoic.*

Four distal tephra beds occur in and just above the upper White Channel Gravel and provide an opportunity for an improved chronology through application of glass-fission-track (ft) dating methods (Westgate, 1989; Sandhu et al., 1993; Sandhu and Westgate, 1995). The objectives of this paper are to give the compositional characteristics of these distal tephra beds, noting their significance with respect to source volcanoes, and to present five glass-ft age estimates, which the authors evaluate in the light of other age constraints, including biostratigraphic controls.

LITHOSTRATIGRAPHIC SETTING OF TEPHRA BEDS

McConnell (1905, 1907) first recognized the lower (white) and upper (yellow) subdivisions of the White Channel Gravel on the basis of colour, lithology, and clast preservation. The older unit is typically quartz-rich gravel, which, in places, has been altered. The younger unit has a similar lithology, although the clasts are better preserved, and contains periglacial features such as ice-wedge casts and involutions (Froese et al., 2000). It is locally separated from the older gravels by an unconformity.

Four geological sections are particularly pertinent to the problem of the age of White Channel Gravel, namely, the Quartz Creek site, Dago Hill, Paradise Hill and Jackson Hill (Figs. 1 and 3). Quartz Creek tephra (UT1001, UT1634) occurs within the sedimentary fill of an ice-wedge cast in the upper White Channel Gravel at Quartz Creek (locality 4, Fig. 1; Sandhu, et al., 2001). Two tephra beds are exposed at Paradise Hill: Little Blanche Creek tephra (UT1623) is preserved as pods, up to 5 cm thick (Fig. 4), about 4 m below the top of the upper White Channel Gravel; and Paradise Hill tephra (UT1624) has been reworked into multiple, thin, discontinuous beds over a stratigraphic interval of 20 cm in sands and silts about 50 cm above the top of the upper White Channel Gravel. Colluvial silt with organic-rich beds overlies Paradise Hill tephra (Fig. 3). The mode of occurrence of Dago Hill tephra (UT1553) is very similar to that of Little Blanche Creek tephra, except that in this case only a wispy lens was preserved in the upper White Channel

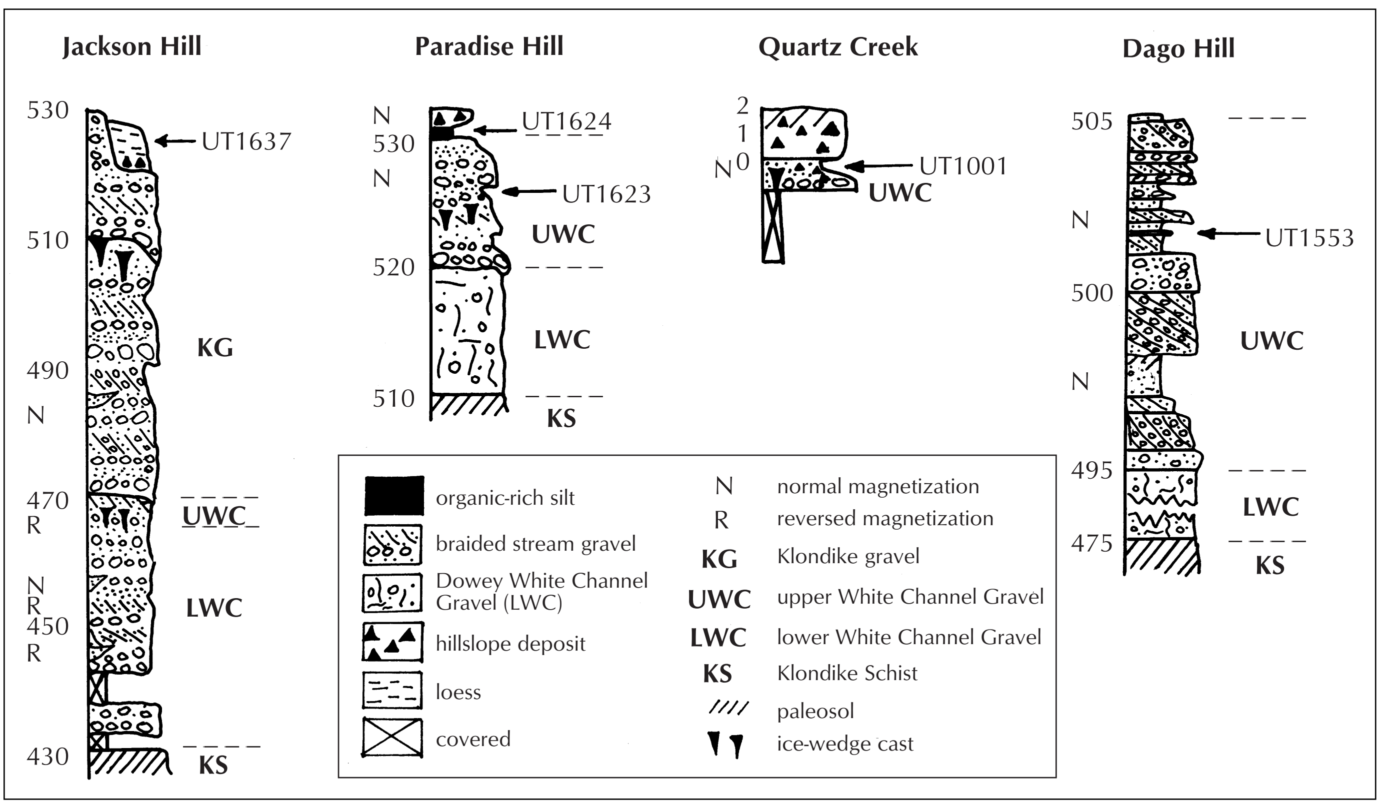


Figure 3. *Lithostratigraphic setting of tephra beds and paleomagnetic measurements at Jackson Hill, Paradise Hill, Quartz Creek and Dago Hill (modified from Sandhu et al., 2001, p. 249). Identity of tephra beds as follows: UT1637, VT tephra; UT1623, Little Blanche Creek tephra; UT1624, Paradise Hill tephra; UT1001, Quartz Creek tephra; UT1553, Dago Hill tephra. Elevation in metres is given for all sites except Quartz Creek, where only the thickness is given.*

Gravel (Fig. 5). In all, three tephra beds offer the potential of improving age controls on the upper White Channel Gravel (Quartz Creek, Little Blanche Creek and Dago Hill), with one other, Paradise Hill tephra, likely giving a close minimum age for this unit.

DESCRIPTION OF TEPHRA BEDS

Quartz Creek, Little Blanche Creek and Paradise Hill tephra beds are crystal-rich with abundant hornblende, plagioclase and Fe-Ti oxides, and minor amounts of hypersthene, apatite and zircon. Their rhyolitic glass (Fig. 6) is mostly in the form of highly inflated pumice, although some chunky glass of low vesicularity is present, but very rare, in Quartz Creek and Paradise Hill tephra beds. These three tephra beds can be readily distinguished from one another on the basis of their glass composition, each bed possessing a homogeneous population (Table 1; Fig. 7). Quartz Creek tephra is relatively enriched in K, Little Blanche Creek tephra has relatively high values for Al, Fe, and Ca (Table 1), and Paradise Hill tephra has the highest values of heavy rare-earth elements in its glass (Fig. 7b). In addition, their compositional fields are quite distinct on the K_2O-Al_2O_3 plot (Fig. 7c). These compositional characteristics, including the weak Eu anomaly in their rare-earth-element profiles (Fig. 7b), demonstrate that these three tephra

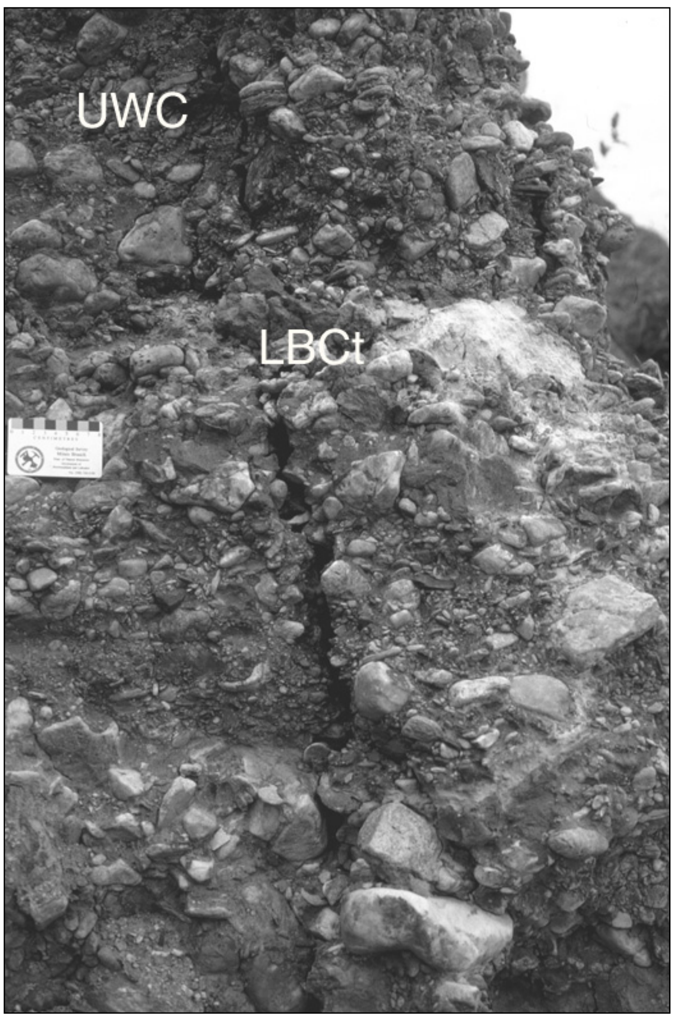


Figure 4. *Little Blanche Creek tephra (LBCt, UT1623) in the upper White Channel gravel (UWC) at Paradise Hill. Scale is in centimetres.*

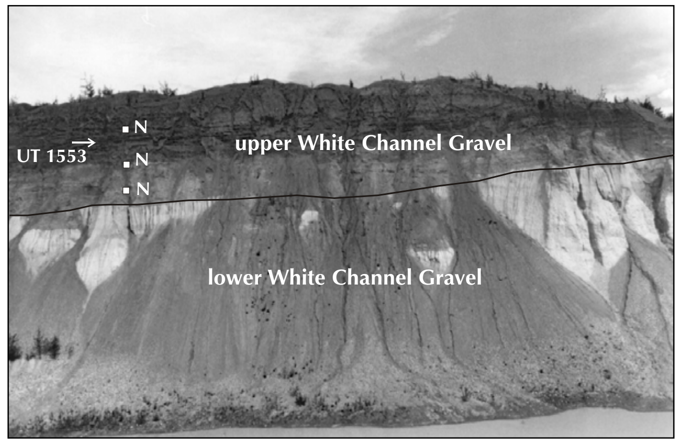


Figure 5. *Relationship between the upper and altered lower White Channel Gravel at Dago Hill. These two units are here separated by a conspicuous unconformity. The stratigraphic position of Dago Hill tephra (UT1553) and normally (N) magnetized sediment are shown in the upper White Channel gravel.*

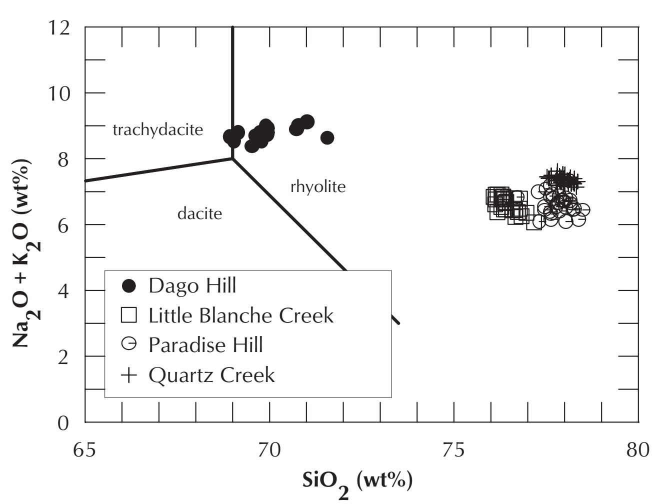
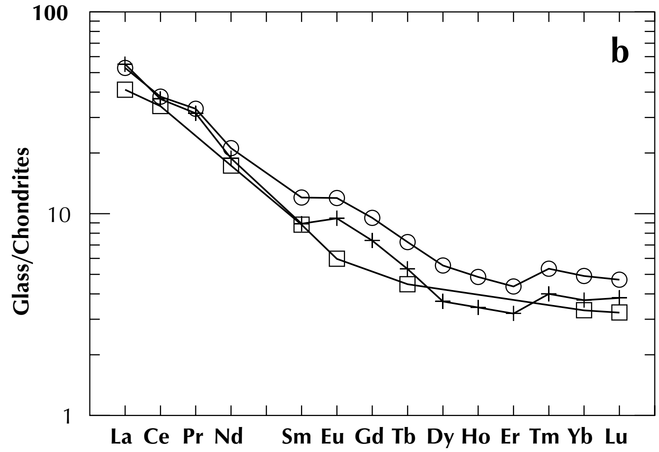


Figure 6. *Chemical classification of tephra beds in the upper White Channel Gravel and immediately overlying sediment based on the composition of their glass shards using the total alkali-silica (TAS) diagram.*

beds belong to the type II class of Preece et al. (1999) and come from vents in the Wrangell volcanic field of Alaska (Fig. 1).

Dago Hill tephra is very different. It has abundant bubble-wall glass shards, mostly of a brownish hue. The small amount of material available prevented a representative description of its mineralogy. However, being a type I tephra bed (see below), crystals would be sparse and consist of plagioclase and pyroxene with minor amounts of amphibole, magnetite, ilmenite, apatite and zircon. Glass shards have a rhyolitic composition with some shards straddling the boundary between the trachydacite



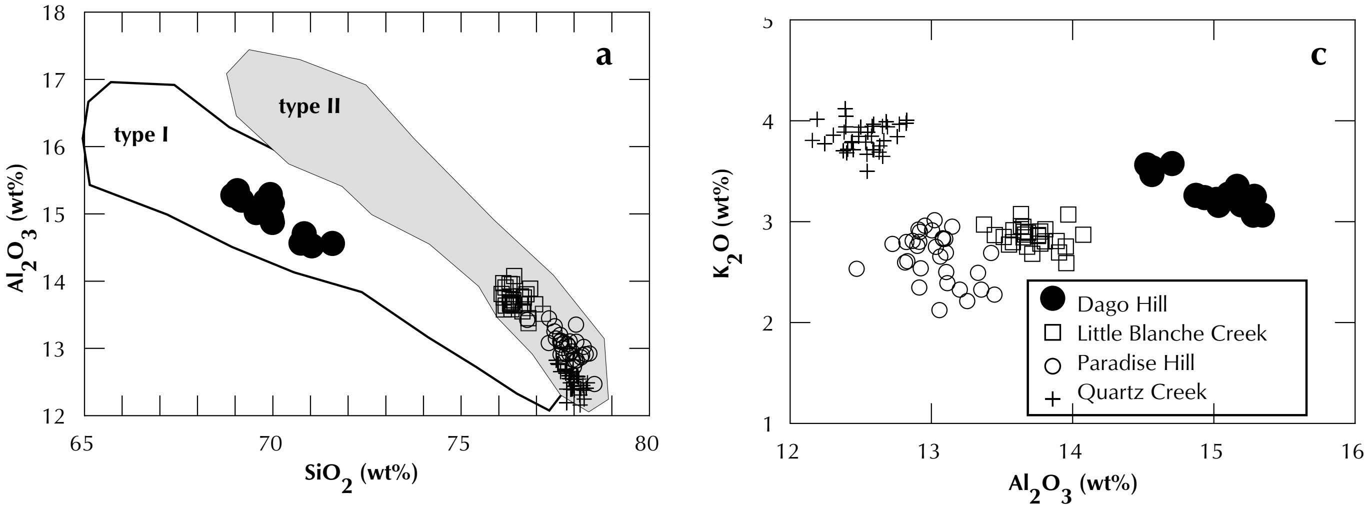


Figure 7. *Major- and rare-earth-element composition of glass shards in Dago Hill, Paradise Hill, Little Blanche Creek, and Quartz Creek tephra beds.* ***(a)*** *Classification of tephra beds into type I and type II groups of Preece et al. (1999).* ***(b)*** *Rare-earth element profiles of the type II tephra beds showing pronounced enrichment of light rare-earth elements over heavy rare-earth elements and weak Eu anomaly.* ***(c)*** *Oxide variation plot showing good separation of the four tephra beds on the basis of their K and Al contents.*

Table 1. *Average glass major-element composition of tephra beds.*

	Dago Hill		Little Blanche Creek		Paradise Hill		Quartz Creek	
SiO_2	70.00	(0.77)	76.46	(0.26)	77.83	(0.36)	77.96	(0.21)
TiO_2	0.56	(0.06)	0.18	(0.07)	0.16	(0.05)	0.17	(0.06)
Al_2O_3	14.99	(0.29)	13.72	(0.17)	13.03	(0.21)	12.52	(0.16)
FeO_t	3.69	(0.29)	1.14	(0.08)	0.89	(0.07)	0.83	(0.07)
MnO	0.13	(0.03)	0.05	(0.02)	0.03	(0.03)	0.03	(0.02)
CaO	1.38	(0.21)	1.53	(0.07)	1.23	(0.16)	0.93	(0.05)
MgO	0.43	(0.09)	0.29	(0.03)	0.22	(0.04)	0.16	(0.03)
Na_2O	5.44	(0.14)	3.75	(0.24)	3.93	(0.20)	3.52	(0.13)
K_2O	3.29	(0.17)	2.85	(0.11)	2.65	(0.24)	3.84	(0.13)
Cl	0.07	(0.02)	0.03	(0.02)	0.03	(0.02)	0.04	(0.02)
H_2O_d	3.94	(1.63)	5.55	(1.52)	5.41	(1.04)	5.06	(0.93)
n	15		27		31		37	

Notes: Analyses (wt%) done on a Cameca SX-50 wave-length dispersive microprobe operating at 15 kV accelerating voltage, 10 μm beam diameter, and 6nA beam current.

Standardization achieved by use of mineral and glass standards. Analyses recast to 100% on a water-free basis. (#) = standard deviation, n = number of analyses, FeO_t = total iron oxide as FeO, H_2O_d = water by difference. Average composition based on non-zero values for the following samples: Dago Hill (UT1553), Little Blanche Creek (UT1054, UT1455, UT1623), Paradise Hill (UT1556, UT1624), Quartz Creek (UT1001, UT1053, UT1544). Compositional data on Quartz Creek tephra is from Sandhu et al., 2001, p. 252.

and rhyolite fields on the total alkali-silica (TAS) diagram (Fig. 6). The silica content at a given Al_2O_3 concentration is low relative to the type II tephra beds (Fig. 7A) and indicates a type I identity (Preece et al., 1999), the source vent being located in the Alaska Peninsula-Aleutian arc region (Fig.1).

GLASS-FISSION-TRACK AGES

The age of the distal tephra beds in the upper White Channel Gravel and overlying sediments was determined by the population-subtraction fission-track method (Wagner and Van den haute, 1992). Glass is the dated phase, and, in all cases, the fundamental requirement of a unimodal population was met (Fig. 7). Correction for partial fading of fission tracks was done in two ways. A heat treatment approach was used for tephra beds with glass shards larger than 120 µm (ITPFT method; Westgate, 1989), whereas finer grained tephra beds were corrected by comparison of the size of the induced and spontaneous fission tracks in the irradiated and natural glass aliquots of a particular tephra bed, respectively (DCFT method; Sandhu and Westgate, 1995; Westgate et al., 1997). These two procedures are entirely independent of one another, and they can thus be used on the same tephra bed — provided the glass shards are large enough — as a means of evaluating the reliability of the age data.

An internal glass standard is included in each irradiation can as a means of assessing the accuracy of the age determinations. The 2 million-year-old rhyolitic Huckleberry Ridge tephra (UT1366), derived from the cataclysmic eruption at Yellowstone, U.S.A., is used for this purpose. The sample comes from an air-fall deposit at Meade County, Kansas. Ages obtained on this glass standard for four separate irradiations are presented in Table 2. Both ITPFT and DCFT methods have been used. Ages range from 2.00 to 1.97 Ma, which is within 2% of the $^{40}Ar/^{39}Ar$ age of 2.003 ± 0.014 Ma (Gansecki et al., 1998). The relative standard error (Bigazzi and Galbraith, 1999) associated with a single age determination varies from 11-13% (Table 2), but this is dramatically reduced when several age determinations are done. For example, the weighted mean age of UT1366 based on four age determinations is 1.99 ± 0.11 Ma, giving a relative standard error of less than 6%.

Another indication that our glass-fission-track (glass-ft) age estimates are of acceptable accuracy comes from the Midnight Dome tephra (UT1552) at the Midnight Dome Terrace site (Fig. 1). Its glass-DCFT age of 1.09 ± 0.18 Ma

Table 2. *Glass-fission-track ages of the internal standard (Huckleberry Ridge tephra).*

Sample number Analyst	Date irradiated	Spontaneous track density $10^2 t/cm^2$	Corrected spontaneous track density $10^2 t/cm^2$	Induced track density $10^5 t/cm^2$	Track density on muscovite detector over dosimeter glass $10^5 t/cm^2$	Etching conditions HF:temp:time %:°C:s	D_s µm	D_i µm	D_s/D_i OR D_i/D_s #	Age Ma
Huckleberry Ridge tephra: internal standard										
UT1094	31/01/00	43.23 ± 1.42		4.21 ± 0.03	4.87 ± 0.04	24:21:120	6.09 ± 0.07	7.54 ± 0.09	0.81 ± 0.01	1.59 ± 0.17
JAW		(931)		(25152)	(12744)					
UT1094*			53.57 ± 1.76	4.20 ± 0.03	4.87 ± 0.04	24:21:120	6.09 ± 0.07	7.54 ± 0.09	1.24 ± 0.02#	1.97 ± 0.21*
			(931)	(25152)	(12744)					
UT1366$	26/04/00	12.80 ± 0.91		1.15 ± 0.02	5.63 ± 0.03	24:22:140	6.47 ± 0.08	6.58 ± 0.05	0.98 ± 0.01	2.00 ± 0.25$
AS		(200)		(5741)	(43489)					
UT1366$	11/09/00	23.50 ± 1.66		2.07 ± 0.01	5.47 ± 0.04	24:25:140	6.15 ± 0.11	6.19 ± 0.08	0.99 ± 0.02	1.98 ± 0.26$
AS		(200)		(10267)	(20991)					
UT1366	23/11/00	40.75 ± 1.30		4.64 ± 0.03	5.61 ± 0.05	24:25:100	5.98 ± 0.06	7.63 ± 0.09	0.78 ± 0.01	1.57 ± 0.16
JAW		(980)		(27443)	(14359)					
UT1366*			52.00 ± 1.66	4.63 ± 0.03	5.61 ± 0.05	24:25:100	5.98 ± 0.06	7.63 ± 0.09	1.28 ± 0.02#	2.00 ± 0.21*
			(980)	(27443)	(14359)					

Notes: See Table 3 for details on dating procedures and explanation of symbols. The single-crystal(sanidine) laser-fusion $^{40}Ar/^{39}Ar$ age of Huckleberry Ridge tephra is 2.003 ± 0.014 Ma(2σ error) (Gansecki et al.,1998). The weighted mean corrected age of UT1366 based on these four glass-ft age estimates is 1.99 ± 0.11 Ma.

agrees well with a position immediately below the lower boundary of the Jaramillo magnetozone (Froese et al., 2000), dated at 1.07 Ma on the geomagnetic polarity time scale of Cande and Kent (1992, 1995). This age estimate also lends weight to the accuracy of the similarly dated Mosquito Gulch tephra (UT1592; 1.45 ± 0.14 Ma), which occurs at the base of the loess sequence at the same locality, about 8 m below Midnight Dome tephra. The glass-ft age of Mosquito Gulch tephra is, in turn, supported by its occurrence halfway between the AT (UT1098; 1 Ma) and PA (UT497; 2.02 ± 0.14 Ma) tephra beds at Fairbanks, Alaska (Preece et al., 1999).

Table 3. *Glass-fission-track ages of distal tephra beds in upper White Channel Gravel and immediately overlying sediments, Klondike district, Yukon.*

Sample number Analyst	Date irradiated	Spontaneous track density 10^2t/cm^2	Corrected spontaneous track density 10^2t/cm^2	Induced track density 10^5t/cm^2	Track density on muscovite detector over dosimeter glass 10^5t/cm^2	Etching conditions HF:temp:time %:°C:s	D_s µm	D_i µm	D_s/D_i OR D_i/D_s#	Age Ma
UPPER WHITE CHANNEL GRAVEL										
Quartz Creek tephra										
UT1001	31/01/00	39.30 ± 1.96		2.69 ± 0.02	5.01 ± 0.04	24: 22: 110	6.01 ± 0.09	7.61 ± 0.10	0.79 ± 0.02	2.36 ± 0.26
AS		(401)		(14637)	(12744)					
UT1001*			49.75 ± 2.50	2.64 ± 0.02	5.01 ± 0.04	24: 22: 110	6.01 ± 0.09	7.61 ± 0.10	1.27 ± 0.02#	3.00 ± 0.33*
			(401)	(14637)	(12744)					
UT1634$	26/04/00	24.50 ± 1.70		1.50 ± 0.01	5.63 ± 0.03	24: 23: 150	6.09 ± 0.17	6.05 ± 0.07	1.01 ± 0.03	2.93 ± 0.36$
AS		(200)		(11113)	(43489)					
									Weighted Mean Corrected Age	2.97 ± 0.24
Dago Hill tephra										
UT1553	23/11/00	17.80 ± 1.26		1.18 ± 0.02	5.61 ± 0.05	24: 25: 60	5.59 ± 0.14	6.60 ± 0.08	0.85 ± 0.02	2.68 ± 0.35
AS		(200)		(5749)	(14359)					
UT1553*			21.02 ± 1.49	1.18 ± 0.02	5.61 ± 0.05	24: 25: 60	5.59 ± 0.14	6.60 ± 0.08	1.18 ± 0.03#	3.18 ± 0.41*
			(200)	(5749)	(14359)					
SEDIMENTS IMMEDIATELY ABOVE UPPER WHITE CHANNEL GRAVEL										
Paradise Hill tephra										
UT1624	11/09/00	6.29 ± 0.46		0.84 ± 0.01	5.47 ± 0.04	24: 25: 90	5.42 ± 0.12	6.18 ± 0.09	0.88 ± 0.02	1.30 ± 0.15
JAW		(188)		(6970)	(20991)					
UT1624*			7.17 ± 0.52	0.84 ± 0.01	5.47 ± 0.04	24: 25: 90	5.42 ± 0.12	6.18 ± 0.09	1.14 ± 0.03#	1.48 ± 0.17*
			(188)	(6970)	(20991)					
UT1624	11/09/00	7.10 ± 0.64		0.86 ± 0.01	5.47 ± 0.04	24: 25: 90	5.42 ± 0.12	6.18 ± 0.09	0.88 ± 0.02	1.43 ± 0.19
AS		(125)		(4282)	(20991)					
UT1624*			8.09 ± 0.72	0.86 ± 0.01	5.47 ± 0.04	24: 25: 90	5.42 ± 0.12	6.18 ± 0.09	1.14 ± 0.03#	1.63 ± 0.22*
			(125)	(4282)	(20991)					
									Weighted Mean Corrected Age	1.54 ± 0.13

Notes: The population-subtraction method was used; details are given in Westgate et al. (1997). Samples with asterisk corrected for partial track fading by the track-size (DCFT) method (Sandhu and Westgate, 1995); samples with a dollar sign corrected by heating the spontaneous and induced glass aliquots at 150°C for 30 days, the ITPFT method (Westgate, 1989); the uncorrected age is noted simply by the sample number. Ages calculated using the Zeta approach and λ_D =1.551 x 10^{-10}yr^{-1}. Zeta value is 318 ± 3 based on six irradiations at the McMaster Nuclear Reactor, Hamilton, Ontario, using the NIST SRM 612 glass dosimeter and the Moldavite tektite glass (Lhenice locality) with an $^{40}Ar/^{39}Ar$ plateau age of 15.21 ± 0.15 Ma (Staudacher et al., 1982). Standard error (±1σ) on age estimate is calculated according to Bigazzi and Galbraith (1999). Area estimated using the point-counting technique (Sandhu et al., 1993). D_s = mean spontaneous track diameter, D_i = mean induced track diameter. Number of tracks counted is given in brackets. See Table 2 for information on internal standards. Information on the DCFT age of Quartz Creek tephra (UT1001*) is from Sandhu et al., 2001.

Glass-ft ages on distal tephra beds in the upper White Channel Gravel are given in Table 3. Quartz Creek tephra (UT1001, UT1634) at Quartz Creek (Fig. 1) has a DCFT age of 3.00 ± 0.33 Ma and an ITPFT age of 2.93 ± 0.36 Ma, giving a weighted mean age of 2.97 ± 0.24 Ma. This age estimate is compatible with the normal magnetic polarity of the enclosing sediments (Figs. 3, 8; C2An.1n of Cande and Kent, 1995). Dago Hill tephra (UT1553) has a DCFT age of 3.18 ± 0.41 Ma, very similar to that of Quartz Creek tephra. It also agrees with the normal polarity of sediments just above it (Fig. 3), which would belong to the normal magnetozone C2An.2n of Cande and Kent (1995) if the accuracy of this age estimate is comparable to that of the internal standard (Fig. 8). Hence, the upper White Channel Gravel is of Late Pliocene age.

At the nearby Paradise Hill site (Figs. 1 and 3), another tephra bed was found in the upper White Channel Gravel, namely, the Little Blanche Creek tephra (UT1623). This unit is not datable by glass-ft methods because of its highly pumiceous glass, but the abundance of hornblende suggests that it might be possible to determine its age by the $^{40}Ar/^{39}Ar$ method. The same tephra bed has been found in White Channel Gravel to the south of the King

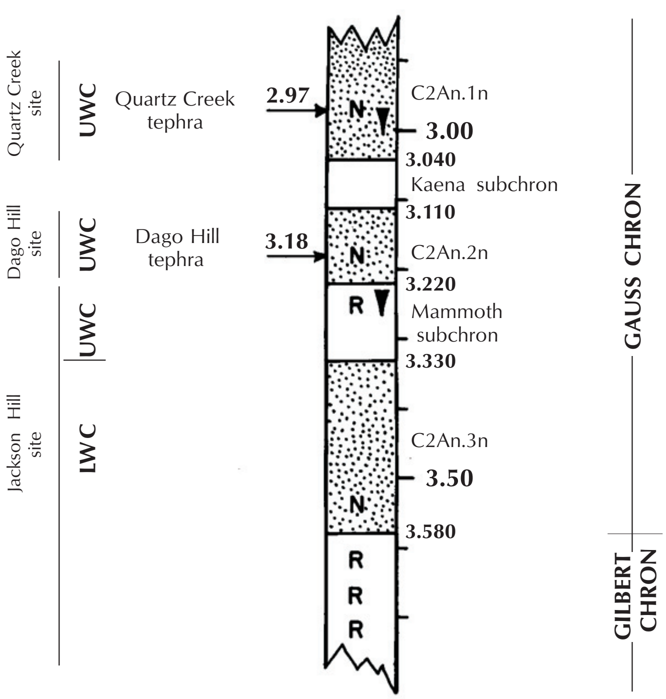


Figure 8. *Proposed correlation of the upper and lower White Channel Gravel to the geomagnetic polarity time scale of Cande and Kent (1995). Ages in Ma.*

Solomon Dome drainage divide along Quartz Creek (locality 5, Fig. 1; Preece et al., 2000).

Another rhyolitic tephra bed was discovered at Paradise Hill in silts just above the White Channel Gravel (Fig. 3). We have named this unit the Paradise Hill tephra (UT1624), and, although its glass is predominantly pumiceous, it does have some bubble-wall shards of low vesicularity that have enabled us to determine its age by the glass-DCFT method (Table 3). Given its stratigraphic position, we anticipated an age slightly younger than 3 Ma, based on the ages of Quartz Creek and Dago Hill tephra beds. The weighted mean age of Paradise Hill tephra is 1.54 ± 0.13 Ma, which is considerably younger than expected. The top of the White Channel Gravel at this locality must be defined by a significant unconformity.

DISCUSSION

Only one $^{40}Ar/^{39}Ar$ age determination has been made on the distal, late Cenozoic tephra beds of the Klondike region. Quartz Creek tephra has a minimum age of 2.71 Ma, a total gas (maximum) age of 3.01 Ma, and an isochron age of 2.64 ± 0.24 Ma (Kunk, 1995). Our glass-fission track age of 2.97 ± 0.24 Ma is in good agreement with the former two age estimates and within 1σ of the isochron age. Hence, a Late Pliocene age for this tephra bed and its enclosing sediments can be considered secure, as is the age of the upper White Channel Gravel with its paleomagnetic measurements (Froese et al., 2000) calibrated with fission-track ages that place its range between 2.6-3.3 Ma (Fig. 8).

The correlation of the White Channel Gravel to the geomagnetic time scale of Cande and Kent (1995) shown in Figure 8 is suggested if we accept the criteria of Froese et al. (2000) for identification of the lower White Channel and upper White Channel Gravel, note their paleomagnetic measurements, and assume that the accuracy of the glass-ft age of Dago Hill tephra is comparable to that of the internal standard (Table 2). This correlation suggests that climatic conditions conducive to the growth of ice wedges in the Klondike region started some time during the Mammoth Subchron and that part of the lower White Channel Gravel was deposited during the Gilbert Chron.

The age of the lower White Channel Gravel is only loosely constrained by its associated paleomagnetism and a single pollen sample recovered from the middle part of this unit at Jackson Hill (Fig. 3). This sample is dominated by Picea and *Pinus* pollen with Abies and traces of *Corylus* and *Poacea* (J. White, unpublished Geological Survey of Canada Paleontological report 7-JMW-1996; sample C-248449). This assemblage is similar to other Pliocene flora that have been recovered from sediments at sites in adjacent Alaska, including the Nenana gravel and Circle terrace gravel, but is most similar to the slightly younger Lost Chicken flora (Ager et al., 1994; White et al., 1997). Relevant to a maximum age estimate for the lower White Channel Gravel, however, is the absence of *Tsuga* (hemlock) pollen. At other late Miocene-earliest Pliocene sites in Alaska, particularly at Nenana and Circle, the presence of Tsuga has been used to infer a latest Miocene age or early Pliocene age (ca. 5 Ma). Thus, we conclude, based on the limited paleobotanical evidence presently available, that the lower White Channel Gravel is post-Miocene and pre-Late Pliocene and likely represents approximately 2 million years of gravelly deposition in the Klondike.

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Plants, bugs, and a giant mammoth tusk: Paleoecology of Last Chance Creek, Yukon Territory

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ABSTRACT

An exceptional, complete tusk of a mature male woolly mammoth (*Mammuthus primigenius*) was recovered from a placer mining exposure on Last Chance Creek, Yukon Territory in July, 2002. The tusk is associated with peat dated to 25 700 ± 400 ^{14}C yrs BP. The direct association of Pleistocene fossils with past vegetation is rare, and allows a comparison between the local vegetation of Last Chance Creek and megafauna during the last glaciation. Preliminary analyses of plant and insect macrofossils from the peat indicate a vegetation cover composed of a mosaic of mesic riparian meadows with sedges, mosses, and willows, and well-drained grasslands or steppe with diverse herbs and sage. This discovery supports the interpretation that the "Mammoth-Steppe" biome existed near the onset of the last glaciation in eastern Beringia.

RÉSUMÉ

En juillet 2002, on a récupéré une défense exceptionnelle de mammouth mâle mature laineux (*Mammuthus primigenius*) dans un gîte placérien sur le ruisseau Last Chance (Yukon). La défense est associée à une tourbe datée à 25 700 ± 400 ans BP (^{14}C). Il est rare de faire une association directe entre des fossiles pléistocènes et la paléovégétation; elle permet de comparer la végétation locale du ruisseau Last Chance avec la mégafaune de la dernière glaciation. Les premières analyses de macrofossiles de plantes et d'insectes contenus dans la tourbe indiquent une couverture végétale composée d'une mosaïque de prés ripicoles mésiques avec des laîches, des mousses et des saules ainsi que des prairies ou une steppe bien drainées avec diverses herbes et sauges. Cette découverte appuie l'interprétation selon laquelle il existait un biome productif « mammouth-steppe » à l'approche de la dernière glaciation dans la Béringie orientale.

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INTRODUCTION

In July, 2002, two of the authors (Froese and Zazula) were conducting fieldwork on Last Chance Creek in the Klondike goldfields as part of the Ancient Pacific Margin NATMAP program (Fig. 1). Part of the program involves collecting sediment samples to establish ages and environmental settings of placer gold deposits. After finishing sample collection, Froese noticed the mid-portion of a tusk exposed in the creek gravel. After two hours of excavation, a complete tusk was recovered of exceptional quality from an adult mammoth and peat beds associated with the tusk and gravel. Given the rarity of recovering Pleistocene fossils with a clear geologic setting, this afforded a unique opportunity to examine the paleoenvironment inhabited by the mammoth. The following is a summary of the preliminary results of that work. A context for this work is also provided in relation to larger controversies regarding the paleoenvironments associated with large mammals in unglaciated Yukon and Alaska (eastern Beringia) during the last glaciation.

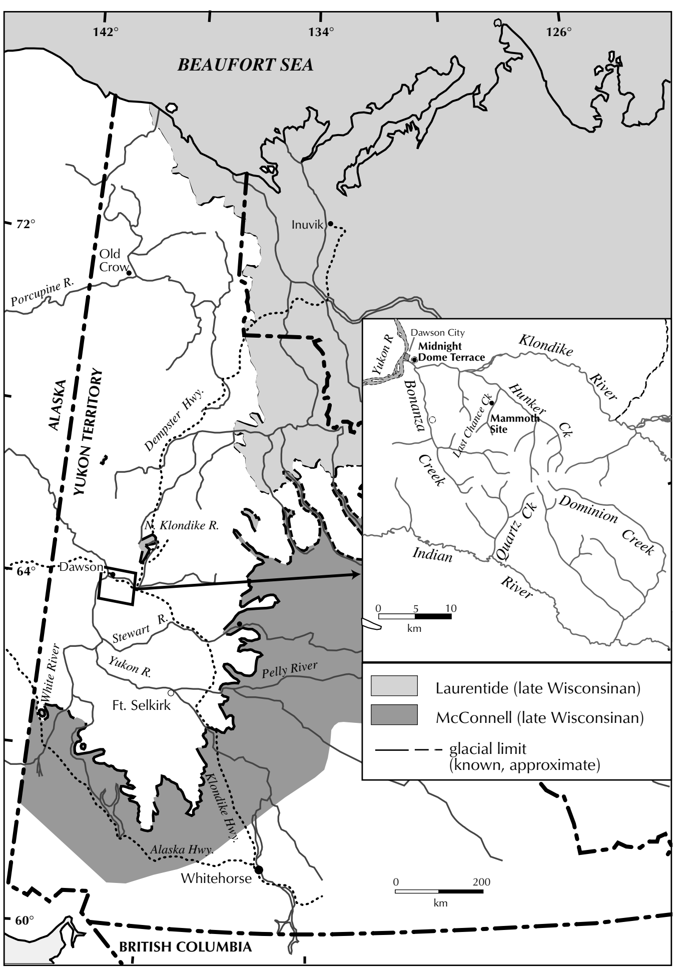

Figure 1. *Location of Last Chance Creek site in relation to late Wisconsinan and McConnell age continental ice margins (after Westgate et al., 2001).*

THE BERINGIA REFUGIUM

During the last glaciation or late Wisconsinan, *ca.* 27 000 to 12 000 years ago, the Laurentide ice sheet advanced from centres in the Northwest Territories to the eastern flanks of the Richardson and Mackenzie mountains, while the northern Cordillera was covered by the Cordilleran ice sheet from the south (Duk-Rodkin and Froese, 2001). Coalescence of these glaciers formed a barrier between the unglaciated region of interior Yukon and Alaska and the rest of North America. A drop in global sea level, by as much as 120 m, exposed the Bering Land Bridge between western Alaska and northeastern Siberia. The unglaciated landmass from Yukon to Siberia is known collectively as Beringia, a region that functioned as a refugium for plants and animals, and a migration corridor between the Old and New Worlds (Hopkins et al., 1982).

PALEOENVIRONMENTS OF BERINGIA

Early paleoenvironmental research portrayed Late Pleistocene Beringia as a productive arctic grassland inhabited by diverse megafauna (Colinvaux, 1964; Hopkins, 1967; Guthrie 1968). Pollen analyses of lake cores and alluvial sections from Alaska and Yukon (Colinvaux, 1964; Rampton, 1971) indicates that Beringian vegetation was dominated by grasses (Poaceae), sedge (Cyperaceae), sage (*Artemisia*) and a variety of arctic herbs during the last glaciation (reviewed in Schweger, 1997). Investigation of fossils recovered from Alaska and Yukon placer mines indicates that the Pleistocene fauna was dominated by large mammal grazers, including steppe bison (*Bison priscus*), woolly mammoth (*Mammuthus primigenius*), and horse (*Equus* sp.) which relied heavily on grasses for their diet (Guthrie, 1968; Harington, 1979, 1989).

The hypothesized Beringian grassland or "Mammoth-Steppe" as synthesized by Guthrie (1990) has been challenged by other paleoecologists, and the nature of the full glacial environment of Beringia became a topic of heated debate. Cwynar and Ritchie (1980), for instance, emphasized that fossil pollen influx from lake sediments, an indirect measure of vegetation cover, was very low during glacial times and included many tundra species. This suggested that Beringian vegetation was more similar to a sparse herb tundra such as found in the high arctic today and not grassland or steppe (Cwynar and Ritchie, 1980), and implied a marginal environment for megafauna (Colinvaux, 1980, 1996; Colinvaux and West, 1984). The conflicting observations of limited vegetation cover and a diverse and abundant grazing megafauna has been termed the "productivity-paradox" (Schweger et al., 1982). Simply put, how could Beringia support large mammals during a time of extensive glaciation and limited plant productivity when present vegetation and milder climate in this region cannot maintain such a fauna? A solution to this problem rests in the detailed reconstruction of Beringian environments through the study of paleoecological data, including pollen, spores, and plant and insect macrofossils from sites that also contain Pleistocene mammal fossils. Discovery of the mammoth tusk frozen in gravel and associated with peat at Last Chance Creek affords a unique opportunity to directly study Late Pleistocene environments incontrovertibly inhabited by woolly mammoth and other Beringian megafauna.

KLONDIKE PALEONTOLOGY IN THE 'MUCKS'

The investigation of Beringian environments in the Klondike has largely focussed on the abundant Pleistocene bones that are readily observed during placer mining. Efforts to study Pleistocene bones in the Klondike were initiated through the efforts of C.R. (Dick) Harington of the National Museum of Canada during the 1960s (Harington, 1978). Harington and others collected Pleistocene bones from placer mines, including specimens of woolly mammoth, horse, bison, American lion, mountain sheep, giant beaver, mastodon, muskox, caribou, moose, camel, brown bear, and saiga antelope (Harington, 1978, 1989). Typically, the bones were recovered from near the base of 'muck' deposits, an informal name for the unconsolidated, fine-grained, ice-rich silts that are found in valley-bottom sites overlying gold-bearing gravel. These deposits originate from the reworking of loess (windblown silts) by small streams and hillslope processes in the Klondike (Fraser and Burn, 1997). In rare circumstances, mummified flesh from these animals has been recovered. The most dramatic discovery was a partial adult horse (*Equus lambei*) carcass found at Last Chance Creek in 1993, dating to about 26 300 years ago (Harington and Eggleston-Stott, 1996; Harington, 2002). Recently, J. Storer has continued with collection and analysis of mammal fossils in the Klondike (Storer, 2001). Although much research has focussed on Pleistocene bones, little systematic attention has been given to studying fossil pollen, spores or plant and insect macrofossils from the Klondike.

LAST CHANCE CREEK LITHOSTRATIGRAPHY

In late 2001, local miner Lee Olynyk started excavating at 5-Above-Discovery-Pup (local name) along the left limit of Last Chance Creek. By mid-summer of 2002, hydraulic monitoring had cut through the middle of a loess/muck fan on the margin of Last Chance Creek. The cut produced a 15-m section consisting of cobble-gravel, 3 m thick, overlain by up to 12 m of massive- to weakly stratified silt (Fig. 2). Paleocurrent indicators within the gravel indicate a flow direction parallel to Last Chance Creek, suggesting the gravel is derived from the creek. A prominent silty peat bed approximately 5-10 cm thick occurring within the gravel was traced over a lateral distance of *ca.* 5 m, and represents a former floodplain surface. Within the silt, 3-4 m above the gravel-silt contact, a prominent volcanic ash (tephra) was found (Fig. 3). The tephra is a fine-grained, glass-rich bed with a white to pinkish colour. The bed lacks the coarse texture, pumice and hornblende typically associated with tephra beds from the Wrangell volcanic field (Type II beds such as the White River or Sheep Creek tephras). Given the appearance of this bed and its stratigraphic setting, we ascribe it to the Late Pleistocene Dawson tephra (Westgate et al., 2000; Froese et al., 2002). The tephra can be traced laterally in each face of the exposure,

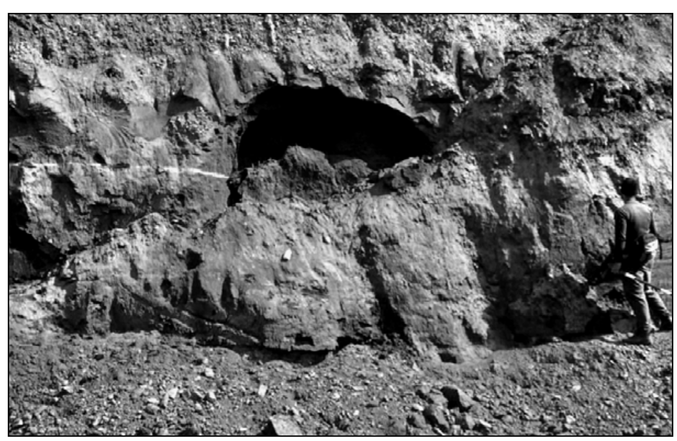

Figure 2. *Exposure at Last Chance Creek. Gravel at base, overlain by silt, with Dawson tephra. Photo by D. Froese, July, 2002.*

Figure 3. *Tephra bed, assumed to be Dawson tephra (ca. 24 000 years old), occurring 4 m above the mammoth tusk and peat. Photo by B. Alloway, July, 2002.*

indicating the entire gravel and silt sequence below is older than 24 000 ^{14}C yrs BP (Froese et al., 2002). Stratigraphy observed at Last Chance Creek is consistent with other Late Pleistocene 'muck' exposures in the Klondike (Fraser and Burn, 1997; Kotler and Burn, 2000).

THE MAMMOTH TUSK

The mammoth tusk was recovered from the frozen gravel within the peat, 4 m below Dawson tephra. It weighs 85 kg (183 lbs), is 2.8 m (10' 6") long and has a maximum circumference of 0.56 m (22") (Fig. 4). The authors identified the tusk as an adult male woolly mammoth (*Mammuthus primigenious*) based on its double helical spiral and large size. This designation was made because tusks from female mammoths and both sexes of mastodon tend to be thinner, shorter and straighter (Vereschagin and Baryshnikov, 1982; Kubiak, 1982). This

Figure 4. *Mammoth tusk excavated from Last Chance Creek gravel and peat. Left to right are D. Froese, L. Olynyk and S. Armstrong. Photo by G. Zazula, July, 2002.*

specimen displayed exceptional preservation, with minimal longitudinal desiccation cracking and minimal post-mortem scratching or scouring. These conditions suggest that the animal died and was rapidly buried in close proximity to the site of recovery with little reworking by the stream. The gravel was examined further for other bones from the mammoth or other mammals but none were found. Other bones observed at the mine, however not in direct association with the tusk, included a partial skull of both a bison (*Bison priscus*) and a horse (*Equus lambei*).

A prominent abrasion zone is visible at the tip of the tusk on both the lower and upper surfaces (Fig. 5). Abrasion on the lower surface is common on many tusks recovered in Beringia. This has been hypothesized to represent a wear facet that developed as the mammoth used their tusks to sweep aside snow to assist with winter grazing (Vereschagin and Baryshnikov, 1982; Kubiak, 1982).

Figure 5. *Abrasion zone at the distal end of the mammoth tusk. Photo by B. Alloway, July, 2002.*

However, abrasion zones on juvenile tusk specimens typically only appear on the bottom of the tusk. The observation of abrasion zones on both the upper and lower surfaces of our tusk also suggests it was from an adult. (Vereschagin and Baryshnikov, 1982). Because tusks grow continually through life and spiral with age, the observed abrasion pattern probably reflects wear incurred both during young and old age (Kubiak, 1982). This abrasion feature provides potential insight regarding the behaviour of this extinct mammal.

ANALYSIS OF FOSSIL PEAT

During excavation, three bags (*ca.* 2.0 l) of frozen silt-rich peat were collected from around the tusk. For laboratory analyses, 500 ml of peat was measured by water displacement and washed through stacked 2.00, 0.25 and 0.125 mm sieves. From the retained material, plant macrofossils were isolated and identified by Zazula. A portion of the sample was submitted to Telka for the identification of insects. Several sedge (*Carex*) seeds were submitted for AMS radiocarbon dating and yielded a date of 25 700 ± 400 yrs BP (BETA-171748), placing the deposition of peat and the mammoth tusk near the onset of the late Wisconsinan glacial interval.

The peat contains diverse and abundant, well preserved plant remains. The plant macrofossil assemblage is dominated by well preserved sedge (*Carex*) rhizomes and stems, various mosses, willow (*Salix*) twigs and persistent buds, various seeds, and smaller herbaceous plant fragments. Seeds of grasses and grass-like plants are common, and there was an abundance of sedge achenes, with occasional specimens of wild-rye (*Elymus*), fescue (*Festuca*), blue grass (*Poa*), and rushes (*Juncus*). Flowers of sage (*Artemisia*) are present but rare in the assemblage. Seeds of herbaceous flowering plants are diverse, but comprise a minor component of the assemblage and consistently show more evidence of abrasion than other specimens. These include seeds of yarrow (*Achillea millefolium*), chickweed (*Cerastium*), sandwort (*Minuartia rubella*), campion (*Silene*), goosefoot (*Chenopodium*), knotweed (*Polygonum*), mountain sorrel (*Oxyria digyna*), mustards (*Draba type*), cinquefoil (*Potentilla*), buttercup (*Ranunculus*), fairy-candelabra (*Androsace septentrionalis*) and poppy (*Papaver*). No large pieces of wood or other macrofossils from trees were recovered.

Insect remains are abundant and generally well preserved in the peat. These are dominated by ground beetles (*Carabidae*), rove beetles (*Staphylinidae*) and weevils

(*Curculionidae*). Most of the insects recovered are presently common to moist stream-side environments. A few specimens indicate better drained environments. Importantly, specimens of the weevil *Connatichela artemisiae* were recovered, which is known to presently inhabit southern steppe habitats today, including dry south-facing slopes where it feeds on sage (*Artemisia*). Other insects observed in lower frequencies include the rare fossil remains of Hymenoptera (*Cheloninae*), leafhopper (*Cicadellidae*) and leaf-beetle *Chrysolina*. These taxa are common to open grassland vegetation dominated by grasses and other forbs. The authors did not recover any remains of forest insects. However, the presence of the fly *Xylophagus*, whose larvae live in decaying wood, suggests that some large shrubs were probably present.

LATE PLEISTOCENE VEGETATION AND MEGAFAUNA

The sedimentary context of the peat suggests it is primarily autochthonous, formed by small overbank flood events burying local riparian vegetation. However, the diverse habitat preferences for many taxa identified in the macrofossil assemblage suggests a mosaic of habitats and vegetation types were dispersed locally. Particularly, the habitat preferences of taxa differ in their tolerance to either mesic or xeric conditions. Thus, some taxa found within the peat were probably incorporated as detrital components derived from habitats adjacent to the riparian zone during stream aggradation events. The location of vegetation types was probably controlled primarily by available moisture, soil conditions and topographic setting. The combined macrofossil assemblage, however, suggests that trees were either absent or a minor component of the vegetation near Last Chance Creek near the onset of the last glaciation, 25 000 years ago.

Concordant with the sedimentological interpretation of our autochthonous peat, the macrofossil assemblage is dominated by well preserved macrofossils representing mesic sedge-moss meadows with willows buried *in situ* by silt within the riparian zone. The predominance of these taxa probably reflects the availability of water within the riparian zone of Last Chance Creek. The availability of abundant vegetation, as well as a water source, suggests that riparian meadows may have been an important habitat for woolly mammoths. Further, several taxa in the macrofossil assemblage have preferences for dry sites, suggesting the local presence of grassland or steppe vegetation, with sage and flowering forbs. The relative rarity of these taxa and in most cases poorer preservation suggests that they probably have origins from vegetation that inhabited dry open slopes adjacent to the valley bottom. Recovery of plant and insect specimens confirming the local presence of sage (*Artemisia*) are important ecologically because this taxon is a key component of dry steppe vegetation. Bunch-grasses, and perennial herbs, too, were probably important sources of fodder for grazing megafauna.

The deposition of fine-grained loess sediments, the retransported components of which form the Klondike 'muck' deposits, may have been an important factor in the formation of productive soils and the maintenance of open grassland or steppe vegetation (Laxton et al., 1996; Schweger, 1992). The established ages for the Dawson tephra (*ca.* 24 000 yr BP) and our radiocarbon date from the peat indicate that loess began rapidly accumulating in the Klondike shortly after 25 700 ±400 yr BP. Thus, these ages place important chronological context to the dramatic environmental changes in the region associated with the onset of late Wisconsinan glaciation and climates.

Macrofossils associated with the Last Chance Creek mammoth tusk are contemporaneous and similar to those recovered from around the carcass and within the intestinal contents of the Last Chance Creek horse mummy (Harington, 2002). Macrofossil analysis indicates that this horse had been feeding on grassland vegetation similar in composition to that found in our peat. The abundance of plant remains within the intestinal tract, especially grasses, indicates the horse did not die of starvation and did not inhabit a marginal habitat with sparse vegetation (Harington, 2002). Analyses of intestinal contents and plant fragments preserved in tooth pits of Beringian woolly mammoths concluded that they relied heavily on grasses and herbs for their diet (Guthrie, 2001; Ukraintseva, 1993). The diversity of habitats near Last Chance Creek was probably important to provide sufficient fodder year round for Pleistocene megafauna. One can readily imagine mammoths foraging in meadows, drinking water from Last Chance Creek during the spring and summer, and sweeping the light snow cover away with their tusks to eat dried grasses and other forage during the long, cold winter.

The vegetation reconstructed for Last Chance Creek is similar to the Late Pleistocene vegetation near Old Crow in the northern Yukon as proposed by Zazula (2002).

Multi-proxy paleoecological data, including pollen, insects and plant macrofossils from the Bluefish Basin also indicate a mosaic of vegetation types dominated by open steppe vegetation with sedge-moss riparian meadows (Zazula, 2002). The Bluefish Basin was also home to a community of grazing megafauna during the last glaciation (Cinq-Mars, 1990; Cinq-Mars and Morlan, 1999; Harington, 1989). These combined results suggest that the Yukon refugium probably constituted the easternmost extension of a more widespread biome that is hypothesized to have spanned across Beringia. Several lines of evidence suggest that a widespread "Mammoth-Steppe" biome was alive and well in Yukon during the last glaciation.

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PROPERTY DESCRIPTIONS

Ultramafic nickel-bearing magmas of the Nadaleen River map area (106C/3) and associated listwaenites: New exploration targets in the Mayo Mining District, Yukon

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Jutras, J.-P., 2003. Ultramafic nickel-bearing magmas of the Nadaleen River map area (106C/3) and associated listwaenites: New exploration targets in the Mayo Mining District, Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 261-266.

ABSTRACT

Pentlandite-bearing serpentinized ultramafic flows with a komatiitic composition have been identified within volcano-sedimentary stratigraphy in the Nadaleen Range. Associated listwaenites or silica-carbonate-fuchsite-altered serpentinites carry locally significant gold, copper, nickel and cobalt values. The occurrence of laterally extensive ultramafic units at the northern edge of the Selwyn Basin remains difficult to explain within the current scope of geological knowledge in the area. However, it represents a new style of exploration target for copper-nickel-bearing massive sulphide deposits, as well as listwaenite-associated gold.

RÉSUMÉ

Des coulées de lave ultramafiques de composition komatiitique contenant de la pentlandite ont été reconnues au sein de la séquence volcano-sédimentaire des Monts Nadaleen. Des roches listwanitiques à dominance de silica-carbonate-fuchsite associées aux coulées représentent une forte altération des unitées ultramafiques et contiennent localement des teneurs importantes en or, cuivre, nickel et cobalt. La présence d'unitées ultramafiques d'étendue importante en bordure nord du Bassin de Selwyn demeure énigmatique dans l'état actuel des connaissances de la géologie du district. Par-contre, leur présence souligne de nouvelles cibles d'exploration dont l'objectif serait la découverte de dépots de sulphures massifs contenant du nickel et du cuivre ainsi que des dépots aurifères associés aux listwaenites.

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INTRODUCTION

Strongly serpentinized ultramafic units and associated zones of quartz-carbonate rocks have been described in the literature for the Nadaleen Range since at least 1977. Recent work in the area by Manson Creek Resources Ltd. has revealed that these units are contributors to nickel stream geochemical anomalies documented for this area (Hart et al., 2001). Short field mapping programs in 1998 and 2001 have established that the ultramafic units are locally conformable with the underlying volcano-sedimentary stratigraphy. Geochemical data suggests that the rocks are komatiites. Locally significant (tens of metres), resistant quartz-carbonate-fuchsite units are developed as listwaenites, an altered phase of the ultramafic units. The ultramafic flows themselves contain high background nickel values (up to 2080 ppm nickel), and local occurrences of massive sulphide mineralization within the listwaenite units have assayed as high as 20.37 g/t Au, 6.85% Cu, 0.56% Ni and 0.16% Co.

HISTORY

The area of known ultramafic occurrences in the Nadaleen Range lies on NTS Map Sheet 106C/3 (Fig. 1). This area has seen comparatively little work as it has only been mapped once as part of a 1:250 000-scale program (Blusson, 1974). One wave of grassroots exploration in the late 1970s, aimed at discovering Mississippi Valley Type (MVT) carbonate-hosted silver-lead-zinc deposits, provides the bulk of available information in the Nadaleen Range area, although on a property by property basis. No airborne geophysical surveys have been flown over the area as part of regional coverage by government agencies.

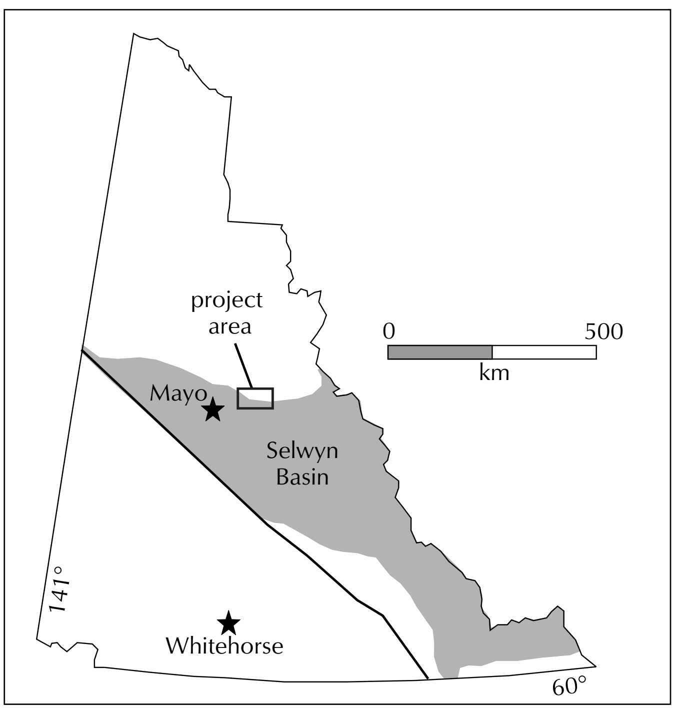

Figure 1. *Location sketch map of study area (Fig. 2).*

Exploration work in the 1970s resulted in the publication of an initial property evaluation and summary report by Tempelman-Kluit (1980). At that time, it was recognized that the “serpentinites,” “quartz-carbonate rocks” and volcanic strata from the Nadaleen Range were genetically related, although the ultramafic parent to the serpentinites was not observed.

Work by Manson Creek Resources Ltd. since 1997, including regional mapping programs in the Nadaleen Range, has led to more detailed data being available within the area. Specifically, it has been determined that the ultramafic units were, at least locally, emplaced as flows, as evidenced by the presence in outcrop of serpentinite-filled, well preserved megascopic pillow structures in a basalt flow.

REGIONAL GEOLOGY

The geology of the Nadaleen Range is characterized by a large-scale anticlinal closure exposing a sequence which, from bottom to top, includes 1) a basaltic/andesitic-dominated volcanic sequence overlain by 2) ultramafic, serpentinized units, locally altered to quartz-carbonate-fuchsite facies overlain by 3) transitional shales grading into sandstones, polymictic to chert-pebble conglomerates, and thinly bedded to massive limestone units (Fig. 2).

Within the known regional geological context and in light of the work recently performed on the adjoining Mount Westman and Tiny Island map sheets (Abbott, 1990; Gordey, 1990), the intermediate volcanic units and associated ultramafic flows are tentatively assigned to the Devono-Mississippian Earn Group.

Structure in the area is dominated by large-scale isoclinal folding (F_1) with development of a pronounced schistosity (S_1) within the finer grained or more plastic units. Local folding of the S_1 schistosity subparallel to the east-trending F_1 axial planes suggests a second phase of tectonic stress or a reactivation of the first folding event at a minor scale. A third event of regional-scale folding with a north-trending axial plane is also present over the area. These structural observations are, on a regional scale, in

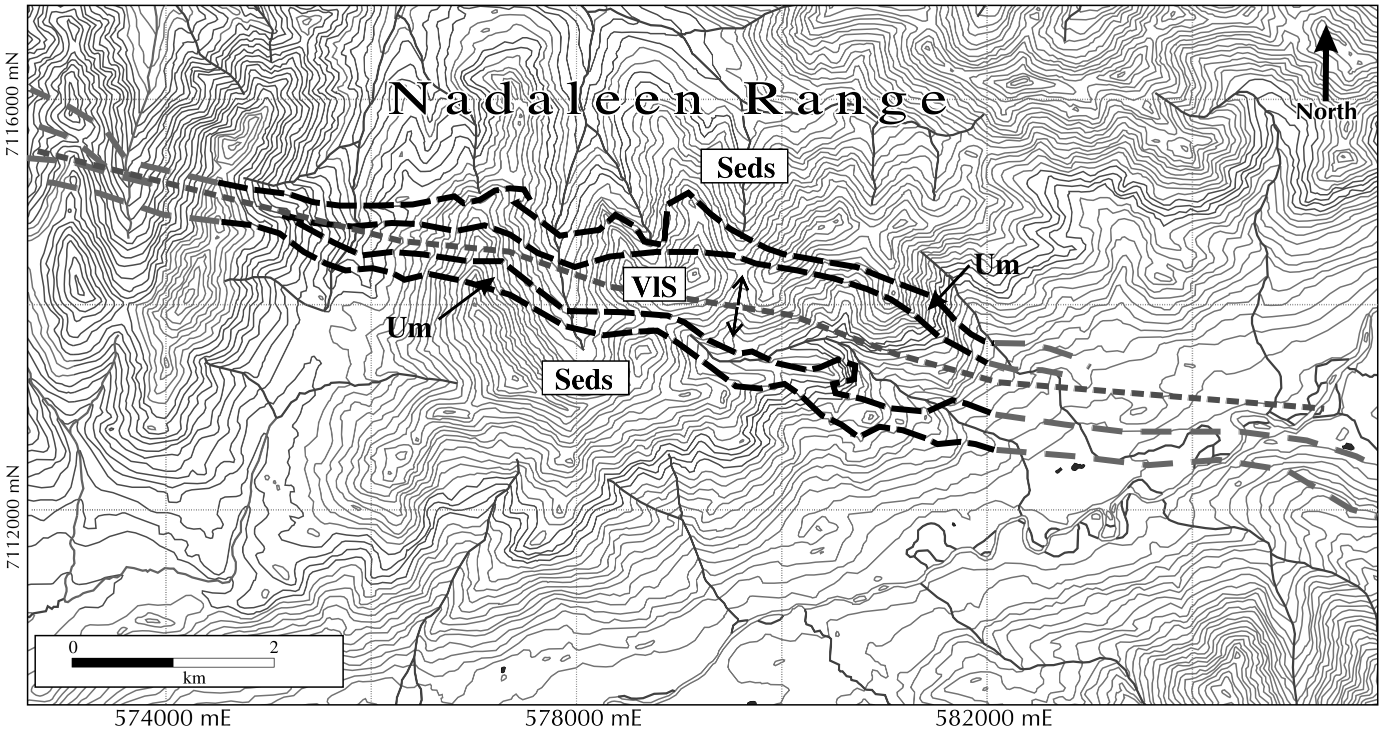

Figure 2. *Regional geology of the Nadaleen Range. Centre of area of interest is characterized by a broad, regional-scale anticlinal axis exposing volcano-sedimentary stratigraphy (VlS) dominated by pillow basalts, andesite flows and minor quartz-eye dacites. The ultramafic unit (Um) and its altered equivalents (listwaenites) are exposed in both limbs of the fold and appear to close to the west. Overlying the ultramafic units is a sedimentary sequence (Seds) volumetrically dominated by shales, sandstones and conglomerates. Resistant limestone units within the sedimentary sequence form prominent hilltops and thus locally appear much more significant than their true extent.*

accordance with the observations presented by Gordey (1990) on the Tiny Island Lake map sheet located to the southwest of the Nadaleen Range.

ULTRAMAFIC UNITS

The presence of ultramafic units in the Nadaleen Range was documented as far back as 1997 during a property visit and mapping exercise conducted by MacIntyre Mines Ltd. during regional exploration of carbonate units of the Nadaleen Range aimed at the discovery of Mississippi Valley Type silver-lead-zinc mineralization.

Upon reactivation of exploration in the area in 1997, the serpentinite units were mapped in greater detail in order to unravel their relationship with the surrounding country rocks as well as obtain information about the parent material. Whole rock and trace element geochemistry was also conducted in 1999-2000. The discovery in 1998 of significantly elevated nickel background values within the serpentinites, as well as the presence of copper and gold mineralization in the associated silica-rich carbonate units, provided the main impetus for further work, which included an airborne magnetic/electromagnetic survey and further mapping in 2001.

The serpentinite units typically weather to a fine greenish black talus and consist predominantly of talc, serpentine and few preserved mafic phases such as magnetite. They vary in thickness from a few metres to over 50-60 m where well exposed. In most cases, primary textures have been obliterated by the serpentinization process and only relict textures can be observed. These generally include fine-grained and porphyritic facies, but suspect cumulate textures are also present in outcrop. No flow tops or spinifex textures have been conclusively identified in the field to date. This could be a function of either insufficient mapping or pervasive alteration. The units are laterally extensive, with a strike length of over 10 km known by exposure of both limbs of a regional-scale anticline (Fig. 2). Original thickness of the units is difficult to determine as the serpentinites have absorbed a large amount of regional strain during deformation due to their ductile nature. Numerous sliding/shear planes, highlighted by the development of slickensides and fibrous antigorite, are present at all scales, even where small-scale faulting/rotation within the units occurred. However, shearing does not extend into the lithological units above and below the serpentinites.

In one outcrop, the relationship between the ultramafic unit and the underlying pillow basalt is well preserved (Fig. 3). At this location, the serpentinized material is seen infilling well preserved megascopic pillows. The implications of the textural relationship are that the ultramafic magmas were extruded slightly after formation of the basaltic flows, and that the two magmas are therefore coeval.

Analysis of whole rock geochemistry results shows that the rocks are classified as komatiites as they contain greater than at least 18% MgO on an anhydrous basis (S. Ebert, pers. comm., 2001) and have low TiO_2 (Le Maitre, 1989, Fig. 4). The ultramafic rocks also plot in the komatiitic field of Jensen (1976, Fig. 5).

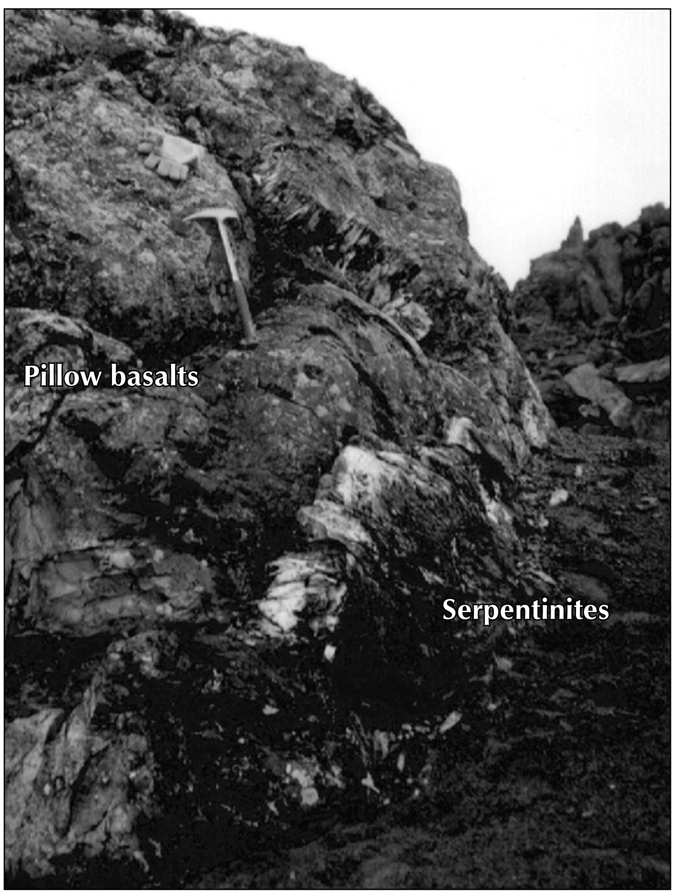

Figure 3. *Well preserved megascopic pillows in a basaltic flow stratigraphically overturned by serpentinized rocks (weathering to fine-grained talus). The field relationship suggests emplacement of the ultramafic magma as coeval with the rest of the volcanic sequence. Hammer for scale.*

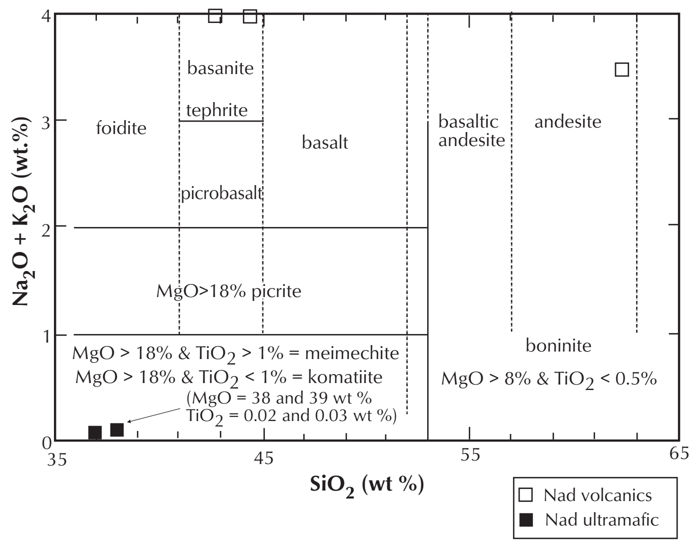

Figure 4. *Alkalies versus silica diagram for mafic volcanic rocks from Le Maitre (1989). Geochemistry shows distinct compositions for the ultramafic and mafic to intermediate flows of the Nadaleen Range. The Nad ultramafic rocks are high Mg and low Ti, consistent with komatiite geochemistry.*

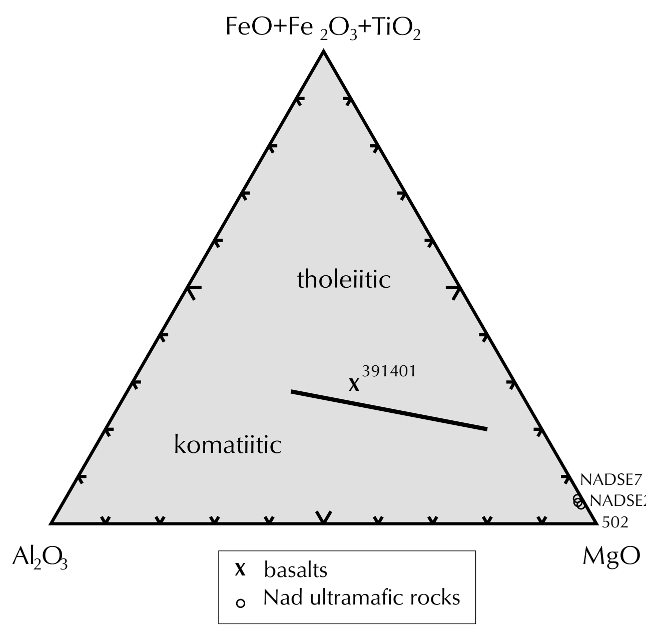

Figure 5. *Komatiite versus tholeiite ternary diagram (Jensen, 1976). The serpentinized ultramafic rocks plot within the komatiitic field, while one of the basalt sample from the Nadaleen Range plots within the tholeitiic field.*

A suite of grab samples highlighted a high nickel background associated with the serpentinized units. A total of 19 grab samples at numerous sites along the unit averaged 1580 ppm Ni, with a range of 720 to 2080 ppm. Scanning electron microscopy allowed for the determination that pentlandite, a nickel-bearing sulphide phase, is present within the samples examined (Fig. 6). A suite of rocks with high nickel values was also sent for assay for platinum group elements (PGEs), but results for 11 samples were consistently at or near the lower detection limit for both platinum and palladium.

ALTERED ULTRAMAFIC FACIES

Units consisting predominantly of quartz-carbonate-fuchsite with locally minor disseminated pyrite have been mapped in association with the serpentinites. These units can range to over 70 m in thickness and are systematically found stratigraphically above the ultramafic flows. Mapping has shown them to form a progressive alteration front into the ultramafic units. The intensity of alteration locally ranges from minor quartz-carbonate veining and stockwork, to a massively replaced phase that is resistant to weathering and forms orange bluffs. Because field relationships indicate these units are a quartz-carbonate alteration product of serpentinites, they are tentatively being termed listwaenites in the broad sense of the term; this is with reference to descriptions of similar units in British Columbia (Ash and Arksey, 1990).

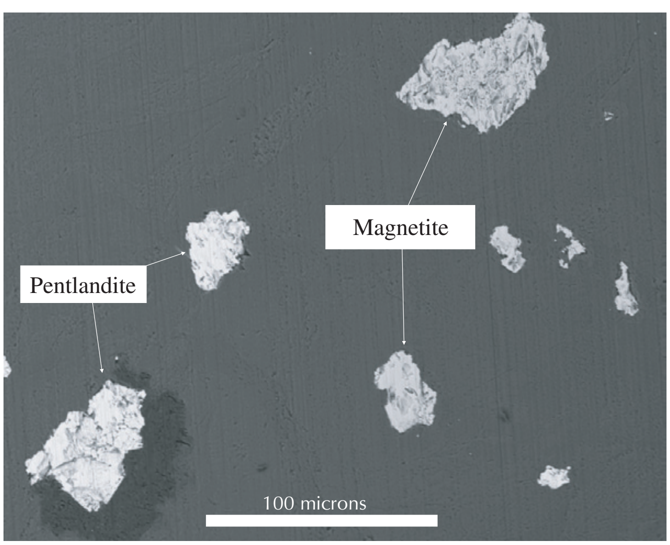

Figure 6. *Scanning electron backscattered image. Aphanitic altered matrix (light gray) with disseminated grains of pentlandite and magnetite.*

Mineralization within the listwaenite units is associated with disseminated to massive pyrite-dominated sulphide pods and veins. One such occurrence consists of an irregular lens of pyrite-chalcopyrite mineralization with minor malachite and azurite staining. The lens is located at the base of a listwaenite unit and is roughly 1 m thick and 3-4 m long. Grab samples from this outcrop have returned values of up to 20.37 g/t Au, 6.8 g/t Ag, 6.85% Cu, 0.56% Ni and 0.16% Co. Grab samples of another sulphide-rich showing some 3 km to the west of this showing, returned values of up to 5.27% Cu. The listwaenites also have a high nickel background, with 17 samples averaging 1997 ppm Ni and having a range of 14 to 5680 ppm. This data also supports the interpretation that listwaenites are an alteration phase of the serpentinites, as nickel has not been identified in any other rock type within the volcano-sedimentary sequence in the Nadaleen Range.

DISCUSSION

The presence of ultramafic units with a komatiitic geochemistry within the Selwyn Basin is not consistent with current knowledge of the area. More work is required before a mechanism can be suggested for the emplacement of these units within the Devono-Mississippian volcano-sedimentary package of the Nadaleen Range. However, in terms of mineral exploration, the units outline the possibility that deep crustal features may be present in the area. This is an important factor in terms of introducing base and precious metals into the existing sequence, as well as potentially outlining the presence of regional-scale heat sources that could have driven paleo-hydrothermal systems. Heat sources are important in both sedimentary-exhalative and volcanogenic massive sulphide style ore deposit models.

Earn Group stratigraphy locally contains abundant sulphur in the form of diagenetic as well as exhalative pyrite and barite (Yukon MINFILE, 2002). Following this, the presence of nickel-rich ultramafic magmas intruding Earn Group outlines potential for copper-nickel-bearing ultramafic-associated massive sulphide deposits, such as those found in the Proterozoic Raglan belt of northern Quebec.

Extensive associated belts of listwaenites could also be a target for lode gold deposits such as those associated with similar alteration of ultramafic units in California, the Urals, British Columbia and Alaska.

ACKNOWLEDGEMENTS

Geological descriptions in this paper are based on field work conducted on behalf of Manson Creek Resources Ltd. Whole rock analytical work and scanning electron microscopy was performed by Dr. Shane Ebert of the Mineral Deposit Research Unit. This paper summarizes the findings to date on the Nadaleen ultramafic occurrences and is a result of dedicated work from the field to the laboratory from an excellent team including all the geoscientists who worked on the project to date. The process of generating and interpreting this data was helped tremendously by Yukon exploration incentive programs such as Yukon Mineral Exploration Tax Credit, as well as discussions with Grant Abbott, Mike Burke, Craig Hart and Ken Galambos.

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Structure and alteration related to gold-silver veins at the Skukum Creek deposit, southern Yukon

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Lang, J., Rhys, D. and Naas, C., 2003. Structure and alteration related to gold-silver veins at the Skukum Creek deposit, southern Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 267-280.

ABSTRACT

A detailed evaluation of structure and alteration related to gold- and silver-rich, base metal-bearing veins was completed at the Skukum property as part of the 2002 mineral exploration program.

The structural setting is an east-trending sinistral strike-slip system bounded by the Berney Creek and Goddell faults to the south and north, respectively. The deposit comprises northeast-trending quartz-sulphide mineral shear veins that formed during syn-tectonic intrusion of rhyolite and andesite dykes related to the Eocene Mount Skukum caldera complex. A genetic relationship between mineralization and certain rhyolite dykes is indicated by patterns of alteration and mineralization. Dilational, northeast-trending structures interconnect and splay off the controlling faults, and host extensional quartz-sulphide mineral veins.

At Skukum Creek the main gold-silver-bearing minerals are electrum and freibergite, which precipitated with late galena-stibnite mineralization, whereas refractory gold in arsenopyrite is the main style at Goddell. A geological model is proposed that facilitates identification of prospective structures within the property.

RÉSUMÉ

Dans le cadre d'un programme d'exploration minière réalisé en 2002, on a terminé l'évaluation détaillée de la structure et de l'altération associées aux filons de métaux communs riches en argent et en or sur la propriété de Skukum.

Le cadre structural est un jeu de décrochements senestres à direction est qui est limité par les failles de Berney Creek et de Goddell au sud et au nord, respectivement. Le gisement est formé de filons de cisaillement à quartz-sulfures à direction nord-est mis en place au cours d'une intrusion syntectonique de dykes de rhyolite et d'andésite associés à l'ensemble de caldéras éocènes de Mount Skukum. Il ressort clairement qu'il existe un lien génétique entre la minéralisation et certains dykes de rhyolite. Les structures de dilatation à direction nord-est relient les failles de contrôle et s'en éloignent en divergeant; ces stuctures logent des filons de distension à quartz-sulfures.

Au gisement de Skukum Creek, les principaux minéraux aurifères-argentifères sont l'électrum et la freibergite qui ont précipité avec la minéralisation tardive de galène-stibnite, alors que c'est de l'or réfractaire dans de l'arsénopyrite qui caractérise le gisement de Goddell. Un modèle géologique est proposé pour faciliter l'identification des structures prometteuses dans cette propriété.

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INTRODUCTION

The Skukum Creek gold–silver deposit is located within the Skukum property, 60 km southwest of Whitehorse in the Wheaton River mining district. The 171.1 km^2 property also encompasses the Mt. Skukum gold mine, which produced 77 790 ounces (2419 kg) of gold from 233 440 tonnes of ore between 1986 and 1988 (McDonald, 1987 and 1990), the Goddell gold deposit (Hart, 1992a), the Becker-Cochran antimony deposit (Hylands, 1966), and additional gold, silver and copper prospects.

This paper describes a detailed field and petrographic examination of structure and alteration at Skukum Creek. Work included a review of published geological reports, and unpublished exploration reports and data; examination of underground workings and drill core; optical petrography on 63 polished thin sections; and scanning electron microscopy on 26 sections. The paper first summarizes regional and local geology, followed by a review of exploration history and results from drilling in 2002. Structure, alteration and mineralization at Skukum Creek are then described, and the paper concludes with a district-scale geological model.

REGIONAL AND LOCAL GEOLOGICAL SETTING

The regional geological setting of the Skukum project area is described in Wheeler (1961), Doherty and Hart (1988),

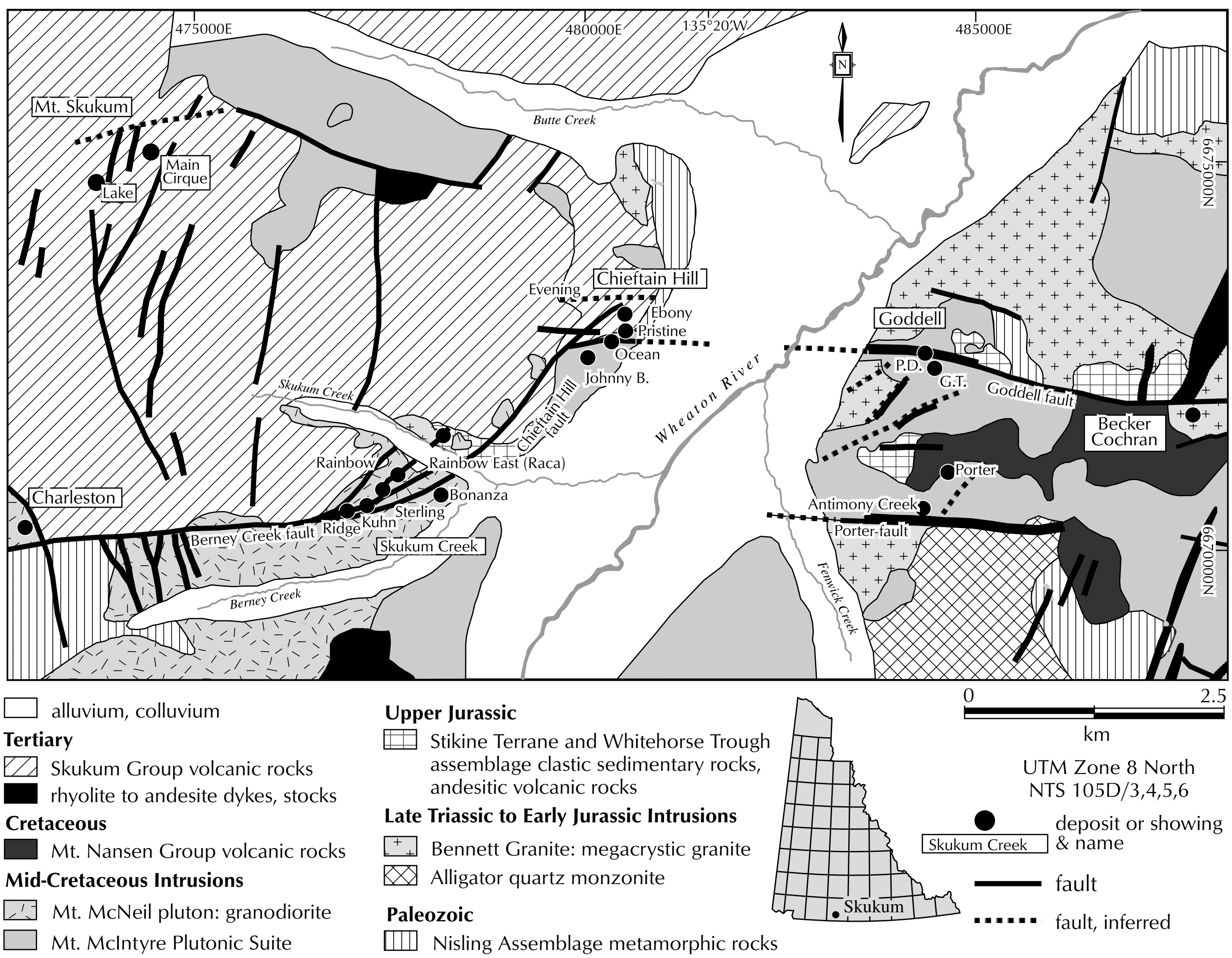

Figure 1. *Geology of the Skukum project area. Data compiled from Hart and Radloff (1990) and unpublished company maps.*

and Hart and Radloff (1990), from which most of the following is summarized. The oldest rocks in the area comprise gneiss of probable Paleozoic age, assigned to the Nisling Terrane by Hart and Radloff (1990), and Jurassic andesitic volcanic and siliciclastic sedimentary rocks of the Stikine Terrane and Whitehorse Trough overlap assemblage, respectively (Fig. 1).

Mesozoic plutonic rocks underlie much of the project area and separate the Jurassic units and Nisling Assemblage into isolated domains (Fig. 1). The most abundant rock types in the region (Hart and Radloff, 1990) are metaluminous Cretaceous intrusions of the Coast Plutonic Complex that comprise the Mt. McIntyre Plutonic Suite (96-119 Ma), which includes the Mt. Ward granite and Carbon Hill quartz monzonite, and the Whitehorse Plutonic Suite (116-119 Ma), locally represented by the Mt. McNeil granodiorite (Fig. 1). Intermediate Cretaceous volcanic rocks of the Mt. Nansen Group are present regionally, and in the project area occur east of the Wheaton River (Fig. 1). Jurassic plutonic rocks, such as the Bennett Granite (regional U-Pb ages around 175 Ma; J.K. Mortensen, pers. comm., 2002), are also widely distributed through the district.

The early Eocene Mount Skukum volcanic complex, part of widespread late Paleocene to early Eocene felsic to intermediate volcanism of the Skukum Group (Smith, 1982 and 1983; Pride, 1986), is a caldera sequence that underlies the western portion of the study area (Fig. 1). The Mount Skukum complex consists of up to 800 m of mainly porphyritic andesitic flows and tuff exposed over an area of approximately 200 km^2 (Fig. 1; B.W. McDonald et al., unpublished company report for Total Energold, 1990). These volcanic rocks are locally separated from pre-Tertiary rocks by curved, east- to northeast-trending structures such as the Berney Creek fault (Fig. 1) and Wheaton lineament (coincident with the Wheaton River valley on Fig. 1) that have been inferred to be syn-volcanic, caldera-bounding faults (Hart and Radloff, 1990). These and parallel structures host or control gold-silver mineralization in the district.

The structural history of the region that is most relevant to the Skukum Creek deposits began in the early Mesozoic. Strata of the Whitehorse Trough are affected by open to tight, northwest-trending folds that probably formed in the Late Jurassic to Early Cretaceous. The folds are superimposed on probable pre-Triassic metamorphic fabrics and the northwest-trending Tally-Ho shear zone, a major Late Triassic structure 15 km northeast of the project area that defines the eastern limit of Nisling Terrane exposures. The brittle, dextral Llewellyn fault system reflects Late Cretaceous and early Paleocene reactivation of the Triassic Tally-Ho shear zone (Hart and Radloff, 1990), and caldera-bounding structures may be reactivated subsidiary faults related to the Llewellyn Fault.

Known mineralization in the district occurs at the Mount Skukum mine, and in the Skukum Creek, Chieftain Hill, Goddell, Becker-Cochran and Charleston zones (Fig. 1). Skukum Creek has received the most exploration attention and comprises the Ridge, Kuhn, Sterling, Rainbow, Rainbow East (formerly Raca) and Taxi zones (Fig. 2). At Goddell, mineralization exposed on surface and intersected by drilling from underground has been called the Golden Tusk and PD zones (G.T. and P.D. on Fig. 1), respectively, but these are separated by a gap in drilling and may be continuous. Host rocks at Mount Skukum and the Charleston zone are Eocene volcanic rocks (Fig. 1). Intrusions are the main hosts at Skukum Creek (Cretaceous Mt. McNeil granodiorite), Goddell (Cretaceous Carbon Hill pluton), Becker-Cochran (Jurassic Bennett Granite) and Chieftain Hill (Cretaceous Mount Ward granite); intermediate volcanic rocks of probable Jurassic age host some veins on Chieftain Hill, and also at the Rainbow East vein where Jurassic Bennett Granite is also present (Fig. 1). Minor rock types at Skukum Creek include dykes or small, irregular bodies of biotite granite, monzodiorite, monzonite, and pegmatite and aplite that mostly appear to crosscut the main Mt. McNeil pluton; they did not substantially influence structure or hydrothermal activity and are not discussed further. A small volume of conglomerate lies beneath cover between the Rainbow and Rainbow East zones and is considered part of the Jurassic Tantalus formation.

EXPLORATION HISTORY

The Skukum Creek area was originally staked in 1922 to cover anomalous gold and antimony showings. Between 1964 and 1967, Yukon Antimony Corporation staked claims, including ground covering the veins at Skukum Creek, for copper and antimony potential. The company completed road access and several bulldozer trenches. Claims at Skukum Creek were again staked in 1973 by W. Kuhn, and were transferred, first to E. Bergvinson in 1980, and then from Bergvinson to Omni Resources Ltd. in 1984. The area was explored intermittently on surface during this period.

Systematic exploration at Skukum Creek began in 1985, and included geological mapping, trenching, soil sampling, and diamond and reverse circulation drilling. The work outlined 10 zones anomalous in gold, including Rainbow, Kuhn and Sterling, which were the focus of additional mapping and 8301 m of diamond drilling in 53 holes in 1986. A production-sized adit was collared at 1300-m elevation in 1987 and 823 m of underground work was completed along and across the Rainbow and Kuhn zones, followed by 7446 m of diamond drilling in 80 surface and underground holes.

In 1988, Skukum Gold Inc. and Omni Resources formed a joint venture to bring Skukum Creek to production. Surface mapping and geophysical surveys were completed in the Taxi zone. Additional underground development included a 1571-m decline to the 1218-level, a new adit on the 1350-level at Rainbow, and a raise to the 1350-level at Kuhn; 6581 m of underground and surface drilling in 37 holes further tested the Kuhn, Rainbow and Sterling zones.

The property reverted to Omni in 1991, when the joint venture failed to put the property into production. Later that year, Wheaton River Minerals Ltd. purchased the assets of Mt Skukum Gold Mining Corp., which included the Mount Skukum property and mill, and penned an agreement with Omni to purchase the Skukum Creek property. Wheaton declined to proceed, and in 1994 the Skukum Creek claims and the Mount Skukum claims and mill were transferred to Omni. In 1995 Omni acquired a 70% interest in the Goddell property from Arkona Resources, and consolidated three gold deposits and numerous showings into the Skukum property. During 1996 Omni drifted 100 m off the 1225-m level and drilled 1647 m in 15 holes that extended Rainbow zone mineralization to the 1050-level. In 1996 Trumpeter Yukon Gold Inc. negotiated an option, exercised in 1997, that gave them a 50% interest in the Skukum property. In that year, 2739 m of diamond drilling in seven surface

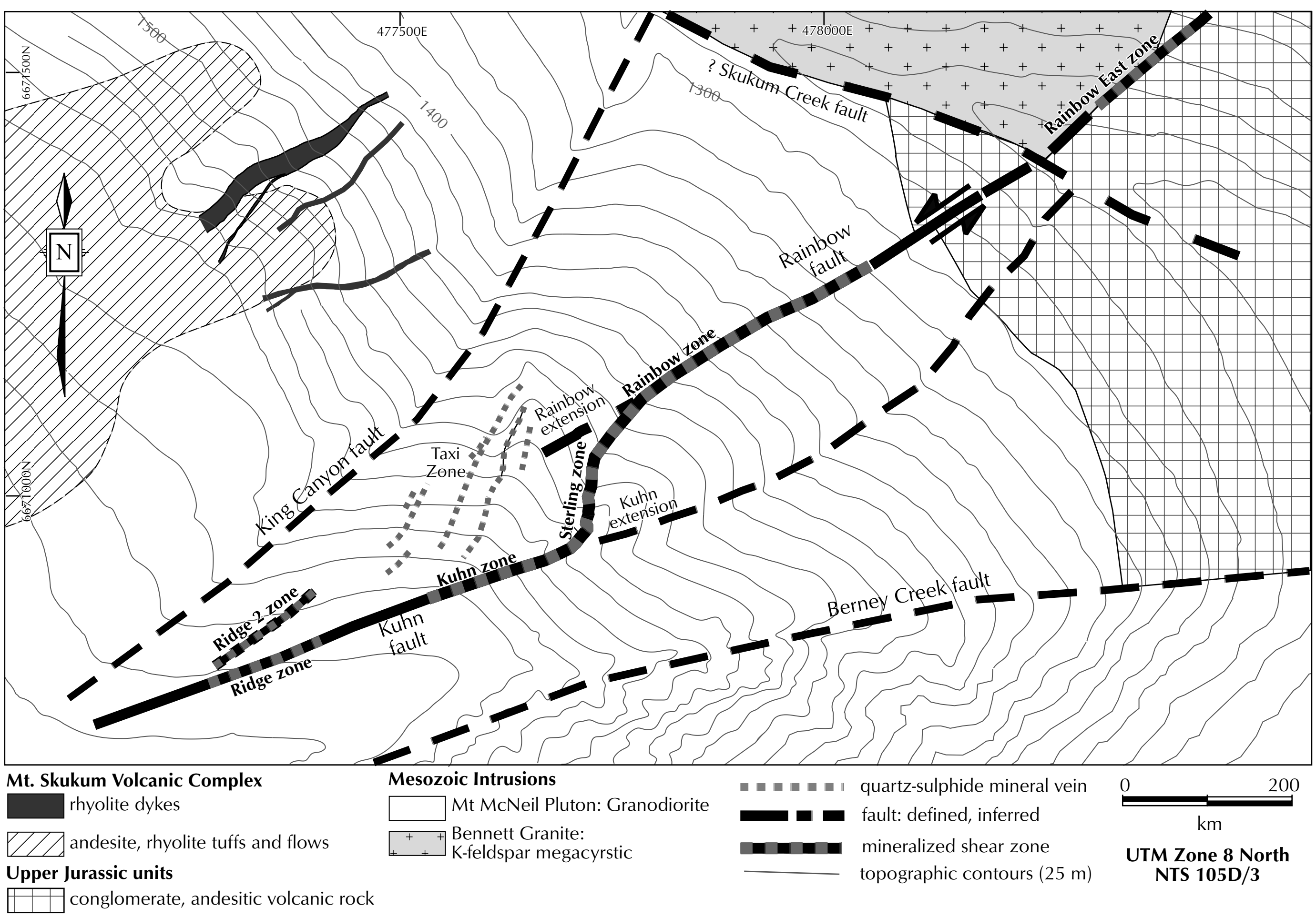

Figure 2. *Geological map of the Skukum Creek zone, compiled from company maps.*

holes tested the Ridge and Rainbow East zones, and led to discovery of the Ridge 2 zone in the footwall to the Ridge zone. Mineralization similar to that at Rainbow was encountered at Rainbow East. In 2000, Trumpeter Yukon Gold and Omni amalgamated into Tagish Lake Gold Corp. The Ridge and Ridge 2 zones were further tested in 2001 by 1502 m of drill core in four holes.

2002 EXPLORATION RESULTS

Drilling continued at Skukum Creek in 2002, with 2502 m in 15 underground holes (Fig. 3) designed to increase and improve the resource base estimate. Mineralization was intersected in each drill hole with results from the Rainbow zone of 3.9-33.5 g/t Au and 62-1627 g/t Ag across widths of 0.6 to 13.6 m; these are comparable to most historical intersections of the mineralized zones. The drilling had three other important results. The first was the determination of the geometry of the Portal dyke, which had historically been considered to intrude along a fault that terminated mineralization at the east end of the Rainbow zone. The recognition that the dyke crosscuts the mineralized zone at a low angle, combined with the similarity of mineralization at Rainbow East, now suggests the potential for mineralization in the footwall of the dyke. Second, one drill hole documented mineralization in the Sterling zone; this supports the structural model outlined in the following discussion, and indicates additional potential at depth in this area. Finally, drilling in the Kuhn zone intersected mineralization and confirmed continuation of the known, steeply northeast-raking ore shoot that is related to the junction of the Kuhn and Sterling zones, thereby confirming the exploration potential of this area.

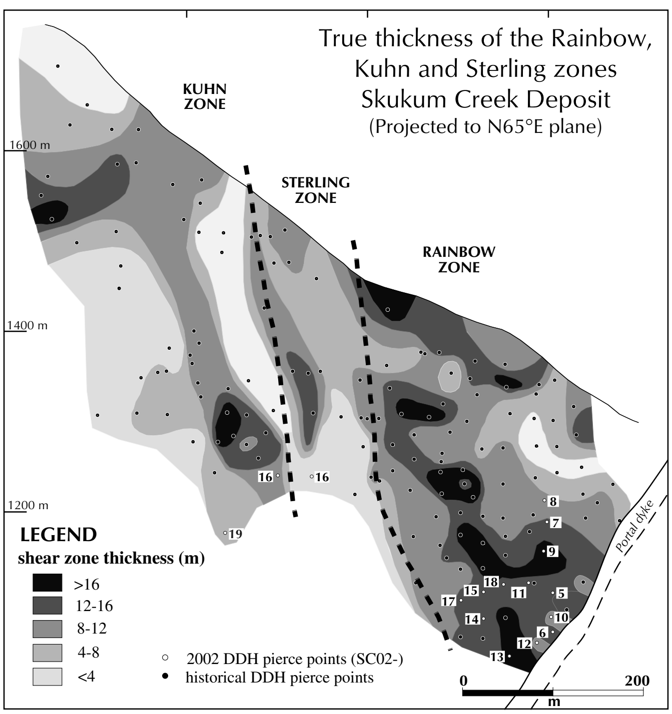

Figure 3. *Long-section through the Skukum Creek zone showing total zone thickness and location of drill holes. Data are projected onto a 065° plane.*

GEOLOGY

The Skukum Creek zone includes the Rainbow East, Rainbow, Sterling, Kuhn and Ridge zones (Fig. 2). These occur along a 1.3-km segment of a fault system that comprises the parallel, northeast-trending and southeast-dipping Rainbow and Kuhn semi-brittle shear zones and the north-trending, steeply east-dipping Sterling zone that structurally connects them (Fig. 2). The King Canyon fault, a northeast-trending splay off the Kuhn fault, and the Skukum Creek fault, postulated to underlie the Skukum Creek drainage (Fig. 2), are not known to host mineralization. Mineralized extension veins with northeast trend occur in the Taxi zone, north of the Kuhn shear zone.

GENERAL FORM OF MINERALIZED ZONES

The Skukum Creek zones lie within a semi-brittle shear zone that comprises rhyolite and andesite dykes, monolithic rhyolite and polylithic phreatomagmatic breccias; second-order semi-brittle shear zones that include cataclasites and stylolitic pressure solution surfaces and quartz-sulphide mineral veins; and late, brittle, gouge-filled faults (Fig. 4). The formation of these features during a protracted, syn-tectonic igneous and hydrothermal event, except perhaps for the latest brittle faults, is supported by 1) mineralized vein fragments in phreatomagmatic breccias; 2) deformed veins as well as veins that cut shear fabrics; 3) a quartz-sulphide mineral matrix to some hydrothermal breccias; 4) a spatial relationship among veins, alteration, shear zones and dykes; and 5) kinematically compatible orientations of veins and second-order faults/shears with shear sense on first-order faults.

RHYOLITE AND ANDESITE DYKES

Rhyolite and andesite dykes form the greatest proportion of the Rainbow and Kuhn zones (Fig. 4). Single or multiple bodies of either or both types of dyke may be present along a given zone segment. Dykes are typically lenticular and extend tens of metres along strike, but are possibly more continuous down-dip; terminations are commonly abrupt and reflect dismemberment by the main shear or later, brittle faults.

MONOLITHIC AND POLYLITHIC BRECCIAS

Both monolithic and polylithic breccias are spatially related to dykes. Monolithic breccias contain rhyolite fragments of highly variable size (mostly <5 cm) and rounding in a sericite-chlorite matrix. Matrix- and clast-supported breccias locally occur in the same body. The thickness of breccia bodies ranges from <10 cm to several metres. Monolithic breccias locally grade into unbrecciated rhyolite dykes, but contacts with other rock types are sharp. They are most abundant between the 1200- and 1350-levels in the Rainbow zone, and are more sporadic in the Kuhn and Sterling zones. Although most breccias are foliated, altered and cut by veins, a syn-mineral timing for some is indicated by rare sulphide mineral-rich vein fragments.

Polylithic breccias mostly contain <30% angular to rounded fragments 0.1 to 10 cm in size that can include any combination of altered granodiorite, rhyolite, andesite, monzonite, and lesser quartz-sulphide mineral vein material in a sericite-chlorite-quartz ± pyrite matrix. Contacts are generally sharp with host rocks, but are locally gradational with monolithic rhyolite breccias. They are largest and most common between the 1000- and 1200-levels at Rainbow, and many are 2 to 10 m thick and extend for at least 40 m along strike; at Kuhn they occur mostly below the 1400-level. The local, weak deformation, and restriction of mineralization to vein fragments indicate late to post-mineral timing.

QUARTZ-SULPHIDE MINERAL VEINS AND BRECCIAS

Most mineralization occurs in quartz veins that formed within and parallel to the main shear zones along slip surfaces and dyke margins. The veins are variably deformed, and the mostly fine-grained sulphide minerals occur in fractures, along pressure solution seams, and in breccia matrices. Initial formation in open space is indicated by prismatic quartz bands; and multiple episodes of vein re-opening are suggested by alternating sulphide-mineral and quartz-rich bands. The Rainbow and

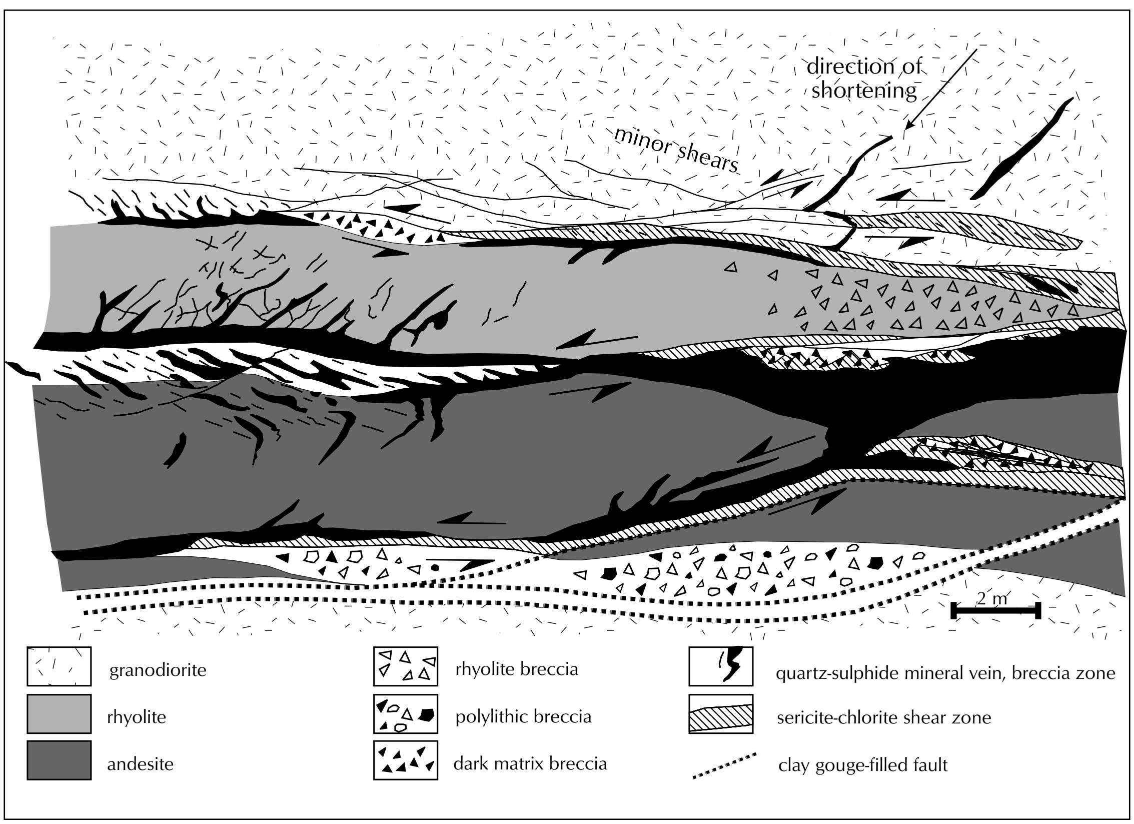

***Figure 4.** Schematic plan view of typical features and relationships in the Rainbow zone. The zone is a well layered, heterogeneous zone of andesite and rhyolite dykes, hydrothermal and phreatic breccias, shear zones, quartz-sulphide mineral veins and late brittle faults filled with clay gouge. See text for discussion.*

Kuhn zones contain multiple veins and single veins. Individual veins are commonly lenticular, range up to >5 m thick and extend for tens of metres along strike. Greater continuity down-dip is suggested by steep easterly plunges in the thickest parts of the veins and of the shear zone overall; and a shallow, second-order easterly plunge may reflect modification of ore shoot geometry in the slip direction of late, brittle faults (Fig. 3).

The main quartz-sulphide mineral veins are commonly brecciated and textures indicate formation by both cataclastic and hydrothermal processes. Breccias are mostly composed of quartz-sulphide mineral vein and altered wallrock fragments in a grey matrix. The matrices of cataclastic breccias range from primarily deformed quartz-sulphide mineral veins, to mostly phyllosilicate-rich, sulphide mineral-bearing, non-vein material. Some breccias have a hydrothermal quartz-sulphide mineral matrix with fragments of deformed quartz-sulphide material. These breccia styles can grade laterally into one another, and reflect varying tectonic intermixing of shear zone matrix and brecciated quartz vein material. Shear zones and cataclasites can also grade laterally into quartz-sulphide mineral veins through transitional zones of brecciation (Fig. 4).

Volumetrically minor mineralization is found in quartz-sulphide mineral extension veins that occur as sheeted sets partially transposed into foliation within the main shear zones, and as discrete, north- to northeast-trending veins outside the main shear zones (e.g., Taxi zone; Fig. 2). In the workings, quartz-sulphide mineral extension veins are generally spaced >5 m apart, lack alteration envelopes, are mostly 0.5 to 5 cm in thickness and commonly at least 4 m in length; and generally have a northeast strike and northwest dip (Fig. 5b). They are cut by late-mineral, narrow, commonly vuggy carbonate veinlets.

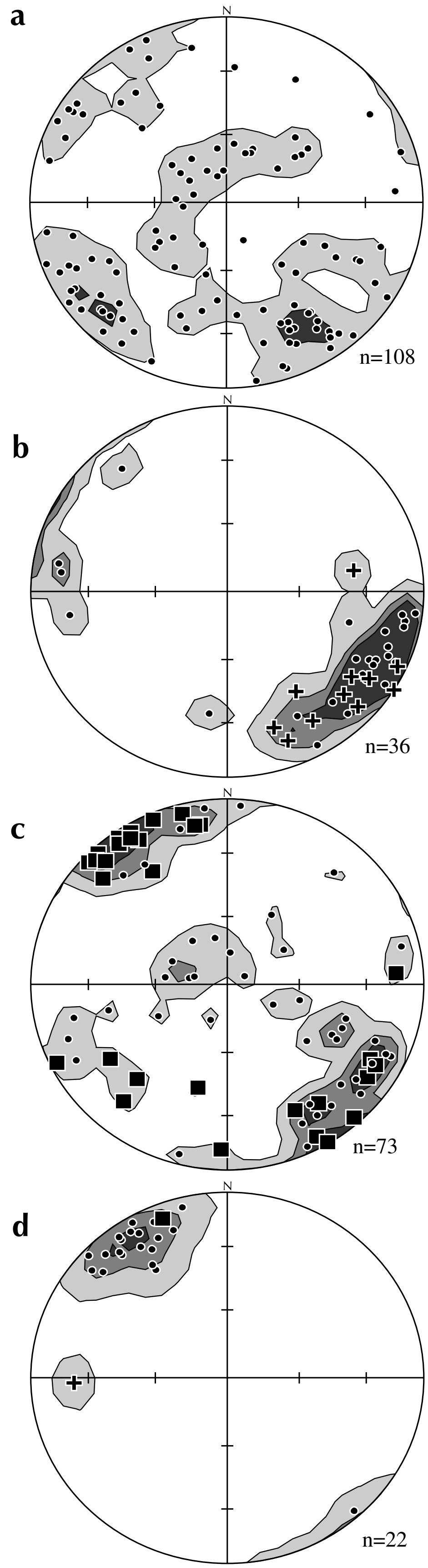

Figure 5. *Contoured equal area (Schmidt) projections of poles to major and minor structures and vein types.* ***(a)*** *Minor shear zones outside the Rainbow and Kuhn zones.* ***(b)*** *Quartz-sulphide mineral extension veins. Contouring peak 209/75. Pluses measured from maps of Taxi zone; circles from measurements underground in the Rainbow zone.* ***(c)*** *Poles to brittle, gouge-filled faults in Rainbow underground workings. Squares are faults with >1 cm of gouge.* ***(d)*** *Poles to Rainbow zone slip surfaces (shear zones). Contouring peak is 056/79. The plus and square indicate the average trend of the Sterling and Kuhn zones, respectively, as determined from historical maps.*

STRUCTURE

DISTRICT-SCALE FAULTS

The structural history of the Skukum Creek deposit is inferred to be related to district-scale faults which include the east to northeast-trending Berney Creek, Chieftain Hill, Goddell and Porter faults (Fig. 1). These faults probably form a single, anastomosing and bifurcating system, and each fault contains Eocene dykes and gold-silver ± antimony mineralization. General descriptions of these structures are available in Hart and Radloff (1990), McDonald et al. (unpublished company report for Total Energold, 1990) and Hart (1992a,b,c,d).

RAINBOW, KUHN AND STERLING ZONES

The Rainbow zone is oriented 050-070°, dips 65-85° to the southeast, and extends 400 m along strike and down dip. The Rainbow East zone may be the eastern continuation of the Rainbow zone (Fig. 2). The Kuhn zone is a 200-m-long mineralized segment of the Kuhn shear zone, which has slightly more easterly (065-080°) trend and steeper southeast dip than the Rainbow zone. Kuhn and Rainbow are linked by the north-trending, steeply east-dipping Sterling zone (Fig. 2). The Sterling zone is 180 m long and has characteristics similar to the Rainbow and Kuhn zones. The juncture between the three zones defines a continuous, S-shaped bend with steep, east-plunging inflection points. Most dykes and shear zones in the Rainbow and Kuhn zones bend into the Sterling zone, but some extend beyond the juncture along the strike of the main shear zones where they form the Rainbow Extension and Kuhn Extension zones.

Shear zones at Skukum Creek form a braided network commonly developed on the margins of, or between, andesite dykes, rhyolite dykes, and associated monolithic and polylithic breccias. They locally cut across the dykes to form lenticular, discontinuous lozenges of dyke rock separated by thin slivers of shear zone material (Fig. 4). Multiple shear zones are commonly present across the width of the zones, and typically vary from <1-cm-thick slip surfaces to broader zones of foliated cataclasite (intensely fractured rock) up to several metres in width. Shear fabrics are strongest in altered granodiorite within and adjacent to the zones, and weakest in rhyolite dykes, which behaved as comparatively rigid blocks.

The main shear zones consist of sericite-chlorite phyllite and foliated cataclasite interlayered with foliated wallrock and quartz-sulphide veins (Fig. 4). Shear zones are commonly cored by lithified, foliated, fine-grained cataclasite with a matrix of sericite-carbonate-quartz ± chlorite ± sulphide minerals. Angular to subrounded fragments of quartz, rhyolite, quartz-sulphide mineral vein and/or altered granodiorite are abundant, are generally <1 cm in diameter, and typically form <30% of cataclasites which are mostly matrix-supported. Internal strain in quartz fragments is typified by undulose extinction without evidence for crystal plastic deformation (i.e., dynamic recrystallization). Cataclasites commonly grade outward into foliated wallrocks with well developed spaced stylolitic pressure solution surfaces defined by sericite-chlorite and/or sulphide minerals. Pressure solution fabrics overprint, and are found in fragments within, the cataclasites, thereby demonstrating that pressure solution and cataclasis operated synchronously.

The main shear zones are surrounded by structural damage zones 5 to 10 m in width that are defined by minor shears that formed mostly in the footwall. More widely spaced minor shears extend up to at least 150 m from the main shear zones. Three orientations of shears and veins were measured (Fig. 5a,b): 1) northwest strike, steep northeast dip and normal, northeast-side-down displacement; 2) east to northeast strike with steep south to southeast dips, parallel to the main zones; and 3) shallow structures with mostly south to southwest dips. A sinistral shear sense is indicated by foliation oriented 10-30° to narrow cataclasites and slip surfaces.

Kinematic indicators in sheared veins suggest a left-lateral shear sense with a reverse (southeast-side-up) component, compatible with formation during left-lateral displacement along the Rainbow and Kuhn shear zones. The orientations of extension veins are also compatible with sinistral displacement on these shear zones. The slip direction on the main Rainbow shear zone, calculated from measurements of oblique cleavage and shear bands (Fig. 5d), indicates a shallow westerly plunge. This plunge is approximately orthogonal to the steep plunge of the thickest parts of the shear zones (Fig. 3), a pattern that would develop if dilation occurred at bends and steps during displacement on the controlling structures.

LATE BRITTLE FAULTS

Brittle, gouge-filled faults are the youngest structures in the mineralized zones. They exploit shear zones, veins and dyke contacts, and exhibit the same three orientations recognized in minor shears and veins (Fig. 5c). The larger faults occur within the main zones as single seams or braided networks. Kinematic indicators consistently suggest left lateral/normal shear sense, but magnitude of displacement could not be determined. Brittle faults commonly cross the main shear zones and displace dykes, shears and quartz-sulphide mineral veins; given their sinistral movement, tectonic thickening of the zones results where brittle faults pass, from east to west, from hanging wall to footwall.

STRUCTURAL MODEL

A simplified structural model for the Skukum Creek zone is shown on Figure 6. The main structures are the Rainbow and Kuhn faults, which represent probable splays off the Berney Creek fault to the south. Kinematic indicators suggest that deformation reflects northeast-directed shortening with 1) left lateral displacement on shear zones; and 2) formation of northeast-trending, steeply-dipping extension veins at a high angle to σ_3. Most mineralization thus far identified occurs on the Rainbow and Kuhn faults near the Sterling zone step-over, a classic dilational jog setting.

ALTERATION AND MINERALIZATION

Alteration at Skukum Creek occurs as pervasive and fracture-controlled K-feldspar, chlorite-sericite-carbonate, and epidote assemblages within and adjacent to the main shear zones. Most alteration formed during a single, protracted hydrothermal event likely related to Eocene volcanism, but a few effects may be older and related to cooling of Cretaceous intrusions. Argillic alteration occurs only within late, brittle faults and is not discussed further.

PRE-SHEAR VEINS

These comprise barren quartz and magnetite-pyrite-chalcopyrite veins hosted primarily by the Mt. McNeil granodiorite. Both types are rare, sinuous to planar and mostly <2 cm in width. The magnetite veins have weak albitic alteration envelopes, and molybdenite was found in one quartz vein. Both vein types are cut by shear-related veins, have characteristics compatible with formation at high temperature, and are interpreted to be related to cooling of Cretaceous intrusions.

EPIDOTE-K-FELDSPAR VEINS

These veins are abundant throughout the Cretaceous intrusions at Skukum Creek. They are planar and are mostly <5 mm in width. They are dominated by epidote with trace to minor calcite and quartz, and locally contain hematite and/or chlorite. They have K-feldspar envelopes from <1 to several centimetres in width that also contain epidote, calcite and rare pyrite; and igneous magnetite remained partly stable. Their timing is unclear. They are

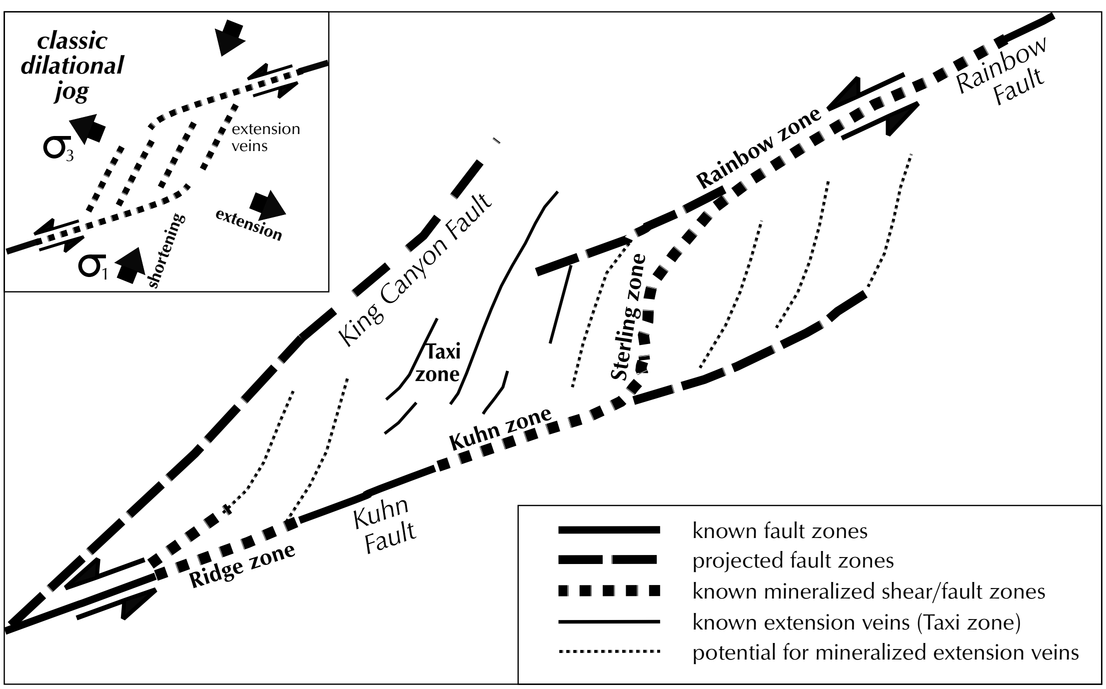

Figure 6. *Structural model for the Skukum Creek zone during mineralization and sinistral displacement on the controlling shear/fault zones. The sinistral shear sense interpreted from underground relationships is opposite the dextral sense suggested by Hart (1992b), who interpreted kinematics on general vein morphology and orientation.*

found in unsheared sets without preferred orientation, and at the scale of observation have no spatial relationship to the main shear zones. They crosscut magnetite veins, but are cut by veins related to the main shear zones. They are provisionally considered intrinsic to the Cretaceous intrusive complex, but they may be related to sheared epidote veins that are part of the main hydrothermal event (see below).

K-FELDSPAR ALTERATION

K-feldspar alteration is the earliest assemblage related to mineralization. It is minor and found mostly in the Ridge and Taxi zones. It is only evident in stained specimens, and consists of narrow K-feldspar envelopes to fractures and irregular chlorite veinlets. In one case K-feldspar was found in a dilatant veinlet accompanied by calcite, and cut by mineralized veinlets.

SERICITE-CHLORITE-CARBONATE ALTERATION

Sericite, chlorite and carbonate are the main alteration minerals at Skukum Creek. They are centred upon the main shear zones, and both pervasive and fracture-controlled alteration have been observed. Individual veinlets can be dominated by either sericite or chlorite, and typically contain abundant carbonate. Veinlets dominated by each of the three minerals have mutual crosscutting relationships that indicate coeval precipitation.

Alteration observed farthest from the main shear zones is dominated by green, Mg-rich chlorite (all compositional information is qualitative and based upon SEM spectra) that replaces hornblende and biotite. It is accompanied by trace to minor calcite, rutile, apatite and rare epidote, partially hematized magnetite, and weak sericite after feldspar. This low intensity chlorite alteration may be a deuteric effect related to cooling of the Cretaceous intrusions, or a wide alteration envelope around the main shear zones.

Fracture density and intensity of chlorite, sericite, pyrite and carbonate alteration increase markedly toward the main shear zones. The strongest chlorite alteration is related to numerous, narrow, irregular to planar veinlets filled with chlorite, lesser quartz, carbonate and sericite, and minor to trace epidote, pyrite, chalcopyrite and galena. Veinlets peripheral to the main shear zones occur individually or in swarms surrounded by sericite-quartz-(pyrite) envelopes and separated by less-altered granodiorite. Similar envelopes form around rare quartz-carbonate ± sulphide veinlets. This style of alteration is best developed in the hanging wall up to 200 m from the main shear zones. Sericite increasingly overprints chlorite as the main shear zones are approached, but veins dominated by each phase continue to crosscut one another. Strong pervasive sericite alteration within the main shear zones commonly bleaches andesite dykes to a tan colour that makes them difficult to distinguish from rhyolite dykes. Minerals that accompany proximal sericite alteration include quartz, chlorite, pyrite, carbonate (variable and commonly paragenetically later), rutile, and trace chalcopyrite, arsenopyrite, hematite and/or galena. Pyrite can exceed 10%, but is typically much less abundant. Igneous K-feldspar is locally preserved. Chlorite proximal to the main shear zones is black and is Fe-rich. A similar assemblage forms the matrices to cataclastic, polylithic and monolithic breccias.

Higher concentrations of pyrite and other sulphide minerals are commonly related to carbonate that replaces chlorite-sericite. Carbonate also occurs in narrow, barren, post-mineralization veinlets. Most carbonate is calcite (± trace Mn), with minor, typically younger ferroan dolomite or ankerite. Carbonate in late veinlets and surrounding brecciated quartz-sulphide mineral vein material includes manganosiderite (enriched in Fe-Mn) and Fe-Mg compositions, both accompanied by Fe-rich chlorite.

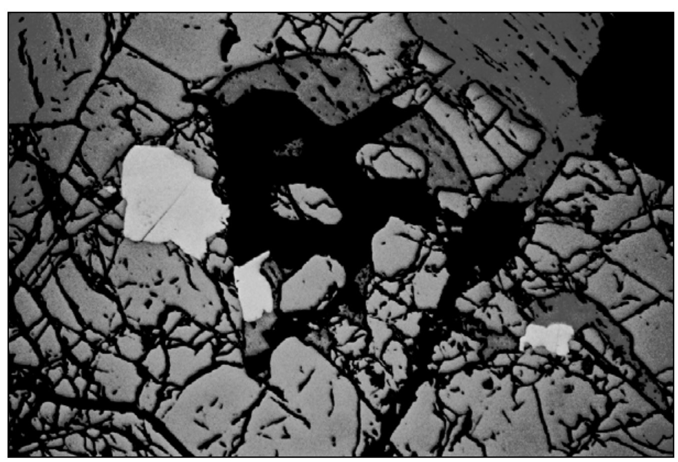

Figure 7. *Photomicrograph that illustrates the paragenetic relationship between electrum (white) and late galena (darkest grey with larger black pits). Both minerals replace early, coarse-grained pyrite (medium grey) in a quartz-sulphide mineral extension vein. The largest electrum grain is about 200 microns across. Sample is from the 1300-level in the Rainbow zone. Reflected light, field of view 0.16 mm.*

SHEARED EPIDOTE VEINS

Sheared epidote-rich veinlets up to 1 cm in width occur within a few tens of metres of the footwall to the main shear zones. Their formation overlapped in time, but extended beyond, sericite-chlorite alteration. They contain minor sericite, calcite and pyrite, and rarely hematite. They lack alteration envelopes and adjacent K-feldspar is stable. They may, at least in part, be sheared equivalents of the epidote-K-feldspar veins, although crosscutting relationships demonstrate that some of them are also younger.

MINERALIZATION

Mineral assemblages are similar in deformed and undeformed quartz-sulphide mineral veins, but paragenetic relationships are much clearer in the latter. Quartz-sulphide mineral extension veins have an early stage of coarse-grained, commonly euhedral quartz, accompanied by several percent coarse-grained pyrite and/or arsenopyrite, and lesser, temporally overlapping to slightly younger sphalerite. Precious metals are texturally related to a younger stage of fine-grained quartz that replaces the early, coarse-grained quartz and sulphide minerals along grain boundaries. Other minerals in the main ore stage include calcite, sericite and rare epidote, chlorite, pyrite, arsenopyrite, sphalerite and galena, and trace to minor freibergite, chalcopyrite, electrum, argentite and stibnite. Rare minerals include barite (in one vein from the Ridge zone), native silver and gold, specular hematite and molybdenite (in one galena-rich vein from the Taxi zone).

Gold occurs mostly as electrum that is paragenetically related to galena and/or stibnite that replace early sphalerite, pyrite and arsenopyrite (Fig. 7). Freibergite occupies the same paragenetic position as electrum (Fig. 8) and is the main host for silver; chalcopyrite, galena, stibnite and sphalerite can exhibit silver peaks on SEM

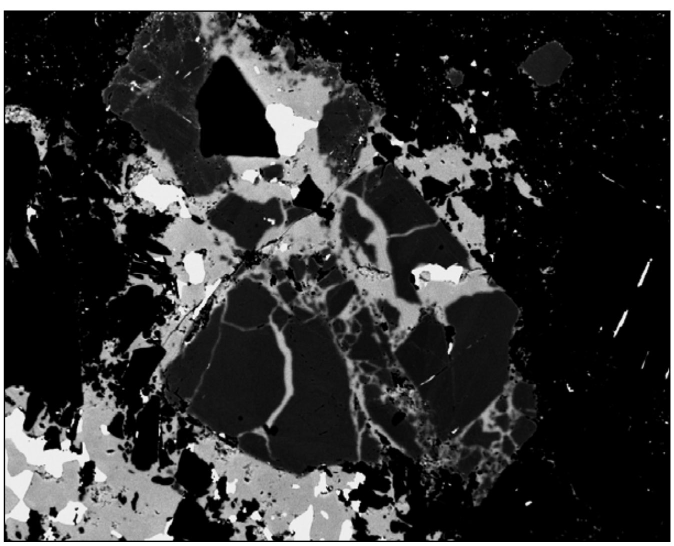

Figure 8. *Backscatter electron image showing freibergite (medium grey) and galena (white) replacing early, coarse-grained, fractured arsenopyrite (dark grey) and pyrite (in black areas to right and left) in a quartz-sulphide mineral extension vein. Matrix to brecciated pyrite also includes fine-grained quartz and minor carbonate. Sample from the Ocean vein; field of view 170 microns.*

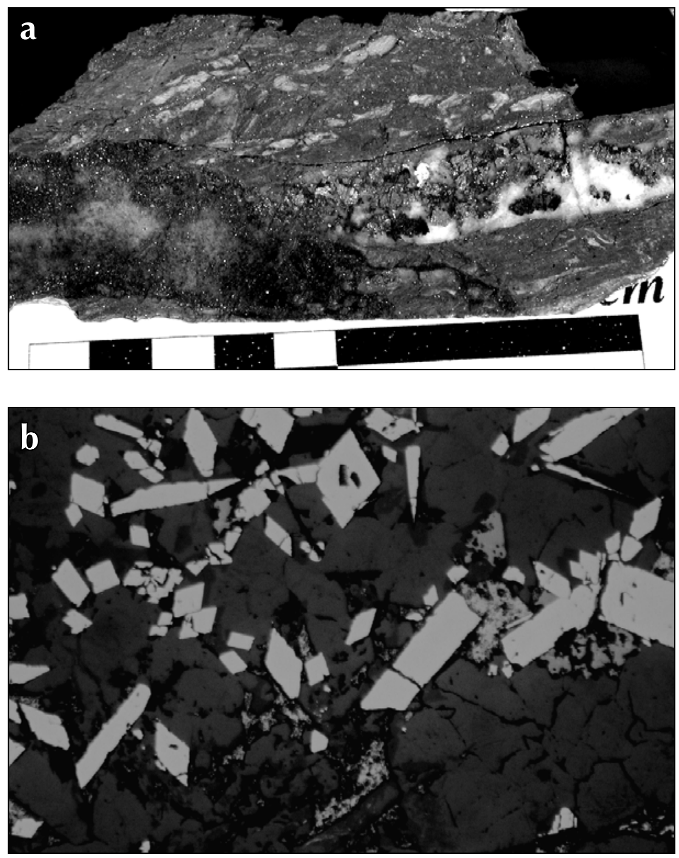

Figure 9. (a) *Timing of different mineralization styles in the Rainbow East vein. A pyrite-rich cataclastic breccia is first cut along foliation by a quartz-sulphide mineral extension vein (right-centre), and both are replaced by quartz with disseminated acicular arsenopyrite (lower left). Field of view about 10 cm.* ***(b)*** *Photomicrograph showing detail of the late quartz-acicular arsenopyrite mineralization stage. Dark gangue is quartz. Bright diamond-shaped crystals are arsenopyrite. Irregular, medium grey grains are stibnite and lesser sphalerite. Reflected light, field of view 0.64 mm.*

spectra, but this occurrence is insignificant in the overall silver budget. An increase in Ag/Au ratios in quartz-sulphide mineral extension veins peripheral to the main shear zones reflects a paucity of electrum, as freibergite abundance and silver grades remain high.

Acicular arsenopyrite, which at Goddell is the principal style of mineralization and contains refractory gold (G.L. Wesa and T.M. Elliott, unpublished company report for Omni Resources Inc./Arkona Resources Inc., 1999), was observed as a very minor, late hydrothermal stage at Rainbow and Rainbow East zones (Fig. 9) but is absent from Ridge zone. In one case from Rainbow, acicular arsenopyrite was found in rounded fragments of quartz vein that preceded the main stage of gold-silver mineralization.

DISCUSSION

A provisional structural model for mineralization in the Skukum project area is shown in Figure 10. The model hinges on the interpretation of oblique left-lateral - reverse kinematic indicators in the Rainbow zone, and reported apparent left-lateral displacements on faults and shear zones at Chieftain Hill and south of the Goddell fault (G.L. Wesa, unpublished company report for Omni Resources Inc./Arkona Resources Inc., 1998; G.L. Wesa and T.M. Elliott, unpublished company report for Omni Resources Inc./Arkona Resources Inc., 1999). The inferred setting of the district is a left-lateral strike-slip fault system with a reverse, south-side-up component. Master structures are the Berney Creek, Goddell and Porter faults. Mineralization occurs in dilational zones where displacement on the Goddell fault is transferred on northeast-trending structures to the Berney Creek and Porter faults, and more locally along the master structures near northeast-trending splays. In the Skukum Creek zone, mineralization occurs in areas of second-order dilational stepovers and bifurcations in the northeast-trending faults, as represented by the Sterling zone. The left-lateral shear sense and overall structural geometry are compatible with relationships between northeast-trending veins and east-trending faults at the Mount Skukum mine (McDonald, 1987 and B.W. McDonald et al., unpublished company report for Total Energold, 1990). Structural features at Skukum Creek formed during a protracted, syn-tectonic igneous and hydrothermal event, except for late brittle faults, which could be much younger.

The hydrothermal fluids have a direct genetic relationship to some rhyolite dykes. Monolithic rhyolite breccias plausibly formed by interaction of rhyolite magmas with fluids in the controlling structures. Several rhyolite dykes in the Taxi zone, however, lack such breccias, yet they contain disseminated sulphide minerals and quartz-sulphide mineral veinlets anomalous in base and precious metals, and have envelopes of alteration identical to those that encompass the main shear zones. A genetic link is further supported by relationships at Goddell (C.R. Robertson, unpublished company report for Berglynn Resources Inc., 1987), and by the consistent background enrichment of gold in rhyolite intrusions at the Mount Skukum mine (B.W. McDonald et al., unpublished company report for Total Energold, 1990). It can be concluded that one or more stages of rhyolite, or their parental magmas, contributed to the fluid and metal budget of the district.

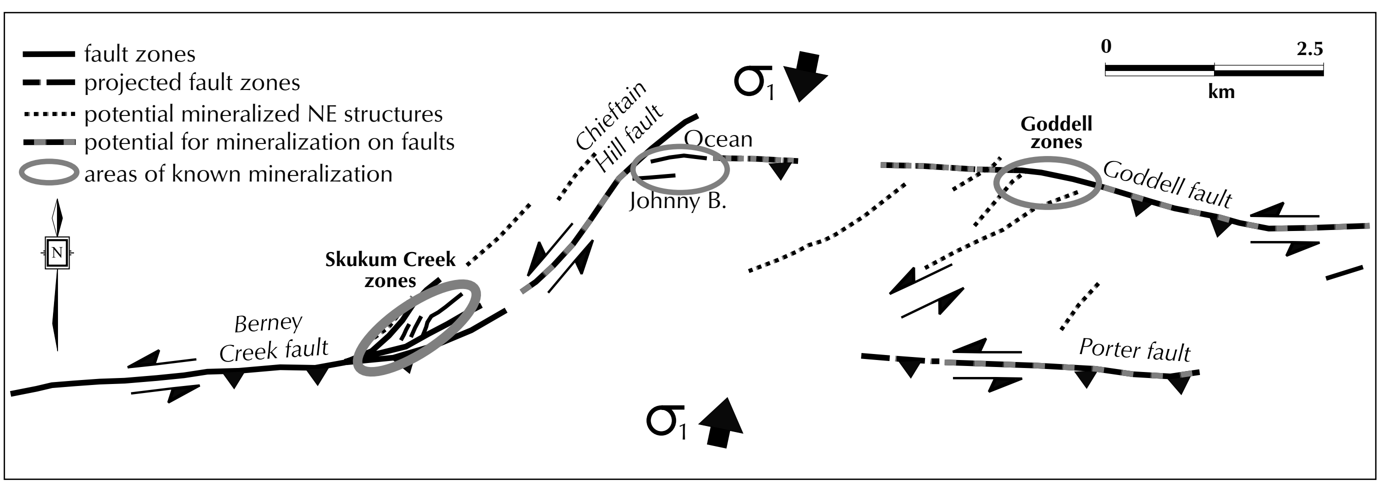

Figure 10. *Provisional syn-hydrothermal structural model for the Skukum project area. Areas with exploration potential are also indicated by shaded ellipses. See Figure 1 for location of mineralized zones. See text for details.*

Timing of deformation and hydrothermal activity with respect to the Skukum Creek caldera complex could not be fully assessed during this study. Hart (1992b) reports a ~58 Ma whole rock K-Ar date on a rhyolite dyke from the Rainbow zone, which is 5-7 Ma older than 51-53 Ma Rb-Sr ages from the Skukum Creek volcanic complex (Pride and Clark, 1985; McDonald and Godwin, 1986). This discrepancy has significant implications for the timing and nature of the faults that control mineralization, and suggests that some might not be caldera-bounding structures. A more plausible alternative is that the dates, which are based on methods of relatively low precision, are not representative. Precise U-Pb dates would more accurately determine if mineralization, shear zones and dykes exploit older, caldera-bounding structures.

Finally, the study highlights a significant potential for discovery of additional mineralization in diverse structural settings in the project area. In addition to continued exploration of known mineralized zones, most of which remain open in at least two directions, other potential areas are 1) northeast-trending extensions of shear zones at Skukum Creek; 2) splays, junctions and extension veins at stepovers of mineralized shear zones at Skukum Creek, such as the junction between the Kuhn and King Canyon faults; 3) the northeast-trending Chieftain Hill fault system; 4) near fault splays and bends along the Goddell and Porter faults; and 5) northeast-trending, locally exposed and mineralized structures between the Goddell and Porter faults. These highly prospective environments clearly warrant additional exploration.

ACKNOWLEDGEMENTS

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Preliminary investigations of emerald mineralization in the Regal Ridge area, Finlayson Lake district, southeastern Yukon

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Neufeld, H.L.D., Groat, L.A. and Mortensen, J.K., 2003. Preliminary investigations of emerald mineralization in the Regal Ridge area, Finlayson Lake district, southeastern Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 281-284.

ABSTRACT

Emerald has recently been discovered in two areas in the northern Cordillera, the Lened area immediately east of the Yukon/NWT border and the Regal Ridge property in the Finlayson Lake district of southeastern Yukon; potential for additional emerald occurrences is thought to be very good. Preliminary results from investigations at Regal Ridge in 2002 reveal a continuum between typical biotite (± muscovite) quartz monzonite to quartz-rich, tourmaline-bearing granitic pegmatite and aplite (locally containing beryl) to quartz-tourmaline veins that either contain emerald or carry emerald in associated alteration envelopes. It is likely (but still unproven) that the chromium in emeralds at Regal Ridge is derived from the mafic metavolcanic host rocks. Detailed petrographic examination of the veins and altered host rocks is aimed at constraining the composition and nature of the mineralizing fluids responsible for formation of the emeralds.

RÉSUMÉ

On a récemment découvert des émeraudes dans deux zones de la Cordillère septentrionale, la région de la propriété minière de Lened, située juste à l'est de la frontière du Yukon et des T.N.-O., et la région de la propriété minière de Regal Ridge dans le district du lac Finlayson, dans le sud-est du Yukon. Le potentiel de découverte d'autres venues d'émeraude y est, par conséquent, très élevé. Les résultats provisoires des travaux de recherche à Regal Ridge en 2002 révélent un continuum : monzonite quartzique à biotite (± muscovite) typique passant à pegmatite et aplite granitiques à tourmaline riche en quartz (contenant ici et là du béryl) pour aboutir à des filons de quartz-tourmaline recelant des émeraudes ou en renfermant dans des enveloppes d'altération associées. Il est probable (mais encore non prouvé) que le chromium dans les émeraudes à Regal Ridge provient des roches encaissantes métavolcaniques mafiques. L'examen pétrographique détaillé des filons et des roches encaissantes altérées vise à mieux définir la composition et la nature des fluides minéralisateurs qui sont à l'origine des émeraudes.

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INTRODUCTION

In 1998, W. Wengzynowski, while prospecting with Expatriate Resources Ltd., discovered Cr-dominant emeralds near a zoned felsic pluton within the Yukon-Tanana Terrane in the Finlayson Lake district of southeastern Yukon. Subsequent work at this locality (the 'Regal Ridge' showing, Fig. 1, currently held by True North Gems Inc.) has outlined numerous emerald-bearing float trains and six main bedrock sources within a 900 by 400-m area. The geology, mineralogy, and origin of the occurrence are discussed in Groat et al. (2002) and Marshall et al. (in press) and are discussed in detail below.

GEOLOGY AND MINERALOGY

Emerald crystals at Regal Ridge occur where quartz veins cut mica-rich layers in a schist of the Upper Devonian Fire Lake mafic metavolcanic unit (unit DMF of Murphy and Piercey, 2000). At least eight such veins have been discovered, and most are enveloped by a mass of fine, dark tourmaline crystals. The tourmaline crystals are locally associated with minor amounts of scheelite; and small amounts of sulphide minerals, especially chalcopyrite, have been observed within the quartz veins. A zone of sparse, disseminated sulphide minerals appears to coincide with the tourmaline envelope, which is characterized on surface by a pronounced jarosite-dominant gossan. The emerald crystals occur within the tourmaline zones and, rarely, in the quartz veins.

Washing and hand sorting of approximately 6 m^3 of material thus far has yielded more than 6 kg of green beryl and emerald. A number of small gems (up to ~0.5 ct; see Fig. 2) have been fashioned from the Regal Ridge samples. It is still too soon to tell if the showing will become an emerald producer; additional work (including bulk sampling) must be completed before the economic potential can be assessed.

Fieldwork in 2002 revealed an apparent continuum at Regal Ridge between typical biotite (± muscovite) quartz monzonite to quartz-rich, tourmaline-bearing granitic pegmatite and aplite (locally containing beryl) to quartz-tourmaline veins that either contain emerald or carry emerald in associated alteration envelopes. Several lines of investigation are underway to further constrain the nature and origin of emerald mineralization at Regal Ridge. These include (1) mineralogy of the regional and vein-scale alteration; (2) geochemistry of the host rocks; (3) geochemistry of the emeralds; (4) fluid inclusion study;

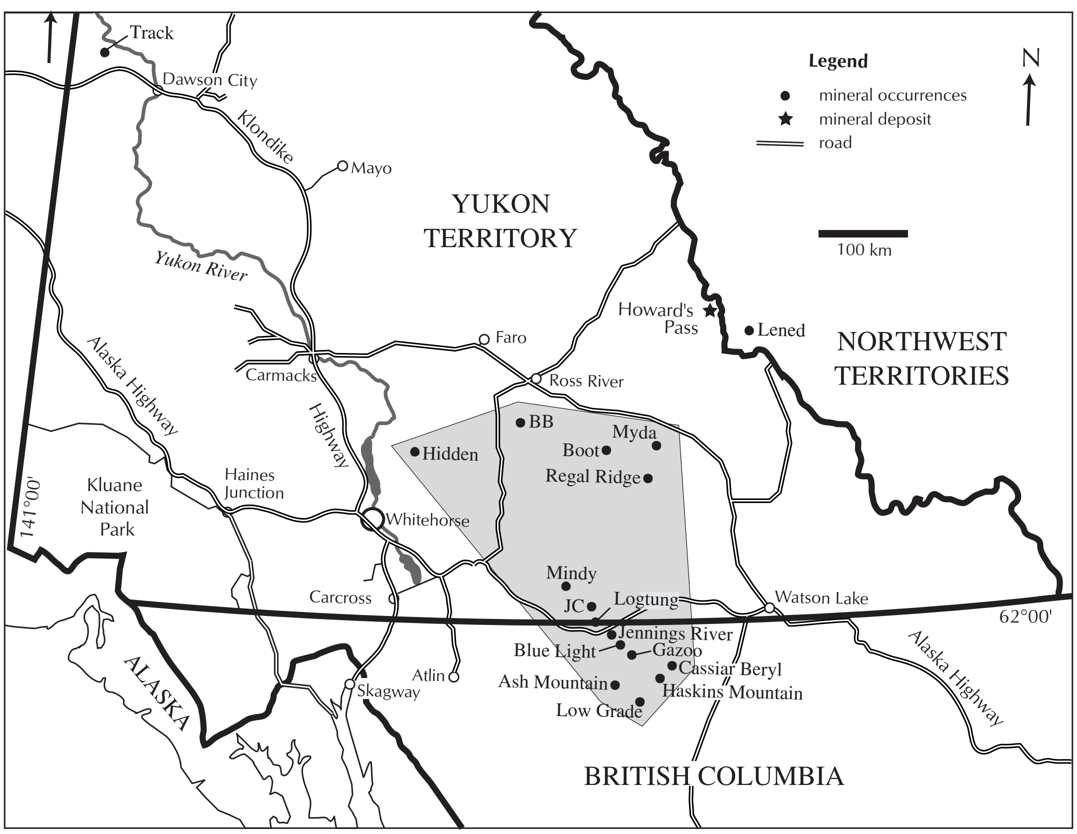

Figure 1. *Map of the Yukon Territory showing reported beryl/beryllium occurrences. The potential beryl/emerald camp is shown in grey.*

(5) stable isotope study; (6) Be-Cr-V-B mobility modelling; (7) beryl precipitation mechanisms; (8) geochronology of intrusives, alteration and veins; and (9) identification of possible geochemical signature of mineralized zones for exploration purposes.

LABORATORY RESULTS AND GENESIS

Fluid inclusion data indicate that the emerald precipitated from a fluid whose maximum salinities were 3 wt% NaCl equivalent. The oxygen isotopic composition of the emerald is variable (12.3 to 14.8‰), but there is little difference in corresponding δD values (-57.3 and -59.8‰, respectively). This suggests formation from an isotopically homogeneous fluid. The $\delta^{18}O$ values for coexisting quartz and tourmaline from the quartz veins yield temperatures of formation of approximately 365 and 498°C, respectively. Based on fluid inclusion isochoric data, these temperatures correspond to pressures of 1.0 to 2.5 kbar, and inferred depths of 3 to 7.7 km (Marshall et al, in press).

The close proximity of the granite suggests that it is likely the source of the beryllium in the formation of emerald, although the present Be concentration in the granite is low (12 and 13.2 ppm). Electron microprobe analyses show that Cr (average of 85 analyses is 3208 ppm) is the predominant chromophore in emerald from this occurrence. The source of the Cr is thought to be the host schist (520 ppm Cr). An $^{40}Ar/^{39}Ar$ age of 109 Ma obtained on phlogopite from the schist is not significantly different in age from the U-Pb ages of ca. 112 Ma reported for the granite pluton (Mortensen 1999; J.K. Mortensen and D.C. Murphy, pers. comm., 2002). This is interpreted to reflect either a thermal overprint age related to the event that produced the emeralds, or cooling following intrusion of the adjacent pluton, or both.

Figure 2. *Cut emerald from the Regal Ridge property. For scale, the largest rectangular cut gem in right centre of photo is approximately 5 mm in length. Photo courtesy of True North Gems Inc.*

LENED PROPERTY

In 1997 R. Berdahl, an independent prospector from Whitehorse, Yukon, discovered Vanadium-dominant emeralds near the Lened pluton in the southwestern Northwest Territories (Fig. 1). Emerald crystals at Lened are transparent to translucent, pale green in colour, and are up to 2.0 cm in length (L. Walton and R. Berdahl, pers. comm., 2002). Some yellow-green, and some darker-green crystals have been found.

The emerald crystals at Lened occur in quartz-carbonate veins within a garnet-diopside skarn. The skarn is hosted within the Rabbitkettle Formation which overlies Earn Group black shales. The skarn and the later veins are the result of contact metamorphism related to the adjacent 93 Ma Lened granitic pluton.

Fluid inclusion studies from emerald at Lened reveal the presence of two distinct fluids: a CO_2-bearing fluid related to emerald precipitation and a later brine limited to quartz crystals. The CO_2-bearing fluid is dominantly a dilute aqueous brine with approximately 4.5 mole percent CO_2 and minor amounts of CH_4, N_2, and H_2S. Formational pressures range up to 3.85 MPa and are limited by the presence of andalusite in the pluton. Formational temperatures of approximately 200-690°C are constrained by fluid inclusion homogenization temperatures and isochore intersections with the 3.85 MPa pressure maximum (Marshall et al, in press). Oxygen isotope, fluid compositions, formational pressures and temperatures are similar to those for the Regal Ridge occurrence.

OTHER PROPERTIES, BRITISH COLUMBIA AND YUKON

A review of assessment reports (BC MINFILE Mineral Inventory, 2001, *www.em.gov.bc.ca/Mining/Geolsurv/Minfile/default.htm;* and Yukon MINFILE, 2001) and other published and unpublished reports shows that numerous other beryllium and beryl occurrences exist in southern Yukon and northern British Columbia (Fig. 1). Analyses of a scheelite-bearing scapolite skarn at the Myda claim (Yukon MINFILE, 2001, 105G 071), approximately 20 km south of the Crown occurrence, show 0.05 to 0.09 wt% BeO. Beryl has also been reported from the Logtung W-Mo deposit (Yukon MINFILE, 2001, 105B 039), the JC (Viola) Sn-bearing skarn claims (Yukon MINFILE, 2001, 105B 040), and the Ice Lakes area (Groat et al. 1995), all in southern Yukon just north of the British Columbian-Yukon border. Beryl has also been reported from the following showings and prospects in northern British Columbia (listed west to east): Jennings River (British Columbia MINFILE, 2001, 104O 028), Ash Mountain (104O 021), Blue Light (104O 005), Gazoo (104O 045), Low Grade (104P 026), Haskins Mountain (104P 020), and Cassiar Beryl (104P 024). Most of these are associated with Cretaceous plutons, in particular the Cassiar Batholith.

CONCLUSION

At both the Regal Ridge and Lened showings, and at the Logtung beryl occurrence in southern Yukon, the Be is associated with elevated concentrations of W (including W skarn); the geochemical reasons for this association are unclear, but it also suggests a possible genetic association with intrusions.

In most emerald-producing nations, emeralds come from a number of mines within a mineralized region. The discovery of emerald at Regal Ridge and Lened along with numerous reports of anomalous levels of Be and/or the presence of beryl in the northern Cordillera suggest the potential for more emerald occurrences in the Yukon, western Northwest Territories, and northern British Columbia. This area could represent one (or possibly more) distinct beryl/emerald camp(s), as has been recognized at other places in the world.

ACKNOWLEDGEMENTS

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Structural settings and geochemistry of the Cynthia gold prospect, Tintina Gold Belt, Hess River area (105O/6), Yukon

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Soloviev, S.G., Schulze, C.M. and Baklyukov, O.E., 2003. Structural settings and geochemistry of the Cynthia gold prospect, Tintina Gold Belt, Hess River area (105O/6), Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 285-294.

ABSTRACT

The Cynthia property overlies a large (greater than 2x2 km) area of gold mineralization related to a Cretaceous Tombstone Suite quartz monzonite intrusive body. The mineralization is controlled by two district-scale fault zones and is especially intensive in the area of their intersection, located above and adjacent to the intrusive body. These larger structures host abundant gold-bearing massive and drusy quartz and chalcedony veins, zones of intense stockwork and strong brecciation, as well as numerous mineralized felsic dykes.

The gold grades within the mineralized structures are commonly in the range of 200 ppb to 2.0-3.0 g/t Au, with higher (up to 16 g/t Au) values attributed to the fault intersection area. Multi-staged gold mineralization found in the quartz veins, stockwork and altered dykes is associated with sulphide minerals (mainly pyrite and arsenopyrite) and elevated As, Bi and Ag values. A later mineralizing episode produced sulphide mineral-bearing chalcedony and drusy quartz veins, with gold concentrations accompanied by elevated Sb, Hg, Ag and Pb values, indicating the affinity of epithermal style gold mineralization.

The property is considered to represent a bulk-tonnage exploration target, with potential of the structures to host a major gold deposit. During the 2002 exploration program, the prospect has been advanced to a drill-ready stage.

RÉSUMÉ

La propriété de Cynthia couvre une grande zone (plus de 2x2 km) de minéralisation aurifère associée à une intrusion de monzonite quartzique de la Suite de Tombstone du Crétacé. La minéralisation est contrôlée par deux zones faillées à l'échelle du district et elle est particulièrement riche dans la zone de leur intersection au-dessus et près de l'intrusion. Ces vastes structures recèlent des essaims de filons de quartz et de calcédoine aurifères massifs et drusiques, des stockworks et des zones intensément bréchifiées ainsi que de nombreux dykes felsiques minéralisés.

Les teneurs en or dans les structures minéralisées varient de 200 ppb à 2,0-3,0 g/t Au, les teneurs les plus élevées (jusqu'à 16 g/t Au) attribuées à la zone faillée de l'intersection. Plusieurs étapes de minéralisation en or dans les filons de quartz, les stockworks et les dykes altérés est associée à des sulfures (principalement pyrite et arsénopyrite) et des teneurs élevées en As, Bi et Ag. Un épisode de minéralisation tardif a produit des filons de calcédoine et de quartz drusique sulfurés ainsi que des concentrations d'or accompagnées de valeurs élevées de Sb, Hg, Ag et Pb, ce qui indique une affinité avec une minéralisation d'or de style épithermal.

La propriété pourrait représenter une vaste cible d'exploration, les structures offrant le potentiel de loger un important gisement d'or. Les travaux d'exploration de 2002 ont permis de préparer la zone d'intérêt jusqu'au stage des forages.

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INTRODUCTION

The Cynthia property is 100% owned by Klad Enterprises Ltd. The property is centred at 63°23.5' north latitude, 131°21' west longitude on NTS map sheet 105O/6. It consists of 50 contiguous Yukon mining claims covering 1045.5 hectares (2582 acres).

The property is situated within the Tintina Gold Belt, 160 km north of the village of Ross River, Yukon and 80 km north of the Sheldon Lake airstrip along the North Canol Road (Fig. 1). A winter road extending from the Canol Road west to the Plata airstrip is located roughly 10 km south of the property.

PROPERTY EXPLORATION HISTORY

The Cynthia property was first staked as the Art 1-12 claims in 1967 by the Hess Project (Atlas EL, Quebec Cartier Mining Company, and Phillips Brothers (Canada) Ltd.). In 1968, the companies performed grid soil sampling, and magnetic and electromagnetic surveys (Yukon MINFILE, 2001).

The eastern part of the project site was restaked as the Emmy 1-16 claims in 1981 by Union Carbide Canada Ltd., which conducted geological mapping and rock sampling in 1981 and 1982 (James, 1982). The program located weakly pyritic to arsenopyritic quartz veins that returned values up to 3130 g/t Au, 775 g/t Ag, 795 g/t Sb and 1.7% Pb. Breccia zones returned values up to 660 ppb Au; a black chert breccia returned 3.7% Pb and 948 g/t Ag (Union Carbide, 1982, in-house report).

The property was restaked in 1991 as the Hess 1-64 claims by Noranda Exploration Company Ltd. In 1995, the entire present property area was staked as the EM 1-112 claims by Brian Lueck, who optioned the property to Yukon Gold Corporation, which conducted geological mapping, and rock and soil sampling. This program defined three anomalous areas, including one hosted by brecciated argillite between two prominent quartz monzonite intrusive bodies (Lueck, 1996). In 1997, Cyprus Canada Inc. optioned the claims and performed a helicopter reconnaissance program. Cyprus Canada sampled the hornfelsed metasedimentary rocks between the two intrusive bodies, obtaining values from 0.5 to 1.0 g/t Au; a sample of quartz-feldspar dyke material returned 1.8 g/t Au (Yukon MINFILE, 2001). In 2002, shortly after the EM 1-112 claims lapsed, Klad Enterprises Ltd. staked the present Cynthia 1-50 claims.

REGIONAL GEOLOGY

The Cynthia property is located within the Tintina Gold Belt (British Columbia and Yukon Chamber of Mines, 2000), which occurs along a trend of mid- to Late Cretaceous granitoid (diorite, granodiorite, quartz monzonite, syenite) intrusions extending from central Alaska, across central Yukon, to the Yukon-British Columbia border, roughly parallel to the ancient

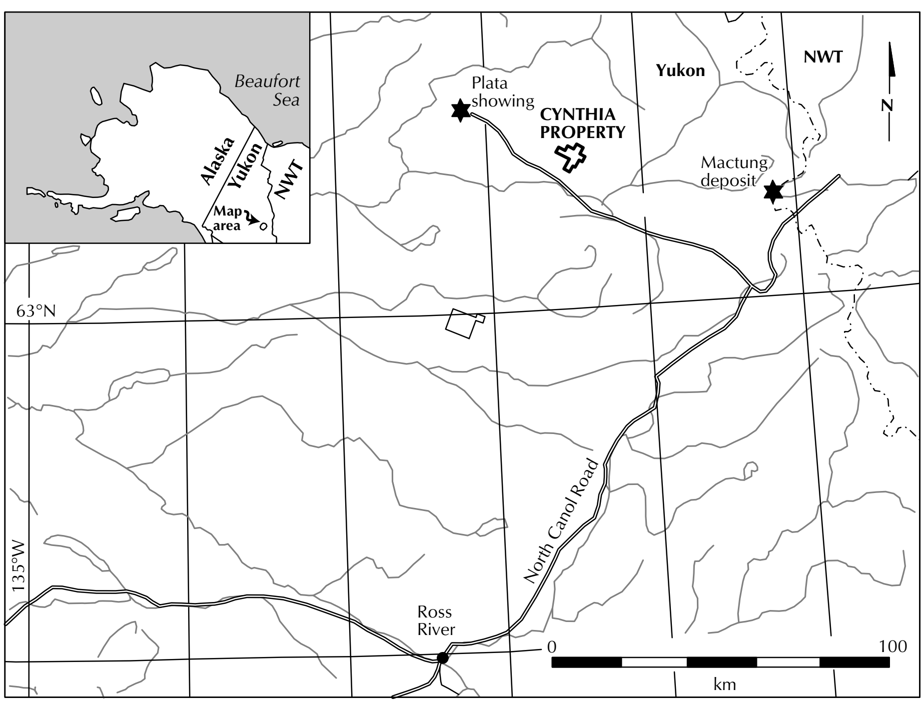


Figure 1. *Location of Cynthia property.*

North America craton boundary. In Yukon, the belt is superimposed on the Selwyn Basin, a thick sequence of shelf and off-shelf continental margin metasedimentary rocks formed from late Precambrian to Triassic time (Gordey and Anderson, 1993).

The southeastern portion of the Selwyn Basin, including the Cynthia property, is underlain by a broad package of Ordovician to Devonian Road River Group and Devono-Mississippian Earn Group sedimentary rocks, with west-northwest-trending upper Precambrian to Lower Cambrian Hyland Group sedimentary units occurring to the southwest. Hyland Group sedimentary rocks consist largely of coarse clastic 'grits', shale, and lesser limestone and calcareous clastic rocks. Road River Group sedimentary rocks consist mostly of thick chert horizons with lesser interbedded shale, limestone and calcareous mudstone, with minor mafic volcanic units. Earn Group sedimentary rocks consist of chert-pebble conglomerate and greywacke, as well as lesser shale and sandstone.

The area is transected by a number of variably striking faults and fault zones that represent portions (branches) of regional-scale lineaments. Most prominent among them are west-northwest and north-northeast-trending faults that control the majority of larger intrusive stocks, dykes and zones of mineralization, both in regional and local scales.

PROPERTY GEOLOGY

The Cynthia property is situated between and adjacent to two mid-sized (5 by 3 km and 3 by 2 km) exposures of quartz monzonite belonging to the Cretaceous Tombstone Intrusive Suite (Fig. 2). These have been

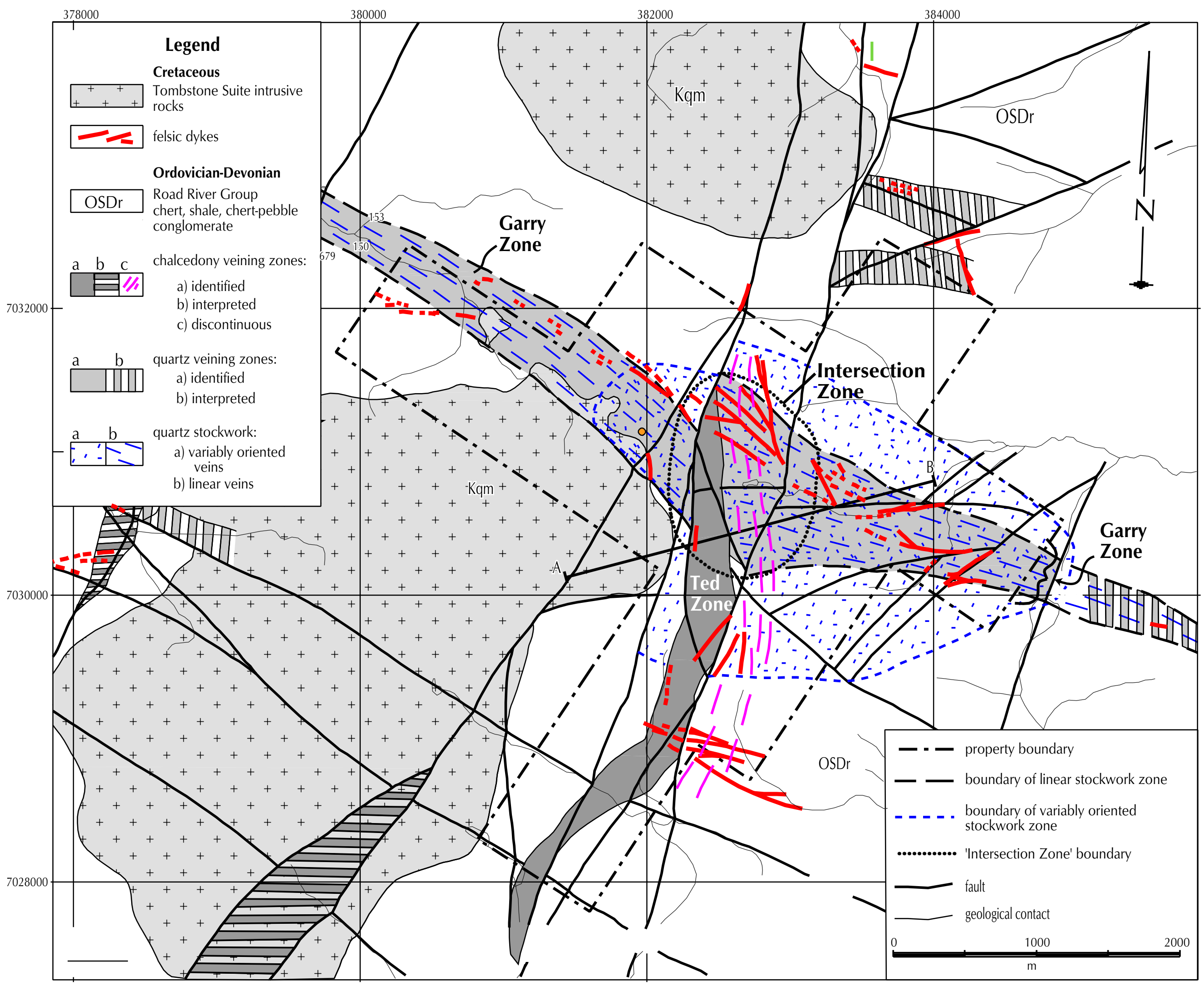


Figure 2. *Geology map of Cynthia property and vicinity.*

interpreted as surface exposures of a single large pluton. The larger southern exposure is coarse-grained and equigranular, whereas the northern one is K-feldspar-porphyritic, possibly suggesting a shallower emplacement depth. Small apophyses of the southern intrusive body occur along its northern contact. Numerous quartz and quartz-feldspar porphyritic dykes are found along structural corridors across the property, but are especially concentrated in the central, western and extreme southern parts of the property.

Sedimentary rock on the property consists primarily of Ordovician-Devonian Road River Group chert and interbedded shale, with minor limestone in the northern part of the property and extending farther northward. Devono-Mississippian Earn Group chert-pebble conglomerate has been identified in the centre of the property but the contacts remain undetermined. Previous mapping has identified the entire sedimentary package as Road River Group; however, local greywacke and limestone units in the southern part of the property suggest at least the partial presence of Earn Group sedimentary rocks.

A broad district-scale fault zone incorporating several north-northeast-trending faults occurs across the central property area where it is superimposed on a large arcuate band of silicified limestone. This unit varies from a maximum thickness of roughly 500 m in the central region to a minimum of 100 m in extreme southern portions. The faults, interpreted as steeply east-dipping reverse faults, have caused lateral and vertical stratigraphic displacement, resulting in downward displacement of stratigraphy along the western side. The fault zone hosts several quartz-feldspar porphyry dykes and numerous chalcedony and drusy quartz veins, as well as intensive quartz stockwork. It bears significant gold mineralization, and has been delineated as the Ted Zone (Fig. 2). North-south-trending chalcedony veins also occur east of the Ted Zone.

Another wide (0.5-1.0 km) district-scale fault zone strikes west-northwest through the property centre, parallel to regional-scale strike-slip faulting of the Tintina fault system. This zone hosts numerous dyke swarms, suggesting it represents a continuous dilational corridor. The zone also hosts intensive quartz stockwork and thicker linear veins, with minor chalcedony veining. Within the stockwork zone, quartz veins and stringers strike predominantly east-southeast, and dip steeply to the south-southwest, although a significant number strike roughly north-south, dipping steeply westward. Vein densities range from 5 to 10 veins per metre, with locally much higher concentrations. Veins are generally centimetre- to millimetre-scale, although veins up to 30 cm wide are present locally. This broad fault zone also bears significant gold mineralization and has been delineated as the Garry Zone (Fig. 2).

The intersection of the Ted Zone and Garry Zone occurs in the central part of the property. This 1.5 by 1.5 km intersection area is characterized by the most intensive fracturing and brecciation, the highest quartz vein density, and the strongest silicification and hydrothermal alteration on the property. This area also hosts the most intensive gold mineralization, and has been delineated as the Intersection Zone (Fig. 2).

ALTERATION

Metasedimentary rocks adjacent to the intrusive rocks have been intensely hornfelsed, with pyrite and pyrrhotite development, and are strongly gossanous for several hundred metres outbound from the intrusive contacts.

Multiple episodes of quartz-dominated mineral assemblage formation occurred through hydrothermal processes related to the intrusive activity. At least three major episodes of silicification have occurred:

1. An event or sequence of events of pervasive replacement-style (within limestone) and fracture-controlled (in the form of intensive stockwork) silicification;
2. A subsequent episode of chalcedony formation along fractures and open spaces, and;
3. A later episode of drusy to cockscomb quartz formation.

All three episodes have occurred intensely within the Ted Zone limestone horizon in the central part of the property; intensive silica replacement suggests the limestone was the most reactive and easily replaced unit. Quartz veining is most intensive within the Garry Zone, forming stockwork locally, and indicating mineral formation occurred mainly as fracture-filling veins within less reactive rocks.

Late quartz-porphyritic and quartz-feldspar-porphyritic dykes display silicification and late-stage quartz veining, indicating dyke emplacement preceded early silicification. Locally, the dykes have been brecciated, cemented by quartz, then rebrecciated and recemented by chalcedony and/or drusy quartz. Argillic alteration is common both within dykes and metasedimentary rocks. Sericitization, as part of the quartz-sericite-iron carbonate-pyrite assemblage, is most pronounced within dykes.

MINERALIZED ZONES

Auriferous mineralization occurs primarily within broad fault zones delineated above as the Ted, Garry and Intersection zones (Figs. 2, 3). The intensity of the mineralization and sets of mineral assemblages depend on local structural settings, host rock lithology and style of hydrothermal alteration. The geochemical signatures of mineral assemblages most typical for each zone are summarized in Table 1.

TED ZONE

The Ted Zone hosts abundant north-northeast-striking, steeply east-dipping chalcedony veins superimposed on the wide unit of strongly pervasive silicified limestone and subordinate quartz stockwork. To the east, the Ted Zone grades into the area of discontinuous chalcedony and less pervasive silicification.

Rock sampling along the northern 2.0-km portion of the Ted Zone returned strongly anomalous gold values along the entire sampled length. Gold values range from background levels to a high of 2.56 g/t Au. The higher grades are attributed to the chalcedony veins and north-northeast-trending altered dykes. Typically lower, but also anomalous (within 200-400 ppb Au range), numbers are related to the quartz-dominated assemblages of the quartz stockwork.

To the south, rock chip sampling of the chalcedonic and pervasively silicified material returned values up to 1.24 g/t Au over 0.9 m and 1.125 g/t Au over 1.1 m. Composite grab sampling returned values up to 2.54 g/t Au. Further south, the Ted Zone narrows somewhat; however, sampling of abundant chalcedonic float and rubblecrop returned values in the 150-500 ppb Au range to a maximum of 944 ppb Au.

Roughly 2 km south of the sampled area, several grab samples were taken in a broad unit of silicified fine clastic sedimentary rocks with local chalcedony veining, interpreted to be an extension of the Ted Zone. Although most returned background gold values, several were weakly anomalous, with one returning a value of 349 ppb Au. This suggests the Ted Zone has a minimum extent of 4.0 km, and remains open to the south.

To the north of the main sampled zone, systematic chip sampling returned low values, although composite grab samples returned values up to 310 ppb Au. However, 2 km further north along the strike of the Ted Zone,

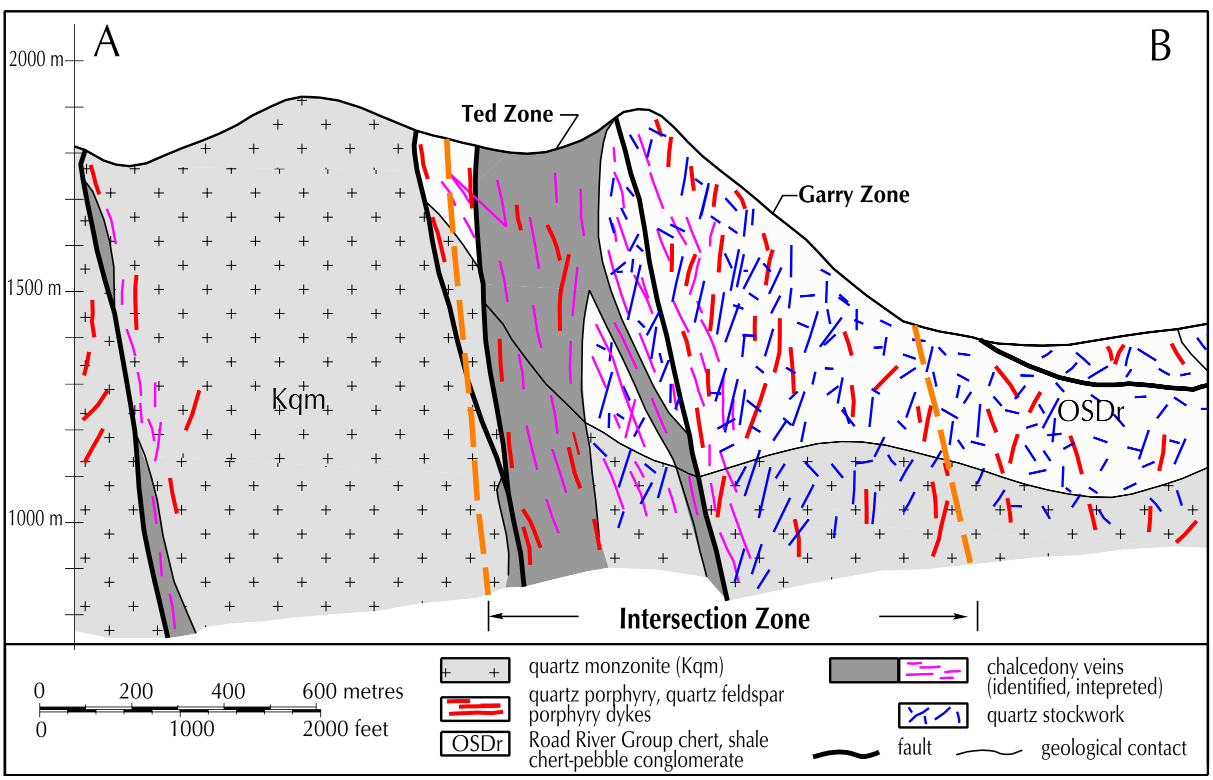


Figure 3. *Hypothetical section: line A-B (see Figure 2), Cynthia property, looking north.*

Table 1. *Representative rock sample assay results for various auriferous assemblages in the Ted, Garry and Intersection zones*[1].

Sample	Au (ppb)	Ag (ppm)	As (ppm)	Bi (ppm)	Cu (ppm)	Pb (ppm)	Sb (ppm)	Zn (ppm)
Ted Zone, gold-arsenic assemblage								
C1021	1125	5.5	2730	<2	40	7	79	2
C1022	1240	4.6	3920	<2	62	7	98	5
CY4126	944	3.8	780	<2	31	9	69	25
CY4249	2560	2.2	>10 000	32	67	17	137	38
C4048	490	11.6	1060	<2	41	4	41	5
C1018	2540	4.4	8290	<2	410	11	198	9
Ted Zone, gold-quartz assemblage								
CY4251	349	0.2	232	<2	24	2	6	27
Garry Zone, gold-quartz assemblage								
C4081	930	12.9	240	<2	9	9	44	2
CY4114	888	2.6	345	<2	4	5	81	5
C4014	380	1.2	369	<2	10	4	171	<2
CY4105	658	2.1	367	<2	13	5	255	2
Intersection Zone, gold-arsenic assemblage								
C4078	3200	25.4	>10 000	39	90	48	73	10
C4079	711	9.8	>10 000	5	51	36	32	27
CY4003	1965	2.5	>10 000	<2	46	11	60	5
CY4142	16 000	22.3	>10 000	114	140	21	201	8
Intersection Zone, gold-quartz assemblage								
CY4138	890	3.5	341	<2	15	7	68	43
CY4140	1010	10.2	580	<2	4	13	94	3
CY4155	406	3.6	538	<2	58	6	27	14
C4080	534	1.4	963	<2	6	10	43	2
C1011	430	6.4	724	<2	6	14	60	8
Intersection Zone, gold-silver-lead-antimony-arsenic assemblage								
C1004	2650	376	>10 000	386	161	3100	2590	28
C3001	440	59.8	>10 000	44	44	1220	860	134
C4058	590	85.0	9040	145	32	580	518	34
C3005	2500	328	3070	618	29	836	614	6
C4004	555	114	>10 000	167	206	1475	1525	16
C4005	3250	246	7320	420	140	323	176	6
C4010	3190	63.0	>10 000	136	294	119	102	24
C4057	4650	479	>10 000	780	209	6720	5480	17

[1]Assays were performed in ALS Chemex labs of North Vancouver, B.C. All rock samples were pulverized until 85% of fragments were less than 75 microns in size; then an evenly mixed 30 g portion was analysed for 34-element aqua regia ICP-AES, as well as gold by fire assay with atomic absorption finish. «Overlimits» of Ag, Pb, Sb, Cu were reanalysed to provide respective elemental contents.

samples of altered dyke material returned values up to 2.56 g/t Au.

The most pronounced geochemical signature of Ted Zone auriferous mineral assemblages is the strong enrichment in arsenic as arsenopyrite (Table 1). Pyrite is also widespread; however, the importance of other sulphide minerals is negligible. Sample CY4251, taken from the southern end of the 4-km-long sampled interval of the Ted Zone, returned a low arsenic value. This low-sulphide quartz stockwork mineralization, rather than a highly arsenical sulphide-rich assemblage, is more typical for the flanks of the mineralized zone.

GARRY ZONE

The Garry Zone occurs as a kilometre-wide zone extending west-northwest across the property. The zone hosts intensive quartz stockwork with a dominant west-northwest orientation of thicker quartz veins, and minor chalcedony veins; central portions also host dyke swarms. This central portion also incorporates and is surrounded by an area of variably oriented thin quartz veins forming a stockwork zone 2.0-2.5 km in width. The density of veinlets within this stockwork varies from 5 to 10 per m, with local concentrations of up to 20 veinlets per metre. These are generally centimetre- to millimetre-scale in thickness. The stockwork is superimposed on dykes, indicating post-intrusive formation.

Gold values typical of the Garry Zone, commonly in the range of 300-900 ppb Au, are somewhat lower than those of the Ted Zone. The Garry Zone extends at least 2 km east-southeast of the Ted Zone, and for 3 km to the west-northwest. Sampling of the dyke swarm along the southeast property boundary (Fig. 2) returned values up to 296 ppb Au, although most samples returned low anomalous values. To the west-northwest, the Garry Zone returned less consistent and generally lower gold values, although anomalous results up to 679 ppb Au were also obtained 3 km west-northwest of the intersection with the Ted Zone.

The Garry Zone quartz stockwork bears low-sulphide auriferous mineralization associated with minor fine-grained pyrite and trace arsenopyrite (Table 1). Notably, these gold grades are associated with low arsenic values, even where the quartz veins are superimposed on dykes (e.g., sample CY4114). On the other hand, some highly altered dykes bearing abundant arsenopyrite contain only

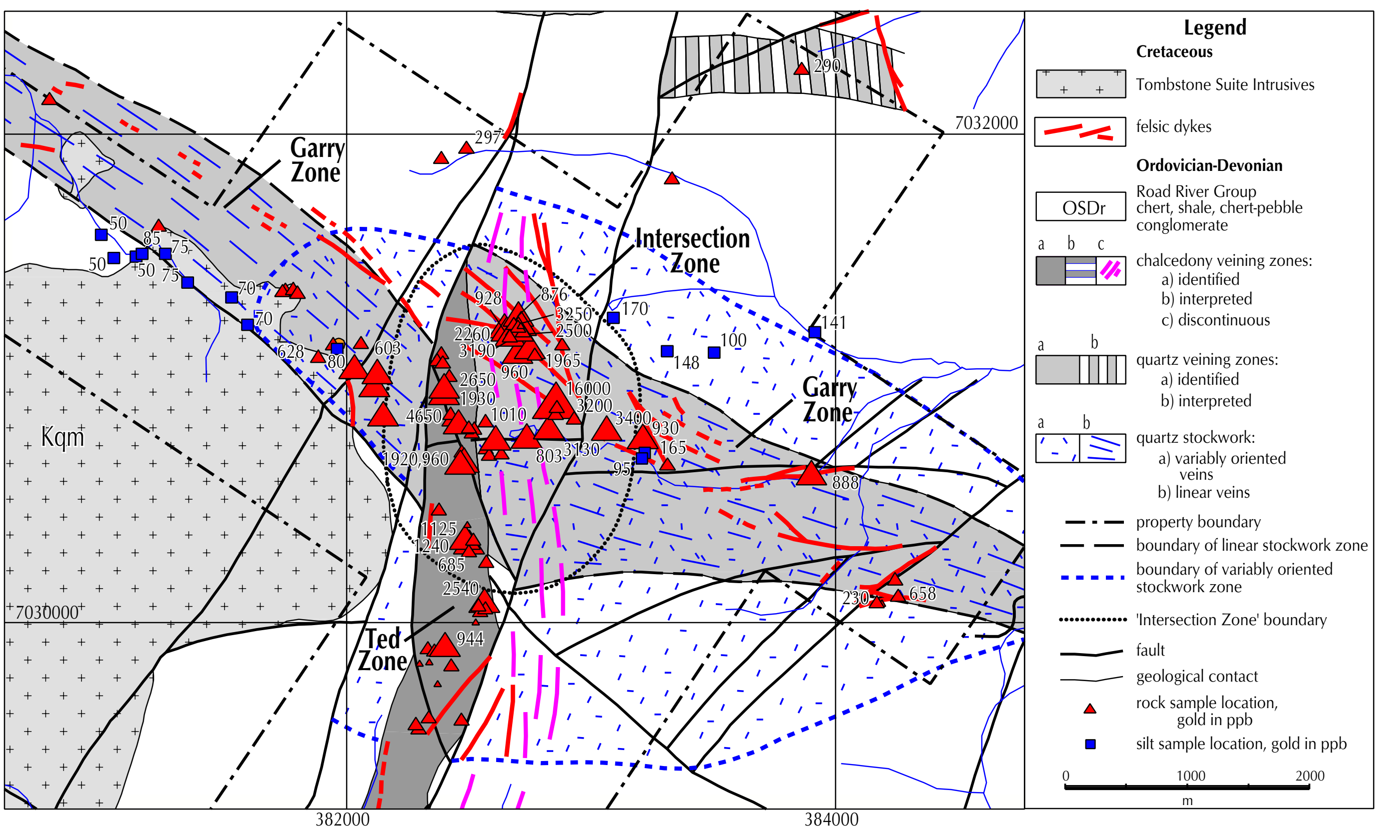
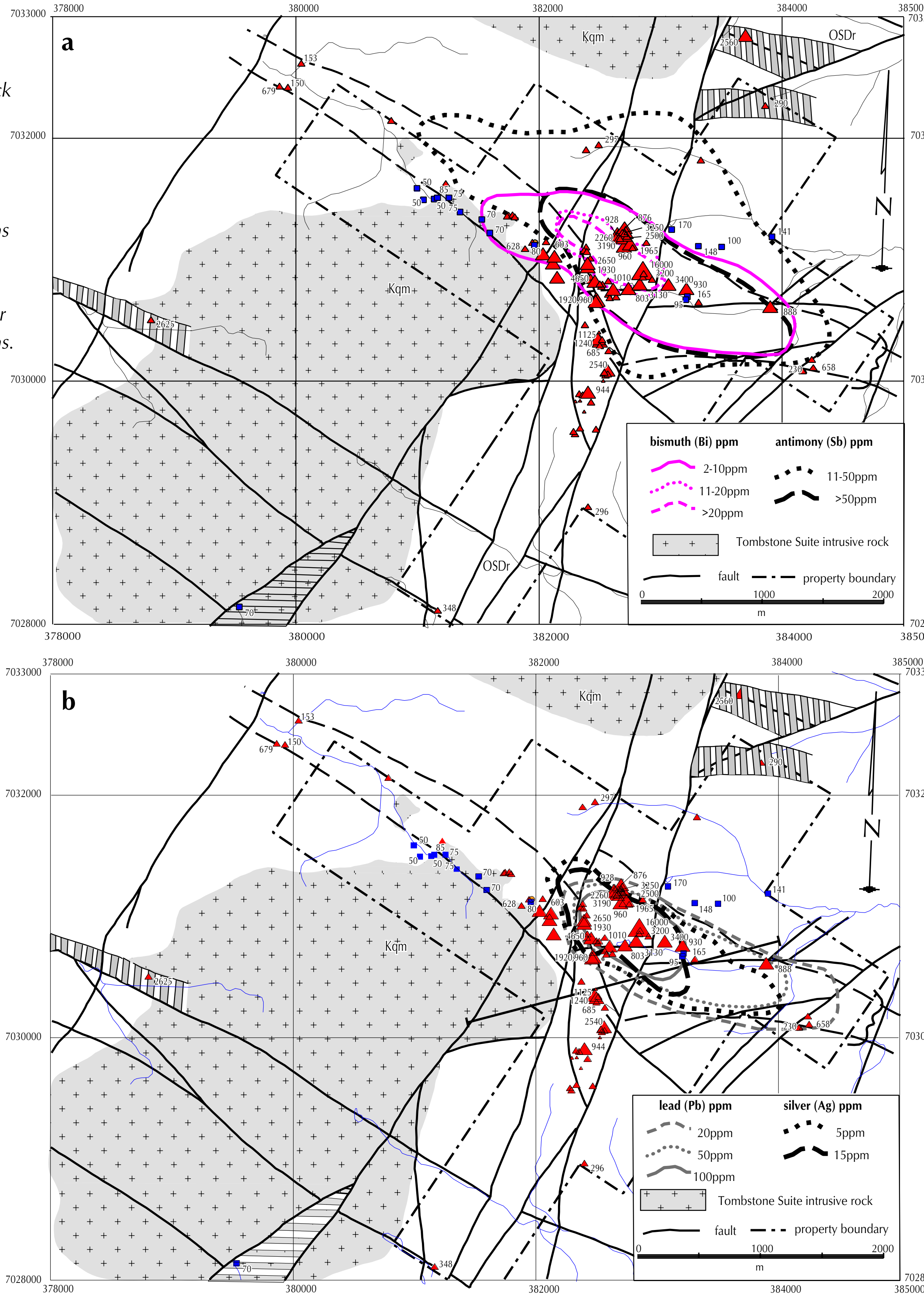


Figure 4. *Sample locations with anomalous gold values (in ppb).*

Figure 5. *Geochemical contour plots (based on rock sampling):* ***(a)*** *showing bismuth and antimony concentrations and* ***(b)*** *showing lead and silver concentrations.*



low gold values. Thus, in contrast to the Ted Zone where auriferous mineralization is associated mainly with arsenopyrite, with only minor importance of gold in quartz stockwork, in the Garry Zone the vast majority of gold is found in the low sulphide quartz stockwork, and only a minor fraction is related to altered dykes and stocks containing arsenopyrite.

INTERSECTION ZONE

The Intersection Zone is a conditionally contoured, circular area, outlined to incorporate the zone of mutual intersection and influence of the Ted and Garry zones (Fig. 2). As a result, all mineralized occurrences, veins, stockwork and dykes found within the Intersection Zone can be attributed either to the Ted Zone or to the Garry Zone (Fig. 3). These occurrences, however, exhibit characteristics that differ from those found within the Ted and Garry zones outside the Intersection Zone.

The most pronounced feature of the Intersection Zone is the greater abundance of mineralized veins and dykes, and a much higher density of quartz stockwork compared with the outlying Ted and Garry zones. This is not surprising, due to the much higher degree of structural preparation within this zone of intersecting district-scale faults. The location of the Intersection Zone, close to or just above the ‘saddle’ between the two intrusive exposures (probably surface expressions of a single continuous intrusion extending under the ‘saddle’), has strongly influenced the strength of thermal preparation and hydrothermal activity.

As a result, the second most pronounced, and most important feature of the Intersection Zone is that it hosts the most intense gold mineralization found on the property (Fig. 4). Gold grades are commonly in the 1.0-4.0 g/t Au range; one sample returned 16.0 g/t Au. Notably, both styles (highly arsenical and low-sulphide) of auriferous mineralization within the Intersection Zone bear higher gold grades than respective assemblages in the outlying Ted and Garry zones (Table 1). In particular, the gold-arsenic assemblage in the Intersection Zone returned values typically up to 3.20 g/t Au, and includes the sample returning 16.0 g/t Au. Similarly, the low-sulphide quartz stockwork assemblage within the Intersection Zone returned numerous values exceeding 1.0 g/t Au.

The third major feature of the Intersection Zone is the existence of a broadly occurring third gold-bearing mineral assemblage absent from the outlying Ted and Garry zones. This is a highly sulphidized, highly arsenical gold-rich assemblage, also bearing very high bismuth (up to 780 ppm Bi), antimony (up to 6720 g/t Sb; Fig. 5a), silver (up to 479 g/t Ag) and lead (up to 3100 ppm Pb; Fig. 5b) values (Table 1). This set of elements associated with gold indicates an epithermal affinity of this mineral assemblage.

The structural settings of the fault-controlled mineralized zones forming the Intersection Zone, particularly the steep eastward dip of the Ted Zone and southward dip of the Garry Zone, suggest a southeast plunge of the Intersection Zone.

CONCLUSIONS

The Cynthia property represents a large and very prospective target with potential to host significant bulk-tonnage gold mineralization. This is defined by

1. The presence of the large (1.5 by 1.5 km) Intersection Zone mineralized structure formed at the intersection of two district-scale faults; this structural setting is typical of large gold deposits. In particular, this occurs at the largest known Tintina Gold Belt deposit, the Donlin Creek deposit, hosting a resource exceeding 780 million g (25 million ounces) gold, with a similar lateral extent of mineralization;
2. The location of the mineralized structure within and adjacent to the ’saddle‘ area between the two intrusive exposures, thus increasing the intensity of thermal preparation, and channeling the hydrothermal activity related to the magmatic process;
3. The presence of consistent gold mineralization within mineralized structures, with the potential for local high ’bonanza-type‘ gold concentrations; and
4. The occurrence and superposition of several stages of gold mineralization, including the later stages of epithermal affinity.

During the 2002 field season, the property has been advanced to a drill-ready stage. A diamond-drilling program proposed for 2003 is designed to test areas of higher gold concentration within the Intersection Zone.

ACKNOWLEDGEMENTS

We would like to gratefully acknowledge Mr. Ron Berdahl for much of the claim staking of the property. We would also like to acknowledge Mr. Jeff Boyce, field technician, for his contribution to the project during the 2002 field season, and Aurora Geosciences Ltd., Ross River Expediting, Trans North Helicopters, Fireweed Helicopters, Heli-Dynamics Ltd., A-1 Delivery, the Welcome Inn, and all other supply and service industries that supported the project. We would also like to acknowledge Kevin Franck and Associates for preparation of digital figures, and Lara Lewis and Diane Emond for editing this paper.

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Structural settings and geochemistry of the Myschka gold prospect, Tintina Gold Belt, Mt. Selous area (105K/16, 105N/1), Yukon

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Soloviev, S.G., Schulze, C.M. and Baklyukov, O.E., 2003. Structural settings and geochemistry of the Myschka gold prospect, Tintina Gold Belt, Mt. Selous area (105K/16, 105N/1), Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 295-306.

ABSTRACT

The Myschka property overlies a large mineralized area within and adjacent to a 1200 m by 600 m Cretaceous Tombstone Suite granodioritic intrusion. Mineralization is controlled by at least four wide east-west-trending lensoid zones of faulting, brecciation and hydrothermal alteration. Just north of the intrusion, the zones were followed for a distance of 1500 m; widths of individual zones vary from 20 to 100 m. The zones tend to coalesce into much wider (up to 200 m) brecciated packages that dip steeply (70-85°) to the south and apparently crosscut the intrusive. A network of northerly dipping fault and alteration zones crosscut these breccias.

The breccias include intensive quartz stockwork and thicker quartz-filled shear zones containing disseminated gold-bearing sulphide (pyrite, arsenopyrite) mineralization. Rock samples returned numerous strongly anomalous gold values ranging from 200 ppb to 1.05 g/t throughout the extent of the breccia zones. Larger quartz veins locally exhibit much stronger sulphide enrichment, resulting in higher Ag, Bi, Sb, Pb, Zn and Cu values influencing property-scale geochemical zonation. A distinctive gold and pathfinder element soil anomaly is coincident with the breccia packages.

During the 2002 exploration program, the prospect was advanced to drill-ready stage. Proposed drilling will test subsurface continuation of gold-bearing fault/breccia and alteration zones into the intrusive rock.

RÉSUMÉ

La propriété Myschka repose sur une vaste zone minéralisée qui se trouve à l'intérieur et près d'une intrusion granodioritique de la Suite de Tombstone du Crétacé (1200 m sur 600 m). La minéralisation est contrôlée par au moins quatre grandes zones lenticulaires à direction est qui sont faillées, bréchifiées et altérées par des fluides hydrothermaux. Juste au nord de l'instrusion, on a suivi les zones sur une distance de 1500 m; les largeurs individuelles varient de 20 à 100 m. Elles ont tendance à fusionner pour former de vastes brèches (jusqu'à 200 m de large) qui pendent fortement (70-85°) vers le sud et recoupent apparemment l'intrusion. Un réseau de zones faillées et altérées inclinées vers le nord recoupent ces brèches.

Les brèches incluent un stockwork de quartz et des zones de cisaillement plus épaisses remplies de quartz recelant des sulfures aurifères disséminés (pyrite, arsénopyrite). Les échantillons de roche prélevées sur toute l'étendue des zones bréchifiées ont donné de fortes anomalies d'or variant de 200 ppb à 1,05 g/t. Les plus gros filons de quartz affichent localement un enrichissement plus marqué en sulfures, d'où des teneurs plus élevées en Ag, Bi, Sb, Pb, Zn et Cu qui influent sur la zonation géochimique à l'échelle de la propriété. Une anomalie caractéristique d'or et des éléments indicateurs dans le sol coïncide nettement avec les ensembles de brèches.

Au cours de la campagne d'exploration de 2002, on a poursuivi les travaux de préparation jusqu'à l'étape des forages. Ceux-ci permettront de vérifier la continuation souterraine des zones faillées/bréchifiées et altérées aurifères dans la roche intrusive.

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INTRODUCTION

The Myschka property, 100% owned by Klad Enterprises Ltd., is situated 110 km north of the town of Ross River, Yukon, within the Tintina Gold Belt (Fig. 1). The property is located 60 km west of the North Canol Road, which extends northeast from Ross River to the Yukon-Northwest Territories border near the Mactung tungsten deposit. The property is centred at 62°59' north latitude, 132°07' west longitude on NTS map sheets 105K/16 and 105N/1, and consists of 106 contiguous Yukon quartz mining claims covering 2216 hectares (5475 acres). Two airstrips of unknown condition exist roughly 9 km to the southeast and 5 km to the southwest of the central property area.

The Myschka property is part of a large cluster of base metal, silver and gold occurrences found within or close to the eastern contact of the Mt. Selous Batholith belonging to the 92 Ma mid-Cretaceous Tombstone Intrusive Suite, the major magmatic and metallogenic unit of the Tintina Gold Belt (British Columbia and Yukon Chamber of Mines, 2000). The mineralized cluster in its currently known extent, occupies an area exceeding 20 by 20 km, and incorporates several small granitoid stocks apparently satellitic to the Mt. Selous Batholith. The set of mineral occurrences includes high-grade lead-zinc-silver (galena, sphalerite) veins, chalcopyrite-pyrrhotite (+ scheelite?) skarns, stockwork and disseminated sulphide-related (pyrite, arsenopyrite) gold mineralization, and bismuth-copper (chalcopyrite), arsenic (arsenopyrite) and antimony (stibnite) veins. This is very similar to the set of intrusive-related mineral deposits and occurrences known within some other large mineralized districts of the Tintina Gold Belt. The broad occurrence of lead-zinc-silver and gold shows the Mt. Selous cluster to be most similar to mineralization in the Mayo and Keno Hill areas, although some local variations (in particular, greater abundance of sphalerite in the base metal veins) are well pronounced. A base metal (+As, Sb) signature is usually considered to reflect a distal position of gold mineralization relative to a parental pluton (Mortensen et al., 1996), although some variations in metallogenic specialization of the intrusives (and related mineralized districts) can also be considered.

EXPLORATION HISTORY

In 1967, the Lad claims were staked roughly 5 km west-southwest of the present Myschka property centre by the Hess Project (Atlas EL, Quebec Cartier Mining Company and Phillips Brothers (Canada) Ltd.). Work consisted of geological and geochemical surveying, and hand trenching, followed in 1969 by road construction and bulldozer trenching. The program revealed a Pb-Zn-Ag occurrence exposed for 15 m, with values averaging 205.7 g/t Ag, 6% Pb, 3% Zn and 2% Cu across widths of

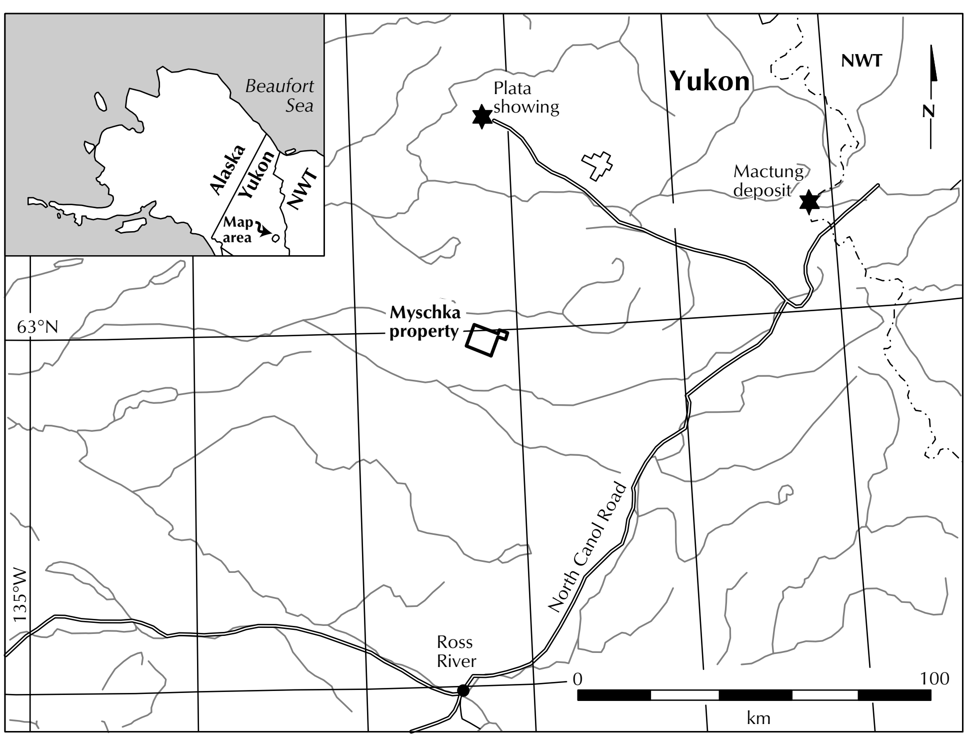


Figure 1. *Location of Myschka property.*

0.3 to 3.0 m. In 1974, the Atlas interest was transferred to Cima Resources Ltd., which, in 1977, drilled two holes totaling 252 m. The drilling intersected two parallel veins within a fault zone; the upper vein returned 133.7 g/t Ag, 5.3% Pb and 4.7% Zn across 1.2 m, and the lower one returned values up to 48.0 g/t Ag, 0.4% Pb and 1.6% Zn across 2.1 m (Yukon MINFILE, 2001).

The current north-central portion of the Myschka property was originally staked in 1968 as the Solo claims by the Hudson Bay Mining and Smelting Company, which conducted grid soil sampling and geological mapping in 1968 and 1969. In 1990, Noranda Exploration Company Ltd. staked the Rush claims covering portions of the southern Myschka claims. Selected samples returned values up to 3017 g/t Ag, 75% Pb and 0.2% Zn; a separate sample returned 665 g/t Ag (Yukon MINFILE, 2001).

In 1996-1997, Mr. Ron Berdahl, a Yukon prospector, staked the Andrew claims centred about 6 km southwest of the present Myschka property centre to cover an old occurrence described as Ag-Pb-Zn-Cu veins. A composite grab sample of oxidized surface material returned a value of 17% Zn (Burke, 2000). Subsequently, the claims were optioned to Noranda Exploration Company Ltd., which added the AMB 1-111 claims, and followed up in 2001-2002 with surface exploration and a diamond-drilling program. This work investigated the potential of this mineralization, considered to be of a sedimentary-exhalative (SEDEX) style. The work, however, proved that the mineralization is of hydrothermal origin (M. Burke, pers. comm., 2002).

The area has been mapped by the Geological Survey of Canada and has been covered by the National Geochemical Reconaissance stream-sediment sampling program (Friske et al., 1990), which has identified the property area as having highly anomalous arsenic, antimony and gold values. In 1998, Viceroy International Exploration Ltd., in the course of a regional gold reconnaissance program, conducted limited surface geochemical sampling and geological mapping in the area and staked the Myschka 1-16 claims. Viceroy also staked the Tarakan claims, 15 km northwest, and the Uragan claims, 6 km northeast, to cover gold occurrences. In 1999 Viceroy transferred its 100% interest in the claims to Novagold Resources Inc. which allowed the Myschka claims to lapse. In 2001, the central portion of the Myschka property was staked as the Sophia claims by Ron Berdahl. In 2002, Klad Enterprises Ltd. optioned these claims and staked the adjoining Myschka 1-96 and Dasha 1-6 claims, obtaining a 100% interest in the entire package.

REGIONAL GEOLOGY

The Myschka property is located within the Tintina Gold Belt (British Columbia and Yukon Chamber of Mines, 2000), which follows a trend of mid- to Late Cretaceous granitoid (diorite, granodiorite, quartz monzonite, syenite) intrusions that extend from central Alaska, across central Yukon, to the Yukon-British Columbia border. This belt is roughly parallel to the ancient North America craton boundary. In Yukon, the belt is superimposed on the Selwyn Basin, a thick sequence of shelf and off-shelf continental margin sedimentary rocks formed from late Precambrian to Triassic time (Gordey and Anderson, 1993).

The southeastern portion of the Selwyn Basin, including the Myschka property, is underlain by a broad package of Ordovician to Devonian Road River Group and Devono-Mississippian Earn Group sedimentary rocks, with upper Precambrian to Lower Cambrian Hyland Group sedimentary units extending northwest of the property. Hyland Group sedimentary rocks consist largely of coarse clastic 'grits', shales and lesser limestone and calcareous clastic rocks. Road River Group rocks consist mostly of thick chert horizons with lesser interbedded shale, limestone and calcareous mudstone, with minor mafic volcanic units. Earn Group rocks consist of chert-pebble conglomerate and greywacke, as well as lesser shale and sandstone.

The Mt. Selous Batholith, roughly 20 by 12 km, represents the largest Tombstone Suite pluton in the property area. The batholith is generally oval-shaped and elongated roughly southeast-northwest; the shape of its eastern contact suggests it extends eastwards beneath the Paleozoic sedimentary rock, which has been intruded by several much smaller satellitic stocks. Notably, the majority of known mineral occurrences in the area are found to the east of the batholith exposure. The intrusive rocks are largely medium- to coarse-grained weakly porphyritic hornblende-biotite to biotite-hornblende quartz diorite to quartz monzonite. Late felsic dykes (quartz-feldspar porphyritic granites) occur locally.

The area is transected by a number of northwest-striking faults and fault zones, the largest of which is attributed to an eastern extension of the Jurassic–Early Cretaceous Robert Service Thrust. This major regional-scale south-dipping thrust fault extends across the southern property boundary, emplacing Hyland Group sedimentary rocks over the Road River and Earn Group packages, and forming an east-trending thrust fault (GSC Open File 2174). Distinctive fault zones found within the mid- to Late Cretaceous Tombstone Suite intrusive rocks suggest, however, that faulting could also be syn-plutonic (and control the mineralization). Faulting could even postdate the Late Cretaceous, and possibly be synchronous with the initialization of motion along the Tintina Fault (Flanigan et al., 2000b).

PROPERTY GEOLOGY

The property is centred on a 1200 m by 600 m west-southwest-elongated Tombstone Suite quartz diorite intrusion situated 10 km east of the Mt. Selous Batholith (Fig. 2). This apparently satellitic stock intrudes the Road River Group sequence of thin- to medium-bedded chert and lesser shale. A smaller quartz diorite stock occurs some 500 m southeast of the central stock. A swarm of east-southeast-trending quartz-feldspar porphyritic dykes occurs proximal to the central stock, particularly along the southeastern contact. Bedding of the sedimentary rocks extends roughly east-southeast, dipping steeply to the south-southwest. To the west, a northwest-trending fault separates the Road River Group rocks from the Earn Group chert-pebble conglomerate to the west. To the south of the map area, the Robert Service Thrust fault extension separates these rocks from the Hyland Group, which consists primarily of coarse clastic 'grits' and shale, but includes a kilometre-wide southeast-trending crystalline limestone unit.

The area adjacent and immediately north of the central stock contains a suite of east-west-trending lenticular mineralized zones of fracturing, brecciation and hydrothermal alteration. To date, four major zones have been identified: from north to south these are the Rainbow Zone; the Second Zone, which bifurcates into the Second A and Second B Zones; the Upper Zone just north of the intrusive; and the Back Zone along the southern intrusive contact. The zones have been delineated for strike lengths to 1500 m, with widths ranging from 20 to 100 m; they have a tendency to

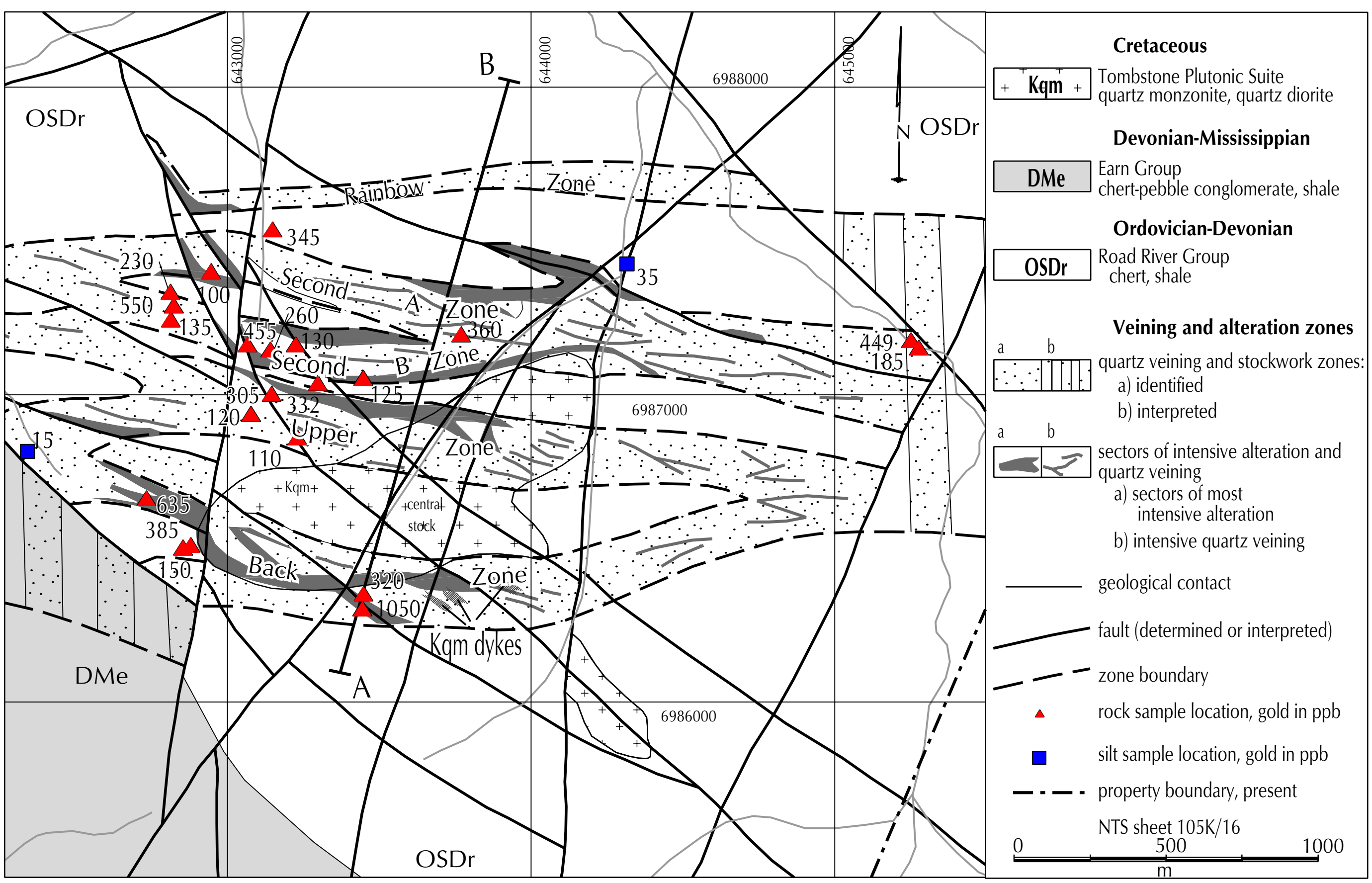


Figure 2. *Compilation map of Myschka area.*

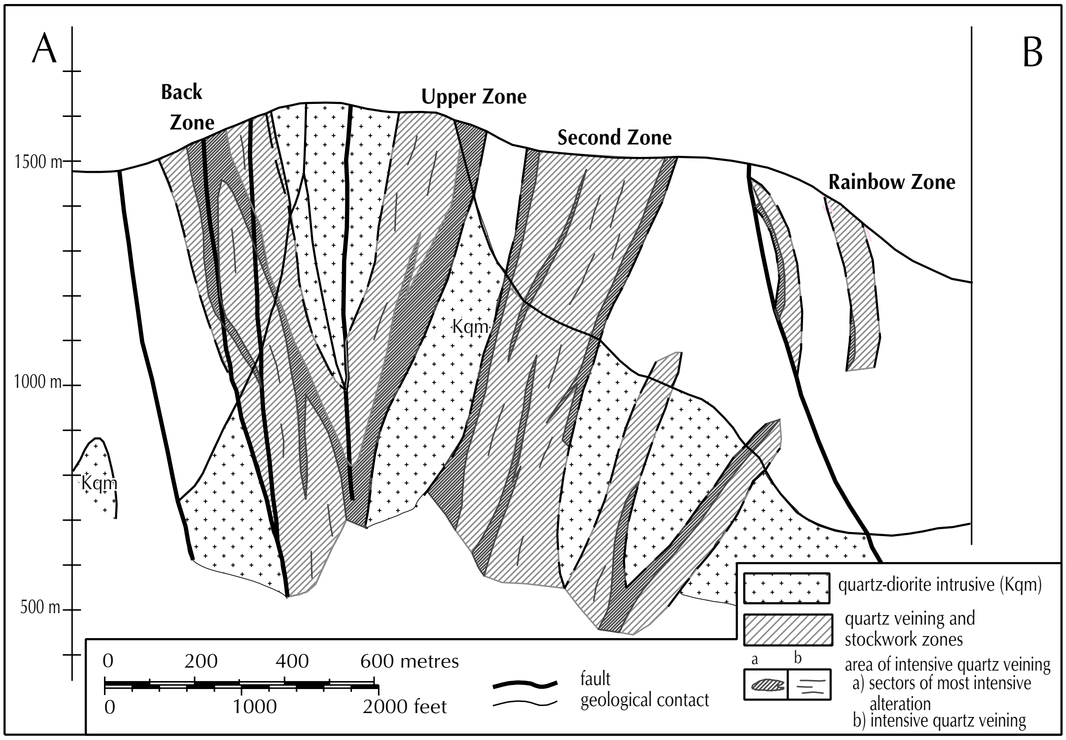


Figure 3. *Hypothetical section: line A-B (see Figure 2), Myschka property, looking west.*

coalesce into much wider brecciated packages up to 200 m wide. These breccia zones dip steeply (70-85°) southwards, with local north-dipping sections; they are interpreted to crosscut the intrusive rocks at shallow depths (Fig. 3). These zones contain intensive auriferous quartz stockwork and larger quartz-filled shear-like fractures, as well as intervals of 'bulk' mineralization. Probably, these and other similarly oriented zones also control some of the lead-zinc-silver veins.

Although narrow and less expressed in the form of brecciation, the west-northwest and north-northeast-trending faults are also important in controlling mineralization. A significant portion of higher grade gold mineralization occurs at the intersections of the major east-west-trending breccia zones and west-northwest-trending fault zones. In contrast, some of the north-south- and north-northeast-trending fault zones locally control high-grade lead-antimony-silver veins. However, these sulphide-enriched veins commonly occur along north- (or north-northwest-) trending faults where they intersect the major east-west-trending breccia zones. Displacement of the major east-west-trending zones by barren or weakly mineralized north-trending faults has occurred locally.

Variably oriented fault zones form a closely spaced intersecting network focusing on and adjacent to the central intrusive stock. This 'intersection area', marked by higher metal values in brecciated sedimentary rocks proximal to the stock, is also coincident with a large and well pronounced Au, Bi, Pb, Ag, Sb and much wider As soil anomaly overlying the essentially overburden-covered stock.

ALTERATION AND MINERALIZATION

A broad system of argillic (clay) alteration, silicification and locally intensive phyllic (sericite) alteration occurs within the Road River Group chert surrounding the central stock, particularly to the north and east, where the alteration extends more than 1 km outbound. Alteration, associated with strongly weathered gossans, is more intense within the east-west-trending breccia zones, which contain local areas of advanced argillic alteration and/or intense silicification. Quartz stockwork and thicker quartz-filled shear zones occur throughout the brecciated packages. Local zones of stronger alteration are also found along the northwest and north-northeast-trending faults. Strong to moderate hornfelsing also occurs adjacent to the stock.

A broad area of disseminated and fracture-controlled sulphide mineralization is coincident with the alteration area, largely north and east of the central stock. Fine- to medium-grained pyrite with subordinate arsenopyrite, commonly altered to scorodite, are disseminated, both within quartz stockwork and altered sedimentary rocks. Local areas of stronger scorodite staining indicate zones of arsenopyrite enrichment.

Most sulphide grains within the mineralized area, typified by well developed gossans, have been completely leached, leaving a strongly limonitic 'boxwork.' However, local zones of relatively unweathered quartz-arsenopyrite veining occur throughout the mineralized area. There is a remarkable difference in gold values returned by strongly weathered and less weathered material. Strongly leached rock samples yielded anomalous but generally low gold values, extending into the 100-200 ppb Au range. In contrast, less weathered quartz-arsenopyrite (± pyrite) veins and strongly silicified rock, with disseminated pyrite ± arsenopyrite, returned higher gold values, commonly in the range of 300-650 ppb Au, extending up to 800 ppb. These variations in gold grades, and characteristic association of gold with high arsenic values, are typical of the exposed portion of the east-west-trending breccia zones in sedimentary rocks outside the intrusive stock.

Table 1. *Representative rock sample assay results for various sulphide assemblages[1].*

Sample	Au (ppb)	Ag (ppm)	As (ppm)	Bi (ppm)	Cu (ppm)	Pb (ppm)	Sb (ppm)	Zn (ppm)
Major gold-arsenic (pyrite-arsenopyrite) assemblage								
M3014	360	4.4	570	62	96	12	8	178
M5004	449	0.7	>10 000	10	70	7	35	18
M5006	185	3.2	405	<2	47	15	32	12
M1003	455	4.0	>10 000	20	84	18	28	22
Copper-arsenic (chalcopyrite-pyrite-arsenopyrite) assemblage								
M2134	125	41.2	>10 000	264	1.73%	<2	82	562
M1060	332	8.2	>10 000	22	744	35	252	15
M2133	40	5.0	18	82	1490	<2	2	542
Zinc-copper (sphalerite-chalcopyrite) assemblage								
M2046	<5	0.6	932	<2	243	34	50	2180
M2128	25	0.4	16	<2	62	12	8	1035
Lead-silver-arsenic-zinc (galena-arsenopyrite-sphalerite) assemblage								
M3023	20	113	250	<2	17	1.32%	168	160
M3024	385	652	>10 000	<2	169	10.85%	558	2270
M3025	25	133	1335	12	23	2.23%	100	1580
M3026	150	197	5760	<2	88	4.22%	178	1020
M3027	75	150	322	<2	42	2.10%	118	462
M1021	135	60.8	566	12	12	1030	212	4
M2104	10	25.4	3620	520	322	1520	102	138
M2075	305	39.6	>10 000	384	627	1770	1195	120
Antimony-lead-arsenic-silver (stibnite-arsenopyrite-galena) assemblage								
M1000	120	49.0	>10 000	834	191	5070	3420	66
M1016	230	46.6	>10 000	<2	33	3.46%	8530	96
M1019	550	57.2	>10 000	<2	15	6.87%	>10 000	228
M1043	1050	560	>10 000	1540	174	4.70%	>10 000	488
M1045	70	54.4	4430	82	13	1.96%	8210	54
M1046	320	116	>10 000	132	120	4.73%	>10 000	1225
M1048	635	409	>10 000	26	832	3820	2960	1955

[1]Assays were performed in ALS Chemex labs of North Vancouver, B.C. All rock samples were pulverized until 85% of fragments were less than 75 microns in size; then an evenly mixed 30 g portion was analysed for 34-element aqua regua ICP-AES, as well as gold by fire assay with atomic absorbtion finish. «Overlimits» of Ag, Pb, Sb, Cu were reanalysed to provide respective elemental contents.

In addition to the major auriferous pyrite-arsenopyrite assemblage, there are several other sulphide-rich mineral assemblages that, although smaller and more sporadically located, contribute to the mineral and geochemical zonation of the property. These assemblages are listed in Table 1. Generally, observed variations in the gold grades and values of associated metals, as well as mineralogical signatures, indicate the existence of several successive sulphide mineral assemblages (stages?) superimposed within the central property area. Auriferous quartz-pyrite-arsenopyrite stockwork and disseminated mineralization apparently represents the earliest stage, whereas other sulphide-rich assemblages occurred later, forming a geochemical evolutionary trend from gold-enriched (with relatively high Au/Ag ratio) associations, toward silver-enriched ones. Also quite evident is the presence of at least two generations of bismuth minerals, one associated with chalcopyrite and probably copper sulphosalts, the other associated with galena and lead-antimony sulphosalts.

SOIL GEOCHEMISTRY

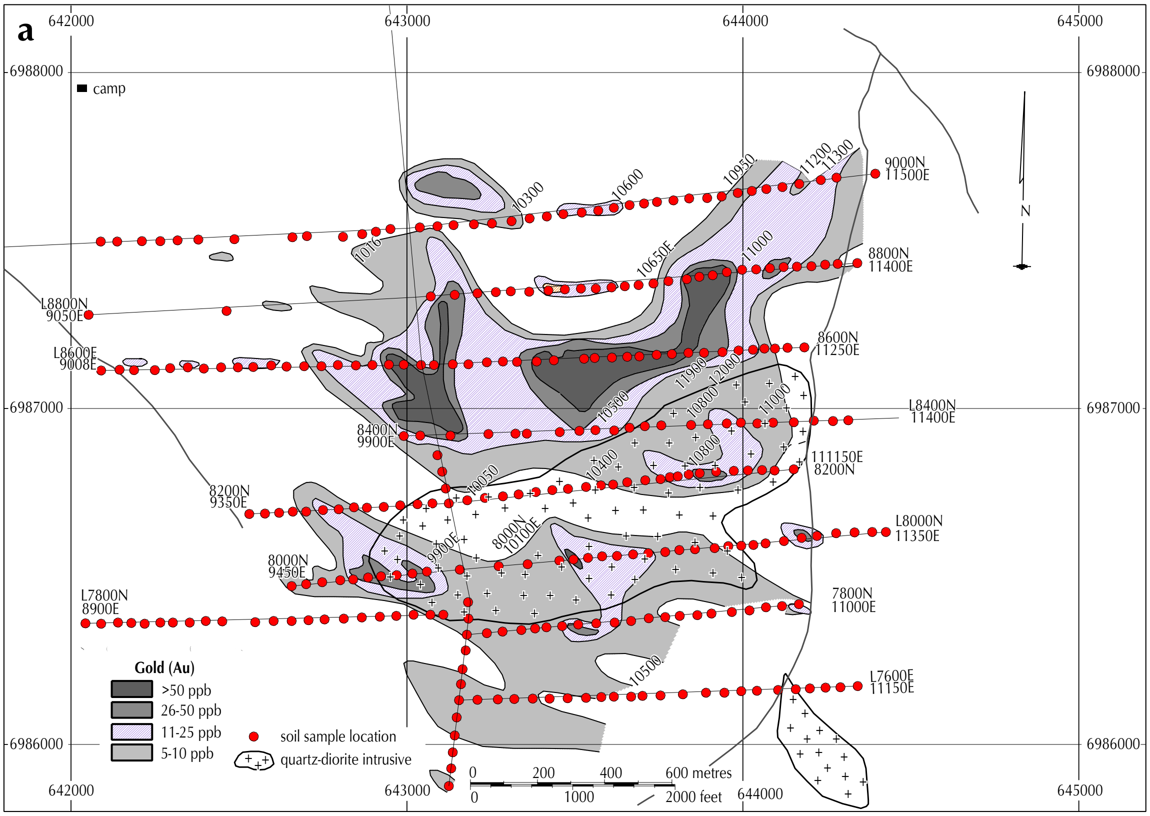
A total of 417 soil samples have been taken to date on the Myschka property. The sampling program revealed a broad area of anomalous values of Au, Ag, As, Pb, Sb, Cu, Zn and Bi (Fig. 4a-f). This complex anomaly covers the central stock, extends far to the east and west along the breccia and alteration zones, and is essentially open in these directions. The anomaly is 'mosaic-textured,' incorporating a number of local maxima attributed to the intersections of the major east-west trending zones with faults of other orientations. Very notably, some of these maxima occur within overburden overlying portions of the central intrusive stock. This supports the idea that major structures extend across (and within) the stock, perhaps hosting higher metal values here than within altered sedimentary rock. This feature, being relatively less pronounced for gold (with higher gold-in-soil values occurring in the breccia packages, mainly outside the stock contours), is clearly evident for Ag, As, Bi, Pb and other elements.

The gold-in-soil anomaly incorporates three well pronounced maxima. From west to east they measure 350 m by 200 m (with values from a minimum of 50 ppb to 260 ppb Au), 400 m by 200 m (50-110 ppb Au), and 300 m by 150 m (50-105 ppb Au; Fig. 4a). The most eastern anomaly is coincident with a west-northwest-trending fault zone crosscutting the major east-west-trending breccia packages at a low angle. Several strong silver-in-soil maxima are also present; the strongest one (with values from 10 to 65.6 g/t Ag), measuring 300 m by 250 m, is coincident with silver-bearing galena veining southwest of the stock (Fig. 4b). Other elements also form strong in-soil-maxima, including Sb (up to 786-990 ppm in soils; Fig. 4c), Bi (up to 72 ppm in soils; Fig. 4d), Pb (up to 1.24% in soils; Fig. 4e), Cu (up to 736 ppm in soils) and Zn (up to 3940 ppm in soils, higher than the highest zinc-in-rock value obtained). These metal anomalies have a larger aerial extent than the gold anomalies.

The largest one is the east-west elongate arsenic anomaly (locally more than 1% arsenic-in-soil values) that covers an area exceeding 1.5 by 2 km (Fig. 4f) and is open to the east and west.

Two very important features of the soil anomalies must be emphasized. Firstly, the occurrence of Ag, Pb, Sb, Bi and Zn maxima and overall anomalies attributed to the later mineralizing stages are found within the much wider As anomaly attributed to the earlier stage; this suggests 'telescoping' of spatial evolution of the mineralization toward the lateral centre of the system, marked by the central intrusive stock. This indicates essentially structural, rather than thermal, controlling factors caused this 'inverse,' or 'backward' (earlier assemblages throughout, later assemblages inside) geochemical trend. Interestingly, a similar geochemical trend apparently occurs on a larger scale within the entire Mt. Selous district, where Pb-Zn-Ag veins are more proximal to the batholith than Au-As mineralization.

Secondly, the stronger expression of Ag, Pb, Sb and Zn (later assemblages) mineralization, including soil anomalies, compared to Au mineralization (earlier assemblage) may indicate that the current erosion level exposes just 'the top' of the system, here dominated by later assemblages. As a result, a much stronger expression of the earlier gold-enriched assemblages can be expected at deeper levels. This model would be in agreement with relatively high As/Bi ratios typical of the property and, similar to numerous other Tintina Gold Belt occurrences, indicates a very high (almost uneroded) vertical level of the exposed mineralized system (Flanigan et al., 2000a).



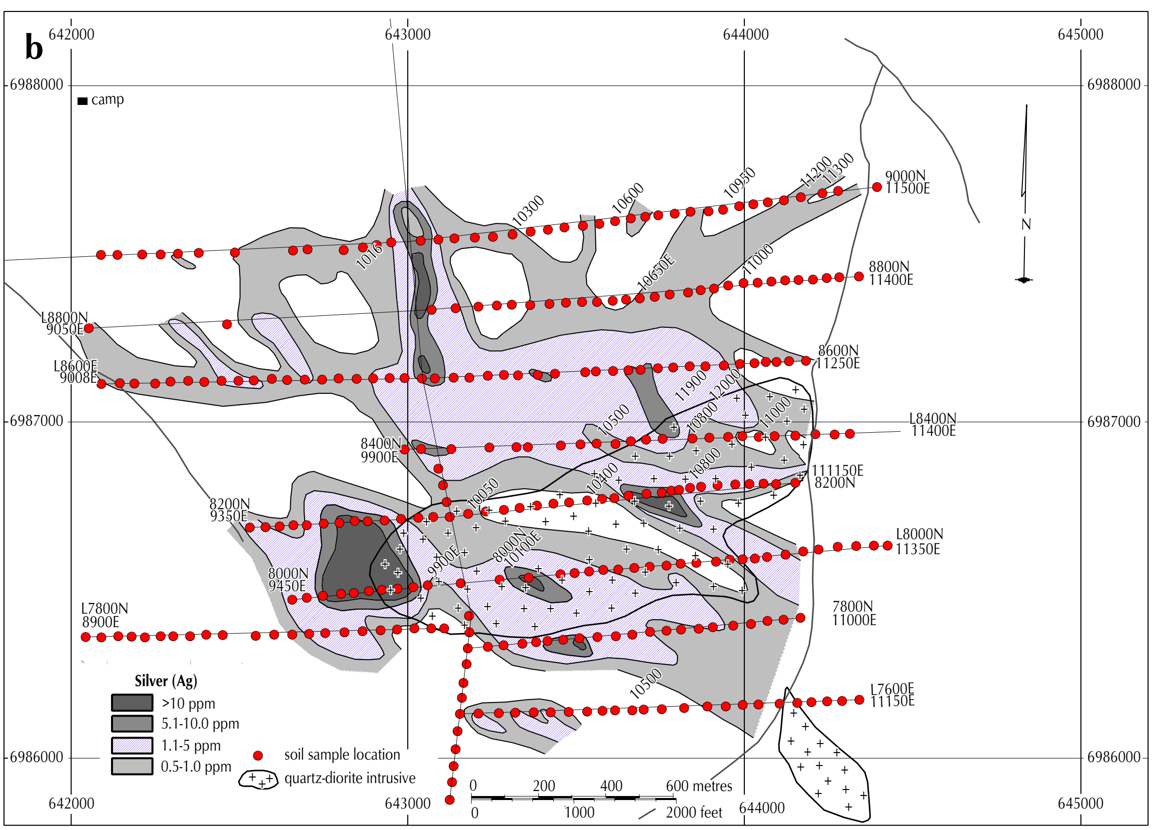
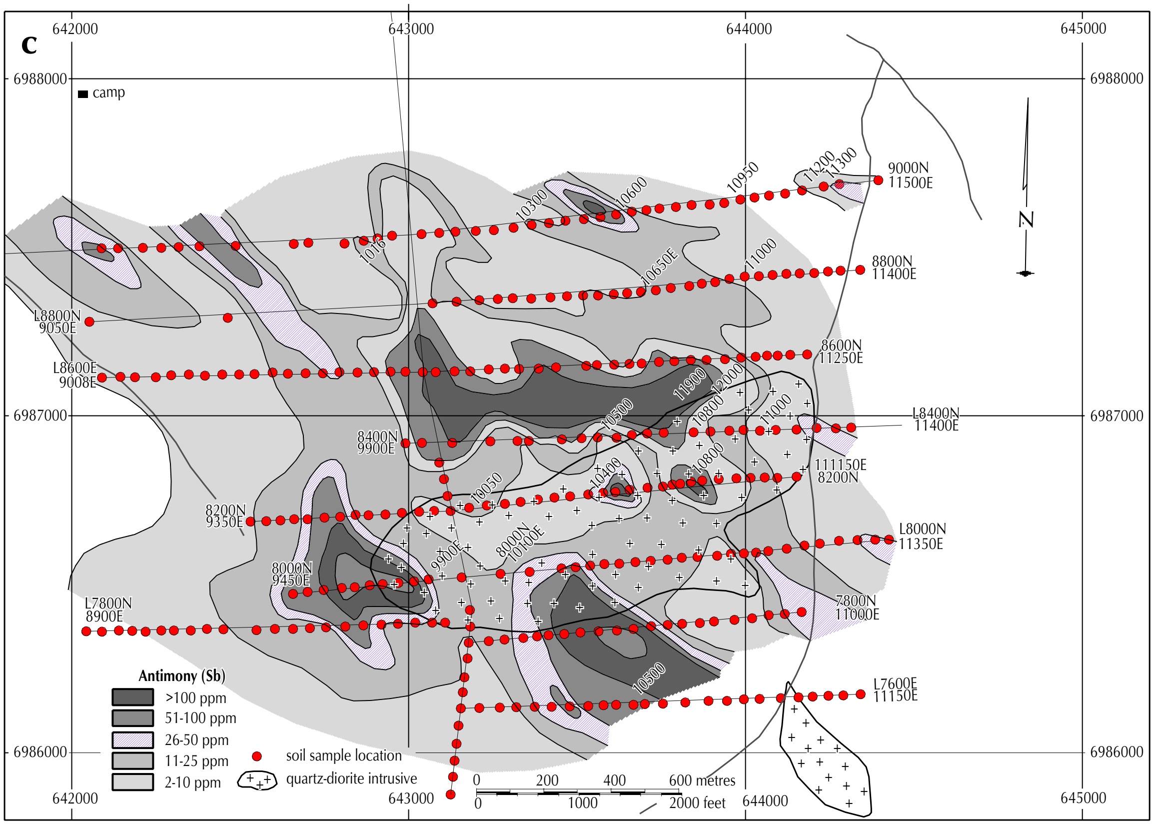


Figure 4. *Soil geochemical contours:*
(a) *gold*
(b) *silver*
(c) *antimony*
(d) *bismuth*
(e) *lead*
(f) *arsenic.*



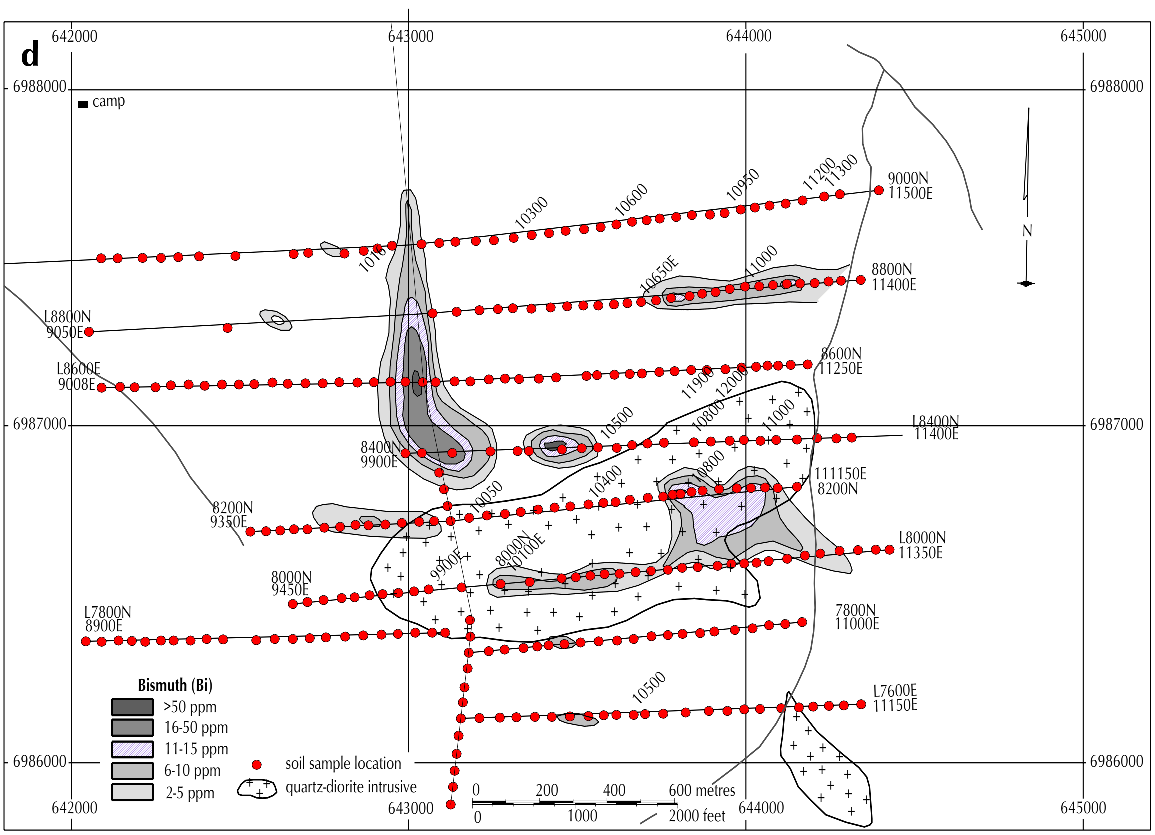


Figure 4. *continued*

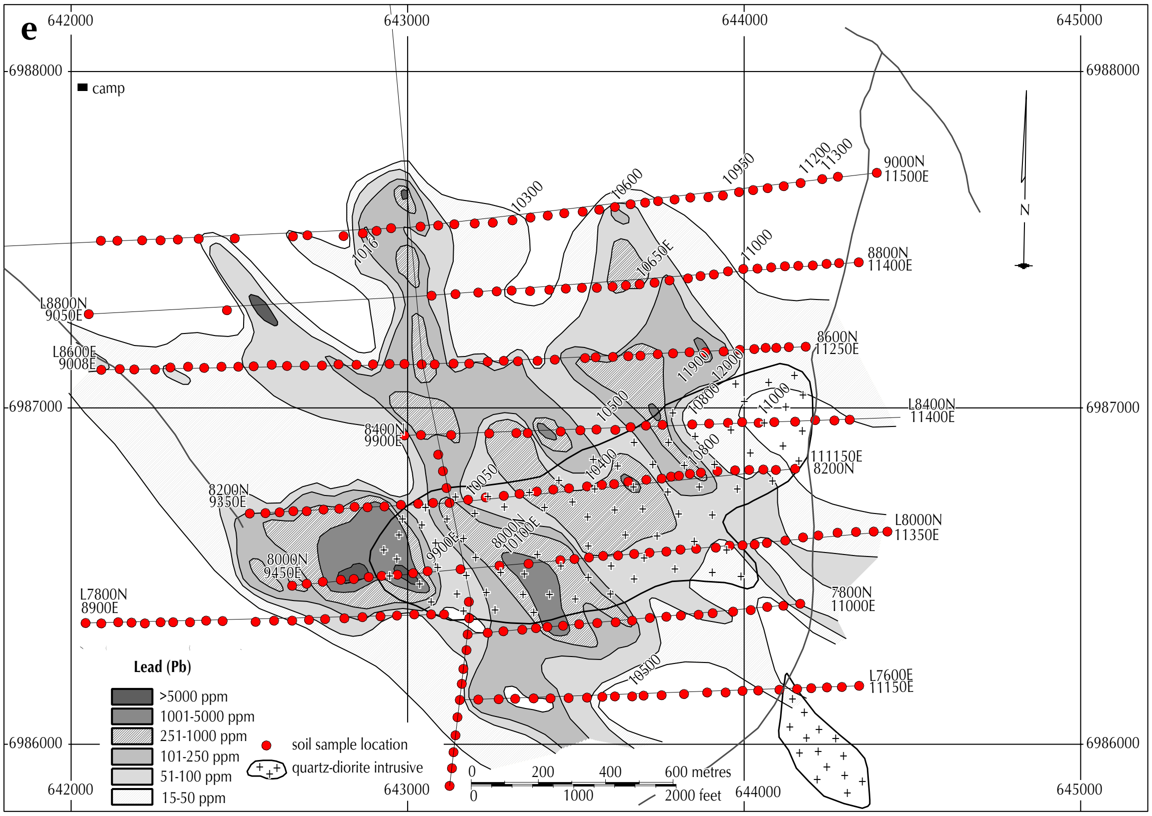


Figure 4.
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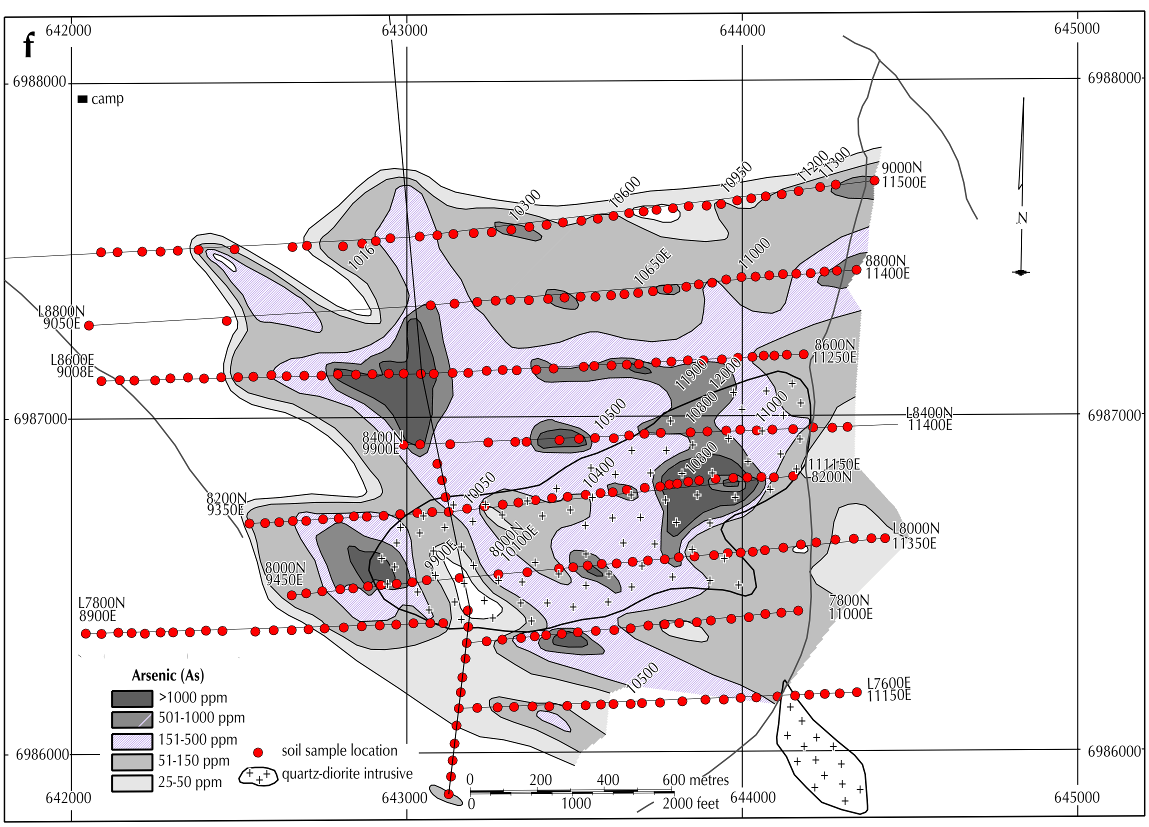

CONCLUSIONS

The Myschka property represents a newly discovered, large and very prospective target with potential to host significant bulk-tonnage gold mineralization. This is defined by the following characteristics:

1. A large cluster of gold, base metal and other occurrences in the area of the property situated above the 'hidden' portion of the Mt. Selous Batholith of the Tombstone Intrusive Suite, and its local control by a satellitic intrusive stock or intrusive centre;
2. Large widths (up to 200 m) and extent (over 1500 m) of breccia with intensive auriferous quartz stockwork and quartz-filled fracture zones;
3. Tendency of these auriferous sedimentary rock-hosted breccia zones to dip toward the intrusive stock, assuming that the mineralization within the stock at depth hosts higher gold values;
4. Large dimensions (1200 m by 600 m on surface) of the potentially mineralized intrusive stock, similar to those of known large gold deposits (e.g., Fort Knox);
5. The occurrence of fault zones of several orientations controlling mineralization and contributing to the abundance and grades of metals superimposed on the intrusive stock and surrounding metasedimentary rocks (fault intersection effect);
6. Multi-staged history of formation of auriferous mineralization;
7. Presence of a large (over 1.5 km by 2 km) multi-element geochemical anomaly coincident with the intrusive stock and adjacent portion of the metasedimentary rocks;
8. Favourable geochemical signatures suggesting minimal erosional levels of the mineralized system.

During the 2002 field season, the property was advanced to a drill-ready stage. A diamond-drill program proposed for 2003 is designed to test the subsurface continuation of major auriferous breccia zones into the intrusive stock.

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