Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

Exploration and Geological Services Division, Yukon Region

BULLETIN 7

Geology of the Mayo Map Area, Yukon Territory (105M)

C. F. Roots
Geological Survey of Canada

with contributions from M. L. Bevier, J. K. Mortensen,
D. C. Murphy and M. J. Orchard

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Canada/Yukon Economic Development Agreement
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Yukon
Economic Development

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1997

Catalogue no. R72-254/1996E

ISBN 0-662-24250-5

Published under the authority of the Minister of Indian and Northern Affairs Canada, Whitehorse, Yukon 1997.

QS-Y111-000-EF-A1

Recommended citation:
Roots, C. F., 1997. Geology of the Mayo Map Area, Yukon Territory (105M).
Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 7, 82 p.

Cover: View northward across Nogold Creek and Mayo to Mount Haldane in the distance. The forground cliff reveals southwest-verging folds of gritty metasandstone (Late Proterozoic to Middle Cambrian Hyland Group); irregular dark patches are cloud shadows.

Preface

It is believed that the Mayo area was first prospected in the late 1880s. In 1898 placer gold was discovered in Duncan Creek. By 1902 Duncan Creek was staked from one end to the other, and the supply settlements of Mayo Landing and Gordon Landing on the Stewart River had been founded. The initial discovery of lead and silver veins at Galena Hill was made in 1906, and by 1919 the vein systems on Keno Hill had been staked. Development of the Mayo area resulted largely from mining of the placer gold and vein silver deposits.

From 1921 to 1988, the Keno Hill/Galena Hill camp produced 13.5 million kg of silver, 547.2 million kg of lead, 306.4 million kg of zinc, 1.8 million kg of cadmium and nearly 100 kg of gold from 9.8 million tonnes of ore, making it Canada's second largest producer of silver.

The Mayo map area was first mapped by H. S. Bostock between 1938 and 1941. Since then the Keno Hill/Galena Hill area has been studied intensively, but the remainder of the map area has received little attention from geologists.

The present study was commenced in 1990 by Dr. C. Roots of the Geological Survey of Canada as part of the GSC's national program of framework mapping and geological re-interpretation. The fieldwork continued between 1991 and 1994 with financial assistance from the Canada/Yukon Cooperation Agreement on Mineral Resource Development. Logistical support was provided by the Canada/Yukon Geoscience Office, a jointly managed project with the Department of Indian Affairs and Northern Development as scientific authority and the Yukon Department of Economic Development as administering agency.

This report includes a comprehensive description of the bedrock map units and the structural geology, and presents summary interpretations of the types of bedrock mineral occurrences found within this economically important part of Yukon.

Trevor Bremner
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Préface

Les premiers prospecteurs seraient arrivés dans la région de Mayo à la fin des années 1880. En 1898, ils ont découvert de l'or alluvionnaire au ruisseau Duncan. En 1902, ce ruisseau était jalonné d'un bout à l'autre et c'est à cette époque qu'ont été fondés sur la rivière Stewart les établissements de Mayo Landing et de Gordon Landing. La première découverte de filons de plomb et d'argent à la colline Galena a été faite en 1906, et en 1919, les réseaux filoniens sur la colline Keno avaient été jalonnés. L'essor de la région de Mayo est principalement attribuable à l'exploitation des gisements d'or alluvionnaire et d'argent filonien.

De 1921 à 1988, le camp de Keno Hill/Galena Hill a produit 13,5 millions de kilogrammes d'argent, 547,2 millions de kilogrammes de plomb, 306,4 millions de kilogrammes de zinc, 1,8 millions de kilogrammes de cadmium et près de 100 kg d'or à partir de 9,8 millions de tonnes de minerai, ce qui lui vaut la réputation de deuxième producteur canadien d'argent.

La région de Mayo a été cartographiée pour la première fois par H. S. Bostock entre 1938 et 1941. Depuis cette époque, la zone de Keno Hill/Galena Hill a fait l'objet d'études poussées, mais pas le reste de la région couverte par la carte, qui n'a pas beaucoup retenu l'attention des géologues.

La présente étude a été entreprise en 1990 par C. Roots de la Commission géologique du Canada dans le cadre du programme national de cartographie générale et de réinterprétation géologique de la CGC. Les travaux sur le terrain se sont poursuivis entre 1991 et 1994 avec l'aide financière de l'Entente de coopération Canada-Yukon sur l'exploitation des ressources minérales.

L'appui logistique a été assuré par le Bureau géoscientifique Canada-Yukon, géré conjointement par le ministère des Affaires indiennes et du Nord Canada, à titre d'autorité scientifique, et par le ministère du Développement économique du Yukon, à titre d'administrateur.

Le présent document contient une description détaillée des unités du substratum rocheux figurées sur la carte et des structures géologiques ainsi que des interprétations sommaires des types d'indices de minéraux encaissés dans le substsratum rocheux de cette région économiquement prospère du Yukon.

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In pocket

Geoscience Map 1997-1 105M

Geology of the Mayo Map Area, Yukon (105M)

Abstract

Late Proterozoic to Triassic, moderately to highly strained sedimentary rocks are exposed in two overlapping thrust sheets in the Mayo map area. The more southerly Robert Service Thrust sheet contains Hyland Group (Late Proterozoic to Cambrian) sandstone and grit with rare limestone and minor maroon argillite, overlain by a Cambrian to Middle Devonian succession of dark coloured siltstone, limestone and chert in the southern quarter of the map area. These strata, a component of the regional Selwyn Basin, are unconformably overlain by Upper Devonian Earn Group argillite, chert and chert-pebble conglomerate. The latter succession contains widespread indications of stratiform Pb-Zn-barite mineralization.

To the north the Tombstone Thrust Sheet consists of highly strained Earn Group (formerly "Lower Schist") carbonaceous phyllite, felsic meta-tuff and metaclastic rocks, succeeded by Carboniferous Keno Hill quartzite, that is thickened by internal recumbent folds or thrusts in the north central part of the map area. These units host the Ag-Pb-Zn veins of the Elsa-Keno Hill camp, and contemporaneous meta-tuff that contains a volcanogenic massive sulphide deposit immediately northeast of the map area.

Jurassic(?) and Cretaceous contraction produced regionally developed penetrative fabrics and folds of various scales as well as thrust faulting. A domain of intensely developed foliation and lineation underlies the northern half of the map area, imparted during two or more phases of movement on the Tombstone Thrust.

Granitic intrusions of the 91-94 Ma Tombstone Suite crosscut regional structure. The McArthur batholith parallels the Tintina Trench and is associated with copper skarns. Other stocks throughout the map area are notable for vein-tungsten and tin, and were the probable heat source for epi- and meso-thermal veins of the Elsa-Keno Hill mining camp. In neighbouring regions, Tombstone intrusions are the focus of exploration for disseminated vein-gold similar to deposits north of Fairbanks, Alaska and east of Dawson, Yukon.

Résumé

Des roches sédimentaires modérément à fortement déformées du Protérozoïque tardif au Trias sont exposées dans deux nappes de charriage chevauchantes dans la région cartographique de Mayo. La nappe la plus méridionale, la nappe de charriage de Robert Service, renferme le grès et le microconglomérat du Groupe de Hyland (Protérozoïque tardif au Cambrien) accompagnés de calcaire rare et d'un peu d'argilite marron. Elle est sous-jacente à une succession du Cambrien au Dévonien moyen composée de siltstone, de calcaire et de chert de couleur foncée dans le quart sud de la région couverte par la carte. Ces couches, qui font partie du bassin régional de Selwyn, reposent en discordance sous l'argilite, le chert et le conglomérat à cailloux de chert du Groupe d'Earn du Dévonien supérieur. La dernière succession contient ici et là des indications de minéralisation stratiforme de Pb-Zn-barytine.

Au nord, la nappe de charriage de Tombstone est formée de phyllades carbonées, de tufs métamorphisés felsiques et de roches métaclastites du Groupe d'Earn (anciennement désigné <<Schiste inférieur>>), auxquels se substitue le quartzite de Keno Hill du Carbonifère qui est épaissi par des plis couchés internes ou des nappes de charriage dans le centre nord de la région cartographiée. Ces unités recèlent les filons à Ag-Pb-Zn du camp d'Elsa-Keno Hill, et le tuf métamorphisé contemporain loge un gisement de sulfures massifs volcanogènes juste au nord-est de la région cartographiée.

La contraction jurassique(?) et crétacée a créé des fabriques pénétratives d'échelle régionale, des plis d'échelles diverses et des failles chevauchantes. Un domaine de foliations et de linéations intenses résultant d'au moins deux phases de déplacement sur la nappe de charriage de Tombstone s'étend sous la moitié septentrionale de la carte.

Les intrusions granitiques de la Suite de Tombstone (91-94 Ma) recoupent la structure régionale. Le batholite de MacArthur est parallèle au sillon de Tintina et est associé à des skarns cuprifères. D'autres stocks de la région cartographiée recèlent du tungstène et de l'étain; ils étaient probablement la source thermique des filons épithermaux et mésothermaux du camp minier d'Elsa-Keno Hill. Dans les régions voisines, les intrusions de Tombstone sont le point de mire de l'exploration minérale visant à découvrir des filons d'or disséminés comme ceux que l'on trouve au nord de Fairbanks en Alaska et à l'est de Dawson au Yukon.

Summary

Mayo map area comprises slightly to highly deformed rocks of two sedimentary sequences deposited between Proterozoic and Triassic time above thinned older sedimentary strata and continental crust of the rifted North American craton. These are displaced north-, northwest- and northeast-ward on two regional thrusts (Robert Service and Tombstone) to their present position near the edge of the Mackenzie Platform.

A deep-water, off-shelf depositional environment characterizes the **Proterozoic to Middle Devonian Selwyn Basin succession**. Oldest strata, the Hyland Group, are turbiditic quartz sandstone and grit with minor limestone and maroon argillite at the top. They are overlain by the Gull Lake (green and dark brown siltstone), Rabbitkettle (thin, discontinuous white limestone), Duo Lake (dark siltstone, argillite and chert) and Steel (green cherty argillite) formations.

A **Late Devonian to Early Jurassic turbidite succession** overlapped the Selwyn Basin. Rift-related faulting and differential erosion heralded deposition of the Earn Group, comprising submarine channel deposits of massive chert-pebble conglomerate, flanked by broad areas of black chert and argillite. Felsic volcanism, localized northeast of the map area, produced at least one massive sulphide deposit. The economically important Keno Hill quartzite is a widespread, shallow marine or lagoonal sandstone with carbonaceous interbeds and minor limestone of Early Carboniferous age. Calcareous sandstone of the Triassic Jones Lake Formation and possible Jurassic strata are poorly exposed in the northeast corner of the map area.

Middle Jurassic through Early Cretaceous regional deformation of autochthonous rocks was more pronounced in northern the Mayo map area than elsewhere in the northern Canadian Cordillera. Earliest structures are east-trending upright folds in the southern part of the map area, and southwest-verging isoclinal to overturned folds in the southwest. The Robert Service Thrust underwent at least 150 kilometres (km) of northerly displacement, bringing Hyland Group rocks to the present level of exposure over half the map area. The culminating event was Tombstone thrusting. Second-phase shearing and northwest transport imparted pervasive foliation high into the hanging wall of this thrust sheet, including the lower part of the overlying Robert Service thrust sheet. The third phase is indicated by tight to isoclinal and recumbent folds and top-to-the-northeast displacement and abundant shear planes that offset regional foliation and produced at least one isoclinal fold of the Robert Service Thrust. Two regional antiforms, trending west-southwest and southeast, are late features that broadly deform the Robert Service thrust sheet.

Undeformed granite and granodiorite of the **91-94 Ma Tombstone Intrusions** comprise three percent of the map area. Most stocks are elliptical with steep contacts, and the largest intrudes the Robert Service Thrust. The mineral potential of the area consists of polymetallic veins in competent host strata spatially related to granitic intrusions (notably the Elsa-Keno Hill mining camp), rare copper skarns, and tungsten vein occurrence above a shallow intrusion.

This bulletin is accompanied by a new map at 1:250 000 scale (Fig. 1, separate enclosure) which synthesizes previous published maps (1:50 000 and 1:100 000 scale) and updates the original regional bedrock map (Bostock, 1947). The bulletin is the reference for 13 new fossil localities and seven previously unpublished isotopic age determinations within the Mayo map area.

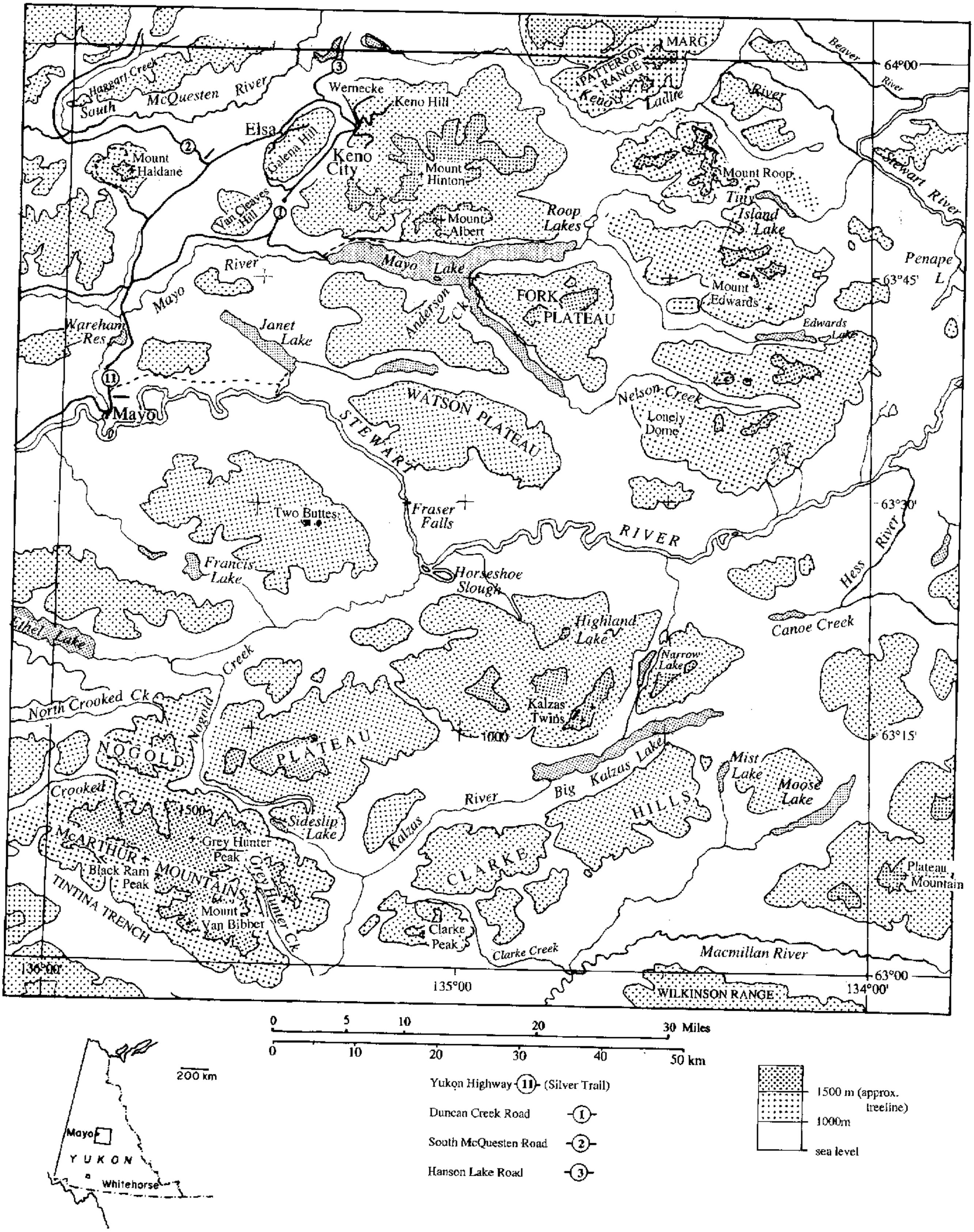


Figure 2. Physiography of Mayo map area, with place names used in text.

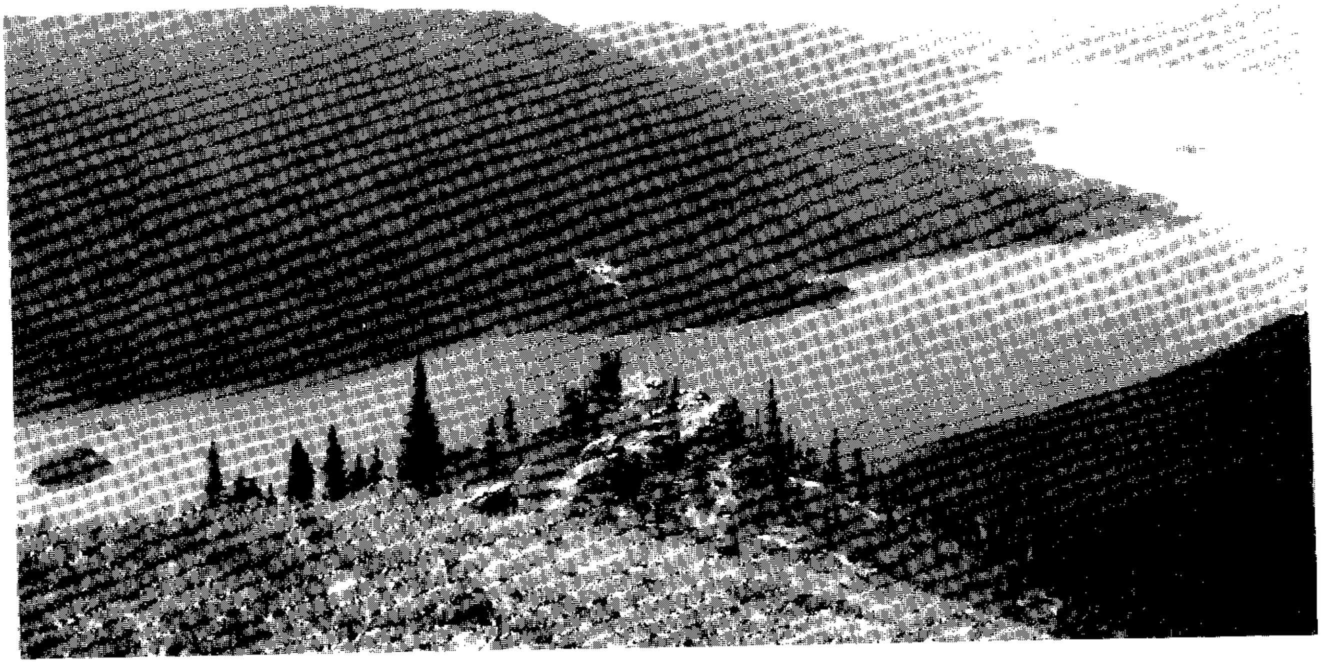


Figure 3. Southwest view, showing flat-topped Yukon Plateau (average elevation 1600 m) and Nelson Arm of Mayo Lake (671 m). The apex of the Anderson Creek delta (centre) is mined for placer gold, as are several streams on the south side of Mayo Lake.

Introduction

Location and access

Mayo map area, between 63° and 64°N, and 134° and 136°W, covers 11,000 sq. km of the central Yukon. The well-travelled roads between the Yukon's major population centres bypass this relatively remote, semi-mountainous region. A branch road, Yukon Highway 11 (the Silver Trail), connects the three settlements of Mayo (population 243 in 1991 census), Elsa (company personnel only) and Keno Hill (population 36 in 1991) in the Mayo map area (Fig. 2). In addition, several hundred people live in the valleys north and west of Mayo where the main non-government employment is related to seasonal placer mining, mineral exploration and sport hunting. Secondary roads extend north and westward into corners of adjacent Nash Creek and McQuesten map areas. Mayo is 443 km by road from Whitehorse, and 320 km by direct flight.

The south half and northeast quadrants of the Mayo map area are without roads and collectively have less than a dozen year-round inhabitants who live along the westward flowing Stewart River, a traditional trade and transport route navigable for small craft with a portage at Fraser Falls near the centre of the map area. Boats are of limited use for geological fieldwork, however, because the river valley has few outcrops and a wide swampy valley floor. Mayo Lake and Ethel Lake, however, have roads at their western ends and allow boat access further east. Fishing and hunting cabins are located on Edwards, Francis, Big Kalzas and Moose lakes. The most efficient access for geological work is by helicopter (seasonally based in Mayo) although there are few landing areas below treeline.

Glacial history, physiography and vegetation

Much of the Mayo map area consists of high, rounded hills and tablelands separated by broad boggy valleys and narrow lakes (Fig. 3). Exceptions are sharp peaks and high ridges north of Mayo Lake and in the extreme southwest (McArthur Mountains). Valleys of the area are within the maximum western limit of McConnell Glaciation (24,000 to about 14,000 radiocarbon years before present: Hughes, 1982; Jackson et al. 1991). Glacial ice filled the valleys to an elevation of 1600 m (5000 ft.) along the east margin of the area and sloped westward, reaching to about 1070 m (3500 ft.) at the west edge (Bostock, 1947), and proglacial lakes formed during the recession (Fig. 4). Previous glaciations were higher and evidence of them is less prominent. Along hillsides the glacial limit is marked by sandy eskers and meltwater channels which locally form labyrinths of dry canyons three to five metres deep (Fig. 5). Hills above the level of glaciation have felsenmeer flanks and scattered erosional remnants (tors) on their tops (Fig. 6).

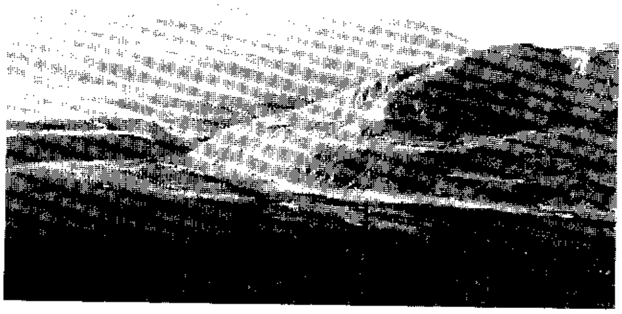


Figure 4. Kame terraces (762 m) formerly flanked the McConnell ice sheet. Above the terraces, Nogold Plateau at an elevation of 1585 m, was near the maximum height of earlier glaciations. McArthur Mountains in background. View southward, from 63°17'N, 135°31'W.

Valleys of the central Yukon have a northern continental climate, dominated by long cold winters and short, hot summers. The valley bottoms show the greatest temperature range: from mean daily temperatures of -30°C in January to 15°C in July (Wahl et al. 1987); Mayo holds the unofficial record as the hottest (36°C) and the coldest (-63.5°C) place in Yukon (H. Wahl, pers. comm. 1995). Permafrost is widespread but discontinuous in the region. Its presence is determined by microclimate variables; sites where the soil is dry or where there is little organic cover commonly lack permafrost. Thermokarst ponds (e.g. Burn and Smith, 1990), collapsing palsas and mudslides attest to the decrease in periods of intense winter cold and possibly greater snow cover (Burn, 1994).

Ecologically, the Mayo map area is entirely within the Yukon Plateau (North) ecoregion (Mougeot and MacLeod, 1995; White and Smith, 1989; Oswald and Senyk, 1977). Slopes and lowland valleys are cloaked in boreal forest dominated by black (*Picea mariana*) and white spruce (*Picea glauca*), and dry southern slopes support thickets of balsam poplar (*Populus balsamifera*), birch (*Betula sp.*) and alpine fir (*Abies lasiocarpa*). Treeline is at an elevation of 1200 m (north) to 1400 m (south slopes). Plateau tops above treeline are covered with clumps of dwarf birch or 'buckbrush' (*B. nana; B. glandiosa*) and labrador tea (*Ledum groenlandicum*) with grass and sphagnum moss. Upland valleys have common patches of hummocky open grassland and swampy fen ('moose pasture'). Pine forest is present in the upper Kalzas River valley and hardy individuals are notable at treeline.

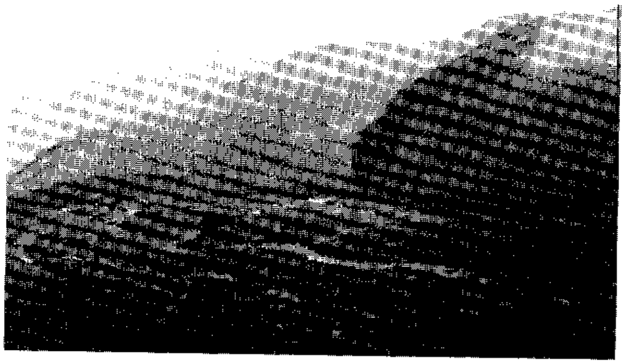


Figure 5. Meltwater channels formed near the maximum height of McConnell Glaciation, (elevation 1410 m) in the Patterson Range, at 63°58'N, 134°45'W.

Figure 6. View southward across meandering Stewart River toward Two Buttes. Only angular summits, now mostly rock rubble, stood above the maximum height of McConnell Glaciation.

Previous geological work

The northeast quarter of the Mayo map area contains most of the geological and mining activity. In that region (here referred to as the Elsa-Keno Hill area) are silver-lead-zinc vein deposits and many gold placers. Early reports refer to the region as "the Mayo district". Accounts of discoveries and early mining are given by Gaffin (1980) and the Mayo Historical Society (1990). To investigate the source of gold which had previously been discovered in Duncan Creek and mined from bars along the Stewart River since 1886, Keele (1906) traversed the headwaters of the Stewart River. The first galena-bearing quartz vein was discovered in 1906 (now Galena Creek), but the mining boom began with staking on Keno Hill in 1916. These two localities were the only places in the mining camp where galena was found in surface outcrop (A. Archer, pers. comm. 1990). To assist exploration Cockfield (1919 and subsequent years) mapped the rock units on Keno Hill and Stockwell (1926) mapped adjacent Galena Hill. Following a topographic survey at a scale of one inch to four miles of Mayo map area, systematic geological reconnaissance (1939-42) led by H. Bostock resulted in a bedrock geological map with marginal notes (Bostock, 1947).

Geological maps of the Keno-Elsa mining area, now of historical value, include those of Cockfield, (1921), Stockwell (1926), McTaggart (1960) and Kindle (1962). Boyle (1965) exhaustively studied mineralized veins and Gleeson (1965, 1966) reported on the metal content of drainages throughout the region. Current understanding of the bedrock geology is depicted on the four 1:50,000 scale maps (Fig. 7).

During the 1950s and 1960s United Keno Hill Mines Limited (UKHM) extracted silver-bearing galena and sphalerite from at least 14 vein deposits (Franzen, 1986). The mine maintained the Yukon economy after the Klondike Gold Rush until the price of gold was deregulated (1968), rejuvenating many placer mines. UKHM closed in February, 1989 as a result of low silver prices and costly infrastructure. With the exception of small-scale, high-grading operations the industry was dormant until 1994. At present underground reserves in the Bellekeno, Silver King and Husky Southwest vein systems are being inventoried.

In 1992 six placer mines operated in the Mayo map area. They were located along Duncan Creek and its tributaries, on streams draining into the southern half of Mayo Lake, and at Empire Creek, 20 km southeast of Mayo. The Clear Creek drainage northwest of Mayo (beyond the map area) has been extensively placer-mined and is currently the focus of exploration for large low-grade gold deposits. Exploration for placer deposits has always required careful attention to ancient erosion and relict glaciation features. Surficial geology maps by Hughes (1982) cover the entire Mayo map area at 1:100,000 scale. Placer occurrences are described by LeBarge (1996a, b) and the Placer Mining Section (1996).

Purpose and field methods

Since Bostock's pioneer reconnaissance mapping the rock units that underlie the Mayo map area have been studied in other places where they are better exposed or less deformed and where their age, depositional history and tectonic relationships are

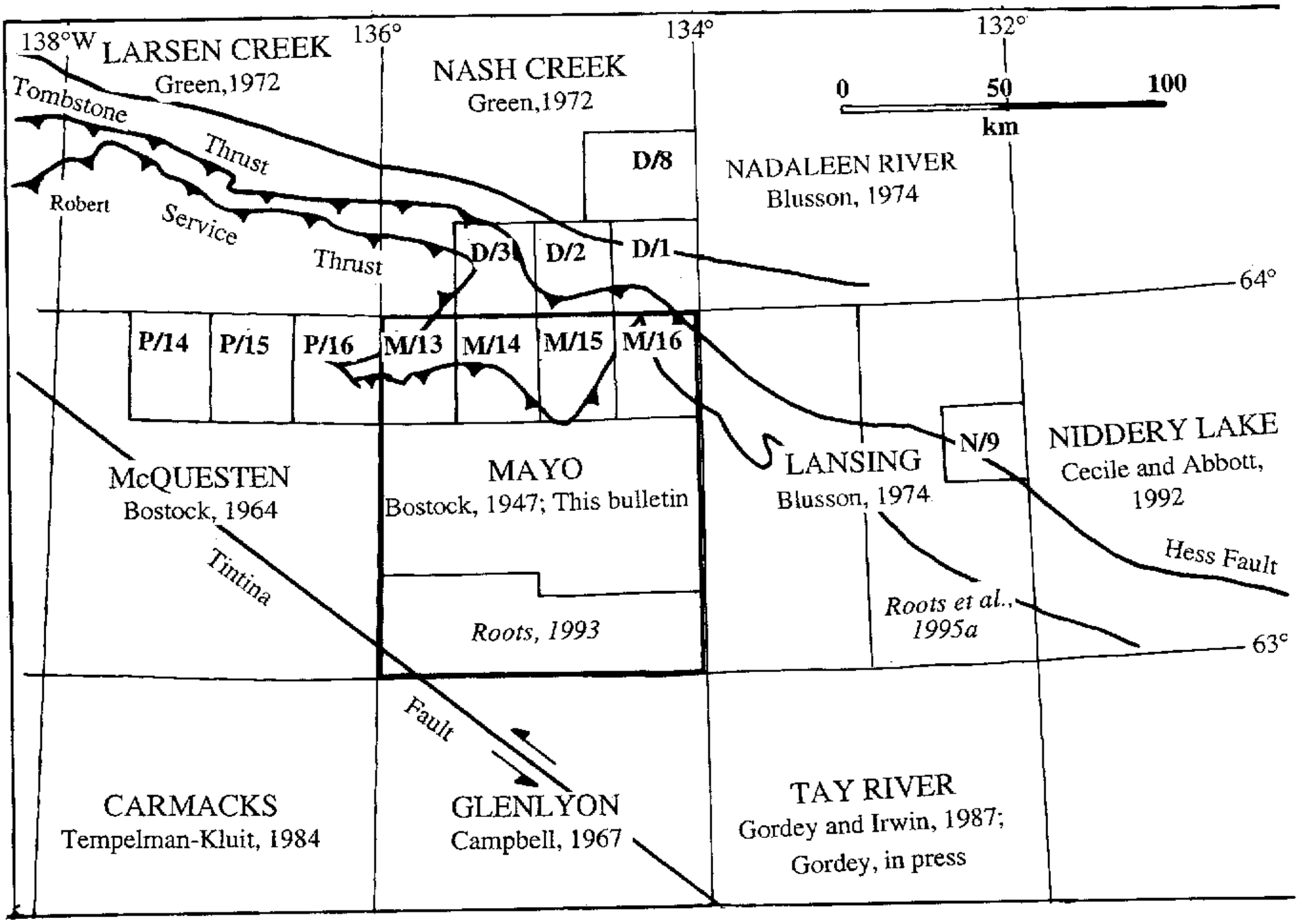


Figure 7. Index to geological maps (names in block capitals denote 1:250 000 scale map areas) surrounding Mayo. Smaller squares (with boldface letters) denote 1:50 000 map areas referenced in Appendix 2.

better understood. Significant advances in knowledge and interpretation have also occurred during the past five decades. For example, the Keno Hill quartzite was considered Precambrian by early workers, later inferred as Cretaceous by Tempelman-Kluit (1970), and finally determined to be Carboniferous by microfossils (Orchard, 1991). As a result of these advances in the understanding of the region, and more recent mapping in the surrounding area, the bedrock geology needed revision.

The present initiative in bedrock mapping commenced in 1989 (Gordey, 1990a, b) and was continued by the author and coworkers in 1990-1992 with some field checks in 1994. Most ridges, canyons and areas with abundant bedrock exposure were traversed on foot (Fig. 8) using road and mining trail access where possible, and 'fly camps' periodically moved by helicopter. A few isolated outcrops were visited by helicopter reconnaissance. I have concentrated upon a better understanding of the rock units

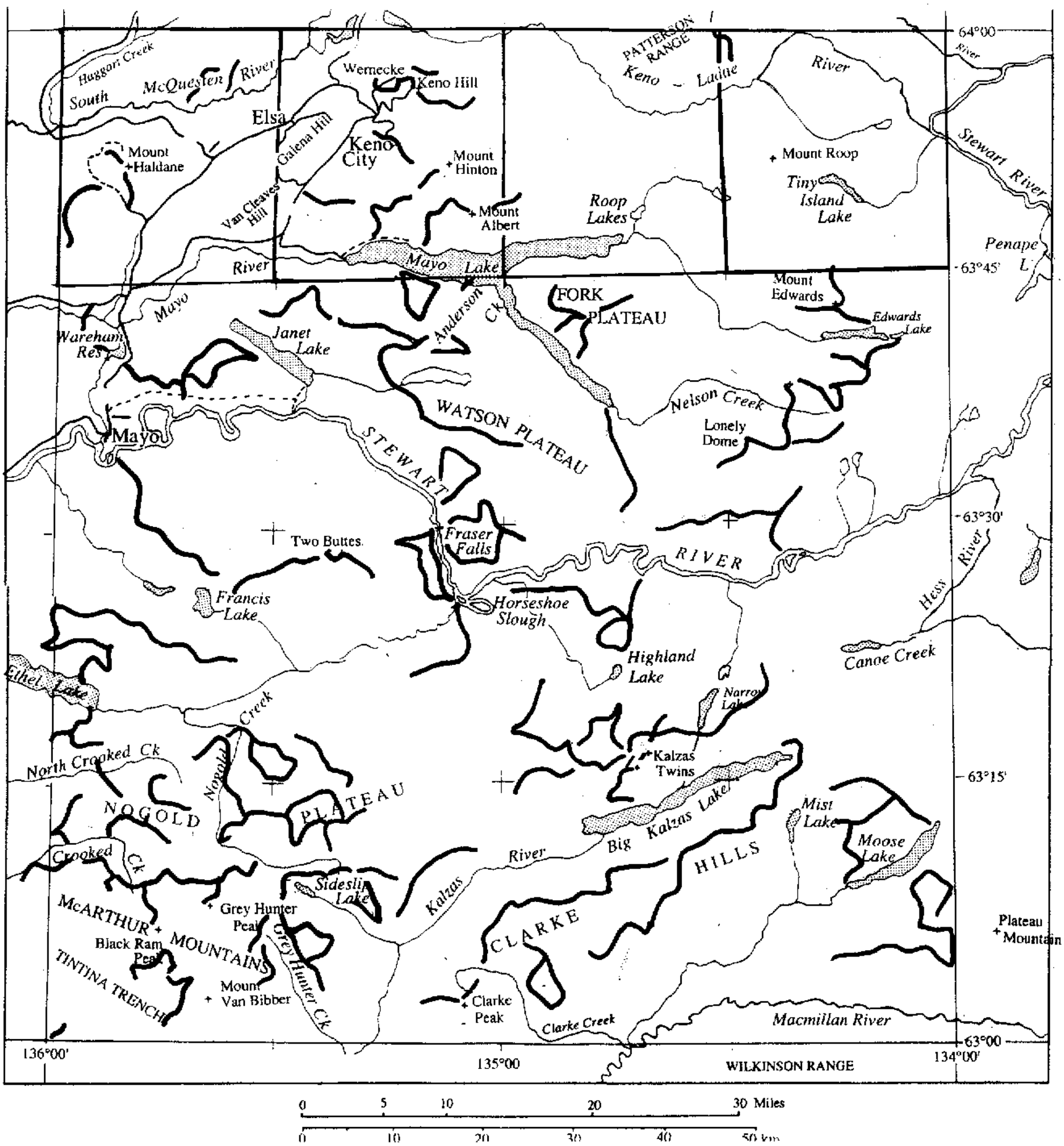


Figure 8. Location of traverses, 1990-1994. Separate traverses were conducted in the four northern 1:50,000 map areas (outlined) by: Hunt et al. (1996); Murphy and Roots (1992), Green (1971), and Gordey (1990a).

in the central and southern parts of the map area while Murphy focused upon the strongly deformed units in the north (see Murphy, 1997). Hunt completed additional traverses and compiled previous work for the Mount Haldane area in the northwest corner (Hunt et al. 1996).

Acknowledgments

Field assistance was provided by P. Daubeny in 1990, F. Roots and D. Lucas in 1991, J. Hunt in 1992, and L. Thorogood and K. Netherton in 1994. Helicopter pilots W. Thomson, D. Reid, D. Holden and J. Bowles provided prompt and efficient camp transportation. The hospitality of Archer Cathro and Associates (1981) Limited at their exploration camps is much appreciated. The author is grateful for the kindness of the late Pat and J. D. Randolph. Support for the project was shown by all residents, including the Nacho N'yak Dun First Nation. The advice of Betty Lucas, Neil Davies, and Shann and Jim Carmichael of Mayo enhanced my appreciation of the landscape and the human history of the region.

The gathering of geological knowledge is an iterative process, and I thank many colleagues for their continuing interest and advice, particularly G. Abbott, S. Gordey and L. Green. Gordey provided thin sections and a date for the metavolcanic unit near Tiny Island Lake; the Patterson Range metavolcanic rock date is from D. Murphy; the Roop Lakes granite sample was collected by G. Lynch and recovered from archives by R. Stevens; and the felsite from Roaring Fork Creek was supplied by T. Heah and R. Hulstein of Kennecott Canada Corporation. The age of these igneous rocks has been a particular interest of J. Mortensen and M-L. Bevier of the Geochronological Laboratory at University of British Columbia. Preliminary work on these samples and single detrital grain dating were carried out by V. McNicholl of the Geochonology Section, Geological Survey of Canada. Many of the new structural ideas presented in this bulletin originated with D. Murphy, whose companion volume (Murphy, 1997) provides a more comprehensive structural analysis of the northwestern part of the map area.

Progress reports (Roots, 1991; Roots and Murphy, 1992a) and interim maps (Murphy and Roots, 1992b; Roots, 1993) benefited from discussions and review by colleagues at the Cordilleran Division of the Geological Survey of Canada (Vancouver) and the Canada-Yukon Geoscience Office (Whitehorse). The accompanying colour map (Fig. 1) was digitized by D. Brent and produced by W. van Randen with the resources of the Canada-Yukon Geoscience Program. This work was supported by the Geological Survey of Canada (Cordilleran Division) and the Canada-Yukon Mineral Development Agreement (1991-1996), a joint arrangement between the Department of Indian and Northern Affairs and the Government of Yukon, Department of Economic Development. After 1996 the arrangement continued as the Yukon Geology Program. D. Tempelman-Kluit, S. Morison, and R. Hill, respectively, provided administrative guidance.

Portions of the text were edited by D. Murphy, C. Burn and J. Bond. The manuscript was critically reviewed by C. Yorath (Geological Survey of Canada) and L. Reynolds (Ampersand Ltd.) The bulletin was designed by P. Halladay.

Inspiration during mapping came from stories of the adventures during packhorse-supported reconnaissance mapping, recorded by the late Hugh Bostock (1979). Now, 50 years later, older Mayo residents fondly remember his brief visits to their village, his gentlemanly manner and encyclopedic knowledge of the country.

Regional Geologic Setting

The five belts of the Canadian Cordillera, marked by differences in physiography, regional structure and origin, were simultaneously recognized by Sutherland Brown et al. (1970) and Wheeler (1970). The two eastern belts (Fig. 9), Foreland (folded and thrusted Phanerozoic strata) and Omineca (uplifted areas of metamorphic and granitic rocks) originated above or adjacent to the stable North American crystalline basement, while the three remaining belts are composed of displaced ancient volcanic arcs, former oceanic crust, foredeep, shelf and slope deposits into which platonic-metamorphic complexes are embedded. These terranes were accreted to, or offset by strike-slip faults along, the western margin of ancestral North America (Gabrielse et al. 1991).

The Mayo map area lies mostly within the northeast half of the Omineca Belt and consists of deformed and uplifted sedimentary rocks of ancient North America which are intruded by mid-Cretaceous S-type granites. The extreme southwest corner of the map area, across Tintina Fault, is within the southwest half of the Omineca Belt. The three rock types exposed there are considered to belong to the Nisutlin sub-terrane, part of the Yukon-Tanana Terrane.

In the northwestern Omineca Belt, Late Proterozoic to Middle Devonian sedimentary rocks (Hyland through Road River groups) were deposited in Selwyn Basin (Fig. 9), a deep water, off-shelf environment that extended across central and eastern Yukon (Gordey and Anderson, 1993). Selwyn Basin ceased in Middle Devonian time. Parts were uplifted by block faults and eroded; other areas were inundated by turbidite fans (Earn Group; Gordey et al. 1987). Subsequent shallow-water, stable shelf environments followed; these are recorded by the Keno Hill quartzite (never formally defined) and Jones Lake Formation.

Although earlier periods of uplift and possible extension are suggested by the distribution (or local absence) of pre-Upper Cambrian and pre-Middle Devonian rocks, the main deformation events occurred between Middle Jurassic and Early Cretaceous time (Gabrielse et al. 1991). Northward (also northeast- and northwest-directed) contraction resulted from the collision of arc and oceanic terranes with the western margin of Ancestral North America (Tempelman-Kluit, 1979). The sedimentary rocks were telescoped through a combination of imbricate faulting, chevron and isoclinal folding and displacement on slaty cleavage.

Northwestern Omineca Belt contains two of the great thrust sheets of the Cordillera. They are named after their underlying faults, the Robert Service and Tombstone thrusts (Fig. 10). Robert Service thrust sheet is more than 350 km wide and uppermost strata are displaced at least 150 km northward (Thompson et al. 1990). This thrust sheet comprises the southern two thirds of the Mayo map area. The northern third of the map area is part of the Tombstone thrust sheet that protrudes structurally beneath the surface trace of the overlying Robert Service thrust. The main displacement on the Tombstone thrust (based upon interpretation of minor structures) was dominantly northwestward, followed by northeastward motion (McTaggart, 1960; Abbott, 1990a; Roots and Murphy, 1992a). All pre-Cretaceous rocks south of the Tombstone Thrust, except for the southern quarter of the map area, are pervasively foliated.

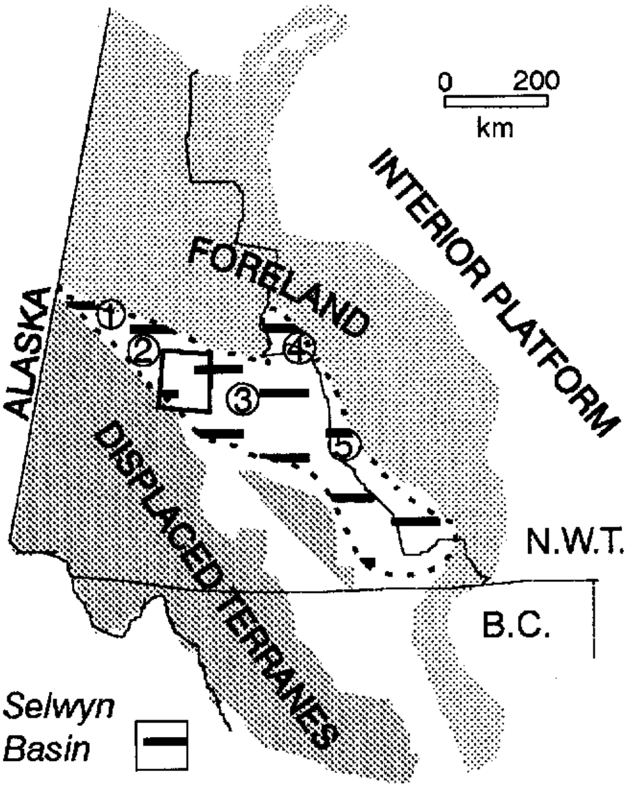


Figure 9. Location of Mayo map area (outlined) within the Omineca Belt (unpatterned) and Selwyn Basin (dotted outline) in the Yukon. Numbers indicate the locations of regional sections (Fig. 11).

The Omineca Belt is generally characterized by two domains with different structural styles: one of ductile recumbent folds and gently dipping foliation, and the other of brittle faults and more upright flexural slip folds (Gordey and Thompson, 1991). The Mayo map area encompasses the transition from dominantly ductile deformation in the north to more brittle deformation in the south. Although the location of the transition is subjective, the parts of the Mayo map area affected by these structural styles are referred to as the North Domain and the South Domain respectively (Fig. 10). The North Domain corresponds to the area of structural overprint inferred to result from later movement on the underlying Tombstone thrust and named the Tombstone Strain Zone by Murphy (Murphy and Héon, 1995; Murphy, 1997).

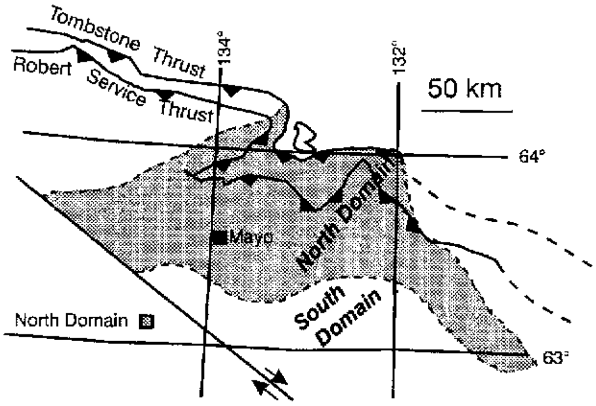


Figure 10. Areas of the North and South structural domains, within the Mayo map area.

Post-tectonic mid-Cretaceous stocks and plutons of the Selwyn Magmatic Province (Murphy et al. 1995) form westerly trends across Selwyn Basin and through the Mayo map area. The intrusions probably resulted from crustal thickening during and after stacking of the thrust sheets.

The southwest corner of the Mayo map area is cut by the Tintina Fault, along which 425-500 km of right lateral, post-Early Cretaceous displacement is estimated (Roddick, 1967; Tempelman-Kluit, 1979). No bedrock is exposed in the four-km-wide valley. Possibly the fault carries several parallel strands, because an elongate granite body, mapped by Bostock (1947) but not investigated since, lies parallel to the Tintina Trench on its northeast side. The southwestern extent of Selwyn Basin rocks that were offset along Tintina Fault probably lies in central Alaska (e.g. Murphy and Abbott, 1995).

Layered Rocks

Bostock (1947) delineated the main map units throughout the Mayo map area, extending the use of some names previously established in the Keno Hill mining district by Cockfield (1919) and Stockwell (1926). Most are metasedimentary rocks although some suggest a volcanic provenance. All have undergone low-grade metamorphism and are moderately deformed; those in the Northern Domain reflect regional polyphase deformation. Stratigraphy is complicated by regional folding and imbrication by thrust faults, obliterating internal details of most bedded units so that stratigraphic sections were not measured, although overall thicknesses are estimated. In much of the area sedimentary features and depositional contacts have been obscured by cleavage. Foliation completely overprints bedding in the Tombstone thrust sheet and the northern part of the Robert Service thrust sheet. Consequently the age, depositional environment and tectonic setting of these rocks is mostly derived from studies of correlative units northwest and southeast of the map area where the effects of structural dislocation and metamorphism are less pronounced.

The northern third of the map area has traditionally been described in terms of three principal metasedimentary units, referred to as the Lower Schist, Keno Hill quartzite and Upper Schist formations (e.g. Boyle, 1965; units 2, 3, and 4 of Bostock, 1947). These were considered a conformable sequence of probable Precambrian age. This framework was radically modified, first in the 1960s, when systematic mapping extended beyond the mining district, and again in the 1980s when reliable biochronology and isotopic dating became available. In the first instance, the Keno Hill quartzite unit was traced 160 km northwest into the Tombstone area (southeast Ogilvie Mountains) by Green (1972). In the latter area Jurassic fossils were found in black slate which is directly overlain by the Keno Hill quartzite (the intervening thrust is not apparent). Tempelman-Kluit (1970) proposed a lower Cretaceous age for the quartzite on the basis of apparent stratigraphy, poorly preserved fossils in the quartzite and similarity to the Cretaceous Kandik Formation of northeastern Alaska and adjacent Yukon. In 1986 this correlation became invalid when a mafic sill within the Keno Hill quartzite produced a Triassic U-Pb age (Mortensen and Thompson, 1990) and Carboniferous conodonts were recovered from a limestone lens in the quartzite (Orchard, 1991). This new information resulted in recognition of the intervening fault, now called the Tombstone Thrust.

These new ages also apply to the Mayo area. Near Keno Hill the Lower Schist contains metadiorite that resemble the Triassic sills and is therefore considered a foliated and lineated correlative of the Earn Group (Abbott, 1990a) lying above the Tombstone Thrust (Roots and Murphy, 1992a). The Upper Schist was correlated (Poole, 1965; Green, 1971) with the regionally extensive Grit Unit (Gabrielse et al. 1973; Blusson, 1974) which has since been formally defined as the Upper Proterozoic-Lower Cambrian (?) Yusezyu Formation (Gordey and Anderson, 1993) of the Hyland Group. The necessity of a thrust separating the Upper Schist from the underlying Keno Hill quartzite was recognized by Green (1971). It is now recognized as the Robert Service Thrust (Gabrielse et al. 1980; Gordey and Thompson, 1991) although it is more obscure in the North Domain than where originally defined north of Dawson.

The Robert Service thrust sheet includes Late Proterozoic to Carboniferous (?) map units which can be correlated with the regionally extensive Selwyn Basin stratigraphy, except for the provisional Nogold unit. Yusezyu Formation is the oldest unit and is overlain by maroon slate (Bostock's unit 9), now correlated with the Precambrian to Cambrian Narchilla Formation (Gordey and Anderson, 1993). Overlying strata extend southeastward, including the Gull Lake (Middle to Upper Cambrian), Rabbitkettle Formation (Upper Cambrian to Ordovician) and Road River Group (Lower Ordovician to Upper Silurian). The disconformably overlying Earn Group (Middle Devonian and Lower Carboniferous) was defined by Campbell (1967) in adjacent northeastern Glenlyon map area. Younger strata, including the Keno Hill quartzite (never formally defined; Lower Carboniferous) and Jones Lake Formation (Jurassic and Triassic?) occur in the North Domain.

Near the head of Nogold Creek, microfossil collections from limestone beds within maroon slate which was previously considered Narchilla Formation contain microfauna of early to late Late Devonian age. In this report these rocks comprise the "Nogold unit", a provisional term because they lithologically mimic the Hyland Group and bounding contacts are undefined. Additional fossiliferous localities must be located before the full extent and nature of the Nogold unit is resolved.

Stratified rocks of the Mayo map area are grouped into four assemblages reflecting broad stages in the development of the Cordilleran miogeocline (Gordey and Anderson, 1993): Selwyn Basin, Shelf Facies, Turbidite Basin, and Clastic Shelf. These assemblages comprise ten stratigraphic units (Table 1). Only the provisional Nogold unit is described for the first time.

PROTEROZOIC TO MIDDLE CAMBRIAN

Hyland Group

Metamorphosed sandstone, grit and lesser maroon argillite, chloritic schist and limestone, here included in the Hyland Group, underlie a 60-km-wide, west-trending swath across the central Mayo map area (Fig. 12). The boundary to the north is the surface trace of the Robert Service Thrust, where it structurally overlies Keno Hill quartzite. To the south the Hyland Group is stratigraphically overlain by the Gull Lake Formation, Road River and Earn groups and probably the Nogold unit (contact not observed).

These metasedimentary rocks lithologically correlate with the Upper Proterozoic to Middle Cambrian Hyland Group, defined by Gordey and Anderson (1993) and they underlie the same younger units. The Hyland Group is divided into two formations. The older Yusezyu Formation consists of sandstone, grit, black slate, minor limestone and chlorite schist. The younger Narchilla Formation comprises maroon slate and lesser dark argillite and phyllite with minor sandstone.

Yusezyu Formation

The oldest rock unit in the map area is the most extensive and contains the few internal markers or mappable divisions. It comprises vast areas of metasandstone (psammite) with less common grit, quartzite and phyllite layers, as well as rare limestone and conglomerate lenses. The formation lacks recognizable stratigraphy. The only mappable marker is the Black Slate member, although sub-units such as chloritic metasiltstone/phyllite, clean sandstone, and carbonate horizons were distinguished where mappable. Rare sedimentary structures are preserved in the South Domain, but in North Domain these have been obliterated and most detrital grains are recrystallized.

Contacts

The base of the Yusezyu Formation has not been observed in the northern Cordillera. In the Mayo area, its structural base is the Robert Service Thrust. The deepest stratigraphic level of the Yusezyu in the map area is probably immediately east of Mayo Lake. The upper contact appears conformable with the

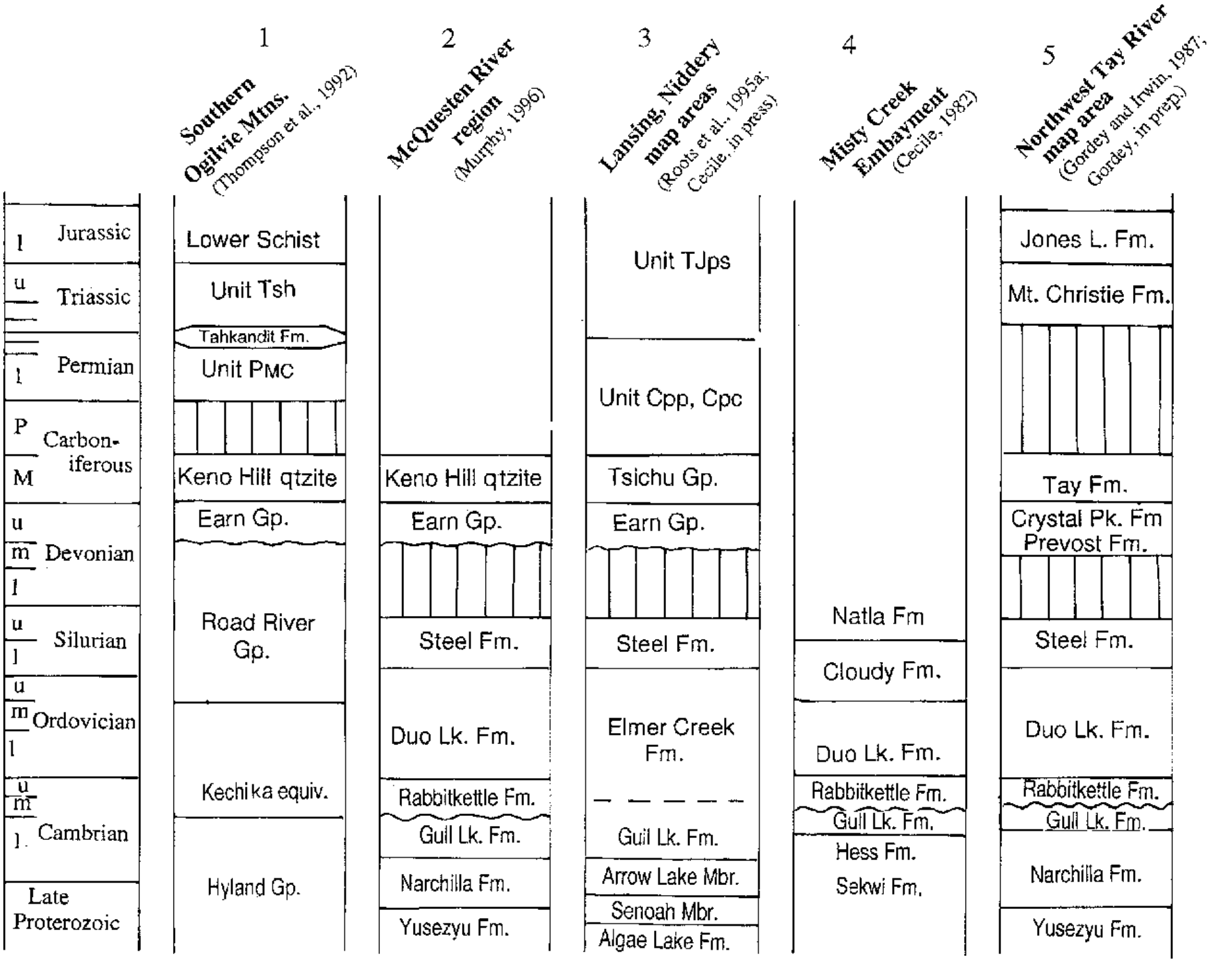


Figure 11. Correlation chart of major rock divisions in Selwyn Basin, central and western Yukon.

Period or Epoch	*Formation*	*Map unit and lithology*	*Thickness (metres)*
Pleistocene to Recent		**Q** unconsolidated glacial and alluvial deposits	
Late Early Createceous	Tombstone Intrusions	**Kr** rhyolite dykes, biotite felsite **KT** quartz monzonite, granodiorite	
Clastic Shelf (Middle Carboniferous to Triassic)			
Triassic	Jones Lake Formation	**TJps** slate, sandy slate, limestone	750 *
unconformable			
Mid.Triassic	Mafic intrusions	**Td** metadiorite, gabbro	
intrusive contact			
Carboniferous	Keno Hill Quartzite	**MKH** quartzite, carbonaceous schist, limestone	500 ?
		MKv chloritic phyllite, meta-tuff	1-50
unconformable			
Turbidite Basin (Devonian to Middle Carboniferous)			
Devonian to Carb'niferous	Earn Group	**DME** - Black shale, sandstone, chert grit, chert pebble conglomerate minor limestone, siltstone and mudstone **DMp** - silicious slate, carbonaceous schist, metachert and meta-conglomerate **DMv** - quartz-sericite-chlorite phyllite, quartz-feldspar augen phyllite	600 ? 200 ?
locally unconformable; not in contact with Nogold unit			
Shelf Facies (Middle Paleozoic; includes Late Silurian to Early Devonian)			
top not preserved			
Late Silurian to Early Devonian	Nogold unit	**PNm** - Maroon argillite and siltstone, minor fossiliferous limestone **PNc** - Chloritic metasandstone, chloritic schist **PNs** - Quartz metasandstone, meta-grit, minor phyllite	100 ? 2-40 ? 200 ?
base not recognized			
Selwyn Basin (Precambrian to Middle Devonian)			
Road River Group (Steel and Duo Lake formations)			
Silurian	Steel Formation	**Ss** - grey-green siltstone, chert, minor carbonate	40
conformable			
Ordovician to Early Devonian	Duo Lake Formation	**OSD** -black, brown argillite, grey and black chert, dark siltstone, minor quartz arenite	~200
conformable			
Up. Cambrian to Ordovician	Rabbitkettle Formation	**COR** - Grey silty limestone, calcareous grit and siltstone	20 ?
unconformable			
Middle Cambrian to Ordovician	Gull Lake Formation	**COG** -Olive and brown siltstone, black argillite and shale; grey dolostone or carbonate breccia at base, minor grey quartzite	100-300
conformable			
Hyland Group (Narchilla, Algae Lake, Yuseyzu formations)			
Late Prot. to Cambrian	Narchilla Formation	**PCN** - Maroon argillite, grey and brown slate, minor quartz sandstone interbeds	50 ?
Late Proterozoic	Yusezyu Formation	**PY**- Sandstone, grit, psammite, metaconglomerate, chloritic metasiltstone; carbonaceous phyllite or graphitic slate near base; grey limestone, marble lenses near top	3000+ *

Table 1. Geological formations

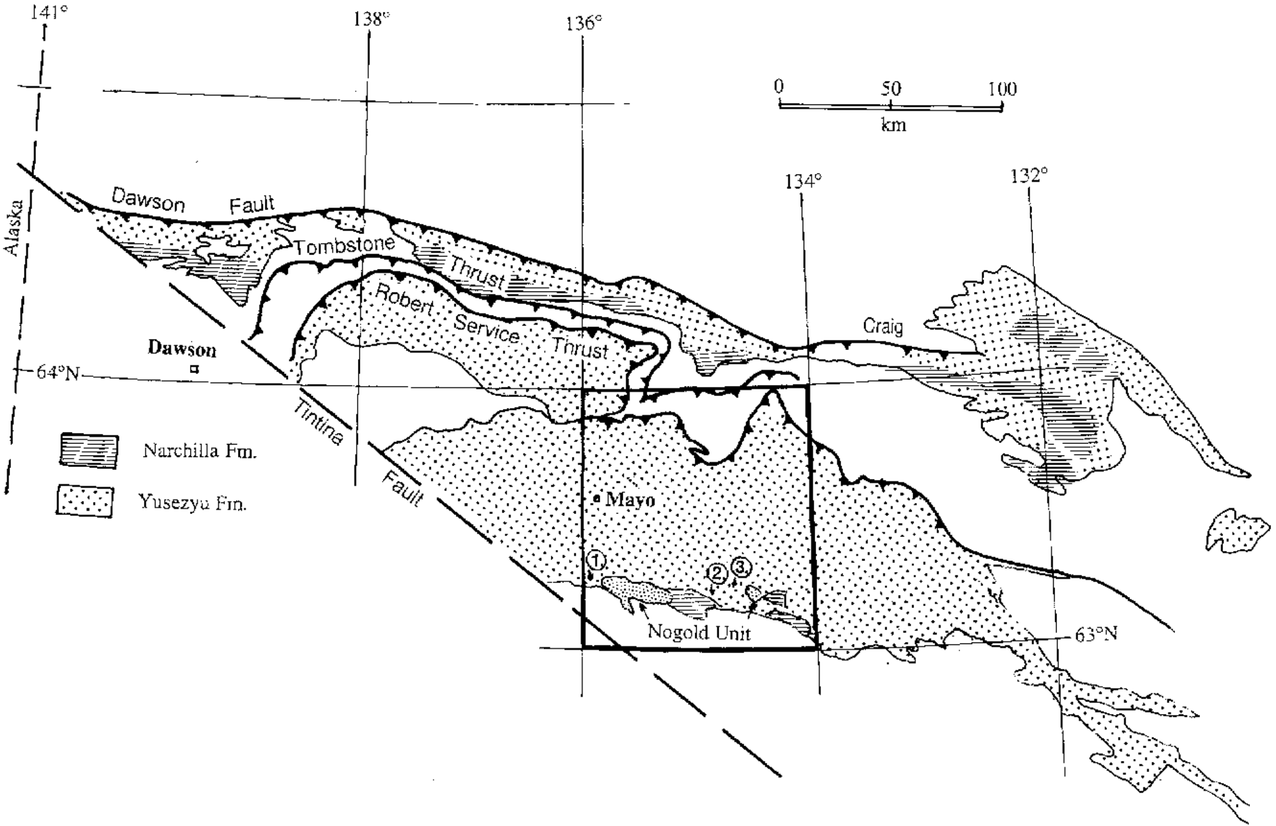


Figure 12. Distribution of Yusezyu and Narchilla formations across Selwyn Basin. Mayo map area is outlined. Numbers indicate locations of sections (Fig. 13).

overlying Narchilla Formation, although it is obscured by cleavage. Yusezyu sandstone is also disconformably overlain by the Earn Group in the northeast part of the map area and is presumably disconformably overlain by the Nogold unit locally in the southwest. The true thickness of the Yusezyu Formation remains unknown but extensive areas of steep-dipping strata without apparent repetition suggest several thousand metres. Several well-exposed sections up to 250 m thick represent typical successions (Fig. 13) but these cannot be correlated because stratigraphic contacts or markers units are not intersected.

Black Slate member (PYB)

This member consists of brown-weathering, black graphitic slate to carbonaceous phyllite with thin beds of fine-grained dark grey quartz sandstone. It forms a discontinuous band north and west of Mount Roop (Gordey, 1990a, b) and can also be traced northwest from Mayo Lake. It was previously mapped as Unit 1b by Green (1971). Although pervasively foliated, linear outcrops of resistant quartzose rock within the phyllite demonstrate continuity of compositional layering that resembles the original stratigraphy. North of Mayo Lake (Locality PY1; Fig. 12 and Appendix 1) the member appears to be 140 m thick with a 2-m-thick limestone band near the top. The member is overlain by thick, parallel layers of gritty metasandstone, the main member of the Yusezyu Formation.

Rock resembling the Black Slate member was also located on the south shore of Mayo Lake east of Anderson Creek (Locality PY2). There chloritic and dominantly carbonaceous phyllite alternates with quartzose bands along the foliation (Fig. 14). The quartz bands may be attenuated, remobilized sandstone layers. Overlying and underlying rocks are not revealed in the shoreline outcrops. Carbonaceous phyllite is otherwise rare in the Yusezyu Formation. In the southern Mayo map area a gulch on the east side of Nogold Creek (Locality PY3) exposes a succession of black phyllitic mudstone at least 20 m thick, overlain by about 100 m of graphitic phyllite with gritty interbeds and capped by cliff-forming, thin bedded beige sandstone. An eight m-thick layer of porous, light grey phyllite separates this succession from thick bedded sandstone and grit typical of the Yusezyu Formation. This occurrence, if correlated with the Black Slate Member, suggests the Nogold Creek area exposes lower Yusezyu Formation, with

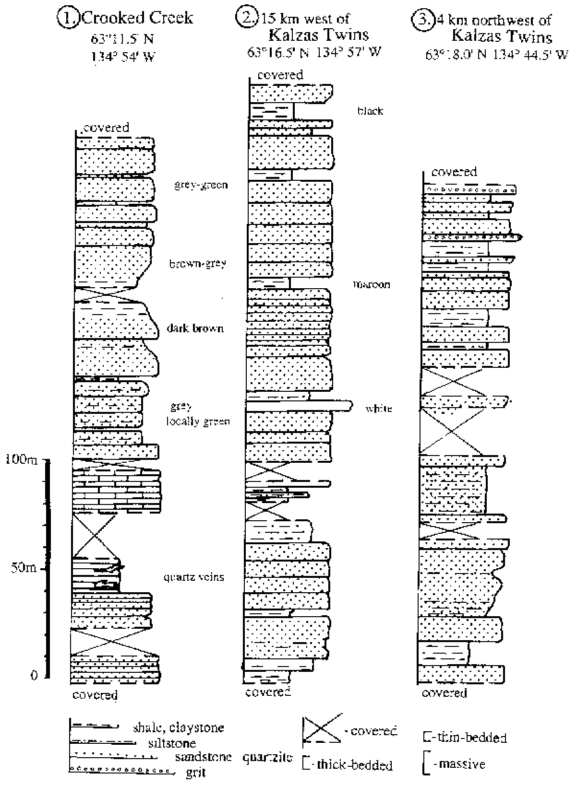


Figure 13. Stratigraphic sections through parts of Yusezyu Formation. For section locations see Figure 12.

implications for depth of erosion preceding deposition of the overlying Nogold unit, and possibly the shallowness of the Robert Service Thrust beneath.

Sandstone-Grit and metamorphic equivalents (PYqps)

The main member of the Yusezyu Formation consists of medium to coarse-grained sandstone and grit that weathers grey-brown to pink or dark grey. Sandstone predominates, with quartz and lesser feldspar grains in varying amounts of fine sand and mud matrix. Gritty sandstone beds and local pebble conglomerate constitute less than 5% of the belt, and some contain appreciable kaolinized feldspar detritus. In the northern two-thirds of the Yusezyu outcrop belt, the rocks have been strained. The mud size fraction is micaceous and only large or compositionally contrasting detrital grains are discernible. Resistant, white-weathering quartz sandstone or quartzite layers, up to 20 m thick, are common, but could rarely be mapped for more than one km.

Unstrained rocks

Figure 14. Strongly cleaved slate member of the Yusezyu Formation. The quartz-rich segregations contain fine laminae, probably a strain feature rather than original bedding. Bar scale graduated in cm at bottom. Locality PY2, on the south shore of Mayo Lake.

In the southern part of the Mayo map area, medium and thick sandstone beds typically are separated by thinner intervals of dark mudstone or siltstone so that outcrops have a ribbed appearance (Fig. 15). The sandstone beds overlie mudstone conformably, although mudstone rip-ups indicate local erosion. Load casts are common, some resembling large ripples. Normal size grading is typical with 2-3 mm granules abundant in the bottom 10-15 cm of a bed (Fig. 16). Festoon- and ripple-cross-laminations commonly occur in the upper parts of sand beds (Fig. 17) where foliation and recrystallization have not obliterated fine textures.

Thick grit layers typically overlie scoured and deformed mudstone and sandstone beds (Fig. 18). The grit is poorly sorted, and the abundance of angular grains denotes its immaturity (Fig. 19). The maximum grain size observed in Yusezyu sediments was 13-mm quartz pebbles at Mount Roop (Gordey, 1990a), although these probably have suffered strain elongation. Dark shale intervals are rare.

Metamorphosed sandstone typically contains 3-10% quartz grains that are larger than average.

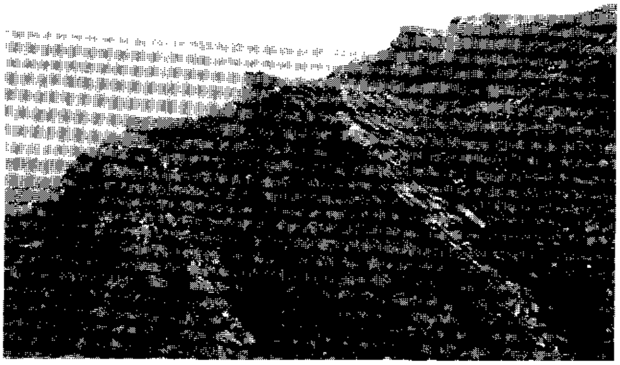


Figure 15. Resistant micaceous meta-sandstone (psammite) layers 2-5 m thick, separated by thin argillaceous interbeds. Northwest edge of Nogold Plateau, four km south of North Crooked Creek.

Figure 16. Normal size grading in Yusezyu Formation. The planar laminated sandstone bed at the bottom is overlain by densely packed angular quartz and feldspar granules, which grade upward into successive planar laminated and ripple-laminated zones overlain by dark coloured siltstone at the top. Irregular blotches are lichen encrustations. Bar scale in centimetres at lower right. Locality PY4; 7.5 km west of Kalzas Twins.

Figure 17. Yusezyu turbidite sequence, showing basal light-weathering gritty sandstone scouring darker shale, grading upward to planar- and ripple-laminated sandstone and darker metasiltstone at the top of the cycle. Scale in cm; 2 km north of Kalzas Twins (a steeply dipping outcrop at base of slope) .

Commonly these are clear or blue and flattened parallel to foliation. Thick beds, uniformly composed of 8-mm white quartz granules, occur along the northeast shore of Big Kalzas Lake. Pink calcareous sandstone was noted on northeast Kalzas Plateau; the calcite cement appears to be primary.

In thin section, the sandstone grains typically have a bimodal size distribution: large granules are floating in a matrix of fine-grained sand or silt particles. Quartz comprises 60-90% of all grains, with accessory tourmaline, pyrite, apatite and zircon. Up to one fifth of the quartz grains have a blue cast, and in the metamorphic aureole of Cretaceous intrusions the recrystallized quartz grains are spherical and glassy. White (kaolinized) feldspar is rare, but locally constitutes 35% of coarser sediments which then superficially resemble a decomposed granitic rock. Notably, carbonate, chert and volcanic clasts are absent.

Strained rocks

This part of the Yusezyu Formation lies within the North Domain, a region where rocks have been overprinted with a shear fabric developed during Tombstone thrusting. Medium- to coarse-grained foliated rock is composed of quartz, feldspar and mica, with varying amounts of chlorite and carbon. The mineral variations are revealed as compositional layers which reflect, and perhaps accentuate, compositional differences in primary bedding, although no depositional features remain. Many areas, however, contain green and grey impure quartzite, gritty phyllite and stretched meta-conglomerate layers, and changes in structural fabric clearly follow original bedding contacts (Fig. 20). Bedding typically is parallel to foliation, but tightly folded beds likely are obscured by the prominent foliation, although its transposition into foliation nearly everywhere allows only fold hinges to be recognized (Fig. 21).

In thin section, these rocks reveal a mosaic of densely packed quartz and feldspar grains. Grains are typically oblate, and appear flattened where viewed in the plane of foliation. Sutured grain boundaries prevail. Tightly buckled white mica (typically muscovite, but sericite also is present) forms ribbons 1 to 5 m wide through some highly strained rocks; in less

Figure 18. Cross-laminated quartz sandstone bed (white) overlain by massive gritty sandstone (grey). The scoured contact (partly obscured by lichen) is overlain by rollups and rip-up clasts of the quartz sandstone. Scale bar in cm; From a structurally overturned outcrop 10 km northwest of outlet of Big Kalzas Lake.

deformed samples the micas are evenly distributed between the quartz grains. In several sections the largest grains have rounded, inclusion-rich cores which may be relics of original detrital clasts, but most grains are unstrained and clear, implying complete recrystallization. Single crystals of pyrite, tourmaline and sphene are common. Rocks near Cretaceous intrusions contain garnet porphyroblasts and biotite has replaced muscovite.

Sandstone member (PYs)

This sub-unit differs from the typical Yusezyu strata in its compositional homogeneity and massive nature. The thick-bedded or massive white sandstone, metamorphosed to quartzite, with rare dark mudstone intervals, covers areas large enough to show on the map on ridges west of Kalzas Twins and south of Williamson Lake.

Figure 19. Irregular, possibly scoured contact between darker argillite and overlying coarse grit. The contact, which slants toward lower right in photo, dips obliquely to lower left in the outcrop. At head of North Crooked Creek.

On the ridge south of Williamson Lake are tor-like outcrops of tabular, coarse-grained, brown and white metasandstone containing abundant opalescent quartz grains. Although this area is in the North Domain, deformation is less destructive than in surrounding rock types; a faint foliation is provided by about 1% dark-coloured mica, and 10-15 cm spaced cleavage reflects zones of minor elongation of quartz grains (Fig. 22). Similar rock was encountered between Nelson and South Nelson creeks (triangulation point 5640) where bedding is suggested by planar breaks about 30 m apart.

Several outcrops consisting of a single very thick bed or multiple beds of mature quartz grit, coarse sandstone or quartzite occur on Kalzas Plateau. The rock weathers white and contains about 40% clear one-mm quartz grains while other grains are white quartz. Quartzite that is black on the fresh surface could be confused with Keno Hill quartzite, but in other places is purple or beige, and scattered 2-3 mm grains of feldspar and fine-grained rock fragments are visible.

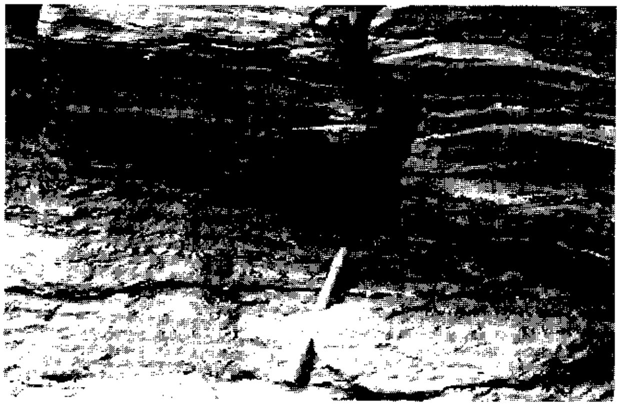


Figure 20. Deformed bedding contact of grit (bottom) with meta siltstone. Sedimentary features are obliterated by oblique foliation. Pencil is 15 cm long; from Nogold Plateau, 2.5 km north of survey marker 5251±'.

The boundaries of this rock type cannot be sharply defined with the typical sandstone-grit succession because compositional purity is a relative distinction; nor can the clean sandstone occurrences be correlated with any assurance of stratigraphic position. In the absence of carbonate horizons this lithology may prove useful in resolving structural complexity in areas to be mapped in greater detail.

Chloritic metasiltsone and phyllite (PYc)

Dark green, thinly layered chlorite metasiltstone underlies an area nine km long and 1.5 km wide near Fraser Falls (Fig. 23). Original bedding has been transposed into the south-dipping foliation and could

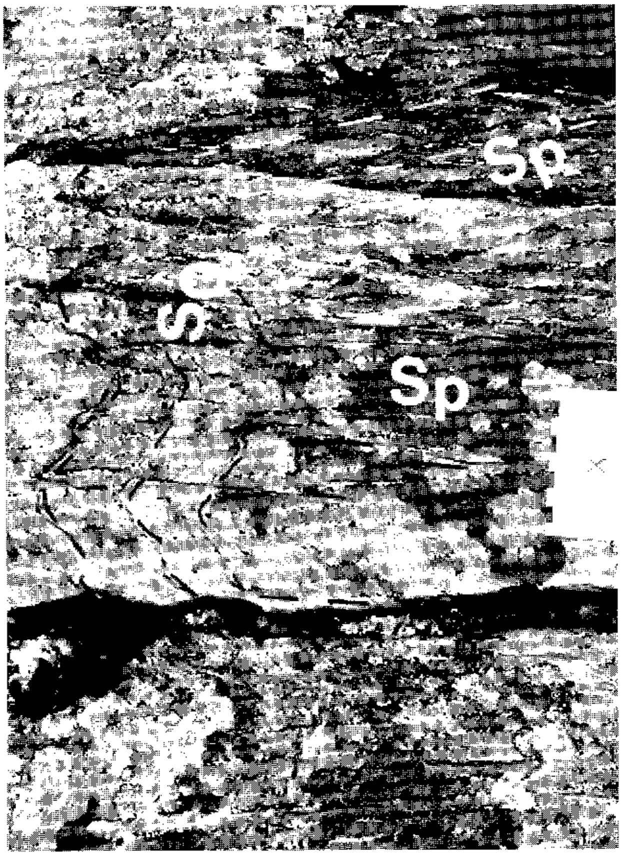


Figure 21. Fold hinges revealed in psammite, the prominent planar feature of which is axial planar foliation (Sp) with an oblique secondary foliation (top, Sp'). Evenly spaced, wavy cracks at left (So) are either original bedding or an earlier foliation. View is southeast, in plane of the gently dipping prominent foliation, 2 km southwest of Lonely Dome.

have originally trended transverse to the foliation (Fig. 24). The northern contact of this member is not exposed, but to the south the layers become less chloritic and lenses with abundant detrital quartz grains more common (Fig. 25). Thin sections show hornblende crystals (typically blunt prisms one mm across) and anorthitic plagioclase granules in the abundant chlorite matrix. Although the prevalence of chlorite might suggest a mafic protolith, detrital quartz clasts are not uncommon. Zircons were extracted from the schist in search of primary igneous crystals, but the morphology of all zircons indicate their detrital history (R. Parrish, pers comm., 1992).

Two other chloritic bands were encountered. A 30-m interval of soft, crumbling dark green phyllite is present among thick brown quartzofeldspathic layers, cut by the northeast fork of Empire Creek, five km northeast of Frances Lake. The phyllite is cleaved and lacks internal features, except for quartz and calcite secondary veinlets. It may have been a metavolcanic horizon or a mafic intrusion before severe deformation. The second locality, a knob south of Edwards Lake, consists predominantly of green metasiltstone and sandstone layers exhibiting normal size-grading and cross-beds. The 60 m wide occurrence is clearly sedimentary and the chlorite may reflect an eroding mafic source rock, or later chloritic alteration.

Carbonate rocks (PY2)

Medium grey-weathering, dark grey limestone lenses and thin, discontinuous beds are sparse but widely distributed in the Yusezyu Formation in the Mayo map area. Locally the limestone appears undeformed but is completely recrystallized, and enveloping foliated quartzose rocks reflect moderate to high regional strain. Three occurrences contain enough carbon to evoke a fetid odor when broken. Only the largest, a 4-ha area atop Van Cleaves Hill west of the mouth of Duncan Creek, reveals possible primary structures, perhaps deformed oncoliths or organic debris (Fig. 26). In other places limestone contains black micaceous layers suggesting stylolitic residue.

Two areas contain limestone horizons that can be intermittently traced over several kilometres, suggesting that map-scale structures do exist. The first area, around Crooked Creek in the southeast part of the map area, includes one or two limestone layers within a metasandstone succession (Fig. 13, Section 1). The second area is between Edwards Lake and Lonely Dome, where beige-weathering limestone with carbonaceous streaks (Fig. 27) may be a regional marker horizon. These occurrence are included in the Yusezyu Formation because they are flanked by quartz sandstone, the dominant lithology of that unit. Both limestone occurrences are, however, candidates for the Rabbitkettle Formation, which may be uncon-

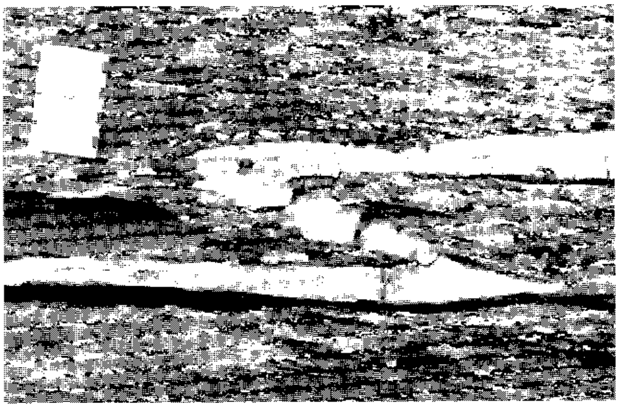


Figure 22. Quartzofeldspathic rock in which recessive micas define a foliation. Bedding is probably more deformed than indicated by the folded white quartz vein, which probably resulted from available silica during pressure solution. Scale in cm; view westward at vertical face; outcrop is on ridge crest 5 km south of Williamson Lake.

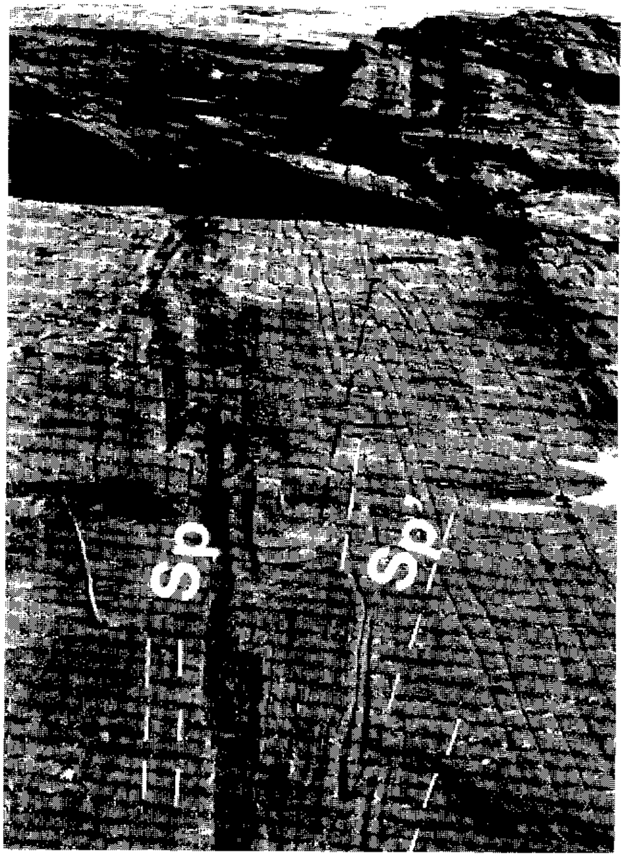


Figure 23. Chloritic metasandstone with steep foliation (Sp) subparallel to compositional layering. Minor folds verge and plunge moderately southeast, producing axial planar secondary foliation (Sp'). One-m stick (foreground) and 33-cm hammer (background) are for scale. West bank of the Stewart River, 100 m north of the upstream entrance of the portage trail around Fraser Falls, looking eastward.

formably overlying the Yusezyu Formation with contacts obliterated by strain. For the Edwards Lake occurrence, a limestone belt along a structural trend 30 km to the southeast and also considered Yusezyu, yielded Late Cambrian or Early Ordovician conodonts. Mapping in progress in the western Lansing map area may demonstrate the continuity of this limestone.

Narchilla Formation (PЄN)

This upper formation of the Hyland Group is characterized by maroon argillite, although grey and khaki argillite locally are present. Single, regularly spaced quartz sandstone beds within the argillite (Fig. 28) are characteristic.

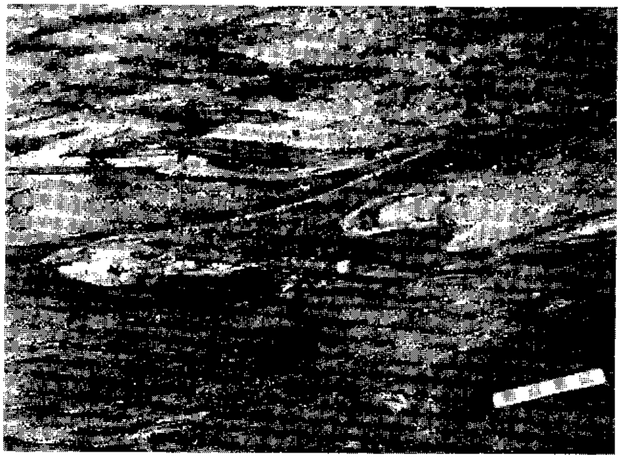


Figure 24. Chloritic member of Yusezyu Formation, showing disharmonic folds and attenuated limbs outlined by darker chloritic bands. Folds illustrate the degree of local shortening as a result of transposition of compositional layering (envelope trends across photo) into the perpendicular foliation. Scale bar is in cm. Stewart River shoreline, 200 m south of the upstream end of portage around Fraser Falls.

Contacts of the recessive Narchilla Formation are tectonically modified and not exposed. In the eastern Clark Hills maroon argillite lies between grit (Yusezyu Formation) and olive siltstone (Gull Lake Formation), a sequence that is repeated by two thrusts. The Narchilla occurrences vary from 50 to 2000 m wide, but the isoclinal fold style suggests that the true thickness is closer to the lesser estimate. Both occurrences terminate along strike but the truncation could be structural or stratigraphic since outcrop is lacking. Between Grey Hunter Creek and Sideslip Lake, a Narchilla succession occupies the core of a southeast plunging antiform, overlapped by several metres of olive siltstone (Gull Lake Formation). In this area and south of Moose Lake, the Narchilla includes unknown thicknesses of grey and dark green mudstone and siltstone which cannot be distinguished from similar rock types present in the adjacent Gull Lake and Duo Lake formations.

The maroon argillite typically lacks internal structure although fine laminae are visible in undeformed mudstone. The quartz sandstone beds are 10-30 cm thick and contain spherical quartz grains with slight normal grading and planar crossbeds near the top. Burrowing imprints are common where the base of sandstone beds is exposed.

Only one exposure of maroon argillite was found within the broad band of Yusezyu Formation spanning the central Mayo map area. A canyon northwest of Big Kalzas Plateau contains a 3.5 m thick bed of maroon mudstone and green siltstone is interbedded with sandstone (Fig. 13, Section 2; Fig. 28). This may be a rare occurrence of maroon argillite within the Yusezyu Formation. It more likely demonstrates the attenuated or structurally dismembered nature of the Hyland Group, which is rarely evident because the Narchilla Formation is recessive.

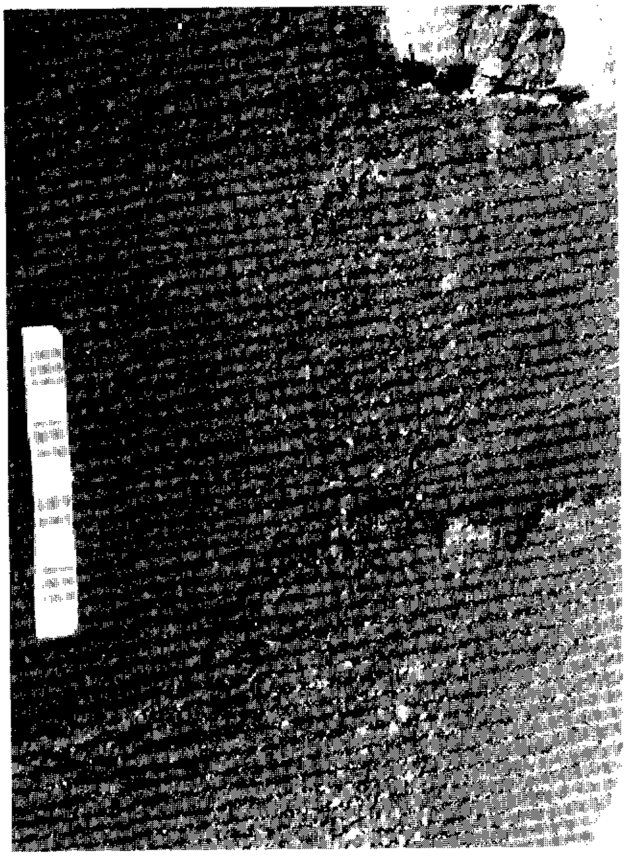


Figure 25. Coarser grained lens with the Chloritic member, showing abundant sub-angular blue-white quartz grains. Shoreline cliff on the west side of Fraser Falls.

South of Tiny Island Lake a strip of dark grey to green slate and phyllite, with minor brick-red argillite and quartz sandstone (Gordey, 1990b) about 1 km wide and 12 km long, is correlated with the Narchilla Formation. It is interpreted as a synclinal keel or fault-bounded slice within the Yusezyu Formation.

Age and correlation

The age of the Hyland Group is based upon Latest Proterozoic and Early Cambrian trace fossils in the maroon argillite (Fritz et al. 1983, Hoffmann and Cecile, 1981; Gordey and Anderson, 1993), as well as Early Cambrian archeocyathid-bearing clasts in the overlying Gull Lake conglomerate (Cecile and Abbott, 1992) in the Niddery Lake map area. The trace fossil *Oldhamia* is ubiquitous among Narchilla argillite in northern Selwyn Basin; it probably existed in the Mayo map area but has been obliterated by pronounced cleavage.

In its Nahanni type area more than 3000 m of the Yusezyu stratigraphy is estimated (Gordey and Anderson, 1993). There, limestone beds define the top of the Yusezyu Formation and overlying Narchilla Formation, although dominantly dark grey-blue shale contains sandstone-rich intervals. In the northeast Niddery Lake map area, Cecile (in press) separated the limestone as the Algae Lake Formation and divided the Narchilla into two members, the uppermost of which is entirely maroon argillite. The small exposures of Narchilla-equivalent rocks in the Mayo map area do not warrant subdivision, nor is limestone present near the contact between the Yusezyu and Narchilla formations. In some regions, such as the north central Lansing map area, the Yusezyu Formation contains a second yellow-weathering carbonate, 10-39 m thick (Roots et al. 1995a, b); this may be correlative with the limestone of the Mayo map area. The northeast Lansing map area contains pink calcareous sandstone in the upper part of the Yusezyu Formation (Roots et al. 1995a; Cecile, in press), a distinctive lithology not encountered in the Mayo map area.

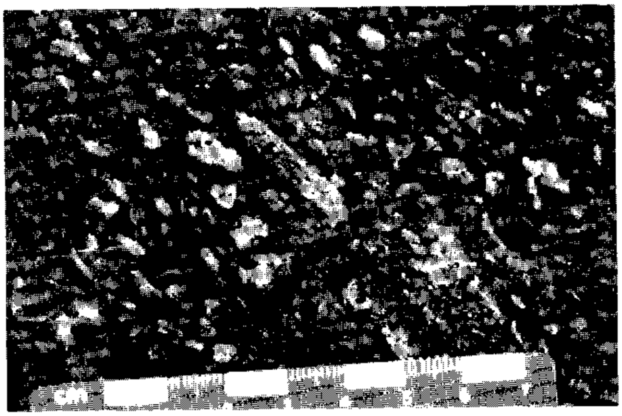


Figure 26. Deformed oncoliths or organic debris highlighted by dolostone replacement in recrystallized limestone. The age of this rock is unknown; it could be Late Proterozoic Yusezyu Formation although the discovery of identifiable organic forms would signify a younger age. Near the top of Van Cleaves Hill, ten km northwest of the outlet of Mayo Lake.

Depositional environment

The least deformed Yusezyu sandstone in the southern part of the Mayo map area exhibits rhythmic layering, cross-bedding and locally scoured beds consistent with ACE and ABE turbidites (terminology of Walker, 1979). The Yusezyu Formation typically represents sediment gravity flows with little background sedimentation (Gordey and Anderson, 1993). The source of abundant coarse-grained sediment for the turbidites could have been subaqueous deltas of braided rivers. Large grains of quartz and feldspar, as well as blue quartz, imply erosion of granitic and metamorphic source areas. Concentrated dark minerals in the chloritic member suggest erosion of mafic igneous rocks. The lack of granitic pebbles and mafic minerals, as well as excellent rounding of

Figure 27. Deformed limestone (possibly Yusezyu Formation) contains abundant carbonaceous phyllite. Curved dark streaks across compositional layers near centre of photograph may be relict cross-lamination, but are more likely remains of an earlier cleavage. View is southeastward, oblique to foliation that dips moderately south and perpendicular to minor southwest-plunging fold axes. Scale bar at bottom marked in cm. Outcrop is at 1310 m (4300') on north-trending spur five km northwest of Lonely Dome.

the quartz sand, however, imply that the Hyland sandstone is not a first-cycle sediment. The immediate source may have been a sedimentary terrane (Gordey and Anderson, 1993; p. 44). Limestone in a turbidite environment likelys represent thin, deep water layers (subsequently pulled apart by folding) rather than isolated, shallow-water reefs.

The Narchilla Formation represents a low-energy, deep-water environment in which burrowing organisms probably thrived. Periodic gravity flows from a well-worked source, such as beach sand, produced the regularly spaced mature quartz sandstone in some maroon argillite sections.

MIDDLE CAMBRIAN TO ORDOVICIAN

Gull Lake Formation (ЄOG)

Brown siltstone and cherty argillite, with lesser black shale, constitute the Gull Lake Formation (Gordey and Anderson, 1993) in the southern part of the Mayo map area. These rocks are poorly exposed and the unit is generally deduced from its stratigraphic position above maroon argillite of the Narchilla Formation and below chert of the Duo Lake Formation at localities where the Rabbitkettle Formation is absent. The diagnostic lithology for Gull Lake Formation in this area is olive and brown siltstone, typically with fine black laminations that are locally 'wispy', indicative of bioturbation. The thickness of the unit, everywhere structurally modified, is between 10 and 300 m.

Reference locality in the Mayo map area

A representative exposure of the Gull lake Formation is on a forested hill immediately west of a small lake seven km south of the outlet of Big Kalzas Lake (Locality ЄOG; Appendix 1). Near the outlet of the pond is a five-m cliff exposing breccia of beige-weathering, fine-laminated grey dolostone in a foliated black mudstone matrix, overlain by olive-coloured, parallel laminated mudstone, with rare planar cross-bedding and basal load-casts. The base is obscured by a thrust over the black slate of the Duo Lake Formation. Scattered outcrops at higher stratigraphic levels consist of mudstone with medium-bedded, brown chert or cherty argillite and black shale partings. A 2 m thick olive-grey limestone bed, containing sparse, centimetre-sized mudstone clasts and a 50 cm thick horizon of fine-grained, light grey quartzite, is high in the stratigraphic succession. This Gull Lake exposure is overlain by medium-bedded chert of the Duo Lake Formation but the contact is covered. The discontinuous exposures have an aggregate thickness of 150-300 m.

Other occurrences in the Mayo map area

The Gull Lake Formation is irregularly exposed by south-draining streams of the Clarke Hills. Most commonly it consists of light-brown-weathering khaki siltstone with interbeds of brown pyritic chert. Brown-weathering olive siltstone with black, thread-like laminae, in beds one to four cm thick, rims a syncline 11 km southwest of Mist Lake. Other localities are found northeast of Sideslip Lake, where grey, wispy laminated argillite and fine brown siltstone is up to 500 m thick; and north of the confluence of Sideslip Creek with the Kalzas River, where the Gull Lake Formation includes light grey argillite.

Figure 28. Maroon argillite (dark bands) interbedded with quartz metasandstone. View is straight down on steeply dipping beds; hammer point indicates top direction. The thickest sandstone bed is 30 cm wide. From the middle of section 2 (Fig. 13), 15 km west of Kalzas Twins.

Age and correlation

A single primitive conodont indicating Late Cambrian or Early Ordovician age (C-202221; Appendix 3) was recovered from the limestone near the top of the reference locality ꞒOG, seven km south of the outlet of Big Kalzas Lake. Although the age determination falls within the range of the Rabbitkettle Formation (Late Cambrian to Middle Ordovician), the dark colour and lithology match known Gull Lake Formation in eastern Lansing (Roots et al. 1995a), Niddery Lake (Cecile and Abbott, 1992) and Nahanni (Gordey and Anderson, 1993) map areas, where fossils are Early to Middle Cambrian. In northeast Niddery Lake, however, the Gull Lake Formation appears conformably overlain by the earliest Ordovician Duo Lake Formation, and there the Rabbitkettle Formation is absent (Cecile, in press).

Depositional Environment

The few sedimentary features observed imply the Gull Lake Formation was deposited below wave base as distal A-E turbidites (terminology of Walker, 1979). Wavy laminations suggest bioturbation, but feeding trails are not preserved.

LATE CAMBRIAN TO MIDDLE ORDOVICIAN

Rabbitkettle Formation (ꞒOR)

Light-grey-weathering, dark grey limestone and grit and siltstone — with a limy matrix which variably overlies the Gull Lake, Narchilla and Yusezyu formations and underlies the Duo Lake Formation — is correlated with the Rabbitkettle Formation (Gabrielse et al. 1973; Gordey and Anderson, 1993). The unit is represented by one discontinuous limestone belt and two widely separated exposures in the southern quarter of the map area.

Reference locality in the Mayo map area

A wooded limestone buttress projecting into a northeast flowing tributary three km southwest of Sideslip Lake (Locality ꞒOR) consists of medium-bedded, beige and light-grey-weathering, dark grey, fine crystalline limestone. A few beds of planar crossbedded limy siltstone are included. Although contacts with surrounding rocks are covered, the moderate south dip of the limestone appears to overlie adjacent, parallel-dipping grey slate (Gull Lake) and maroon argillite (Narchilla Formation) to the north. To the south, dark grey slate and argillite (Duo Lake Formation), is folded and locally overturned in the core of a syncline. This limestone layer can be traced seven km southeast, locally thickening to 120 m in isoclinal fold hinges, but typically 10-15 m thick. To the northwest the limestone is flanked by metasandstone and dark argillite; in the southwest, maroon argillite encloses the limestone. The limestone appears to unconformably rest upon Yusezyu and Narchilla rocks.

Other occurrences in the Mayo map area

Two other occurrences are correlated with the Rabbitkettle Formation. A 10-m thickness of dark grey, platy and thin-bedded, fine crystalline and silty limestone (Fig. 29) is exposed on the ridge crest two km east of Mist Lake. The unit, with wavy laminations and tight folds, lies between Yusezyu metasandstone and dark argillite of the Duo Lake Formation. The second occurrence, in rubble two km west of Mount Van Bibber, also lies on the approximate contact between Yusezyu and Duo Lake formations. At this locality the limestone is within the hornfelsed aureole of the McArthur pluton. It consists of distinctive, alternating purple and green calc-silicate, exactly like known Rabbitkettle Formation on Dromedary Mountain (S. Gordey, pers. comm. 1991) in northeastern Glenlyon map area. Rabbitkettle Formation is absent in the Clarke Hills where Gull Lake mudstone is directly overlain by the Duo Lake chert.

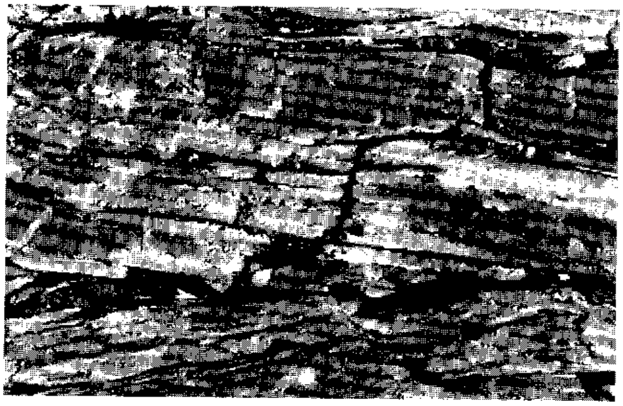


Figure 29. Sandy limestone, interpreted as Rabbitkettle Formation, in limb of isoclinal fold. Width of view is 30 cm. From two km east of Mist Lake.

Age and correlation

Specific age information is lacking for the occurrences of the Rabbitkettle Formation in the Mayo map area, although spicules indicating a Phanerozoic age were recovered at the reference locality (C-202229; Appendix 3). Carbonate units correlated with the Rabbitkettle Formation overlie Yusezyu Formation and other strata older than Duo Lake Formation is present to the northwest, northeast and southeast of the Mayo map area. The nearest dated outcrops of the formation are at Dromedary Mountain (Late Cambrian; S. Gordey, pers. comm. 1991) and between the Hess and Stewart Rivers in western Lansing map area (Late Cambrian or Early Ordovician; GSC-3000460 in Appendix 3). A belt of Rabbitkettle Formation in the northern Tay River map area (Gordey and Irwin, 1987) is probably continuous with a prominent white limestone above maroon argillite in the southeast Lansing map area (Blusson, 1974); this unit trends northwest toward Canoe Creek in the Mayo map area. To the west, in the northern McQuesten map area, calcareous (locally dolomitic) phyllite, marble and rare meta conglomerate correlated with the Rabbitkettle Formation have been traced around a northwest-plunging syncline (Murphy, 1997). The structures outlined by limestone at the reference locality and near Crooked Creek show similar form and vergence. In both Tay River and McQuesten map areas the Rabbitkettle carbonate disconformably overlies several older units. The sub-Rabbitkettle (Upper Cambrian) unconformity suggests a significant episode of erosion resulting in the widespread removal of Narchilla and Gull Lake strata from this part of the Selwyn Basin.

Depositional environment

The carbonate occurrences cited above are dominantly thin-bedded, silty limestone described by Gabrielse et al. (1973) and Gordey and Anderson (1993), who attributed a quiet water, off-shelf setting to the Rabbitkettle Formation. In Sekwi Mountain map area Cecile (1982) described abundant slope breccias, conglomerate and slump folds resulting from slope debris flows in the Rabbitkettle Formation.

ORDOVICIAN TO MIDDLE SILURIAN

Duo Lake Formation (Road River Group) (OSD)

Black and brown argillite, with lesser black and grey chert, dark siltstone and limestone in the southern third of the Mayo map area, comprise the Duo Lake Formation (Cecile, 1982). These rocks are recessive and vegetated, but chert-rich sections underlie ridge crests and spurs. In the absence of distinctive rock types and paleontologic control, the Duo Lake Formation in the Mayo map area is defined from the lowest chert bed in the succession up to the first occurrence of a distinctive Earn Group rock type (such as sandstone with chert clasts or chert pebble conglomerate). Duo Lake Formation is in covered contact with the Rabbitkettle limestone in one place (probably conformable) and in many places succeeds the Gull Lake Formation (arbitrary contact based upon lithology, but probably conformable); elsewhere the unit unconformably rests on Hyland Group. The presence of rare worm burrows and other bioturbation, as well as grey, blue and pink hues, distinguishes Duo Lake chert from Earn Group chert. The Duo Lake Formation comprises the lower Road River Group (Gordey and Anderson, 1993) and only two narrow belts of the upper part — the Steel Formation — were mapped within the Mayo map area.

Reference locality in the Mayo area

A Duo Lake succession is well-exposed on the main ridge northeast of Grey Hunter Creek (Locality OS$_B$; Appendix 1). The rocks are deformed into synclines and anticlines, making measurement difficult; however, several hundred metres of section are likely present. The formation conformably overlies the Rabbitkettle Formation. Thin-bedded black chert and cherty argillite with wavy bedding and load casts occur in the lower part. Upward in the succession the chert becomes medium-bedded and is succeeded by grey-weathering mudstone with rare, locally fossiliferous grey limestone beds or lenses between 1.5 and 3 m thick. The limestone exhibits fine laminae and trough crossbeds; it is characteristic of the middle interval of the unit. The upper half of the succession consists of white-weathering, thin-bedded black chert and recessive black-weathering, medium-bedded black chert with grey-weathering argillaceous interbeds. A sharp colour change from black shale to the overlying brown-weathering chert grit of the Earn Group (Fig. 30) is interpreted as a disconformable upper contact.

Other occurrences in the Mayo map area

Northeast of Sideslip Creek the Duo Lake Formation overlies the Gull Lake Formation. The lower half consists of cherty black argillite in 20 to 30 cm thick beds with mudstone partings; the upper half is orange and white-weathering thin-bedded black chert (2 to 4 cm beds) and is conformably overlain by green cherty argillite of the Steel Formation. In the Clarke Hills east-trending bands of the Duo Lake Formation consist of black and grey chert separated by black argillite and siltstone intervals. The chert is locally rust-stained from oxidization of diagenetic pyrite or blue as a result of chlorite alteration.

A ridge west of Mist Lake is underlain by a deformed and poorly exposed section of black chert beds six to ten m thick and abundant dark fissile shale. The contact with adjacent Narchilla Formation is covered. Assuming this to be the base, the section is at least 50 m thick, with a few metres of sooty black mudstone and conglomerate (Earn Group) at the top.

SILURIAN

Steel Formation (Road River Group) (Ss)

Rocks resembling the Steel Formation as described by Gordey and Anderson (1993) were noted in two places in the Mayo map area. A ridge crest north of Sideslip Creek (Locality Ss) contains a synclinal keel of white and light-brown-weathering, grey to khaki argillite and cream-weathering grey siltstone. Some thin beds are orange-weathering and probably ankeritic. This occurrence conformably overlies well-bedded chert of the Duo Lake Formation. The light-weathering green cherty siltstone closely resembles the Steel Formation in the southeast Lansing map area (Roots et al. 1995a, b).

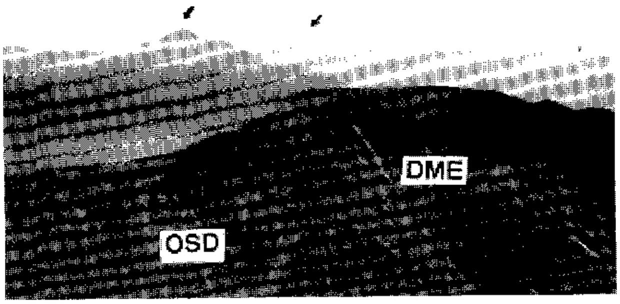


Figure 30. Looking southeast from Grey Hunter Creek toward Clarke Peak (1908 m; left arrow) and Crystal Peak in far distance (right arrow), both largely thick chert pebble conglomerate of the Earn Group. Foreground ridge contains black chert (Duo Lake Formation; OSD) unconformably overlain by light grey, chert-rich sandstone of the Earn Group (DME).

This syncline of Steel strata plunges east-southeast into the broad valley of Kalzas River and is correlated with a light-brown-weathering sandstone and grey-weathering argillite that continues eastward for 18 km. Exposures on ridge crests are 10-30 m wide and flanked on either side by cherty strata (probably Duo Lake Formation). Overlying Earn Group strata are not present.

Age and correlation of the Road River Group

Conodonts of Early to Middle Silurian age were collected from limestone seven km southeast of the lake at the head of Sideslip Creek (C-202240; Appendix 3). The Road River Group (initially a Formation by Jackson and Lenz, 1962) currently includes several off-shelf stratigraphic units of Ordovician and Silurian age. The Duo Lake Formation strata in the Mayo map area resemble rock types in the northern Misty Creek Embayment that are exclusively Ordovician in age (Cecile, 1992), although the correlative unit in Nahanni map area also includes Silurian rocks (Gordey and Anderson, 1993). The trend of Duo Lake exposures in southern Mayo map area extends southeast across the northeast corner of the Glenlyon map area (Campbell, 1967) and into central Tay River and Sheldon Lake map areas (Gordey and Anderson, 1987). A homotaxial unit to the northeast, in Lansing and Niddery lake map areas (Roots et al. 1995a) is the Elmer Creek Formation (Cecile, in press).

Depositional environment

The dark chert and shale was probably deposited in a quiet, oxygen-deficient, off-shelf setting. The chert is presumed to be biogenic but structural deformation has obscured or destroyed identifiable radiolarians. The lighter coloured mudstone and limestone in the middle of most successions suggests a shallow, more oxygenated environment with local influx of fine terrigenous sediments.

MIDDLE PALEOZOIC

Nogold unit (Provisional; PN)

This unit, not part of the established Selwyn Basin stratigraphy, was recently recognized and is incompletely studied within the Mayo map area. Provisionally restricted to strata surrounding the fossil localities which define it, the unit consists of chloritic grit (PNc), buff to brick-red argillite (PNm) and sandstone and quartzite (PNs) that form a crude sequence. In composition and metamorphism these rocks resemble the Hyland Group (with which it is in presumed contact) but the minor limestone occurrences have yielded broadly mid-Paleozoic microfossils. No younger unit is present atop the Nogold unit, and its basal contact with Yusezyu Formation is indistinct. Alternatively, a large area of Yusezyu Formation (whose age is unproven) may also be part of the younger Nogold unit.

Until further data is available the Nogold unit is restricted to rocks immediately surrounding the Paleozoic fossil occurrences on the southern side of Nogold Plateau (Localities PN1, PN2; Appendix 1) and a ridge crest east of Narrow Lake (Locality PN3). Rock types occur in the same sequence at the two localities on Nogold Plateau and are interpreted as south-verging, overturned, synformal keels, enclosed by the older Yusezyu Formation. All strata have a pronounced cleavage, steep dips and sheared contacts. The top of the Nogold unit is not recognized, but distinctive grey-weathering quartzite near the centre of the easternmost Nogold Plateau locality may be the highest preserved stratum. A thickness of about 325 m is estimated from half the exposed thickness at the least deformed western synform. On the plateau east of Narrow Lake a beige and grey-weathering fine-grained limestone, at least four m wide, contains possible foraminifera at two exposures 1.3 km apart. Surrounding rocks are grey to khaki-weathering, fine-grained siltstone superficially resembling Steel Formation. This occurrence is interpreted as a syncline among tight, upright, northwest-plunging folds with fine-grained sandstone, quartz-pebble conglomerate to the northeast, and maroon argillite attributed to Narchilla Formation on the southwest.

Lithologic description

The Nogold unit contains three characteristic rock types, which from presumed lowest to highest are: chloritic grit (PNc); maroon, buff, and brick-red argillite with minor limestone; and sandstone and quartzite (PNs). The chloritic grit is about 15 m thick and thickly bedded. Angular white and blue quartz and white feldspar chips are abundant in the soft, waxy-looking matrix. Some rocks contain irregular, centimetre-sized clasts of sheared chlorite and resemble flattened volcanic agglomerate. Zircons (extracted to investigate whether the chloritic matrix might have a volcanic component) were all detrital grains, but some are younger than Yusezyu Formation (598 and 690 Ma; Appendix 4).

Hematitic argillite (PNm) is the diagnostic rock type of the Nogold unit, but within it are several medium beds of quartz metasandstone and minor siltstone. Local and green iron reduction zones occur along fractures. At Locality PN3, two metres of green chert occur near the bottom, above the chloritic grit. The maroon argillite is lithologically similar to maroon argillite of the Narchilla Formation except that it contains at least four beds of light-grey-weathering, dark grey or black, fine crystalline limestone, each 1 to 25 cm thick, separated by 100 to 200 m of argillite. The argillite is strongly cleaved and may be so imbricated that the limestone occurrences are structural repetitions of the same bed. At the Narrow Lake occurrence, only one limestone bed, as much as four m thick, was encountered. It is similar in appearance but locally the weathering texture is suggestive of recemented algal blocks.

The quartz metasandstone layer is 5 to 50 m thick at the central Nogold Plateau locality. Fresh surfaces are grey and vitreous. Gritty quartzite contains 30% granules of blue and white quartz, 30% white feldspar and 5% pebbles of black argillite up to five mm across.

Age and correlation

Early Devonian to late Late Devonian fauna were recovered from a thin, dark grey limestone bed north of Nogold Creek (Locality PN1; Appendix 1). These include conical fragments with longitudinal and transverse markings suggestive of the cricocanarid genus *Nowakia* of Early to late Late Devonian age (C-203008/203013; Appendix 3). Spines, sponge spicules, sphaeromorphs, icthyoliths and tubes of indeterminate Paleozoic age were found in all other limestone samples. Both Narrow Lake limestone outcrops contain unidentifiable foraminifera.

Cricocanarid fauna are comparatively rare in the northern Cordillera. Specimens of *Nowakia* are abundant in the Siluro-Devonian Sapper Formation in the northeastern quadrant of the Nahanni map area (Gordey and Anderson, 1993). The succession is lithologically varied, but contains dark limestone, commonly argillaceous or silty. Fossil collections indicate that the Sapper Formation is diachronous from Late Ordovician to mid-Devonian age. To the north these rocks are included in the Road River Formation (Gabrielse et al. 1973).

Recognition of the Nogold unit is based upon discovery of middle Paleozoic fossils in rocks that would otherwise be mapped as Narchilla and upper Yusezyu formations. Thus it is possible that large areas currently mapped as Hyland Group also may be of middle Paleozoic age. Few grey or maroon argillite-dominated successions of middle Paleozoic age are known in the northern Cordillera. Some localities are discussed below.

The Craig property in the southern Nadaleen River map area, 140 km northeast of Mayo (Fig. 12) is underlain by a succession of thin-bedded light green chert, sandstone, grit, platy light grey to yellowish-weathering limestone, red and green shale and olive-grey argillite which appears to overlie Road River strata (Tempelman-Kluit in INAC, 1981; p. 225). A single agglutinated foraminifer indicates its Paleozoic age (M. J. Orchard, pers. comm. 1979). Although the Craig succession includes some rock types of the Nogold unit, but it has been interpreted as tectonically dismembered slivers of older Selwyn Basin stratigraphy by G. Abbott (pers. comm. 1992).

Middle to late Paleozoic gritty rocks occur in the Omineca and Kootenay ranges of British Columbia (B.C.). These include the Lay Range assemblage, correlative with the Earn Group (Ferri et al. 1992) in north-central B.C., and the Broadview Formation (Lardeau Group) of Middle Cambrian to Late Devonian age (Klepacki and Wheeler, 1985) in the Selkirk Mountains north of Nelson. Each of these units was previously believed to be of Proterozoic or Cambrian age. The question presented by the Nogold localities is: are the quartz-bearing gritty rocks structurally repeated slices of Hyland grit, or are they middle Paleozoic off-shelf facies equivalents of better-dated platformal clastic rocks? Additional fossils and better understanding of the contacts are required to evaluate the Nogold unit and its extent.

Depositional environment and interpretation of origin

Most fine sedimentary details have been obliterated from the Nogold unit. The argillite and quartzose sediment imply a shallow, oxygenated basin environment with periodic influxes from a terrestrial source. Early in its history the basin was subjected to sediment gravity flows from an area shedding coarse debris. The chloritic matrix and lumps in the breccia suggest mafic input but volcanic activity has not been demonstrated. The latest Proterozoic to Cambrian zircons reflect unknown igneous events. Subsequently fine terrigenous sediments were deposited to form the maroon argillite, followed by quartz sand and grit.

In broad terms this succession appears to be a reversed sequence of Selwyn Basin stratigraphy that could have resulted from sequential erosion of an uplifted scarp, successively exposing the Gull Lake, Narchilla and Yusezyu formations. If Narchilla and Yusezyu formations were the sediment source for the Nogold unit, it is not surprising that the two units have lithological similarities. Until contacts and internal features are better understood, other occurrences of middle Paleozoic maroon argillite and chloritic grit will remain unrecognized within the deformed Hyland Group rocks of Mayo and adjacent map areas.

MIDDLE TO LATE DEVONIAN

Earn Group (DME, DMp)

The Earn Group (Campbell, 1967; Gordey and Anderson 1993) is exposed in two areas in the Mayo map area. In the north and northeast, map unit DMp is penetratively deformed, consisting of carbonaceous phyllite, siliceous carbonaceous metasiltstone, rare calcareous greywacke, metaconglomerate and a felsic metavolcanic member. These rocks are mostly north of the Tombstone Thrust, but two lenticular exposures south of Tiny Island Lake may be interpreted as structural windows through the overthrust Hyland Group. In the Keno Hill area these same rocks comprise the Lower Schist formation of Boyle (1965) and Green (1971). A second belt (map unit DME), across the southern part of the map area, includes black siltstone, shale and chert, brown shale, siltstone, sandstone and grit, as well as chert pebble conglomerate. Neither belt presents a full stratigraphic succession, so the constituent formations of the Earn Group have not been defined.

In map areas to the south and east, rock types unique to the Earn Group include: 1) greyish blue-weathering, jet-black siliceous siltstone; and 2) grit to pebble-size conglomerate. Where these are present in the Mayo map area, the Earn Group is easily recognized. Large areas are underlain, however, by brown shale, siltstone and chert that could be part of either the Duo Lake Formation or Earn Group (especially where the intermediate Steel Formation marker unit is missing). For example, in the succession well-exposed north of Clarke Peak (see marginal notes of Bostock, 1947) both units are probably represented.

Contacts

In this region of sparse dating the base of the Earn Group was arbitrarily defined as the lowest chert pebble conglomerate bed. The contact is probably disconformable because the immediately underlying unit varies regionally: Duo Lake, Gull Lake and Yusezyu formations are locally scoured before Earn Group deposition. The top of the Earn Group and younger strata are not preserved in the southern belt. In the northern belt Earn Group phyllite is overlain by the Keno Hill quartzite and probable Jones Lake Formation, although contact with the latter is covered and intermediate units may exist. The Earn succession in the southern belt is at least 350 m thick. In the structurally imbricated northern belt stratigraphic thickness cannot be determined.

Reference locality in the southern Mayo map area

The Earn Group is well-displayed near Clarke Peak (Locality DME), although neither the top nor the bottom of the unit is clearly defined there. The section described by Bostock (1947) was visited. Near the approximate base, exposed on the slope south of Clarke Creek, fissile black mudstone contains interbedded lenses of sandy conglomerate and quartz sandstone. The conglomerate consists of a framework of rounded chert pebbles one to two cm in diameter, in grey silica cement that commonly weathers white (Fig. 31). About 150 m above the presumed base is white-weathering, thin-bedded grey and black chert, in beds two to four cm thick separated by one-cm-thick black mudstone. At this stratigraphic level are lenses of white limestone and local intraformational breccia cemented with orange-weathering barite. An upper Earn section is revealed in the north face of Clarke Peak (Fig. 30). Brown grit beds 20-30 cm thick with black mudstone interbeds are overlain by clast-supported conglomerate and grit containing well-rounded chert, white quartz and argillite clasts. The summit of Clarke Peak is massive conglomerate at least 60 m thick. The highest stratigraphic level, preserved on a southwestern dip slope, is beige sandstone and grit with white silica cement and unusual rock fragments such as pink chert.

Other occurrences in the Mayo map area

The southern belt of Earn Group rocks is characterized by conglomerate, sandstone and grit. Greyish blue-weathering black siliceous siltstone is notably absent. Typically brown, medium-bedded, fine- to medium-grained arenite contains occasional angular fragments of black mudstone and green argillite. Interbeds of black fissile argillite with worm-burrowed surfaces are 20-60 cm thick. Close to the intrusive rocks in the McArthur Mountains and as pendants within them, the Earn Group rocks are black slate and hornfels, spotted with chlorite and andalusite porphyroblasts.

In the northeastern Mayo map area the Earn Group contains abundant greyish blue-weathering siliceous slate as well as carbonaceous phyllite, siliceous metasiltstone, metaconglomerate and greywacke with a high proportion of chert fragments. Deformed chert pebble meta-conglomerate, probably near the base of the succession, is up to 40 m thick and consists of dark grey to black chert (?) and argillite clasts which have been tectonically flattened to 10 cm wide but less than 1 cm thick. Large, undeformed, equant, well-rounded scattered clasts of fine-grained quartz sandstone are scattered locally in the dark-brown-weathering, medium grey to black slate. Two mineral occurrences, one of pure laminated barite, the other of barite, quartz and pyrite, were found in the black slate (Gordey, 1990a). The three diagnostic elements — the carbonaceous slate, chert-bearing clastic rocks, and stratiform barite — indicate that these highly deformed rocks are part of the Earn Group.

Felsic metavolcanic member (DMv)

On the basis of float and a few outcrops, the foliated quartz-sericite-chlorite phyllite, lesser quartz augen phyllite and minor carbonaceous phyllite

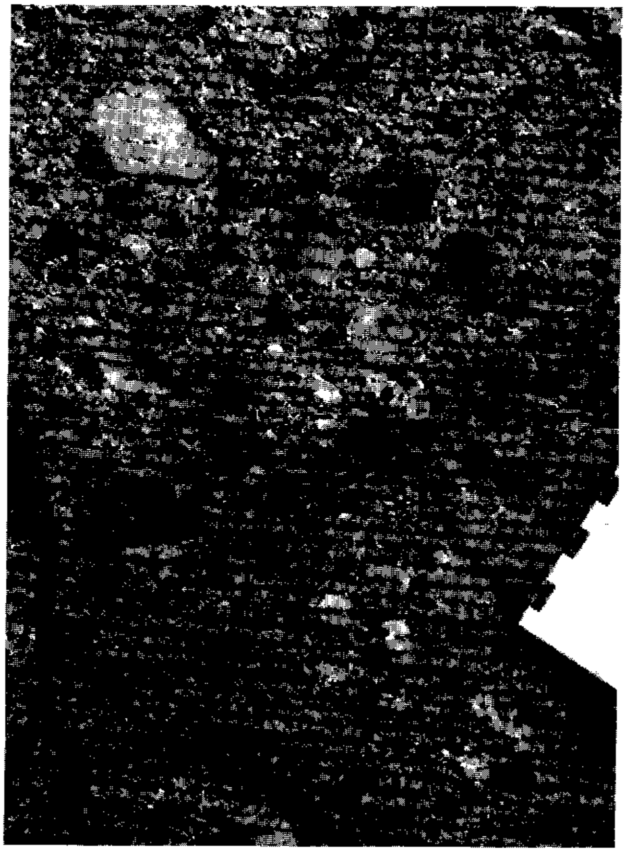


Figure 31. Conglomerate of the Earn Group in the southern part of the map area, containing chert pebbles among angular chert chips in silica cement. From a south-facing, ridge crest outcrop eight km northeast of Clarke Peak.

define a layer exposed across the north-facing slopes of Mount Haldane, Galena Hill and Keno Hill (Hunt et al. 1996; Murphy and Roots, 1992). The layer is at or near the top of the Earn Group strata. This member was formerly referred to as green sericite schist by McTaggart (1960), Kindle (1962) and Boyle (1965). The felsic metavolcanic member extends northeast through the Patterson Range and north of Tiny Island Lake, and mostly consists of chloritic quartz-feldspar augen phyllite (Abbott, 1990b; Gordey, 1990b; D. Murphy, pers. comm. 1992) within black phyllite and siliceous slate of the Earn Group. Chloritic phyllite is waxy green and is distinguished from enclosing rocks by light orange-weathering. The defining characteristic of the felsic metavolcanic member is local concentrations of quartz and less commonly quartz and feldspar phenocrysts in the phyllite. Although superficially the phenocrysts resemble detrital granules, close examination and thin sections reveal embayments, reaction rims and beta-quartz morphology (Fig. 32) indicating the primary igneous protolith. In the Patterson Range the phenocrysts reach one cm in size and are locally interlocking, suggesting an intrusive origin.

The felsic metavolcanic member ranges from several metres to hundreds of metres thick, and is internally deformed. The largest exposure is four km wide, within black siliceous slate north of Tiny Island Lake.

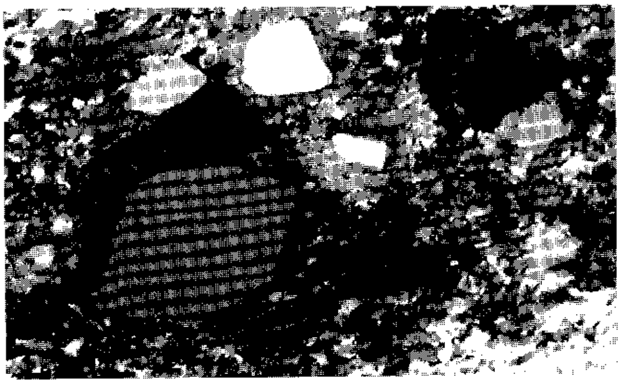


Figure 32. Photomicrograph (plane light) of quartz-feldspar augen phyllite (Earn Group felsic metavolcanic member) showing a euhedral quartz phenocryst (1.2 mm long) surrounded by a silica reaction rim and irregular quartz grains in clay-altered (devitrified?) matrix. From six km north of Tiny Island Lake.

Age and correlation of the Earn Group

A single Early Devonian brachiopod was found four km west of Clarke Peak (GSC-203017; Appendix 3). This is the only paleontologic evidence from this unit in the map area; however, the southern belt trends southeast into the Glenlyon map area, where many collections range from Early to Late Devonian and Early Carboniferous (Campbell, 1967; S. P. Gordey, pers. comm. 1991). Clarke Peak is one of several prominent pyramid-shaped (when viewed along structural trend) peaks underlain by a substantial thickness (60 m or more) of chert pebble conglomerate; others include Crystal Peak (Glenlyon map area), Mount Menzie (Tay River map area), and (in a different belt, to the east) informally named Mount Aho and Gnome Dome in the Lansing map area.

In the northern belt, primary igneous zircons have been recovered from this highly deformed chloritic quartz-eye phyllite in the Patterson Range (DM-91-78; Appendix 4) and north of Tiny Island Lake (GGA-89-137, 157; Appendix 4). The U-Pb dates range from 373 to 380 Ma, indicating Middle Devonian volcanism. In at least three localities between Macmillan Pass and Fairweather Lake (southwest Lansing map area) mafic flows and hyaloclastic breccia in lenses 1-70 m thick occur near the base of the Earn Group (Abbott and Turner, 1990; Cecile and Abbott, 1992; Roots et al. 1995a). Mississippian felsic volcanic rocks in the Pelly Mountains (Cassiar Platform) host volcanogenic massive sulphide (MM prospect; Mortensen and Godwin, 1982) and metavolcanic successions of this age throughout the Yukon have recently become the focus of base metal exploration (Hunt, 1997).

Depositional environment

The dark coloured sedimentary rocks imply deep-water off-shelf deposition punctuated by coarse clastic input. In the central Yukon the Earn Group is westerly derived (Gordey et al. 1987) from uplifted blocks of Selwyn Basin stratigraphy. The Tiny Island Lake area and the central Lansing map area (Gordey and Anderson, 1993; Roots et al. 1995a) are places where lower Paleozoic strata have been eroded and the abundance of chert clasts in conglomerate reflect a Road River provenance.

Near Macmillan Pass pre-Middle Devonian boundary faults are inferred on the basis of abrupt facies and thickness changes; these scarps supplied conglomerate to an adjacent confined depression (Abbott, 1982; Bailes et al. 1986; Abbott and Turner, 1990). This model could explain the local conglomerate thicknesses of the southern belt and its southeastern extension. Alternatively, because Earn Group sediments in this region generally show southeastern transport direction (Gordey et al. 1987), spaced conglomerate accumulations might have resulted from a submarine channel trending southeast across the area. Thin conglomerate beds within the broad area of shale deposition could be overbank deposits on the broad submarine fan traversed by the main channel.

The felsic metavolcanic member has a wide distribution (about 42 km of discontinuous exposure from Tiny Island Lake to the Patterson Range) with only slight compositional variation. It is unlikely to be pyroclastic airfall since such deposits typically contain abundant broken phenocrysts (Fisher and Schminke, 1984). This suggests regional-scale pyroclastic flows from a felsic dome (intrusive) comprise the felsic metavolcanic member, although laterally extensive submarine felsic flows (Cas, 1978) cannot be discounted.

EARLY CARBONIFEROUS

Keno Hill quartzite (MK)

Massive to well-foliated and lineated quartzite with lesser phyllitic quartzite, chloritic and carbonaceous phyllite and minor limestone and metavolcanic rocks comprise the Keno Hill quartzite (Green, 1971, 1972). The unit is of major economic significance because fractures within it host the bulk of the argentiferous galena veins comprising the Elsa-Keno Hill mining camp, and a volcanogenic massive sulphide prospect. Thick, dark grey to black quartzite is the highly distinctive rock of this unit.

The Keno Hill quartzite trends across the northern Mayo map area, reaching a map width of 20 km southeast of Keno Hill where it is exposed within the Mayo Lake antiform. It is also discontinuously exposed in the northwest corner of the map area on the north-dipping flank of the McQuesten antiform. The quartzite is susceptible to frost fracture and lichen encrustation, resulting in steep cirque headwalls and slopes of black rubble. Good exposures have been created by stream canyons and mining. The iron-stained walls of abandoned open pits on Galena Hill reveal compositional layering and rarely visible meso-scale folds. The layers are produced by transposed bedding and pressure solution-enhanced foliation.

The term "Keno Hill quartzite" is well-established in the literature, despite the lack of a formal description. On Keno and Galena hills the unit is highly deformed. Structurally modified sections are described in detail as the Central Quartzite and No. 9 Quartzite (Boyle, 1965) although these sections are now considered part of the same unit, exposed by separate nappe-like folds or thrust sheets (Roots and Murphy, 1992). The best stratigraphic description available comes from near Tombstone Mountain (Tempelman-Kluit, 1970) north of Dawson. Throughout the Mayo map area the degree of internal deformation precludes measurement of its true thickness or description of a stratigraphic type section. Accordingly, the formation status of this unit remains informal, but the quotation marks are omitted for brevity.

Contacts and thickness

Throughout the Mayo map area the Keno Hill quartzite is well-foliated and lineated; stratigraphic details, including contacts, have been obliterated. Underlying this unit are carbonaceous phyllite or quartz-chlorite phyllite schist correlated with the Earn Group (Abbott, 1990a).

The Keno Hill quartzite is structurally overlain by well-foliated waxy phyllite, metasandstone, grit and limestone of the Yusezyu Formation in the hanging wall of the Robert Service thrust. The contact is difficult to map because of the degree of deformation, but its spatial distribution suggests that the Robert Service Thrust is folded. The cross-strike alternation of rock types assigned to the Keno Hill quartzite, and Yusezyu Formation occurring above the Keno Hill quartzite, led early workers to conclude that grit overlay the Keno Hill quartzite conformably, or that the Keno Hill quartzite passed transitionally upward into the grit unit.

Variations in the thickness of the Keno Hill quartzite result from internal folding and imbrication (e.g. Green and McTaggart, 1960) and internal facies transitions (Abbott, 1990a). Boyle (1965) measured a 900 m thick section on Galena Hill and Green (1971) measured a 1134-m-thick exposure north of the Mayo map area. Internal isoclinal folding and possible low-angle (with respect to bedding) thrust faults exist in these sections, although distinctive homoclinal sequences (such as the 250 m thick Hector-Calumet member of Boyle, 1965, p. 22) can be traced up to 10 km along strike. In the stratigraphic type area near Tombstone Mountain, two partial sections have an aggregate thickness of 531 m (Tempelman-Kluit, 1970).

Reference localities in the Mayo map area

Open-pit exposures at the Galkeno, UN, Hector-Calumet and Bermingham mines on Keno Hill best illustrate this unit. Massive quartzite with parting joints (2 to 5 m apart) is interspersed with carbonaceous phyllite containing thinly-parted quartzite, and some calcareous sandy phyllite.

The quartzite is dark grey or grey, finely crystalline to vitreous, siliceous rock. In some places lenses of gritty quartzite contain feldspar grains in a dark argillaceous matrix. Many exposures reveal fine to broad dark bands (Fig. 33). Rare cross-stratified banding is clearly of sedimentary origin. More commonly the banding is compositional and straight or streaky. It results from the segregation of individual dark minerals (graphite and iron oxide) by pressure solution (Fig. 34). Cherty quartzite, as well as blebs and veinlets (locally folded) of white quartz, are repositories for silica dissolved by pressure solution as foliation formed (Fig. 35). Carbonaceous phyllite occurs in lenses within the quartzite and as parallel partings between thick quartzite layers.

Other occurrences in the Mayo map area

Fine-grained dark-grey-weathering quartzite and interbedded carbonaceous phyllite, in layers varying in thickness from a few centimetres to more than 20 m, are present from Mount Haldane across the map area to Tiny Island Lake. The proportion of carbonaceous and chlorite phyllite is greatest near Keno Hill and in the Patterson Range, where the unit consists of subequal proportions of black slate and black quartzite (Abbott, 1990a). Typically the phyllite component is black and scaly with lenticles of quartz (Fig. 36).

Light-weathering powdery sandstone, exposed on a spur 1.2 km southeast of Mount Albert and in other places, is composed of individual quartz grains about two mm across. These 'crush breccias' (Green, 1971, p. 27) may have originated from thin-bedded impure quartzite that contained bands of fine-grained quartz from which the silica cement was removed by hydrothermal alteration. The quartz grains are separated by graphitic partings which are easily weathered.

Grey- to buff-weathering black limestone about three m thick occurs on Mount Albert, near the top of the Keno Hill quartzite. Carbonate at approximately the same stratigraphic horizon is exposed at the head of Duncan Creek and on Sourdough Hill. Some quartzite beds are calcareous, with up to 10% recrystallized calcite (Fig. 37).

Metavolcanic member

Chlorite phyllite containing densely packed quartz and feldspar phenocrysts (Fig. 38) is separately mappable in the Patterson Range (Green, 1971, unit 8a; D. Murphy, pers. comm. 1992) and can be traced northeast to 1.5 km north of the map area at the Marg prospect. There the 'Marg sequence' consists of interleaved massive quartzite and lesser slate with abundant buff- and green-weathering tuffaceous and metavolcanic rocks (Turner and Abbott, 1990). These rocks may be correlative with chloritic phyllite on Keno Hill that is completely infolded with quartzite but lacks quartz phenocrysts. West of Elsa the chloritic phyllite is locally intercalated with dolomitic carbonate and carbonaceous bands.

Petrography and composition

Thin sections of quartzite reveal a mosaic of quartz grains with some chert and stretched quartz particles. Grains range from 0.25 to 0.5 mm in diameter and have sutured boundaries. Within some grains, the pattern of minute opaque inclusions is suggestive of primary grain with metamorphic overgrowth. Between the grains are microscopic carbon platelets as well as accessory white mica, tourmaline and sphene, typically oriented parallel to metamorphic banding. The sutured grains and carbon films result

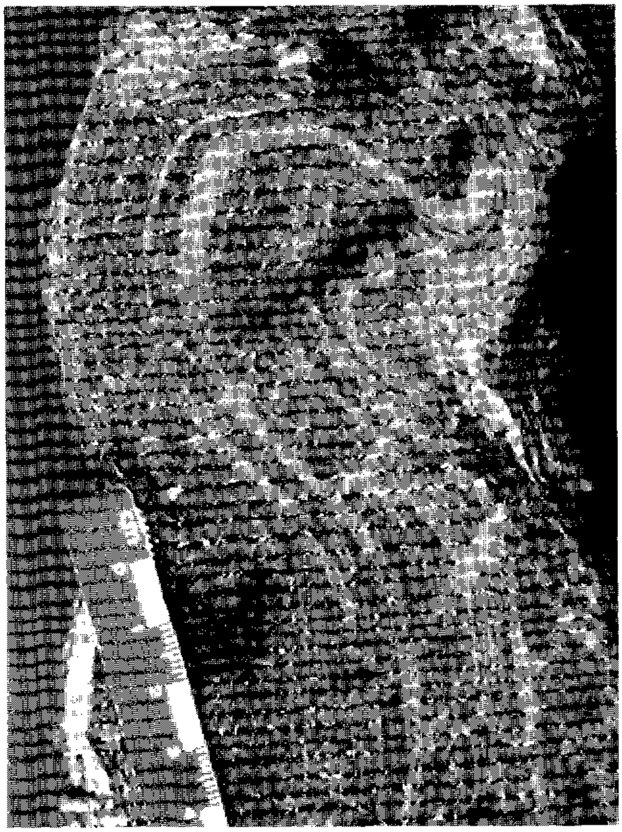


Figure 33. Minor disharmonic fold in Keno Hill quartzite. Lighter bands are quartz-rich segregations that only approximate original bedding. From north rim of Keno Hill; 200 m from Lucky Queen mine shaft.

Figure 34. Photomicrograph (plane light) of vitreous grey Keno Hill quartzite. The mosaic of polygonal quartz grains are separated into lenticular domains by thin, irregular and anastomosing sheets of opaque carbon, iron oxide and mica, interpreted as insoluble residue of pressure solution. Bar is 1 mm long; from 500 m east of Keno Hill summit.

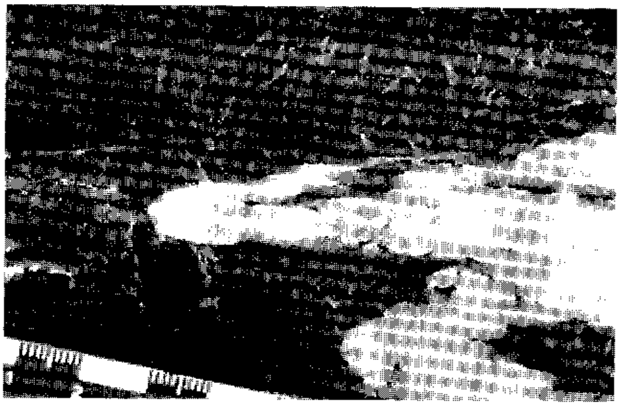


Figure 35. Carbonaceous Keno Hill quartzite, showing faint parallel cleavage lamination, contains excess silica (white), probably derived from pressure solution. From the waste dump at Silver King mine, northwest flank of Galena Hill.

from volume reduction and the loss of some rock constituents, much like stylolites in deformed carbonate rocks. In the case of quartzite the dark bands are foliation and not primary sedimentary layering.

Boyle (1965, Table 19; reproduced in Green, 1971, p. 26) gives six composite analyses of quartzite of varying purity. These analyses represent the products of metamorphism and are a poor indication of primary sediment composition.

Age and correlation

Interpretation of the age of Keno Hill quartzite changed as regional studies added new information. Early workers considered it Precambrian. Tempelman-Kluit (1970) inferred a Late Cretaceous age based upon an apparently conformable succession of Triassic and Jurassic strata beneath the Keno Hill quartzite in the Tombstone area. Blusson (1978) deduced the Late Paleozoic age from structural considerations and correlation with Alaskan strata of this age, similarly intruded by metadiorite sills.

Figure 36. Carbonaceous phyllite with lenticles of quartz in the plane of foliation, near the top of the Keno Hill quartzite. From the waterfall on Duncan Creek, about 300 m upstream from its confluence with Lightning Creek. This was the site of the first gold discovery in the area, in 1898.

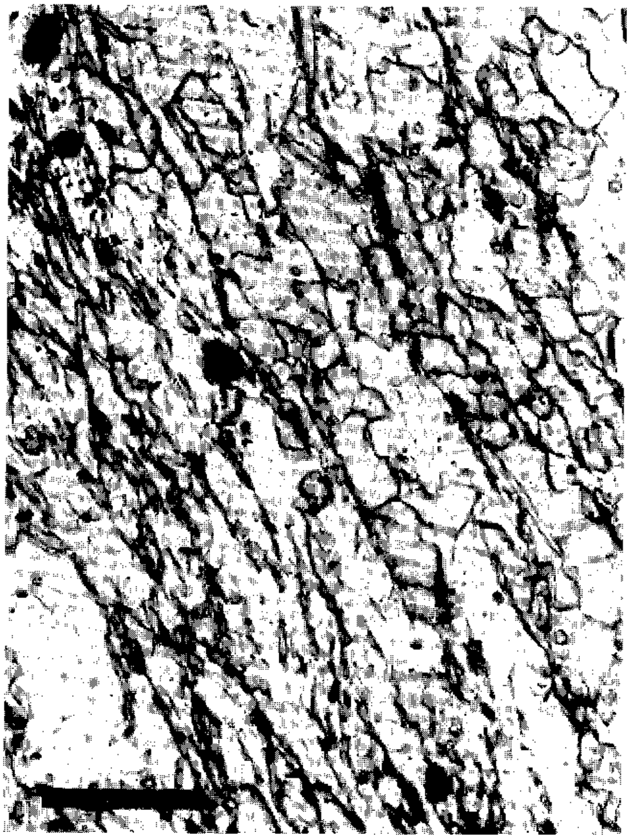


Figure 37. Photomicrograph (plane light) of calcareous quartzite showing recrystallized quartz (q) and calcite (c; higher relief, banded), among scattered platelets of greenish mica and iron oxide (dark blotches). Bar is one mm long. Rock collected atop Keno Hill, near the tourist signpost.

Conodonts of Viséan-Serpukhovian (Early Carboniferous) age (M. Orchard, pers. comm. 1986; Orchard, 1991) were recovered from a limestone lens within the Keno Hill quartzite about six km west of the Dempster Highway (at the North Klondike River bridge). From correlative strata in northeast Niddery Lake map area numerous conodont collections (Cecile, in press), ranging between early to Middle Tournasian and Late Bashkirian (formerly Namurian), have been gathered. Zircons extracted from the Marg sequence (northeast of the map area) provide a broad Late Devonian-Early Carboniferous date (J. Mortensen, pers. comm. 1992).

The Keno Hill quartzite belongs to a regional belt of Carboniferous sandy strata exposed nearly continuously from the Nahanni map area (informal Tsichu formation; Gordey and Anderson, 1993) northeast Niddery (1180-m-thick Tsichu Group; Cecile, in press) and the Macmillan Pass district (Cecile and Abbott, 1992), through Keno Hill to the Tombstone area (Tempelman-Kluit, 1970; Thompson et al.

Figure 38. Metavolcanic member in the Keno Hill quartzite. The densely packed quartz and feldspar phenocrysts in a foliated chloritic matrix superficially resemble Yusezyu gritty rocks (G. Abbott, pers.comm. 1991). From ridge crest one km southeast of the southern high point, Patterson Range.

1992). Truncated by the Tintina Fault, the southwestern correlative may be the Globe unit (Weber et al. 1985), a grey, bimodal vitreous quartzite interleaved with sheared argillite and intruded by numerous hornblende-bearing quartz diorite sills in central Alaska. Similar quartzite occurs in the Rampart Group (Brosgé et al. 1969) and Wickersham terrane (Dover, 1994, p. 161).

Depositional environment

The Keno Hill quartzite is highly strained in the Mayo map area and most sedimentary features have been obliterated. Protoliths were probably sandstone and black shale. In the Tombstone area the Keno Hill quartzite contains non-marine plant remains and gastropods, reflecting a shallow, well-aerated environment with littoral sand, such as longshore bars (Tempelman-Kluit 1970, p. 31). Detrital zircons recovered from the quartzite yield a variety of ages (J. Mortensen, pers. comm. 1995) that indicate a heterogeneous source and probably multiple sedimentary cycles.

TRIASSIC TO JURASSIC

Jones Lake Formation (TRJps)

The youngest strata of the Mayo map area are recessive dark-brown- to light-grey-weathering, friable slate, sandy slate and dark grey fine crystalline limestone in the northeast corner. These strata are coeval with the Jones Lake Formation (Gordey and Irwin, 1987; Gordey and Anderson, 1993) although rock types differ from the type area. Only three exposures have been examined in the Mayo map area.

Structurally disrupted calcareous phyllite and cleaved medium grey argillaceous limestone occurs between the Beaver and Keno-Ladue rivers (Gordey, 1990a). No contacts are exposed, but nearby exposures in all directions are dark grey slate of the Earn Group. The second exposure, near the mouth of the Ladue River, consists of greenish slate and calcareous sandstone. Northeast of the Beaver River grey friable slate, sandy shale and sandstone are exposed (Bostock, 1947).

Adjacent areas and age

The belt of outcrops described above extends northwest into the Nash Creek map area, where it includes recessive black shale, buff-weathering calcareous, micaceous siltstone and lesser ripple cross laminated and plane parallel laminated calcareous sandstone and argillaceous limestone (Unit TRJps; Abbott, 1990a, b). This succession overlies a quartzite-bearing sequence thought to be equivalent to the Keno Hill quartzite. Silvery buff to grey-weathering, non-calcareous grey shale that is interbedded with, or overlies, unit TRJps may be Jurassic (Abbott, 1990a).

Triassic rocks occur along structural trend in Lansing map area. The subdued topography surrounding the Lansing Range and canyon of Murray Creek is underlain by cross-laminated calcareous and argillaceous sandstone containing Triassic conodonts (Roots et al. 1995b). Farther east, Early Triassic conodonts and ammonites (M. Orchard, M. Cecile, pers comm., 1995) occur in grey-weathering limestone pods among sandstone on the same trend in the Niddery Lake map area. This belt extends discontinuously southwestward to Jones Lake in Nahanni map area, where the formation is 750 m thick (Gordey and Anderson, 1993).

Depositional environment

Ripple cross-laminated sandstone and the calcareous nature of the Jones Lake Formation indicate a shallow marine shelf environment, swept by oscillating currents (Gordey and Anderson, 1993).

Intrusive Rocks

Mafic Intrusions

*Metadiorite to gabbro in the Tombstone Thrust sheet (*Td*)*

Numerous grey-green bodies of metamorphosed mafic igneous rocks occur within the Keno Hill quartzite and Earn Group on the north slopes of Mount Haldane, Galena and Keno hills, as well as in plateaus surrounding the east arm of Mayo Lake and in the Patterson Range. The bodies are tabular, and are up to 50 m thick and 4 km long. In the isoclinally deformed Keno Hill area, some bodies resemble mega-boudins and lozenges elongated along the plunge of fold axes.

Where not recrystallized the intrusions range from augite diorite to less common feldspar-phyric pyroxene gabbro. The rock is coarse-grained in thick bodies and fine-grained in intrusions less than two m thick. In most areas, however, mafic minerals are replaced by chlorite and sausserite. On the north side of Keno Hill, medium-grained metadiorite contains 30% acicular chlorite, pseudomorphous after hornblende.

In thin section, the foliated diorite consists of slightly rounded hornblende, locally zoned but now largely saussceritized, and tabular plagioclase laths mainly replaced by clay minerals and zoisite. Blue green pleochroic hornblende and fibrous actinolite are distributed throughout the matrix.

Other areas and age

In the Tombstone area of the southern Ogilvie Mountains, Tempelman-Kluit (1970) recognized that the dozen or more separate, sub-parallel diabase sills were structural repetitions of a single body intruded into a black slate interval within the Keno Hill quartzite. Zircon and baddelyite extracted from the granophyric top of the body yielded a U-Pb isotopic date of 232 +1.5/-1.2 Ma (latest Middle Triassic; Mortensen and Thompson, 1990). Metadiorite in the Keno Hill area is considered to be of similar age.

Metadiorite and peridotite in the Robert Service Thrust sheet (d_1)

Mafic intrusions are sparse within the Hyland, Road River and Earn groups. They lack topographic expression and distinctive weathering characteristics, so that their presence is only known where directly encountered during widely spaced traverses.

Slightly foliated, serpentinized peridotite occurs in two northeast-trending, 5 m wide dykes in Yusezyu phyllite five km east of Roop Lakes (Gordey, 1990a). Medium- to coarse-grained enstatite is partly replaced by talc, and olivine is replaced by serpentine in the peridotite (Green, 1971; p. 36).

A two-m-wide, medium-grained diorite dyke consisting of about 60% actinolite and 40% plagioclase occurs seven km south of Lonely Dome. The alteration envelope, several metres thick, consists of bleached-white Yusezyu metasandstone with disseminated pyrite grains and 1 mm chlorite spots. Hilltops southeast and northwest of the outlet of Moose Lake expose 4 m wide dikes of chloritic diorite with good diabasic texture, and a plug of biotite gabbro at least 6 m wide is at the latter locality. Ridges south of Haggart Creek in the northwest corner of the map area also contain numerous diorite dykes (W. Poole, unpubl. data, 1964; Murphy, 1997).

The age of these bodies is unknown. Mafic volcanism in the northern Cordillera occurred in Late Proterozoic (e.g. Mount Harper complex; Roots and Parrish, 1988), Middle Cambrian to Ordovician (e.g. Old Cabin Formation; Cecile, in press, and Marmot volcanics; Cecile 1982), and Early-Middle Devonian (Macmillan Pass Member; Abbott and Turner, 1990) time, as well as during the Triassic in the Tombstone thrust sheet (Mortensen and Thompson, 1990).

Granitic Rocks: Tombstone Intrusions (KT)

A batholith (McArthur), five stocks and biotite felsite comprise about 3% of the map area. Four new U-Pb isotopic dates are presented (Appendix 4). Formerly considered part of the Selwyn Suite (Woodsworth et al. 1991), numerous intrusions along the northern rim of Selwyn Basin are being redefined according to narrow age ranges. All those in the Mayo map area are embraced by the Tombstone Intrusions (90-95 Ma; J. Mortensen, pers. comm. 1995; Murphy, 1997).

White- and light-grey-weathering, leucocratic granite, quartz monzonite or granodiorite are ubiquitous; only the Roop Lakes and Two Buttes stocks contain a later, porphyritic phase. Feldspars are typically unaltered but hornblende is partly or entirely converted to biotite, and in some rocks the biotite is altered to chlorite. Accessory minerals include magnetite, pyrite, sphene, apatite, titanite and zircon.

McArthur Batholith

The McArthur Mountains are underlain by quartz monzonite and granodiorite that extends 60 km along the northeast side of the Tintina Trench, from the southeastern McQuesten map area across the southwestern Mayo map area and into the northern Glenlyon map area. The batholith is up to 12 km wide and contains large pendants of slate and indurated siltstone. Such contact-metamorphosed rocks comprise Black Ram and Grey Hunter peaks (Fig. 39). Intrusive contacts are steep along the south side, but commonly are gently inclined on the northwest side (Fig. 40). The combination of inclined contacts and incised topography contributes to its irregular map outline.

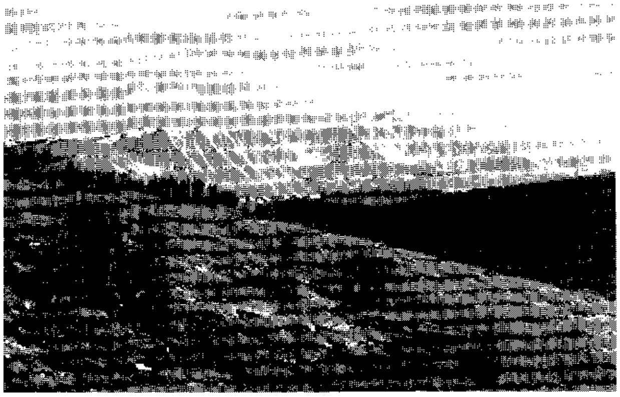


Figure 39. Grey Hunter Peak (2057 m) in the McArthur Mountains, is a pendant of argillite and siltstone (Earn Group?) within jointed granite. View southward from Nogold Plateau.

Medium-grained granodiorite is very common and extends to the outer contact in many places. A fine-grained phase surrounds, and aplitic veins occur within, the central pendants, and both are well exposed north of Black Ram Peak. The pendants suggest that the present level of exposure intersects the undulating roof of the intrusion.

The contact metamorphic aureole is up to three km wide. On the southeast side metasandstone is converted to a purplish black hornfels. On the northeast side, andalusite porphyroblasts (2-20 mm long) and chlorite spots are present in slaty rocks (Fig. 41), and fine examples are found among stream boulders where Nogold Creek flows northward.

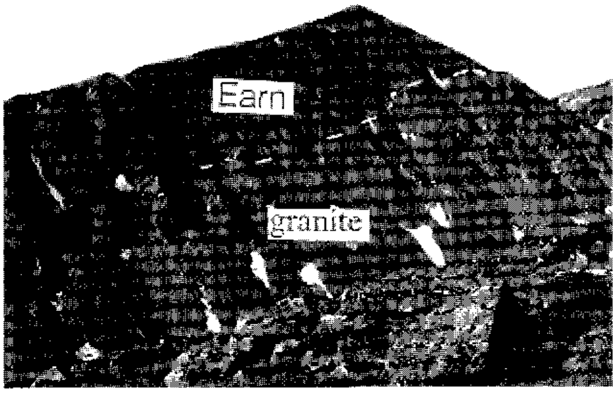


Figure 40. Inclined upper contact of McArthur pluton, southwest of Grey Hunter Creek. Intruded Earn rocks are iron-stained.

Figure 41. Chloritic spotting and siliceous alteration fronts in metasiltstone. White blocks in scale bar are one centimetre. Near the Sideslip mineral occurrence north of Grey Hunter Creek.

Diopside and pyrrhotite skarn occur where thin Rabbitkettle limestone lies adjacent to the intrusion in upper Grey Hunter Creek.

Composition and age

No coarse-grained or megacrystic phase was observed. The medium-grained phase is a biotite hornblende quartz monzonite to granodiorite containing 20% quartz (clear, 3-5 mm), 60% plagioclase (white, interstitial), 7% alkali feldspar (cream-coloured phenocrysts to 1 cm), 10% biotite (black two mm across) and 2% hornblende (clusters to 0.7 mm). Yellow saccharoidal alaskite north of Grey Hunter Peak contains 2% quartz phenocrysts (clear, rounded), 10% hornblende and minor yellow tourmaline.

McArthur Batholith differs from other Tombstone Intrusions in three respects: it is more southerly than the main trend; it lacks the smooth elliptical outline, and it is the only intrusion which contains numerous mappable sedimentary xenoliths. These features of the McArthur Batholith resemble the Anvil Batholith, 75 km southeast and similarly parallel to the Tintina Trench. In composition and age, however, the similarities end. The Anvil Batholith is a two-mica monzogranite to transitional hornblende-biotite granodiorite (Pigage and Anderson, 1985) about 105 Ma (J. Mortensen, pers. comm. 1995). The McArthur batholith is 94.0 ±0.3 Ma on the basis of three zircon and one monazite fractions (RAS-91-57B; Appendix 4) and its composition is also typical of the Tombstone Intrusions.

Roop Lakes stock

All other plutons in the Mayo map area are circular or elliptical, and have steep margins and topographic expression that mainly result from the greater resistance of surrounding contact-metamorphosed host rocks. All the granitic intrusions are unfoliated and fresh-looking. Most of the intrusions are medium-grained.

The 100-sq.-km elliptical stock centered on Roop Lakes clearly crosscuts the Robert Service Thrust, intruding both the Keno Hill quartzite and the Hyland Group. Two plugs of biotite quartz monzonite eight km to the southeast, together with the four-km-wide aureole and elongated aeromagnetic low, suggest that the intrusion extends southeasterly at relatively shallow depth. The long axis of the pluton aligns with the hinge of the southeast-plunging Mayo Lake Antiform, although their genetic relationship is speculative.

The contact locally is a 100-m-wide zone of aplite and pegmatite dykes (Green, 1971) in quartz phyllite. Sillimanite schist at the contact grades outward to staurolite-feldspar schist, and more distally to biotite-muscovite schist at low elevations and garnet-andalusite schist at high elevations (Lynch, 1989a).

Composition and age

The marginal phase is quartz diorite to quartz gabbro with abundant chloritized hornblende. The main phase is medium-grained granodiorite with lesser quartz monzonite. Up to 10% of the rock is fresh biotite; less common hornblende is up to 15 mm long. Green (1971, p. 45) described one specimen in which plagioclase was completely altered to scapolite. Two areas near the centre of the Roop Lakes pluton are underlain by porphyritic phase. Up to 40% alkali feldspar phenocrysts up to two cm long, as well as hornblende and sphene, are present (Green, 1971). Three analyses of composite samples in Boyle (1965, p. 257; also in Green, 1971, p. 44) give the average composition for this pluton (referred to as the Mayo Lake batholith).

The Roop Lakes pluton is 92.8 ±0.5 Ma by U-Pb on titanite (#284; Appendix 4) and appears to contain inherited zircon. The small stock southeast of the main body gave an 81 Ma cooling date by K-Ar on fresh biotite (#66-81; Stevens et al. 1982).

Two Buttes trend

Three plugs, ranging from 0.2 to 5 sq. km, are respectively known as Canoe Creek, Highland Lake and Two Buttes, and an aeromagnetic low northeast of Mayo could reflect the shallow presence of another (D. Teskey, pers. comm. 1993). The plugs consist of unfoliated biotite quartz monzonite, vertically intruded into quartz and chlorite phyllite of the Hyland Group. The sharp contact is broken by fine-grained apophyses extending out along the foliation. Small schistose xenoliths are in the granite near the contact. Adjacent chlorite-plagioclase muscovite phyllite contains garnet and biotite porphyroblasts and purplish hornfels (possible cordierite?) is common. At Two Buttes an irregular carbonate horizon, converted to diopside skarn, has been the focus of tin-tungsten exploration. Scattered exposures of felsite containing 10% transparent quartz phenocrysts and biotite lie west and north of the Two Buttes.

Composition and age

The Two Buttes granodiorite comprises 30% quartz (clear, 2 x 4 mm), 50% plagioclase (white, interstitial), 10% potassium feldspar (chalky phenocrysts to 1 cm) 10% biotite (3 mm) and 3% hornblende. The earlier fine-grained marginal phase weathers dark brown and contains 30% plagioclase, 5% quartz, 5% biotite and 2% hornblende in a very fine-grained epidotized groundmass of quartz, alkali feldspar with minor calcite. The later coarse-grained phase contains packed phenocrysts of euhedral white feldspar (1 x 2 cm) and glomeroporphyritic quartz (dark purple, to two cm in diameter). In this phase hornblende is more abundant than biotite (Fig. 42). The coarse-grained phase locally cross-cuts the fine-grained marginal phase and many quartz veins

Highland Lake stock has steep contacts with a ten-cm-wide fine-grained phase (Fig. 43). The area to the south contains two additional exposures (Bostock, 1947) that were not visited during this study.

The Canoe Creek intrusion is poorly exposed. A sample collected by Bostock (unpubl. data) consists of medium-grained biotite granodiorite. This intrusion coincides with a prominent aeromagnetic low. The Two Buttes trend extends southeast into the Russell Range, comprising a cluster of large plutons within the Lansing map area. Slightly south of this trend is Kalzas Twins, a circular metamorphic halo with wolframite-quartz veins.

A U-Pb date on a titanite separate from Two Buttes yielded an age of 92.5±0.3 Ma (Appendix 4;

Figure 42. Fine grained granodiorite enclosing alkali feldspar-phyric monzogranite and cut by centimetre-wide alaskite veins. From west side of the saddle between Two Buttes.

Figure 43. Contact of granite with thin-layered biotite-garnet meta-siltstone 11 km east of Horseshoe Slough. The contact is an aphite zone 5 cm wide containing 3 mm biotite, and 3 mm red garnet. Medium grained biotite granodiorite of main body is at lower left. Sliver inclusions of the host rock are evident within one m of the contact. From the east side of the granite plug, below the north-facing cliff.

#90-RAS-25). At Kalzas Twins, south of the Highland Lake intrusion, cassiterite and alkali feldspar in the central alteration zone suggest the proximity of a buried intrusion. Metamorphic biotite from this central zone yielded a K-Ar date of 90.7±1.4 Ma (#87-165; Hunt and Roddick, 1987).

Biotite felsite

Massive, unfoliated felsic rocks cover hillsides north and south of Minto Creek at the west-central edge of the Mayo map area. Gently dipping contacts, fine-grain size and monotonous composition all suggest a high-level intrusion. The rock is pink- to white-weathering, grey and siliceous, with biotite (6%) potassium feldspar (3%), and transparent quartz (1%) phenocrysts. The feldspar phenocrysts are 2 to 3 mm long prisms. In many places the biotite crystals are chloritized. The two exposures on the road to Minto Lake are highly fractured and lack fresh rock. Monazite from the biotite felsite in Roaring Fork of Minto Creek gave a U-Pb date of 91.7±0.3 Ma (Appendix 4; #VR-7868) which is probably the age of intrusion and a K-Ar date of 85.3±2.1 Ma (#87-164; Hunt and Roddick, 1987), probably a cooling age.

Granitic dykes

Two, and locally three, parallel granitic dykes up to three m thick trend easterly across Mount Haldane, Galena and Keno hills to the headwaters of McKim Creek. Although locally known as sills they post-date regional metamorphism and are parallel to regional foliation. They are locally offset by northeast- and northwest-trending faults and siderite veins.

The dykes are light coloured, fine-grained granodiorite to quartz gabbro and locally contain biotite phenocrysts, or biotite replaced by chlorite. The matrix contains quartz and myrmekitic feldspar with muscovite and chlorite, accessory sphene, apatite, epidote, carbonate, magnetite, hematite and pyrite. Some zoned feldspar phenocrysts, with calcic cores and sausseritized sodic rims, were noted by Boyle (1965, p. 19). Abundant muscovite in the groundmass occurs as replacement of plagioclase and ferruginous carbonate. The rhyolite dykes are not well dated. A date of 81±5 Ma by the K-Ar method (#65-49; Wanless at al., 1967) probably reflects thermal resetting. A porphyritic plug on the east side of Mount Haldane yielded a K-Ar date of 89.0±2.6 Ma (Stevens et al. 1982).

An intrusion on the east side of Black Ram Creek in the southwest Mayo map area consists of pink-weathering, fine-grained rhyolite containing 15% phenocrysts of white feldspar and grey quartz. About 1% hornblende, in thin prisms 2 x 0.5 mm long, is present but biotite is absent.

Rocks Southwest of Tintina Fault (ⱣMN, ⱣMNc, TRJ?)

Three rock units, all of unknown age, comprise the eight-sq.-km triangular area in the extreme southwest corner of the map area. The oldest, a foliated cherty rock with chloritic streaks, has a southwest dipping foliation that suggests continuity with unit 6e of Campbell (1967) in the adjacent Glenlyon map area, and unit ꞒMN (quartz-muscovite schist) of the Carmacks map area (Tempelman-Kluit, 1984).

The second unit, capping high points of the mountain at the southwest corner, is massive, creamy-white, flaser-textured marble. It is relatively common, but little studied, in the northeastern Carmacks map area. No conodonts were recovered. These two units belong to the Nisutlin Sub-Terrane (Yukon-Tanana Terrane), and may be contemporaneous with the Earn Group across Tintina Fault (D. Tempelman-Kluit, pers. comm. 1992).

The third unit, a northeast-facing rubble slope, is quartz-feldspar porphyry. Quartz phenocrysts are smoky and 2 to 3 mm across, the white feldspar is likely kaolinized orthoclase, and limonitic pseudomorphs suggest the former presence of biotite. The matrix is siliceous, pink and fine-grained. Because Cretaceous intrusions are not known south of Tintina Trench in this vicinity, this porphyry may be an apophysis of the Jurassic or older Tatlemain batholith (Campbell, 1967; Tempelman-Kluit, 1984), 20 km south of this occurrence.

Structural Geology

The rocks in the Mayo map area are moderately deformed in the south and intensely strained further north. In the vicinity of Keno Hill, at least four phases of deformation are known. Recognition of structural phases has been hampered by the complexity of deformation in the north, the lack of stratigraphic markers in the central Mayo map area, and the difficulty of interpreting structure when the boundaries of rock units and the relative age are unknown. This chapter is supported by observations and efforts of many workers in the north part of the map area, particularly those of Green and McTaggart (1960), Abbott (1990a) and Gordey (1990a) as well as the current work of Murphy (1997).

Abundant structural data have been collected in the course of exploration and mining in the Keno Hill-Galena Hill area, but remains in company files. The offsets and displacements of various sets of faults have been investigated in pursuit of ore deposits, and are summarized by Boyle (1965) and Watson (1986).

Early concepts

Structural interpretations of the Mayo map area evolved with each interpretation of stratigraphy. From the regional pattern of attitudes of the prominent foliation, Bostock (1947) deduced a broad southeast-plunging arch in the eastern half of the Mayo map area, now called the Mayo Lake Antiform (Fig. 44). He also recognized a southwest-trending, gently plunging arch projecting southwest across the northwestern Mayo map area, which subsequent workers called the McQuesten Antiform. Bostock's (1947) marginal notes mention west-trending open folds in the central part of the map area, although neither these nor any structural measurements were depicted on his map.

This regional view of a thick (probably Precambrian) layered sequence persisted until the mid-1960s. In 1961 Permian fossils were discovered 12 km north of McQuesten Lake in rocks structurally below the Lower Schist formation (previously shown as unit 1 on all maps of the Mayo area). Their discovery discredited the older concept of a simple stratigraphic succession and confirmed the regional significance of structural complexity. On the basis of detailed mapping and fold analysis, large recumbent folds and low angle faults had been proposed on Keno Hill and in the Davidson Range to the north by McTaggart (1960; Green and McTaggart, 1960). On the basis of structural projection, McTaggart (1960, p. 29) concluded that low-angle faults must lie within the Lower Schist formation. The abrupt increase in thickness of the Keno Hill quartzite unit on Keno Hill was the result of two or more recumbent folds (Fig. 45) rather than an abrupt facies change. Subsequently Green (1971, p. 55) deduced the location of an important thrust by noting that different rock types in different places were structurally emplaced above the Keno Hill quartzite.

Reconnaissance mapping traced the Keno Hill quartzite west to the Tombstone area of the southern Ogilvie Mountains. In this area, which is less penetratively deformed than near Keno Hill, Tempelman-Kluit (1970) surmised that the great thickness of Keno Hill quartzite and extensive diorite were thrust-imbrications of a 1200-m-thick succession containing a single sill. In the southern Ogilvie Mountains he also mapped a thrust where strata as young as Jurassic were structurally overlain by Precambrian grit. This thrust, originally recognized on Robert Service Mountain east of the Dempster Highway, was traced eastward to the Keno Hill area and eastward by Green (1972) and acquired the name Robert Service Thrust (e.g. Gabrielse et al. 1980)

Recent advances

Improved dating techniques refine the structural and tectonic understanding of the region. The Keno Hill quartzite contains Early Carboniferous conodonts (Orchard, 1991) in the southeastern Ogilvie Mountains. Furthermore, a metagabbro-metadiorite sill in the same area yielded a 232 Ma (mid-Triassic) U-Pb isotopic date (Mortensen and Thompson, 1990). These dates confirmed the existence of the Tombstone and Robert Service thrusts in both the southern Ogilvie Mountains and between analagous rocks in northern Mayo map area. It is now recognized that the structurally higher thrust (Robert Service) is older and has been folded by movement on the second thrust (Tombstone) structurally beneath it (Fig. 46). The Lower Schist is now considered equivalent to the Earn Group (Abbott, 1990a; Abbott and Turner, 1990). The Tombstone Thrust is inferred to underlie the valley containing the Hanson Lakes and the Keno-Ladue River.

The Robert Service Thrust occurs between grey quartzite and carbonaceous phyllite of the Keno Hill quartzite and the muscovite-chlorite phyllite and gritty psammite of the Hyland Group. Both the footwall and hanging wall were deformed together and have similar foliation. A rodding lineation on the foliated surface is typically observed on rocks of the Tombstone thrust sheet and structural keels in the lower Robert Service thrust sheet.

Recent studies within the Robert Service thrust sheet have elucidated the sequence of deformation events, the lateral and vertical distribution of structures, and the geometry of areas with strain fabrics. To the west, a Cambrian to Devonian succession within a south-verging, northwest plunging syncline (Lost

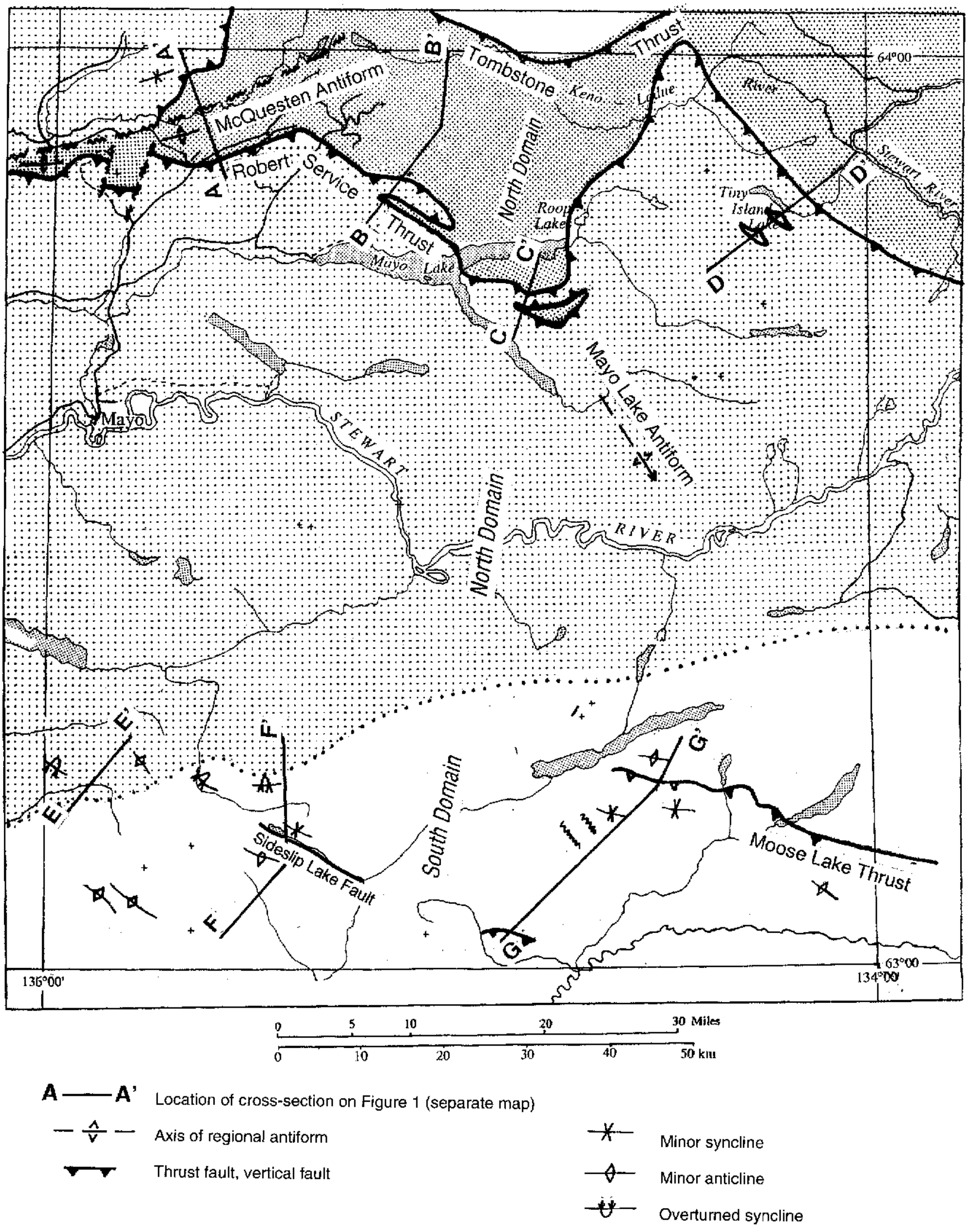
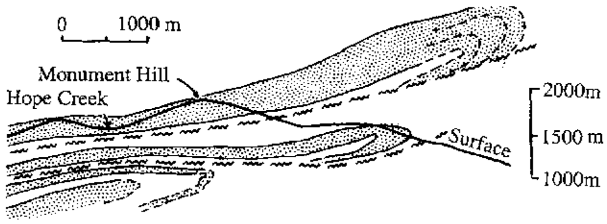


Figure 44. Regional structural elements of Mayo map area. Cross sections are shown on Figure 1 (map separate).



(After McTaggart, 1960)

Figure 45. Projected cross-section of two quartzite exposures on Monument Hill (eastern continuation of Keno Hill), interpreted as faulted recumbent anticlinal nappes by McTaggart (1960). The section plane is vertical, strikes N30°W through the summit of Monument Hill, with data projected along lines plunging 20° in a direction S60°W. Location is shown on Figure 44.

Horses syncline; Murphy, 1997) occurs in the northern quarter of adjacent McQuesten map area. The syncline is enclosed by underlying Yusezyu strata which are only deformed to the north and east of the syncline; one to five km south these rocks are intensely strained. The north limit of penetratively strained rocks intersects stratigraphic boundaries and is thus not the result of progressively deeper burial and level of exposure. The strain fabric matches that related to the Tombstone thrust in the northern part of the Robert Service thrust sheet in the Keno Hill region. Because the strain fabric pervades only some Yusezyu rocks in the McQuesten map area and is interpreted to be the result of Tombstone-age deformation, the region is called the "Tombstone Strain Zone" by Murphy and Héon (1995; Murphy, 1997). The strain zone extends from the northeastern McQuesten map area into the western Mayo map area both north and south of Mount Haldane. The entire northern two thirds of the Mayo map area probably lies within the strain zone, but its southern boundary is not as well-defined as it is in the northern McQuesten map area.

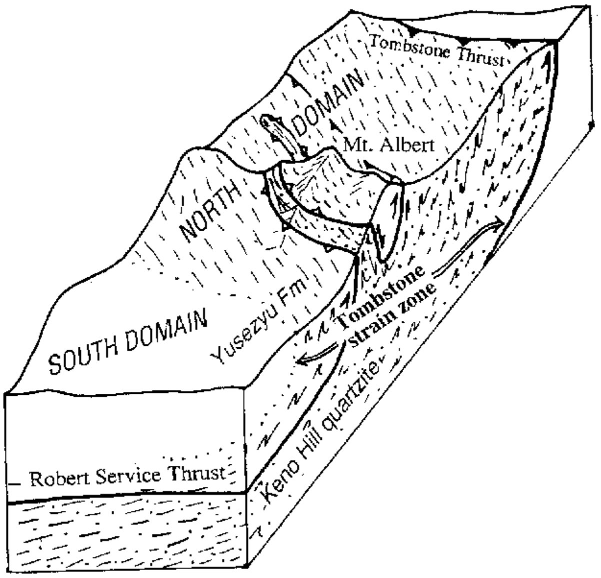


Figure 46. Schematic block view (looking northward across the northern half of the Mayo map area). Yusezyu Formation lies in the hanging wall of the Robert Service Thrust, which is folded south of Mount Albert. Keno Hill quartzite (and Earn Group, not shown) are in the hanging wall of the Tombstone Thrust. The Tombstone Strain Zone extends upward into the hanging wall of the Robert Service Thrust and defines the North Domain.

Structures in the Mayo map area

At a regional scale the Mayo map area consists of two overlapping thrust sheets, each of which ranks, both in terms of stratigraphic separation and degree of shortening, with those in the Canadian Rockies. The only part of the map area not on these thrust sheets is a single outcrop, not visited, at the extreme northern central edge of the map area, between the Hanson Lakes and the Keno-Ladue River valley, that may represent the footwall of the Tombstone Thrust. With this exception the northern quarter of the Mayo map area is part of the Tombstone Thrust sheet. Overlapping the Tombstone thrust sheet and visible across the rest of the map area are rocks of the Robert Service thrust sheet. Therefore the present level of erosion across the map area provides an oblique cross-section, with deeper levels exposed to the north.

Rock fabrics and internal structures are best described in terms of the two structural domains (Figs. 9 and 44). The South Domain comprises weakly deformed strata, for which the dominant phase is attributed to motion on the Robert Service Thrust. The North Domain, including the lower part of the Robert Service thrust sheet and the structurally underlying Tombstone thrust sheet, is characterized by a penetrative deformation fabric and mostly northwest-trending rodding lineation. The North Domain corresponds to the Tombstone Strain Zone. The boundary between the domains is the gradational southern limit of a strongly penetrative fabric; it is the top of strain inferred to be related to movement of the Tombstone Thrust (Fig. 46).

South Domain

This domain extends across the southern quarter of the map area and incorporates rocks which occur relatively high in the Robert Service Thrust sheet. Most common is a south-dipping, east-southeast trending structural grain. Along trend Paleozoic rocks and similar structures continue southeast into the northeast Glenlyon and northwest Tay River map areas (cf. Campbell, 1967; Gordey and Irwin, 1987). Grit and maroon argillite of the Hyland Group, exposed in the northern part of the domain, extend westward into the central McQuesten map area, where only rudimentary structural information currently is available (Bostock, 1964). The domain includes map-scale southeast-plunging synclines and anticlines, as well as thrust faults that repeat the generally south-dipping stratigraphic succession.

Rock fabric elements

In the southern domain gritty rocks are flattened parallel to bedding but detrital grains are generally distinguishable and not overgrown with secondary mica. The rocks probably have undergone considerable strain, but because the plane of flattening is generally parallel to original bedding, this deformation is not clearly evident. Sandstone of the Nogold unit, however, displays a flaser fabric and a waxy, phyllonitic matrix. Large-scale folds rarely are observed, but are probably common in the southern domain. Some areas of resistant grit consist of talus blocks revealing portions of recumbent fold hinges and thereby the presence of complex internal structures.

Pelitic strata commonly exhibit slaty cleavage and zones of brittle buckling. Bedding is obliterated by cleavage and is evident only where contrasting composition, such as sandstone interbeds, are present. Lineations dominantly are cleavage-bedding intersections and axes of minor folds. Mesoscopic chevron folding of chert is exhibited particularly well in a 3 km wide synclinorium in the Clarke Hills. In contrast, pebble conglomerate successions resisted deformation. Slickensides and mullions coat the upper and lower surfaces of thick conglomerate bodies and thinner conglomerate beds are warped into open folds.

In general an increase in intensity of deformation appears in stratigraphically older units. The Yusezyu Formation exhibits steeper primary dips, tighter folding and more closely spaced cleavage than younger strata. The contrast suggests structural complexity increases with depth.

Folds

Steep to overturned beds, common in the Kalzas Twins area, suggest folds and possible thrusts within the Yusezyu Formation. Cleavage is uniformly steep to the south while bedding varies from steep north to gently south-dipping, suggesting north-verging fold geometry and possible south-dipping thrusts. Tight minor folds are commonly observed and plunge moderately to the southeast.

In the southwestern Mayo map area, large synclines are outlined by limestone. Upright isoclinal folds are revealed by thickened hinge zones, and discontinuous outcrop trains are interpreted as limestone mega-boudins in the attenuated limbs. The limestone, although prominent, is white and recrystallized, masking cleavage and bedding. Southwest vergence and southeast plunge, visible in cliff exposures (see cover), also are inferred from the spatial distribution of the limestone (Section B-B'; Roots, 1993). Similar vergence is interpreted for exposures of the Nogold unit, which is interpreted to be synclinal keels preserved within recumbent southwest-verging folds (Fig. 1, Section F'-F").

Thrust faults

Where older units overlie younger ones, thrusts are evident. One such thrust occurs in the central Clarke Hills near the reference locality for the Gull Lake Formation. Cambrian siltstone is exposed in a 3 m cliff which stratigraphically downward is brecciated into metre-sized blocks surrounded by clay gouge. The footwall at the bottom of the cliff is fractured black chert and laminated meta-siltstone correlated with the Road River Group.

The Moose Lake Thrust in the southeastern part of the map area (Fig. 44) juxtaposes Yusezyu sandstone northward over Narchilla and younger rocks. The immediate footwall of the thrust hosts a fine-grained, magnetite-rich mafic body with brecciated margins, probably an intrusion, and a tightly folded to overturned syncline of Narchilla, Gull Lake and Rabbitkettle formations (Section G-G'; Roots, 1993). A minor fold with south vergence and gentle east-southeast plunge (Fig. 47) reflects an opposing sense of motion to that of the north-directed thrust. Possibly the steep south dip of the thrust resulted from later tilting during or after folding, but relationships are inconclusive.

Northwest-trending faults are deduced from lateral offset of bedding contacts. They are the youngest of the large scale geologic features and cut

Figure 47. Eastward view of minor fold in sandy limestone of Rabbitkettle (?) Formation. The axial plane dips steeply northeast and the fold hinge plunges gently east-southeast. The southeast vergence of this fold may reflect bedding plane slip within a tight syncline in the footwall of the Moose Lake Thrust. Hammer point at lower right points upward. On the ridge crest, two km east of Mist Lake.

both thrust faults and southwest-verging folds. In the Clarke Hills two northwest-trending faults, 3 km apart, offset stratigraphic contacts, suggesting opposite relative motion (laterally and vertically) to expose a deeper level of a small thrust sheet containing Yusezyu Formation rocks in the hanging wall. Along the Sideslip Lake valley a major offset is inferred, and may splay northward to offsets in the Nogold unit. At Sideslip Lake the northeast side appears to be uplifted with a stratigraphic offset of at least 400 m (calculated by restoration of the Road River unit in cross-sections). Faults with unknown displacement are indicated by truncation of the eastern exposure of the Nogold unit, and the change in structural orientation of resistant sandstone beds across the head of North Crooked Creek. All these faults are considered late structural readjustment, perhaps coeval with formation of the Mayo Lake Antiform or motion along the Tintina Fault (post-Early Cretaceous).

North Domain

In the northern two thirds of the map area all layered rocks have a penetrative structural fabric. They comprise a low-angle shear zone (the Tombstone Strain Zone) several kilometres thick, above the Tombstone Thrust. The zone is extensive because it is obliquely exposed by moderately gentle southerly dip; thus the apparent northward increase in strain reflects successively deeper levels and proximity to the underlying Tombstone Thrust. The zone also extends laterally southeast into the Lansing map area and northwest into the McQuesten map area (Murphy, 1997).

Tombstone thrusting has overprinted previous structures, and bedding is rarely recognizable. Structurally below the Tombstone Thrust rocks lack the mineral elongation and rodding lineation that typifies the Tombstone thrust sheet (Abbott, 1990a). Both the Tombstone thrust sheet and the less strained rocks beneath it are folded by broad, open folds and cut by northeast-trending faults.

Rock fabric elements

The quartzofeldspathic micaceous rocks readily display planar and linear fabric elements in outcrop and hand sample. The lineation is defined by preferred orientation of elongated minerals in gritty rocks and one or more crenulations in phyllitic rocks. This lineation typically trends northwest in the western half of the domain, and trends gently east to southeast on the east edge of the Mayo map area. The rocks also contain a prominent foliation (S_p), as defined by grey mica and chlorite, that almost everywhere is aligned with compositional layering which replaces bedding in highly deformed rocks. The foliation represents various aspects of rock strain, including shear bands, recrystallized cleavage and S planes. Axial planar cleavage resulting from folding of compositional layering is only rarely observed in small isoclinal folds. With subsequent shear-parallel transport and flattening, axial planar cleavage has generally become coplanar and indistinguishable from S_p (Murphy and Roots, 1992a). The foliation of 'Gleitbrett' folds (Fig. 48), described by Green and McTaggart (1960), are also considered S_p.

Quartzofeldspathic layers commonly have been distorted into laterally tapering sigmoidal domains (Fig. 49). Boundaries of the domains are inferred to be shear bands (S_p') and are inclined approximately 25 degrees to S_p (Figs. 21, 22). Typically the shear bands are regularly spaced, northwest- or west-dipping planes, with S_p preserved in sigmoidal domains and boudins between them (Fig. 50). Similarly the foliation of micaceous rocks is deflected in down-to-the-north wavy bands, suggestive of northerly dipping shear bands.

Lower structural levels are indicated by tighter folds and additional fabric elements. These regions commonly have abundant quartz veinlets and 'sweats' which record later deformation (Fig. 51). The quartz veins may be a relative indicator of refolding (Fig. 52) and multiple generations of folds are visible in some outcrops (Fig. 53). Tight crenulation lineation parallel to northwest-trending mineral elongation is almost ubiquitous in the northern edge of the Robert Service and Tombstone thrust sheets. In the deformed Earn Group in the Tiny Island Lake area, rodding is defined by elongated pebbles in the metaconglomerate (Gordey, 1990a).

Figure 48. Sawn surface of phyllitic layer show fold style of attenuating limbs, thickening of layers in kink-folded hinge zones. This is a 'gleitbrett' structure (Green and McTaggart, 1960) in relatively ductile rocks. Keno Hill quartzite from the Silver King mine.

Figure 49. Carbonaceous shear planes separate lenticular domains of chloritic quartz phyllite. From the immediate hanging wall of Robert Service Thrust, five km north of Mayo Lake.

The Triassic meta-diorite bodies are typically lenticular as a result of compression and plastic flow, and dismemberment by thrust faults has led to boudin development. Some bodies are cigar-shaped along the axial planes of earlier folds (Green and McTaggart, 1960; Green, 1971). Although their margins have undergone both brittle and ductile deformation, the metadiorite within the bodies shows little or no penetrative fabric.

Early faults

Robert Service Thrust

The oldest recognizable fault in the northern Mayo map area is the Robert Service Thrust, which places Proterozoic Hyland Group atop Carboniferous Keno Hill quartzite (Fig. 54). Its actual trace is obscure and lies within a layer (up to several hundred metres thick) of highly deformed rocks similar to the Keno Hill quartzite intercalated with grey-green, waxy lustred phyllonitic quartz-pebble conglomerate, metasandstone and phyllitic marble that resembles the Yusezyu Formation. The thrust is therefore considered to be a zone of structurally imbricated (isoclinally folded or faulted) rocks derived from units immediately above and below (Roots and Murphy, 1992a). The rock fabric within this envelope is strongly foliated, and, in contrast to the northwest-trending lineation common to the thrust sheets above and below, contains deformed lineation and minor structures verging northeast (Roots and Murphy, 1992a; Murphy, 1997). The implication is that the Robert Service Thrust in the central Mayo map area was deformed by top-to-the-northeast transport, which is considered a second phase of movement of the Tombstone Thrust.

The thickness of the thrust envelope is such that locally it is exposed for widths of up to two km in areas of rugged topography. Mappable bands of Keno Hill quartzite are enclosed by Yusezyu grit southeast of Mount Albert (Murphy and Roots, 1992a) and on Fork Plateau (Roots, 1993) either as fault splay slivers or recumbent infolds of the deformed Robert Service Thrust sheet. Its deformation is evident at all scales, obliterating the actual fault trace so that it is unrecognizable even where exposed by mining (M. Phillips, pers. comm. 1994).

In the northeast corner of the map area the hanging wall rocks of the Yusezyu Formation have northeast-dipping foliation and appear to underlie

Figure 50. Regularly spaced cleavage (S_p; parallel to compositional layering and former bedding) is separated into sigmoidal domains by asymptotic, anastomosing shear planes (S_p'; outlined with dots) in layer of metasandstone between phyllite (top and bottom). Movement on shears results in metasandstone layer becoming thinner and extending in the direction of the inclined shear. View westward of vertical face; S_p' dips 26° north; gully outcrop three km south of Francis Lake.

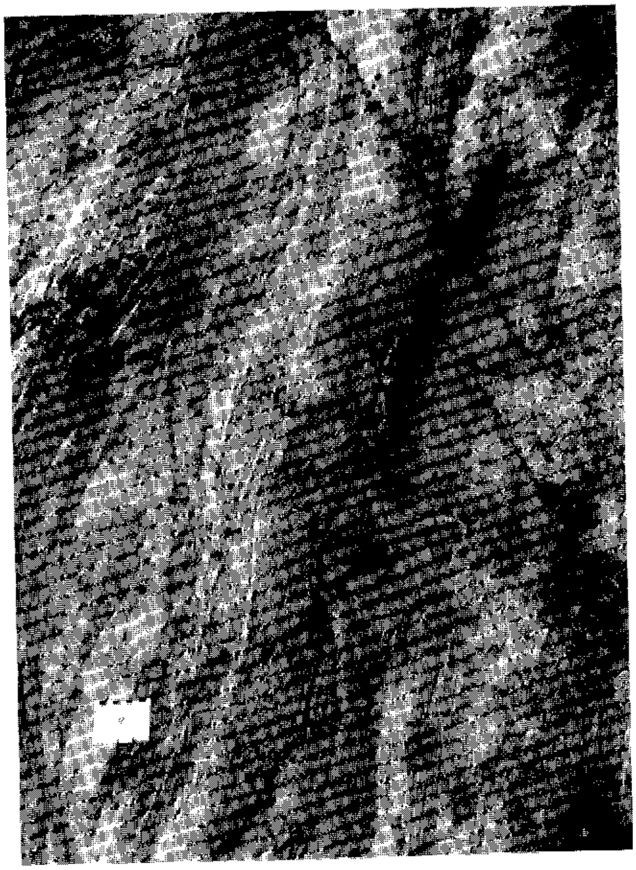


Figure 51. Chloritic phyllite with fine white quartz segregations that outline minor fold (lower right) and fine cleavage (S_p; in centre) whose boundaries are anastomosing shear planes (S_p'; parallel to left side of picture) producing sigmoidal domains (above scale card). Looking steeply down, northeast at top, Yusezyu Formation near Lonely Dome.

Figure 52. Quartz vein is tightly folded and flattened within the enclosing foliation (S_p). The axial plane and compositional layering are also parallel to S_p. The thickened part of the vein contains an earlier, rotated section that suggests top-to-the-north displacement. View is eastward of a psammite (Yusezyu Formation) atop Fork Plateau, eastern Mayo Lake. The entire fold is six cm high.

Keno Hill quartzite, Earn Group and related metavolcanic rocks (Gordey, 1990a, b). The Robert Service Thrust could be overturned to the southwest, although better understanding may come with investigation along the trend of the thrust to the southeast in adjacent Lansing map area.

Tombstone Thrust

In the southern Ogilvie Mountains the Tombstone Thrust lies at the base of the Carboniferous Keno Hill quartzite (R. Thompson, pers. comm. 1987) with Jurassic black siltstone and shale (Poulton and Tempelman-Kluit, 1982) in the footwall. In the Mayo map area, however, rocks underlying the Keno Hill quartzite are unlike those Jurassic rocks. They are considered Earn Group-equivalent (Abbott, 1990a) and contain abundant metadiorite sills. Moreover, the strong contrast in structural style across the Tombstone Thrust, evident in the southern Ogilvie Mountains where recumbent chevron folding with northeast-trending axes occurs in the hanging wall quartzite, is not visible in the Mayo area. The Tombstone Thrust is only recognized about 10 km north of the northeast edge of the Mayo map area where Abbott (1990a, b) noted the northern limit of foliated and lineated Earn Group strata in the hanging wall against the less strongly deformed Earn Group in the footwall to the north.

The prominent mineral lineation, rodding and crenulation axes (L_p) trend northwest in the northern part of the Mayo map area. The leading edge of the northwest-directed Tombstone thrust sheet lies in the southern Ogilvie Mountains, where stratigraphic separation is greatest. The sequence of thrusts, beginning with emplacement of the Robert Service thrust sheet and subsequently deformed by movement on the underlying Tombstone Thrust, is consistent

Figure 53. Refolded fold in micaceous metasandstone, immediately above the Robert Service Thrust. The pattern of compositional layering suggests two generations of folding with axial planes at a high angle to each other. White card is nine cm long. From a boulder in a saddle 5.5 km north of Mayo Lake.

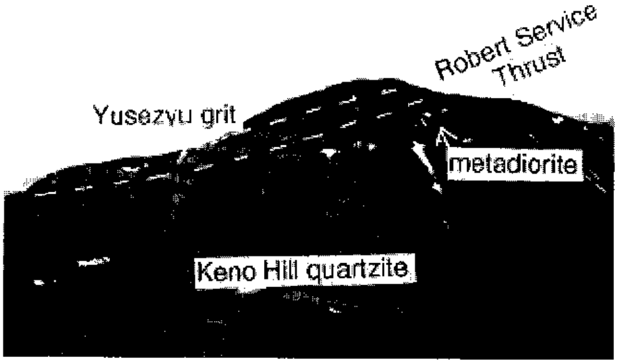


Figure 54. View west toward Mount Albert, showing the Robert Service Thrust. The planar thrust zone, about 70 m thick, contains lenses of chloritic phyllite, quartzite, metasandstone, minor limestone and dark grey phyllite interpreted as interposed slivers of Keno Hill and Yusezyu rocks. The Yusezyu grit moved northward (to the right) over Keno Hill quartzite and Triassic metadiorite.

with Forelandward propagation of thrust faults, although the direction of displacement varies between northeast and northwest.

Folds

Mesoscopic fold hinges are uncommon in outcrop, although minor drag folds are observed. Most drag folds indicate northwest, north or northeast movement of overlying layers relative to underlying layers. In the Keno Hill region, many are probably related to large recumbent folds as suggested by hook terminations of four bands of Keno Hill quartzite (Fig. 45). Resistant layers exposed in steep valley walls also indicate long recumbent limbs (Fig. 55). In the overturned limb of such folds the plunges of lineations are reversed (southeast, instead of northwest) and minor fold verge southwest. In less well exposed areas, such departures from regional attitudes suggest that additional overturned limbs may be present.

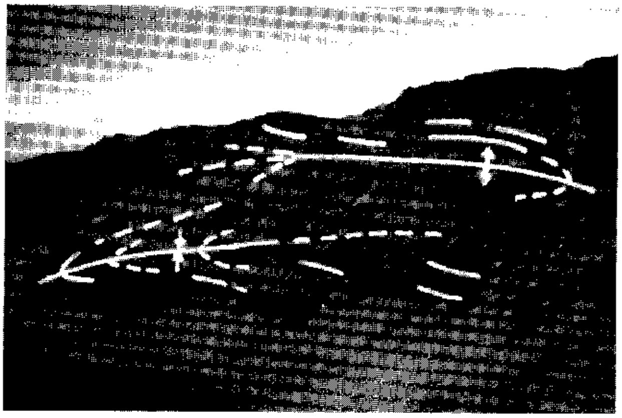


Figure 55. Northeast-trending, southwest-verging fold pair outlined by resistant layers in Keno Hill quartzite. The entire ridge is interpreted as the overturned limb of an antiformal nappe to account for the reversed vergence of the folds. Oblique southward view of the northeast spur of Mount Hinton. Photo by D. Murphy.

Large open folds were first recognized during reconnaissance mapping (Bostock, 1947) by the curvature of units from southeast along Mayo Lake, to northwest near the Keno-Ladue River. The broad arches in the South McQuesten River valley and east of Mayo Lake now are antiforms within which older rocks are separated from younger strata by the Robert Service Thrust. These arches formed after thrusting.

North of Ethel Lake large east-trending folds are distinguished by changes in dip direction of foliation and orientations of contrasting cleavage-bedding intersections. These include synforms beneath Francis Lake, the Janet Lake-Watson Creek valley and the Stewart River upstream of Fraser Falls. Indications of vergence are lacking, although drag folds, which may be related, were infrequently observed in this region. One such structure, well-exposed in a stream cut on the east fork of Empire Creek (north of Francis Lake), includes micaceous metasiltstone, quartzite and green phyllite layers in a drag fold that plunges southwest, indicating a south-over-north sense of transport (Fig. 56).

A second, possibly coeval, trend of open folding is west-southwest along the south McQuesten valley. The antiform is broken by a north-side-down fault, but its westward plunge is traced in the McQuesten map area by Murphy and Héon (1995).

Late-stage brittle faults

Two fault sets are apparent from the offset of rock units, although the surface trace is nowhere exposed. A northeast-trending fault is inferred in the valley of the South McQuesten River to account for the discontinuity of the Keno Hill quartzite across the valley in the broad antiform. This fault is parallel to the trend of mineralized veins in Keno and Galena hills. The mineralized veins have not undergone ductile deformation and therefore probably post-date Tombstone thrusting. Boyle (1965) noted that mineralization is concentrated in fissures that strike northeast and dip steeply southeast. Lynch (1989a) proposed that these Keno Hill vein faults formed in a northeast-trending sinistral brittle shear zone. The north-northeast trending fault set includes probable faults beneath Haldane Creek and Bighorn Creek which offset the Robert Service Thrust.

Interpreted sequence of deformation events

In their synthesis, Green and McTaggart (1960) proposed two phases of deformation in the Keno Hill area: 1) early, low-angle southwest-trending tight folds with northwesterly displacement; and 2) late,

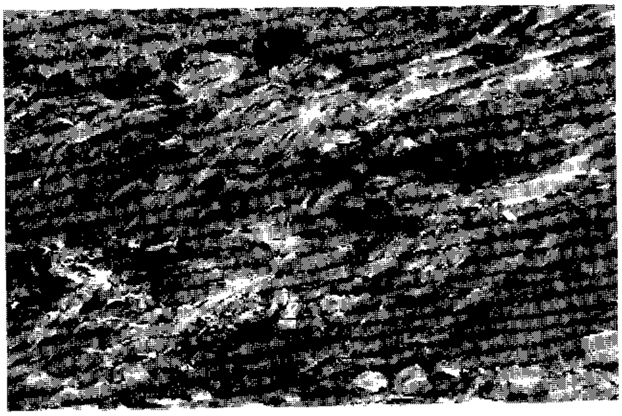


Figure 56. Layers of metasiltstone, chloritic phyllite and quartzite in a south-verging drag fold, interpreted as an early fold, prior to northward shearing on thrust faults. The folds were later tilted southward in a broad synform. View is northwestward, of a stream outcrop in the east tributary of Empire Creek, ten km northeast of Francis Lake.

upright east-west trending upright folds. In this report two high-strain deformation phases are recognized (D2 and D3; Roots and Murphy, 1992). The main deformation was predated by an earlier folding phase, and followed by two (possibly coeval) regional-scale phases of open folding.

The Robert Service Thrust resulted in a flattening of structurally lower Yusezyu rocks and broad, southerly tilting of bedding across the thrust sheet (D1). No penetrative fabric can be isolated and uniquely attributed to Robert Service thrusting because the Tombstone Thrust immediately underlies it throughout the area. The broad area of Yusezyu rocks exposed in the Robert Service thrust sheet implies that the thrust surface lies at a shallow depth beneath most of the Mayo map area.

Tombstone thrusting was attended by high strain (D2) that pervaded rocks of the Tombstone thrust sheet well up into the overlying Robert Service sheet. The first high strain fabrics resulted from shearing and top-to-the-west or northwest sense of displacement and are indicated by Sp and Lp respectively. The northern domain extends westward beyond the map area, toward Dawson in the Tombstone thrust sheet, and eastward into the southwestern Lansing map area. The penetrative fabric matches the area in which the main movement vector of the Tombstone thrust was northwest. At structurally deeper levels, in the Robert Service thrust sheet, compositionally distinct layers have been thinned and their length extended by flattening.

The next phase of deformation (D3) is reflected by tight to isoclinal folds on all scales, including large recumbent folds of the quartzite on Keno Hill. These indicate a top-to-the-northeast sense of displacement. Shear planes — which break up the foliation and cause compositional layers to attenuate or become boudins — are related to this phase. The northeast trending lineation present in rocks within the Robert Service Thrust suggests that the thrust fault was deformed at this time.

The Mayo Lake Antiform may be a flexure of the Robert Service thrust sheet over Keno Hill quartzite that has been structurally thickened by folding and fault imbrications. Alternatively it may have resulted from local uplift during intrusion of the Roop Lakes Stock, or buckling from resistance to northeastward transport, perhaps along a high angle, southwest-directed thrust fault mapped north of the area by Abbott (1990a).

An additional phase, the timing of which remains uncertain, is marked by southwest-verging folds. In the Crooked Creek area (southwest Mayo map area) the outline of the Rabbitkettle Formation limestone indicates both isoclinal and overturned folds. In style, and possibly in age, the overturned folds resemble the Lost Horses syncline in the adjacent McQuesten map area. There structurally shallow rocks in southwest-verging synclines are underlain by rocks exhibiting top-to-the-northwest strain indicators (Murphy and Héon, 1994). The high strain fabric obliterates evidence of earlier folding, and could not have been emplaced with an opposing sense of displacement before the southwest-verging folds. These folds plunge gently southeast, have steep or overturned north limbs and south limbs that dip moderately north. There is no evidence to indicate their relative age.

In summary, the Mayo map area comprises two partly overlapping thrust sheets. Deformation is interpreted to reflect a sequence of low-angle thrust movements and penetrative strain imparted to structurally overlying rocks. Thrusting began after deposition of strata as young as Jurassic, and ceased before emplacement of the Tombstone Intrusions. A K-Ar date of about 142 Ma (J. Mortensen, pers. comm.) from metamorphic muscovite in the Tombstone strain zone in the Clear Creek area (Murphy, 1997) is the first attempt to determine the age of deformation.

Mineral Deposits and Potential

The Mayo map area contains an important silver-mining camp, a tungsten deposit and numerous copper, gold, lead and zinc occurrences, as well as several antimony and barite showings. The Yukon Minfile 1996 for the Mayo map area lists 82 lode occurrences, with an additional 52 claim groups within the holdings of United Keno Hill Mines (UKHM). The Elsa-Keno Hill mining camp produced Ag-Pb-Zn-Cd ore from high-grade silver veins between 1913 and 1989, and may re-open. The area also saw considerable exploration for W and Sn in the 1970s and 1980s, and for large tonnage, low-grade gold deposits in the 1990s.

This chapter addresses the mineral potential of the following types of deposits which are known or suspected in the Mayo map area:

- polymetallic veins, principally those rich in silver, of the Elsa-Keno Hill area;
- replacement, stockwork and 'Carlin-type' gold mineralization;
- sediment-hosted zinc-lead-silver-barite; and
- volcanogenic massive sulphide deposits.

A final section of the chapter discusses bedrock sources of placer gold and construction materials.

Polymetallic veins

The northern quarter of the Mayo map area, as well as adjacent ridges farther north and northwest, contain many mineralized veins. Veins with the highest silver content, as well as the widest and most abundant, are between Galena Creek (Silver King mine) and the top of Keno Hill. The numerous old mines and workings between these end-members are here termed the Elsa-Keno Hill mining camp, an area 22 km long and up to six km wide. With the exception of the Peso and Rex veins, 12 km northwest of Mount Haldane, and the Inca-Plata camp, 160 km east of Keno Hill, the Pb-Zn veins outside the Elsa-Keno Hill camp contain a lower Ag/Pb ratio. In the Mayo map area all but two known vein occurrences are within Keno Hill quartzite or immediately underlying Earn Group phyllite (called "Lower Schist" by previous workers); the exceptions are arsenopyrite-stibnite veins within the Hyland Group. Also, the economically productive sections of the Elsa-Keno Hill veins are generally within 200 m of surface; thus the camp approximately coincides with the surface pattern of the main host Keno Hill quartzite.

The Elsa-Keno Hill mining camp

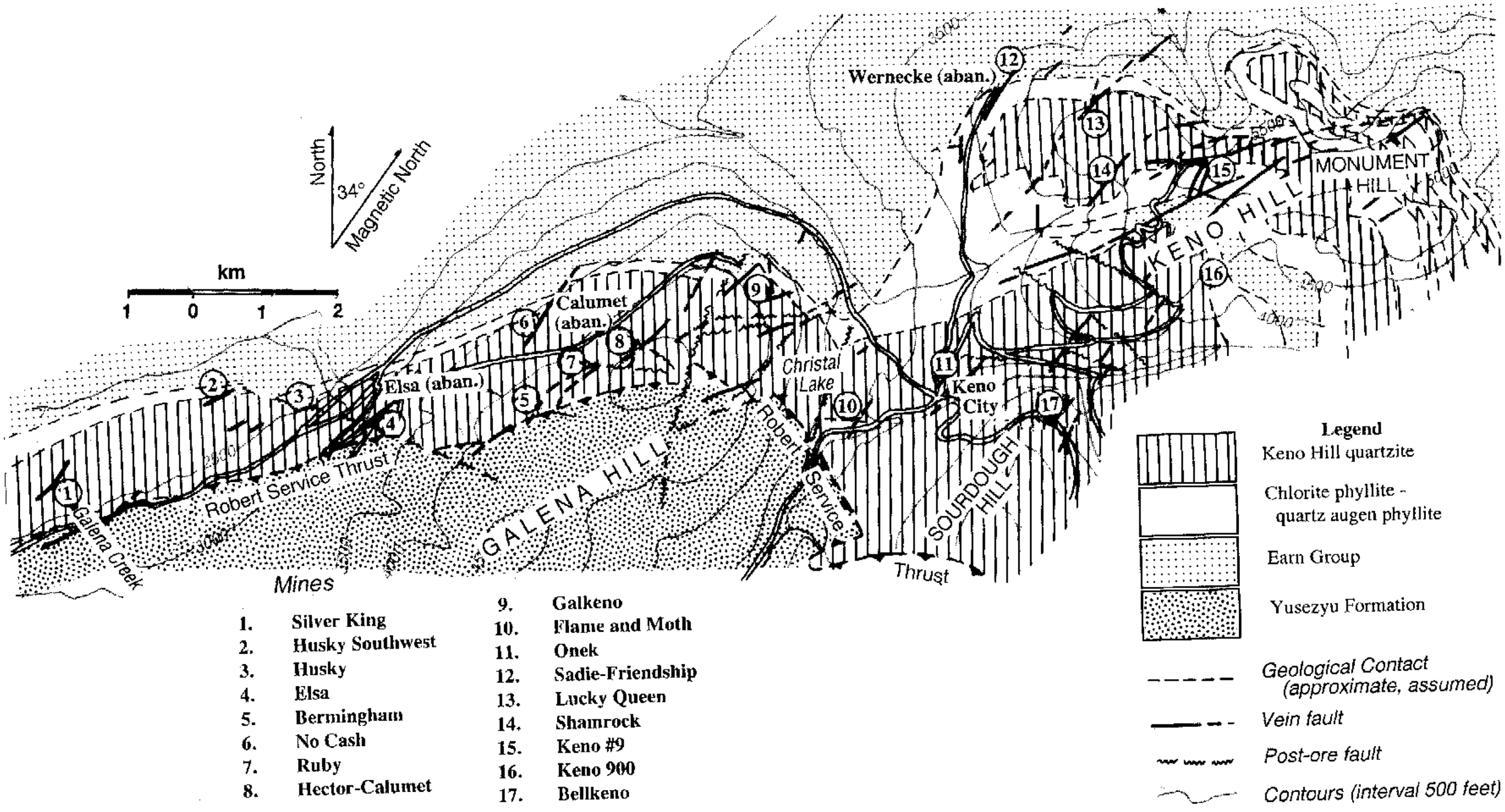
The first 50 years of mining in the area are summarized by Boyle (1965; references therein). In 1963 UKHM began a systematic search within the camp using soil sampling, conductivity geophysical surveys and rotary percussion drilling. This led to the discovery of the Husky and Husky Southwest deposits in the mid-1960s and mid-1970s respectively. Altogether about 65 deposits have been mined. During the 1970s and 1980s the shallow levels of the Hector-Calumet, Bermingham, Galkeno and Onek veins were completely removed by open pit mining. UKHM sustained operations for 40 years with rarely more than three years of known reserves at any time (A. Archer, pers. comm. 1990), but low metal prices and the cost of maintaining infrastructure, including the company town of Elsa, resulted in an indefinite shutdown of mining in February, 1989.

Between 1991 and 1993 several lease-operators used bulldozers and backhoes to extract remaining shallow ore pockets at the former Sadie-Ladue, Lucky Queen, Keno #9 and Shamrock mines on Keno Hill. Currently ten years of reserves have been outlined within the Bellkeno and Silver King vein systems.

Watson (1986) summarized the mining statistics for most of the 75-year history of the Elsa-Keno Hill camp: between 1913 and 1985 over 4.54 million tonnes of ore, with an average grade of 1412 g/t Ag (41.2 oz/ton Ag), 6.8% Pb and 4.6% Zn, was mined. The Hector-Calumet vein system, by far the largest deposit, contained 2.4 million tonnes of ore yielding 2955 million g of silver. The next 13 largest deposits each produced between 31 and 467 million g Ag from between 27 213 and 272 130 tonnes of ore respectively. All these deposits lie within Keno, Galena and Sourdough hills or beneath the valley between the three hills, which is occupied by Christal Lake and the hamlet of Keno City (Fig. 57).

Vein mineralogy varies between deposits and according to depth. General characteristics are summarized here from descriptions of individual veins by Boyle (1965) and UKHM records discussed by Franzen (1986) and Watson (1986). Quartz, calcite and siderite are the principal gangue minerals, along with ubiquitous gouge and angular breccia of the host rock. The main sulphides are galena, sphalerite, pyrite, arsenopyrite, chalcopyrite and tetrahedrite. Secondary minerals include limonite and wad (intergrown pyrolucite, psilomelane and manganite; Boyle, 1965). Silver is mainly present as freiburgite, pyrargarite and as Ag substitution in the galena crystal lattice (Boyle, 1965). Native silver is characteristic of the supergene enrichment zone and is a rare curiosity as wire and platelets in permafrost ice (Boyle, 1960, 1965), as well as in ice filling 60-year-old drifts. Most veins are largely mined out and underground workings inaccessible, but minerals on surface dumps are listed in Sabina (1992).

Figure 57. Principal mines and distribution of rock units in the Elsa-Keno Hill camp. Triassic metadiorite intrusions are omitted for clarity.



(Modified from Boyle, 1960)

Structural and lithological controls on mineralization

The numerous veins in the Keno Hill-Galena Hill area constitute discrete "systems", with splays, parallel and crossed strands, and breccia zones. Boyle (1965) described those exploited before 1960 and Watson (1986) described veins of the Husky and Husky Southwest mines. The vein systems cross-cut the Keno Hill quartzite, Triassic metadiorite and the Earn Group. The veins typically follow faults with demonstrable offset and are referred to as "vein-faults" (Fig. 58a). Most form "ore shoots" in competent host rocks at dilatant zones at the releasing bends of faults. Some systems consist of anastomosing and parallel fractures, partly filled by gouge and breccia, which have been traced for more than two km. Where the fractures pass into incompetent phyllite the veins are narrow and contain little or no ore (Fig. 58b). Similarly, ore grade (silver content) increases with the width of the vein. Throughout this area the regional foliation and general contacts between rock units are moderately south-dipping (south flank of the McQuesten Antiform), and the main veins strike northeast with steep southeast dips.

The camp contains four types of faults, each defined by orientation and relative age. The oldest are "bedding faults" (Boyle, 1965) which typically dip southward and parallel to regional foliation. Their initial movement may have been contemporaneous with motion on the Tombstone Thrust, because bedding faults are either associated with Tombstone strain zone foliation or post-date it. In some mines minor late brittle reactivation also is indicated.

The second type, "longitudinal faults" (Cockfield, 1924; Aho, 1964; "vein faults" on Fig. 58a) trend north-northeast to east-northeast and dip steeply southeast. The most recent sense of movement is generally sinistral although several episodes of movement commonly are indicated. The main productive veins of the camp lie along these faults. The trend of longitudinal vein faults approximates that of both the fault in the South McQuesten River valley, and the axial surface of the McQuesten antiform. This parallelism may be genetically significant (Franzen, 1986; Roots and Murphy, 1992a) although recent data (Murphy, 1997) suggest that both regional structures predate the vein-faults.

The third type are called "transverse faults" (syn-ore). They strike northwest and are, for the most part, dilational zones between *en echelon* longitudinal faults. These dip steeply southeast and are mineralized at Keno No. 9, Moth and a few other occurrences.

The fourth type, post-ore "cross-faults", trend 355° to 35°, dip 60° southwest and offset longitudinal vein faults by as much as 2000 m. Dextral slip is the most recent movement in the west part of the camp, while the Macleod fault and those to the east are sinistral and of less magnitude (Boyle, 1965).

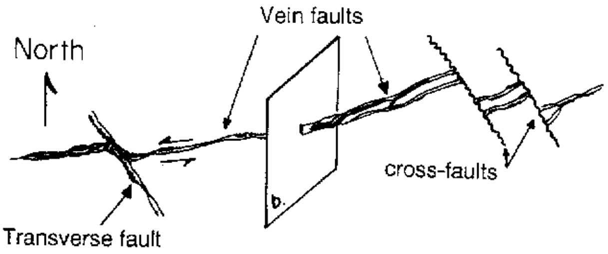


Figure 58a. Diagrammatic orientation of faults and vein structures in the Elsa-Keno Hill mining camp. Dark areas indicate mineralization.

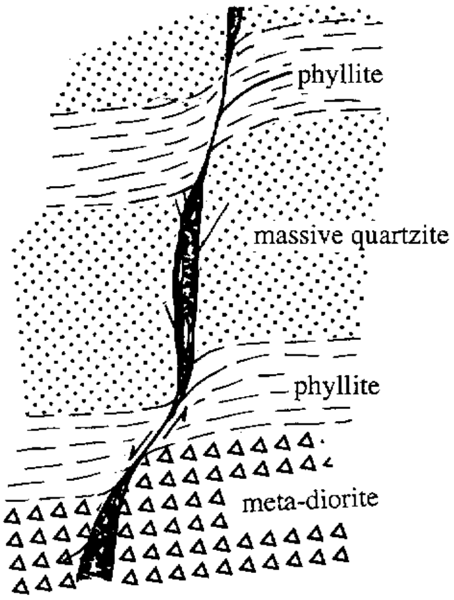


Figure 58b. Schematic cross section of a vein fault showing its relationship to host rock types. No scale is implied; vein may be 3-5 m wide in competent rock types. Modified from Boyle, (1965).

Vein structure varies within longitudinal and transverse faults. In places where the fault is planar, veins are single, parallel or anastomosing; these sections pass into zones of tensional veining and shattered rock. Locally the junction of fault planes provides a larger open space for a rich lode, called an "ore shoot". Microfracturing between some parallel fault strands hosts stockwork mineralization. Obstructions within the fault plane, such as large structural horses, yield an abundance of anastomosing vein sets. This is the setting on the Hector-Calumet vein, which yielded a 40-m-wide zone of disseminated mineralization amenable to open pit mining (Lynch, 1989a).

Vertical and lateral mineral zonation

The distribution of ore minerals is complex but is characterized by a district-wide zonation. Early workers recognized that some mineral associations were characteristic of certain veins and the following paragenetic sequence is generally accepted:

- quartz, pyrite, arsenopyrite and sulphosalts;
- siderite, galena, sphalerite, pyrite and freiburgite (with additional fracturing); and
- cerrusite, anglesite, native silver and argentiferous jarosite (by supergene oxidation of sulphides and sulphosalts), and pyrargarite (Boyle, 1965).

Lynch (1989) outlined three stages — early, main and epithermal — with vein minerals precipitated during various parts of the cycle (Fig. 59).

The supergene enrichment process produced overlapping sequences of sulphates and penetrated to depths of about 150 m below the original surface at the time the veins were emplaced. Glacial scour and other erosion processes have removed all but three m of the oxidized zone on Keno Hill, and six m at Silver King, although 130 m remains at the Elsa mine (Boyle, 1965).

Grade and tonnage records from mining have shown that both Pb/Zn and Ag content decreases with depth (Franzen, 1986). This phenomenon reflects supergene enrichment of silver and leaching of zinc, and deposition of the latter at deeper levels (Franzen, 1986, A. Archer, pers. comm. 1990). Supergene mineralization obscures the vertical zonation of hypogene mineralization.

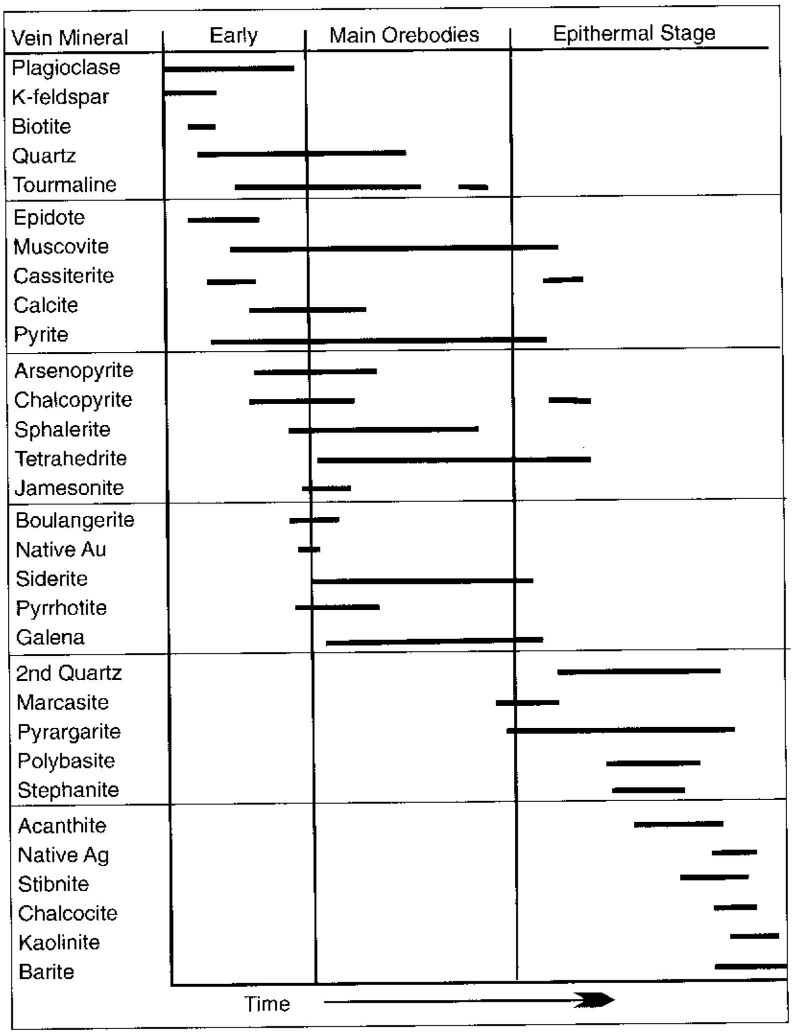
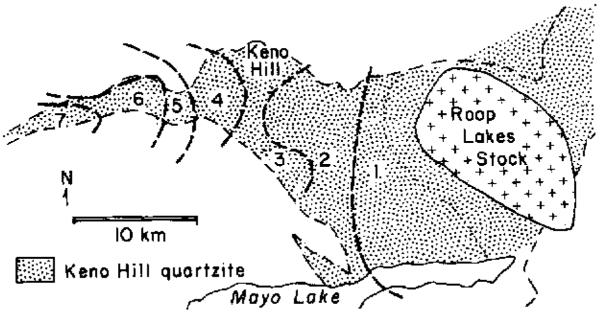


Figure 59. Paranesis diagram for vein minerals in the Elsa-Keno Hill camp. From Lynch (1989a).

A sulphur isotope study by Boyle et al. (1970) first demonstrated systematic change across the district. Lynch (1986, 1989a) showed the spatial distribution of consistent mineral associations (Fig. 60), a zonation similar to that in other hydrothermal districts (e.g. Spurr, 1912). Lynch (1989b) also showed that Ag/Cu and Fe/Zn ratios increase westward. Metal ratios, both vertically in mines (Franzen, 1986), and laterally across the camp, outline zones of maximum permeability, from which the westward flow of mineralizing solutions can be inferred (Goodell and Petersen, 1974; Franzen, 1986). The permeability and relative non-reactive nature of the quartzite, as indicated by generally meager alteration haloes, coupled with likely moderate gradients in pressure and temperature in the lateral dimension, allowed the extensive development of veins in the camp (Lynch, 1989b). Thus the present level of erosion provides an oblique section through the hydrothermal system. Furthermore, the highest temperature mineral assemblages, indicated by the presence of alkali feldspar, epidote ± tourmaline and apatite, are found at the southeast end of the camp. The Roop Lakes pluton, a granite exposed as close as 12 km from Keno Hill is a possible heat source, and its age is consistent with that of the veins.



1. FELDSPAR ZONE:	K-feldspar, plagioclase, quartz, epidote, ± tourmaline, apatite, pyrite, arsenopyrite, ilmenite, cassiterite, muscovite
2. CALCITE ZONE:	calcite, quartz, epidote ± pyrite, chalcopyrite, arsenopyrite, galena
3. JAMESONITE ZONE:	jamesonite, boulangerite, arsenopyrite, sphalerite, chalcopyrite, tetrahedrite, quartz, calcite, native Au (overlaps with zone 4)
4. SIDERITE-CALCITE ZONE:	siderite, quartz, calcite, galena, sphalerite, tetrahedrite, arsenopyrite, pyrite
5. PYRRHOTITE ZONE:	siderite, quartz, calcite, galena, sphalerite, tetrahedrite, pyrrhotite, arenopyrite, pyrite (same as zone 4 with pyrrhotite)
6. SIDERITE ZONE:	siderite, quartz, galena, sphalerite, tetrahedrite, pyrite (similar to zones 4 and 5, but without calcite, arsenopyrite, pyrrhotite)
7. EPITHERMAL ZONE:	quartz, pyrargyrite, acanthite, polybasite, stephanite, native Ag, pyrite, kaolinite ± marcasite, chalcopyrite, stibnite, barite (overlaps with zone 6)

Figure 60. Schematic map of lateral mineral zonation, Elsa-Keno Hill camp. Contours are drawn according to the appearance or disappearance of specific vein minerals away from the Roop Lakes pluton. (Adapted from Lynch, 1989a).

The presence of gold in the veins has become more important in the last decade because even small concentrations significantly affect the value of the ore. Arsenopyrite, the principal gold-bearing mineral, occurs in tension fractures between overlapping ends of strike-slip faults on Keno Hill, and generally at the tips of veinlets. Gold is insignificant in the centre of the camp, but is the most important metal in four occurrences near its southeast end, and is significant at the two northwesternmost mines. On the flanks of **Mount Hinton** (105M/52)* trenching, drilling and short adits exposed about 35 veins that are parallel to foliation near the contact of the Keno Hill quartzite with metadiorite intrusions. The veins contain galena with high silver content as well as arsenopyrite and jamesonite, and significant gold in pyrite. Although rich, the veins are narrow and short. The structural setting differs from that of the northeast striking (longitudinal) silver-lead orebodies in the camp. The **Havrenak** occurrence (105M/70), two km east, contains high silver and some gold, again in narrow veins parallel to foliation. Between McNeil and Macmillan gulches the **Bema** (105M/73) occurrence includes two quartz stockworks with disseminated galena and another stockwork with disseminated arsenopyrite and high gold and silver values in selected specimens. On the north end of Bunker Hill, the **Homestake** (105M/11) property encloses a longitudinal vein with lenses of galena and gold-rich arsenopyrite, as well as a transverse vein containing tetrahedrite and galena.

The **Husky Southwest** and **Silver King** mines, less than five km west of Elsa at the northwest end of the camp, contain significant gold. The Husky Southwest vein is along the trend of the Husky-Silver King structure but is spatially and mineralogically different than either of the flanking deposits. Fracture veinlets within pyritic and graphitic gouge contain native silver with some argentite and stephanite as well as significant gold in pyrite. Galena is rare and not argentiferous, zinc content is low, and barren portions of the vein are identical in appearance to mineralized sections (Watson, 1986).

Zoning in the Elsa-Keno Hill camp shows that the richest silver veins occur near its centre; thus the search for additional orebodies is within the area. The most effective exploration tool within the camp appears to be long-hole drilling from underground along the known vein trends. Significant deposits were found below and parallel to mined-out sections of the Bellekeno and Silver King vein systems using this method.

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* Hereafter, all numbered occurrences are listed in Yukon Minfile 1996.

The vein occurrences outside the Elsa-Keno Hill camp bear testimony to the intense exploration for more silver-rich veins. Exploration is difficult because the thick overburden limits the effectiveness of traditional geochemical sampling, although mercury anomalies in A-horizon soils have been a useful indicator of mineralized veins east of Mount Haldane (INAC, 1981, p. 208). Geophysical exploration techniques are limited by the proportion of graphite and unmineralized fault gouge in the host rocks, but certain aeromagnetic, conductivity and spectral induced polarization surveys have shown significant anomalies (J. McFaull, pers. comm. 1992).

Age and origin of the silver veins

Mineralization clearly post-dates peak metamorphism of the host rock. Whereas the quartzite and phyllite are highly strained, vein minerals are euhedral and unstrained. The mineralization clearly post-dates ductile deformation, which may be of Upper Jurassic age. Following the development of the structural fabric in the host rock, brittle faults allowed metal-rich fluids to permeate the quartzite. The youngest rocks containing veins are quartz-feldspar porphyry dykes (Boyle, 1965), the age of which has not been determined in this area and the relationship of which to the Roop Lakes pluton remains unknown. Five samples of micas from hydrothermally altered Keno Hill quartzite wall rock surrounding the veins gave K-Ar ages between 85 and 103 Ma (Sinclair et al. 1980). The orientation of cross-faults is consistent with the last motion on the Tombstone Thrust (Roots and Murphy, 1992a). The most likely age of the hydrothermal cell and alteration is during and immediately following intrusion of the Roop Lakes pluton.

The abundance and high silver content of veins reflect the following:

- a source of metals;
- open fractures in a competent host rock, allowing long-term circulation of hydrothermal fluids;
- prolonged Tertiary supergene weathering, which enriched the upper 150 m of exposed veins; and
- partial preservation of this enriched zone.

The metals may have been mobilized from underlying rock units, in particular the Lower Schist, now recognized as Earn Group (e.g. Boyle, 1957; 1965). These Devono-Mississippian sediments were deposited with iron sulphide under anaerobic conditions and are rich in organic carbon, an excellent 'sink' for metals in aqueous solution. The metalliferous character of Earn Group strata is widely evident from regional stream sediment surveys and the stratiform deposits at Macmillan Pass (Goodfellow and Rhodes, 1990). The metals could have originated during the interaction of hydrothermal vents and deep sea brines in a submarine crustal extension environment (e.g. Carne, 1979; Turner, 1990).

Summary

The hydrothermal system driven by the Roop Lakes pluton was largely confined to the fractured quartzite. A tensional stress regime created fluid conduits upward through the metalliferous layer into open spaces where temperature, pressure and CO_2 gradients were appropriate for mineral deposition.

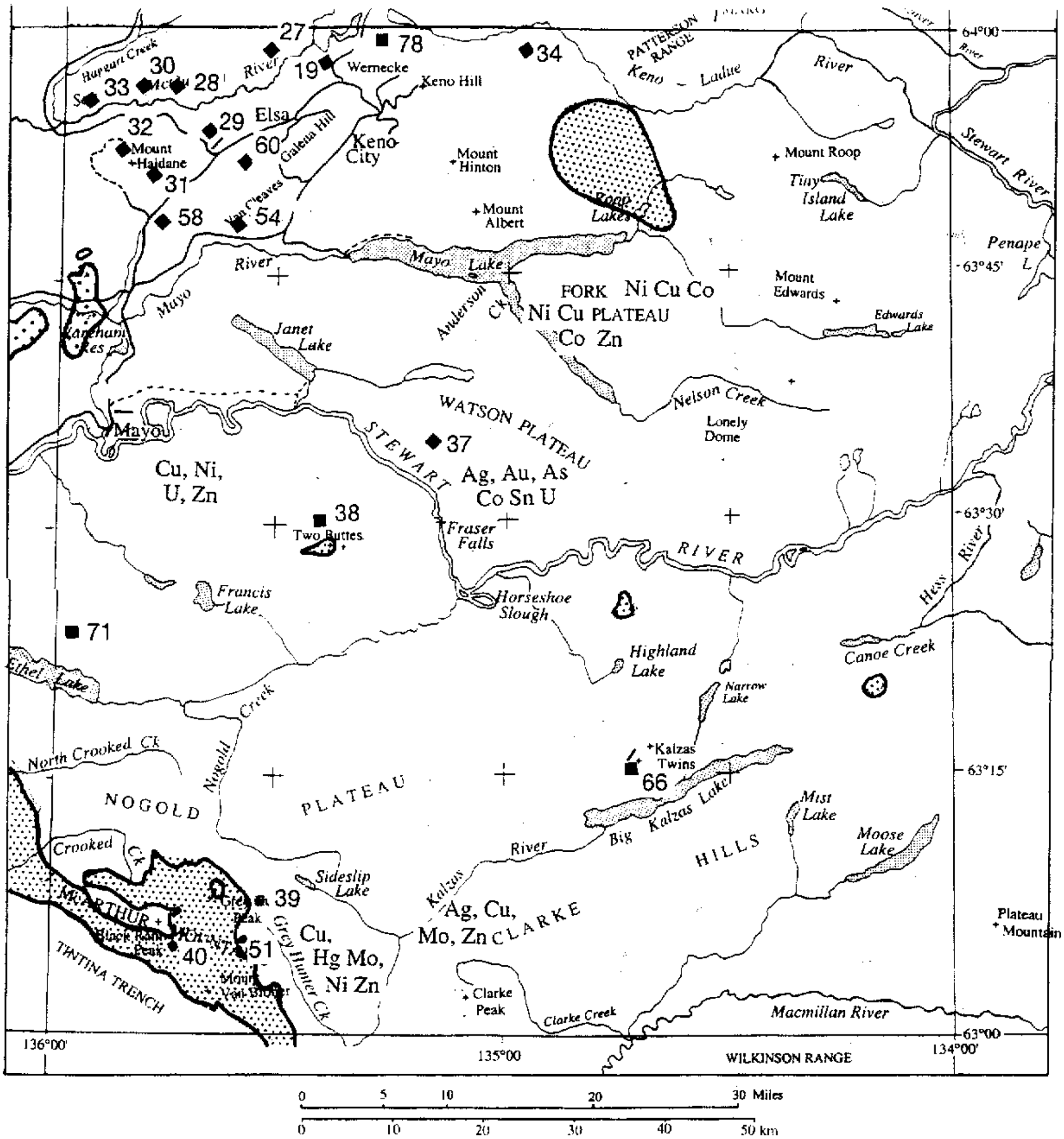
Other polymetallic veins in the Mayo map area

Numerous polymetallic veins are located on the west, north and east margins of the Elsa-Keno Hill camp (Fig. 61). None of them, however, approach the high silver content of the veins in the mining camp. Whereas the Ag/Pb ratio (oz. Ag/ton /% Pb) is greater than 4 for all significant veins in the Elsa-Keno Hill camp, assays for all the outside vein systems are less than 1.5. Veins within the Keno Hill quartzite are described first, followed by those within the Hyland Group.

At **Cobalt Hill** (105M/34), 15 km east of the abandoned Wernecke mining camp, about 4.5 tonnes of galena were extracted from a northwest-trending fracture (Green, 1971, p. 61). The fracture cuts thinly-banded phyllitic quartzite and phyllite containing three metadiorite bodies. This Pb-Zn vein occurrence is similar to several in the Davidson Range, north of the map area (106D/13, 16).

The Shanghai, Titan and Laysier occurrences (Aho, 1964) are north of the South McQuesten River, on the north limb of the McQuesten antiform. At **Shanghai** (105M/28) four branching, transverse Pb-Zn veins were explored underground. The vein-faults dip northwest, have a dextral sense of motion (opposite to that in the Elsa-Keno Hill camp) and are closely overlain by the assumed trace of the Robert Service Thrust with Hyland Group in the hanging wall. The **Titan** (105M/27) and **Laysier** (105M/33) occurrences are vein-faults with abundant siderite and limonite in fault gouge.

Mount Haldane contains a Pb-Zn vein system on the north side, with gold, tin and tungsten mineralization near Fortune Creek on the east side. Around Bighorn Creek are at least three mineralized zones that were mined in 1919 and 1926. They comprise a north-trending, multibranching, transverse vein fault (105M/32). On the east face of Mount Haldane, the **Strebchuk** (Joumbira; 105M/31) occurrence is primarily an arsenopyrite vein within a porphyry dyke; samples with high silver content have been reported from the area. Possibly these vein occurrences reflect a separate hydrothermal system, driven by intrusion of a small granitic plug exposed near the head of Fortune Creek.



			29	Wayne	Ag, Pb, Zn, Au, W
21	Laysier	Ag, Pb, Zn vein	31a	Strebchuk	Sn, Ag, Pb, W
27	Titan	"	38	Two Buttes	W
28	Shanghai	"	39	Sideslip	Cu skarn
31b	Joumbira	Pb, Ag, Sn, W	40	Great Horn	W, Cu, Zn skarn
32	Mount Haldane	Ag, Pb, Zn vein	51	Freisen	Cu, W skarn
34	Cobalt Hill	"	58	Halfway	Au, W
			60	Newry	
37	Gordon	Sb, Ag vein	66	Kalzas	W, Sn vein
54	Chance	Sb vein	71	Drill	W vein
			78	Feed	

Figure 61. Vein and skarn mineral occurrences in the Mayo map area, excluding the Elsa-Keno Hill mining camp. Granitic intrusions are stippled. Abbreviations for elements are shown where reconnaissance stream sediment sampling (Friske and Hornbrook, 1989) indicate metal concentrations in the 95 percentile of all samples in the map area.

Within the Hyland Group are two vein mineral occurrences, neither of which were visited during this study. The **Chance** (105M/54), south of Van Cleaves Hill, contains stibnite. Another vein, bearing antimony, mercury and bismuth (**Gordon**, 105M/37), was discovered by placer prospectors south of Williamson Lake. Near the vein, silt from a stream draining the plateau south of Williamson Lake is anomalous in Au, Ag, As, Co, Hg, Sn, U and Zn (Fig. 61; Friske and Hornbrook, 1989), and the north slope is currently being investigated (L. Dublenko, pers. comm. 1996). Apart from these occurrences, the Hyland Group has not demonstrated a potential for polymetallic vein mineralization, despite the abundance of quartz veins.

Replacement, stockwork and 'Carlin-type' occurrences

In this category are several copper occurrences, a tungsten-tin deposit at Kalzas Twins, and tin-tungsten-molybdenite showings at Two Buttes, Roop Lakes, Mount Haldane and in the South McQuesten River valley. Geographically these occurrences form three northwest-trending belts (Fig. 61), which are described below. The belts are roughly collinear with Cretaceous granitic intrusions; however, the northern and central belts merge in the McQuesten River region, which contains numerous tin, gold and tungsten veins and skarns (Emond, 1986, Emond and Lynch, 1992, Emond, 1992, Murphy, 1997). The **Brewery Creek** (76 km east of Dawson; Diment, 1996) and **Dublin Gulch** (49 km north of Mayo; Smit et al. 1996) properties are large, low-grade gold deposits associated with the Tombstone Plutonic Suite. Potential exists for 'Carlin-type' gold deposits (pyrite and micron-sized gold disseminated in decalcified zones of otherwise carbonate-bearing rocks) where distal portions of large intrusion-centered hydrothermal systems intersect calcareous host rocks (Poulsen, 1996).

Roop Lakes to Mount Haldane

This belt includes skarns associated with the Roop Lakes and McQuesten plutons, and a second group of occurrences along the trend of the Elsa-Keno Hill silver veins. Northwest of the 93 Ma Roop Lakes pluton are scheelite veins within quartz-garnet-diopside skarn of the Hyland Group, located by Bostock (reported in Green, 1971, p. 64). Near Hanson Lakes, powellite, scheelite and magnetite were found in panned concentrates (**Zap,** INAC, 1981, p. 208) and stream silt samples were anomalous in W, Mo, Hg, Pb and Zn (105M/19, 78). Mineralization may be related to the McQuesten pluton (Green, 1971) in the southern Nash Creek area.

West of Elsa and extending to Mount Haldane are several skarn and vein occurrences anomalous in gold. Much of this region is drift- or rubble-covered and exploration programs have used geophysics and geochemical sampling grids. The **Wayne** property (105M/29) originally covered a north-striking Pb-Zn vein but two apparently stratiform, gold-bearing horizons were revealed by drilling in 1981 and 1983. The upper 3.6-m-thick horizon lies in Hyland Group foliated grit about seven m above the top of the Keno Hill quartzite and contains weakly foliated, pyrrhotite-rich diopside and chlorite skarn with crystalline scheelite. The lower horizon is 16 m below the top of the quartzite and consists of disseminated pyrite and pyrrhotite in a phyllitic horizon less than five m thick. This mineralization appears to coincide spatially with the Robert Service Thrust, although no thrust structures are preserved. Foliation-concordant quartz-phyric felsic dykes are located near the property, and may extend to isolated occurrences atop Galena Hill and north of Keno Hill (Kindle, 1962) but their continuity has not been demonstrated.

About five km east of the Wayne occurrence, the Aurex (formerly **Newry**, 105M/60) claims cover a drift-covered hill where trenching revealed chlorite spotting and porphyroblasts (possibly retrograded andalusite) with disseminated pyrrhotite in phyllitic rocks of the Hyland Group. Although contact metamorphism is indicated, no underlying intrusion has been encountered in drilling. Small quartz veins with disseminated arsenopyrite, pyrite and minor pyrrhotite are parallel to regional foliation and soil sampling located bismuth anomalies. The higher metamorphic grade may lie within the plane of the Robert Service Thrust that was later deformed in the Tombstone Strain zone.

The drift-covered valley between Mount Haldane and the west part of Galena Hill has been explored with geophysics and geochemical grids (**Halfway,** 105M/58). The north-trending fault beneath the valley (inferred to be east-side-down; Murphy and Roots, 1992a) truncates three east-trending conductors with anomalous Hg (INAC, 1981, p. 208) that parallel the upper contact of the Keno Hill quartzite, the same stratigraphic and struc-tural horizon encountered at the Wayne occurrence.

On the east side of Mount Haldane considerable attention has been paid to a biotite-hornblende-phyric rhyodacite dyke and a two-mica granitic plug almost 30 m wide in the cirque above Fortune Creek. The surrounding greisen (tourmaline, fluorite and chlorite) contains arsenopyrite, sphalerite, galena and cassiterite, as well as quartz veins with scheelite (Strebchuk, 105M/31). Argentiferous galena samples have also been reported.

Two Buttes and Kalzas Twins

Prominent landmarks Two Buttes and Kalzas Twins consist of Hyland Group hornfels around granite plugs. On the north slope of Two Buttes (105M/38), 29 km southeast of Mayo, a limestone lens within the Hyland Group is replaced by quartz-garnet-diopside-calcite skarn. No evidence was observed to support the Devono-Mississippian age of the host as reported in Yukon Minfile, although the Yusezyu meta-siltstone is converted to purplish-black hornfels which might be mistaken for argillite. Small amounts of scheelite and molybdenite are present in drill core, but the granitic rock reveals the highest tin concentration of 72 plutons within the miogeocline, as tested by the Geological Survey of Canada in 1970 (e.g. Garrett, 1972).

Several felsic (porphyritic dacitic) outcrops within two km west and south of the west butte lithologically resemble flows (or high-level intrusions) near Minto Creek. Anomalous Sb, Zn, Mo and As are present in silt from northward drainages from the Two Buttes area (Friske and Hornbrook, 1989). Empire Creek, a southwest-draining tributary, contains coarse placer gold.

The **Kalzas** occurrence (105M/66), 71 km southeast of Mayo, is on the south slope of Kalzas Twins, an almost bare double peak of hornfelsed Yusezyu Formation. Sheeted quartz veins with long crystals of tourmaline and wolframite are found in a one-km-wide area, surrounding a small core zone with veins containing cassiterite and orthoclase. Float boulders containing molybdenite, arsenopyrite, pyrrhotite and galena are reported in the vicinity. Hydrothermal alteration, veining and fluid inclusion characteristics of the deposit, as reported by Lynch (1983, 1989c) are summarized below.

The Kalzas occurrence lies within a concentrically zoned alteration halo about three km wide. The outer (phyllic) zone consists of quartz-sericite-pyrite, and the rocks weather white where chlorite is converted to sericite and pyrite is oxidized. Barren sheeted quartz veins and minor stockworks are common. Superimposed on this broad alteration is an area of tourmaline-quartz veinlet stockworks and tourmaline preferentially replaces phyllitic horizons. Within the large quartz veins wolframite (iron, manganese tungstate), in crystals up to 20 cm long and in radiating bundles, occurs as comb structure within the quartz veins. Along the outer edge of the 1.5-by-1 km oval mineralized zone fine-grained cassiterite (<1 cm long crystals), coarse muscovite and minor euhedral beryl are associated with the wolframite. Wolframite is segregated from tourmaline and is most common where the vein passes through meta-sandstone horizons. The core of the alteration, less than 200 m wide, is potassic and characterized by coarse-grained orthoclase, minor apatite molybdenite, bismuthenite, pyrargarite, pyrrhotite, galena, chalcopyrite and rutile.

Fluid inclusion studies yielded homogenization temperatures between 160-340° C in quartz, 280-350° in cassiterite and 220-360° in apatite, with a minimum hydrothermal pressure estimate between 300 and 600 bars (Lynch, 1989c). No intrusive rock is exposed, but the concentric alteration aureole, with alteration increasing downward at least 300 m in drill core (C. Forster, pers. comm. 1989), the prominent aeromagnetic low, and the presence of boron to form tourmaline all suggest an underlying granitic body. The formation of a phyllic zone, in which chlorite is converted to sericite without further fracturing, argues for direct contact metamorphism. Furthermore, the borosilicate components, necessary for extensive tourmaline formation, could only have been carried by a magmatic-derived hydrothermal system (Lynch, 1983).

A whole-rock K-Ar age of 90.7 ±1.4 Ma dates from a pervasively biotitized sample, (Hunt and Roddick, 1987), is consistent with the age of the Tombstone Plutonic Suite. Veins and mineralization are undeformed, so the deposit clearly post-dates Jurassic-Early Cretaceous regional metamorphism. Joints generally are parallel to broad fold axes of the Robert Service thrust sheet in this area; veins, without preferred orientation, are at a high angle to these joints.

The extent of mineralization at the surface and the abundance of veins intersected by drilling (Lynch, 1983) indicate a large low-grade tungsten deposit. Veins thicker than 1 cm predominantly are flat-lying (Lynch, 1983), but drill-indicated reserves and the average thickness and spacing of the veins have not been released. The deposit has many geologic similarities to the Panasqueira deposit in Portugal, described by Kelly and Rye (1979). As a vein-type tungsten occurrence (Dick, 1979) its closest regional analogue is the Potato Hills occurrence (106D/26), 50 km north of Mayo. Such vein mineralization reflects a hydrothermal system driven by an intrusion similar in age and composition to that which may have led to Keno Hill style veins at a greater distance.

McArthur Mountains

In the McArthur Mountains the **Sideslip** (105M/39), **Great Horn** (105M/42) and **Freisen** (105M/51) are chalcopyrite- and pyrrhotite-bearing skarns in discontinuous limestone of the Hyland Group and possibly the Rabbitkettle Formation. This area contains numerous Au, W, As, Sb and Cu stream silt anomalies (Friske and Hornbrook, 1989). The

McArthur Mountains are also rumoured to contain a large, low-grade copper deposit (105M/43) but it has not been located, despite concerted exploration.

North of Ethel Lake a scheelite occurrence (**Drill**, 105M/71) is reported to consist of widely spaced quartz-sericite, pyrite and tourmaline veins within the Hyland Group. A source intrusion has not been identified.

Potential for large, low-grade gold deposits

Some areas of the Mayo map area have moderate potential for disseminated gold deposits. Some exploration models are based upon the Fort Knox mine north of Fairbanks, Alaska (Hollister, 1991), where native gold occurs with bismuthenite in biotite-hornblende pegmatitic parts of grey quartz veins. The veins fill reactivated fractures and joints in lower Paleozoic schist and quartzite as the last pulse of a hydrothermal system and alteration around a 90 Ma granite intrusion. Yukon deposits of this type which have reached advanced development are Brewery Creek (Diment, 1996) and Dublin Gulch (Smit et al. 1996). Similar-aged intrusions (90-95 Ma) and anomalous trace elements (high Bi, Ti, W) suggest a link between these deposits. The density of quartz veins and relatively easy surface extraction of the deeply weathered bedrock are important factors. Higher elevations in the Mayo map area are unglaciated and deeply weathered, thus a concentration of low-grade gold-bearing quartz veins could be economically mined. One candidate is the Aurex (Newry) prospect west of Galena Hill, although no intrusion is known.

A second possibility is Grey Hunter Creek at about 63°04'N (Fig. 62) where a thick Earn Group succession, including conglomerate, trends into the McArthur pluton. Silt from the granite, as well as from the surrounding sedimentary rocks in tributaries of Grey Hunter Creek, give the most prominent general anomalies in the southern Mayo map area. These include high Sb, As, Zn, Cd, Ni and Co (Friske and Hornbrook, 1989; Bi in these samples is currently being analyzed). A chloritic sandstone — perhaps of volcanic origin, yet apparently within the Road River Group — may be the source of the Ni, Co and Cu anomalies. Further mineral exploration is unlikely, however, because this area lies within the McArthur Protected Area.

Another possible setting is Carlin-type gold replacement of formerly calcareous strata. Although limestone in the Hyland Group consists of small recrystallized lenses, the Rabbitkettle Formation, intermittently exposed along the northern edge of the McArthur pluton and in slopes south of the headwaters of Nogold Creek, may be productive. It has been noted that the locally calcareous Steel Formation would be a possible host where it lies within the distal extent of a large intrusive related hydrothermal system (Poulsen, 1996).

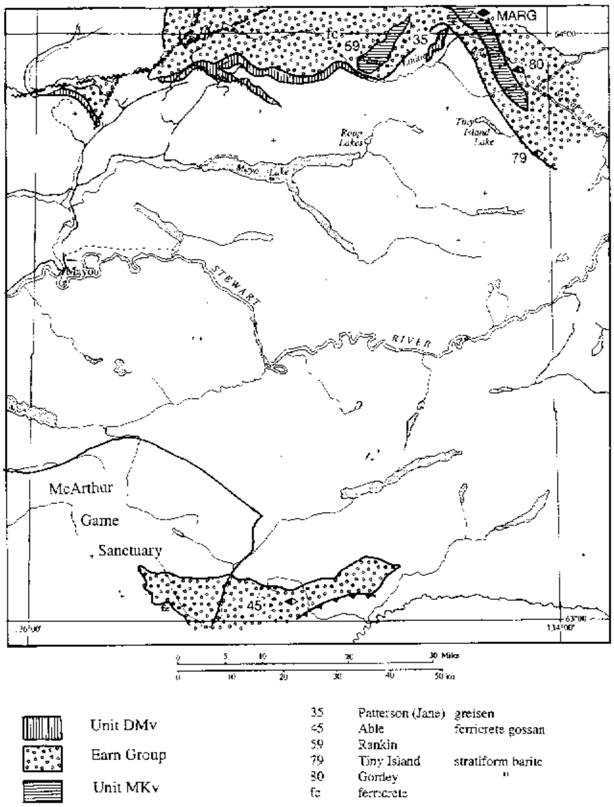


Figure 62. Stratiform occurrences and potential host rocks in the Mayo map area.

Outcrop is poor or nonexistent in some parts of the map area where significant deposits could lie buried by vegetation and overburden. Aeromagnetic anomalies that may reflect buried intrusions are located north of the Stewart River at Fraser Falls and Big Island east of Mayo (D. Teskey, writ. comm. 1992).

Sediment-hosted Zn-Pb-Ag-barite potential

The Cambrian to Upper Devonian off-shelf sequence of Selwyn Basin is characterized by laminated to massive base metal sulphide deposits. Although none are known in the Mayo map area, three world-class districts are present to the southeast: **Anvil** (120 million metric tonnes (mT) of 9.3% Pb-Zn in five deposits in Cambrian strata; Brown and McClay, 1993), **Howard's Pass** (125 mT of 5.4% Zn, 2.1% Pb in Silurian strata; Gordey and Anderson, 1993), and **Macmillan Pass** (30 mT of 7% Zn, 5% Pb, >49 g/t Ag in two deposits in Devonian strata; McClay and Bidwell, 1986, Bailes et al. 1986; Goodfellow and Rhodes, 1990 Abbott and Turner, 1990).

Each of these occurrences coincides with a major facies or thickness change, suggesting that mineralization was related to maximal syndepositional tectonism. Bedded barite, a common exhalitive associated with these deposits, occurs in the northeast Glenlyon map area and uncommonly in Devonian strata of the southern Mayo map area (Fig. 62). The great thicknesses of conglomerate at Clarke Peak (**Able**; 105M/45) and between Kalzas River and Grey Hunter Creek could lie adjacent to unrecognized Devonian faults which may have been conduits for metalliferous brines. Sideslip Lake Fault also could have been a locus of mineralization; its age is unclear but anomalously high Zn, Cd and Ba in stream sediments along its trend (Friske and Hornbrook, 1989) may originate from a covered sulphide deposit.

A second area with stratiform sulphide potential is in the northeastern Mayo map area near Tiny Island Lake, where stratiform barite was noted in two places (Yukon Minfile, 1996; 105M/79,80; Gordey, 1990a, b). There the Earn Group occurs more extensively than was previously recognized. If sulphides are present, they are likely recrystallized and metallurgically more amenable to conventional milling and flotation than those from less metamorphosed areas. The potential of this area extends southeast toward Penape Lake in the adjacent Lansing map area.

Potential for volcanogenic massive sulphide deposits

Although no volcanic-hosted deposit is known within the map area, discontinuous felsic metavolcanic rocks at the top of the Earn Group (unit **DMv**) and lenses within Keno Hill quartzite (Gordey, 1990a) contain the Marg deposit, five km north of the northeastern Mayo map area (Fig. 62). Discovered in 1989, the **Marg** deposit (106D/09) contains 1.9 million tonnes of 1.97% Cu, 5.19% Zn, 2.72% Pb and 55.6 g/t Ag (Abbott and Turner, 1990). Because it lies within or immediately adjacent to the Keno Hill quartzite, it represents a new exploration target within the upper Paleozoic rocks of central Yukon.

The covered Marg deposit was found by drilling a geochemical anomaly. It consists of fine-grained massive pyrite intergrown with quartz, ferroan carbonate, sphalerite, chalcopyrite and galena. It is hosted by carbonaceous pyritic metachert and quartz sericite carbonate schist, locally banded with augen of ferroan carbonate, locally referred to as "the Marg sequence" (Abbott and Turner, 1990). The deposit is interpreted to have formed in an anoxic deep marine basin with biogenic silica during waning volcanic activity. Although lacking barite, it is a product of similar metal-rich brines and fumarolic activity to those generating the Devonian and Mississippian sediment-hosted deposits in the tectonically reactivated Selwyn Basin. The abundant ferroan carbonate in the sulphide and underlying rocks suggest a hydrothermal upflow zone or vent complex (Abbott and Turner, 1990) and alteration varies from a core of carbonate-quartz stockwork (represented by deformed compositional bands) to a peripheral facies of sericite-quartz-pyrite and chlorite-quartz conversion of less altered carbonate rocks, all features consistent with vent complexes at other massive sulphide deposits (e.g. Franklin et al. 1981) and of regional interest, the **MM** occurrence (Mortensen and Godwin, 1982) of the same age in the Pelly Mountains, 270 km southeast.

It is impossible, however, to trace the Marg sequence directly into the Mayo map area as a result of polyphase deformation in the Tombstone Strain Zone. There are two candidates for analogous strata: in the Patterson Range is a thick band of brown-weathering, gritty chloritic phyllite with densely packed quartz and feldspar phenocrysts interbanded with Keno Hill quartzite (D. Murphy, pers. comm. 1991; Green, 1971; his unit 8a). Igneous zircons extracted from this unit yielded a U-Pb date of 378 Ma (Appendix 4) which supports the imprecise Early Mississippian age obtained from drill core of the chloritic phyllite unit at the Marg deposit (J. Mortensen, pers. comm. 1989). These same rocks appear consistently at or near the top of the Earn Group (Lower Schist), based upon isolated outcrops across the north slopes of Mount Haldane (Hunt et al. 1996) and Keno and Galena hills (Murphy, 1997). Second, northeast of Tiny Island Lake (Gordey, 1990b) is a chloritic phyllite containing quartz granules, some of which, in thin section, show resorption and beta-quartz morphology (Fig. 32). U-Pb dating of zircons indicated a Middle or Upper Devonian age (373 and 381 Ma; Appendix 4). These older ages imply that two separate felsic volcanic episodes may be present in the area, although analytical error in the Marg determination is sufficiently wide to overlap the Tiny Island Lake determinations.

Possible bedrock sources of placer gold

The Mayo map area contains placer gold in seven known drainages (Fig. 63). Four of them are discussed below. The largest is the area south of Keno and Galena hills, drained by Duncan Creek and its eastern headwaters, Lightning Creek and Thunder Gulch. Silver nuggets and abundant galena were found in the placers, suggesting that higher, now-eroded portions of the Keno Hill veins might be the source; however, the rough, angular gold from Thunder Gulch implicates the gold-bearing veins on Mount Hinton, at the head of this drainage. On the

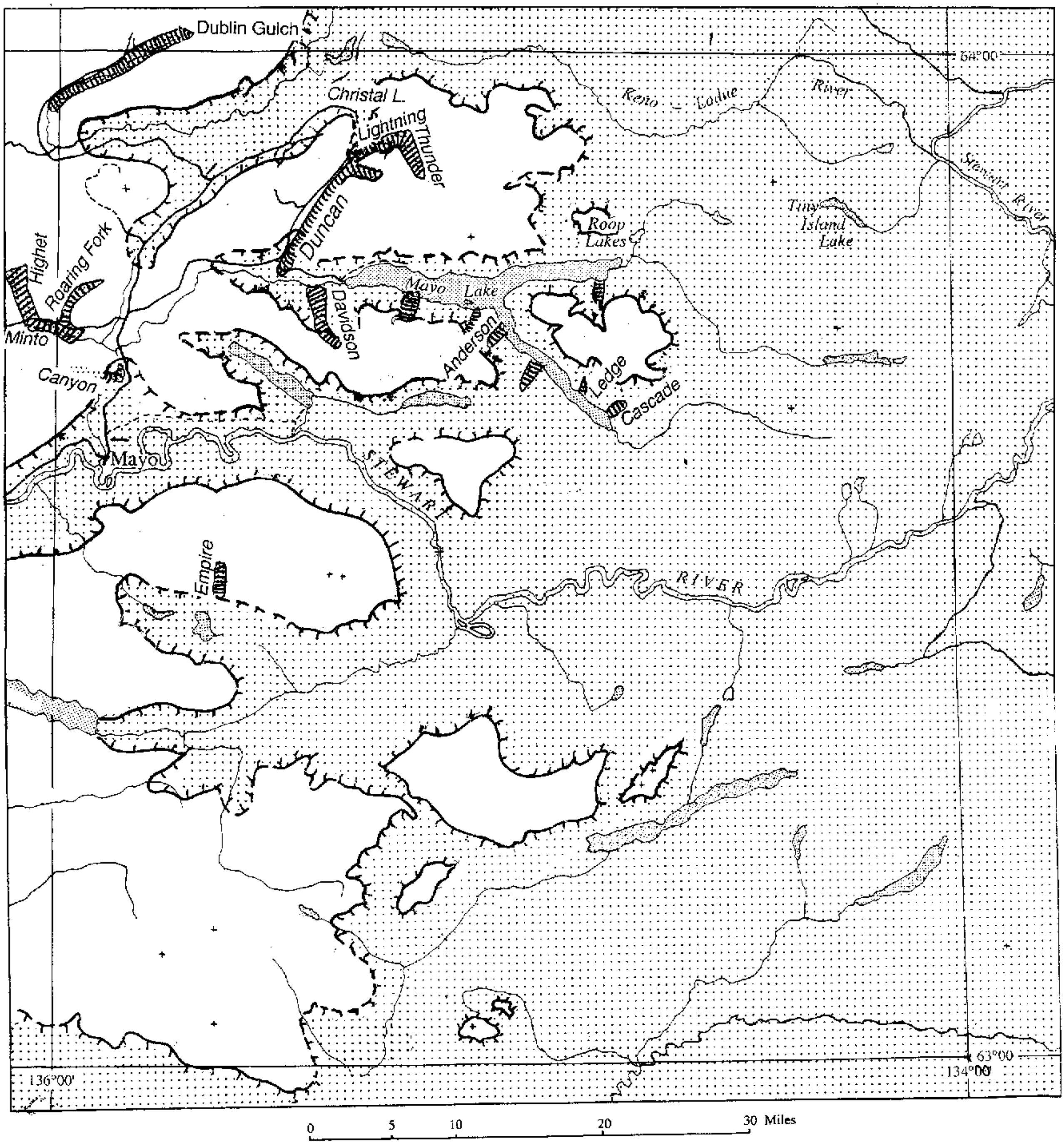


Figure 63. Western extent of McConnell ice advance in the Mayo map area (adapted from Hughes, 1982), and placer gold-bearing streams (dark hachures).

south side of Mount Hinton, where geochemistry and seismic methods have been repeatedly used to probe the thick glacial deposits, Granite and Keystone creeks are reputed to contain gold.

At least eight creeks entering the south side of Mayo Lake and Davidson Creek to the west contained placer gold. During continental glaciation, these drainages were protected from scour by their oblique orientation to the glacier scour of the main valley (Fig. 3). In each creek the gold is concentrated at the apex of the alluvial fan, either in an old channel, among boulder deposits predating the last glaciation, or on bedrock. Ledge, Cascade and Edmonton creeks drain the Fork Plateau, which is capped by gabbroic intrusions. Some of the intrusions are coarser-grained than the metadiorite on Keno Hill, and are a possible magmatic source of gold. Along the south side of the lake, where the other placers are located, grit and phyllite of the Hyland Group predominates. A possible source of the gold is veins in fractures of competent rocks within a hydrothermal system surrounding the Roop Lakes pluton. The headwaters of placer creeks south of Mayo Lake are 20-30 km from the nearest margin of the pluton, and no gold-bearing bedrock veins have yet been found in the area.

Placer gold in Minto Creek is likely derived from veins in and around Cretaceous intrusions north of Minto Lake and at Scheelite Dome (Murphy and Héon, 1995) in the adjacent McQuesten map area. Haggart Creek, which traverses the northwest corner of the Mayo map area, contains gold transported from Dublin Gulch and the Peso and Rex veins in Nash Creek map area to the north. Both these drainages carry considerable scheelite and cassiterite, reflecting the trace metal associations of Scheelite Dome and the Potato Hills stocks, respectively. Canyon Creek, a stream flowing east into Wareham Reservoir nine km north of Mayo, also contained gold. It drains mostly gritty Hyland Group rocks but biotite felsite is abundantly exposed on the hilltop.

Empire Creek, 15 km southeast of Mayo, contains coarse gold in its western tributary. Upstream bedrock is Hyland Group grit with broad bands of chloritic phyllite. At the head of the tributary is the contact metamorphic aureole of the Two Buttes stock and felsite of unknown extent. The possibility that gold-bearing veins may be present in the Two Buttes vicinity may warrant further investigation.

Although the eastern and central Yukon have been subjected to multiple glaciations, the Mayo map area lies near the maximum westward advance of the most recent (McConnell) glaciation. Inside this limit glacial deposition probably dominated over glacial scour and auriferous interglacial deposits, such as those along lower Duncan Creek (LeBarge, 1996b), are preserved. The discovery of new placer reserves requires deciphering the local glacial regime and recognizing areas where interglacial deposits have not been scoured, and where those may be overlain by glacial till or overburden. The Christal Lake divide, plateaus overlooking Williamson and Francis lakes, and high terraces above the most recent glaciation are possible candidates for ancient placer deposits.

Construction materials

The Mayo map area has abundant sand, gravel and coarse aggregate deposits, but no hydrocarbon or exploited clay or dimension stone. High-quality specimens of many sulphate and carbonate mineral species, as well as a number of rare minerals, have been collected in the underground mines of the Elsa-Keno Hill district (see Sabina, 1992, p. 80).

The largest glaciofluvial gravel and till deposits are located in broad valleys on the western side of the map area, near the limits of the McConnell glaciation (Hughes, 1982; J. Bond, pers. comm. 1996). These deposits are commonly high points surrounding the broad flood plain of the meandering Stewart River. McConnell-aged terraces, such as the high sand-rich cliff immediately downstream of the Mayo River, are an important resource for the village of Mayo, which was a poorly drained site where ice dammed the proglacial outflow from the Mayo River. Sand and gravel deposits are located on the McConnell moraine 24 km west of the village, as well as south of both Five Mile Lake and Minto Bridge. Ice-rich lenses and kettles occur within the moraines where overlapped by lake sediments, and north-facing slopes provide difficult ground conditions. Beginning north of Halfway Lakes, the road to Elsa and Keno City largely follows the lateral (McConnell) moraine around Field and Galena hills at the 2500-ft. (760 m) contour. Sand and gravel has been quarried near the airstrip (South McQuesten Road) and the junction of the Hanson Lakes Road (Wind River trail). Abundant aggregate is particularly important for road construction in northern climates where a broad gravel pad elevates the roadbed and minimizes disturbance of the underlying permafrost.

Large heaps of broken rock are located near open pits at Bermingham, Galkeno 200 on Galena Hill and at Onek mine on Keno Hill. These are readily accessible sources of coarse and finely-broken rock. The rock has been used in the construction of tailing impoundments north of Elsa, and for mine access roads, such as to the Silver King and Husky Southwest mines. Until recently, waste rock containing pyrite and marcasite was not separated from barren waste; consequently sulphide rock is oxidizing in these embankments. Generally the oxidation is slow and local because sites are dry or well-drained and are frozen five months of the year. In the case of well-mineralized rock, galvanic protection of iron sulphide by earlier oxidation of immediately adjacent galena and sphalerite grains (Sato, 1992) is likely a factor (Kwong et al. 1996). However, acidic conditions are present in places where constant runoff or fluctuating impoundment levels maintain a wet environment. Future use of mine waste as fill or aggregate should take into account the sulphide contact and humidity of intended site, to avoid ongoing environmental problems.

Many natural drainages on Keno Hill and Galena Hill contain abundant pyrite, and potential acidity is quickly buffered by streaks and pods of carbonate at all scales within the Keno Hill quartzite and Earn Group host rocks. The most accessible surface exposure of limestone in the area is atop Sourdough Hill, about 250 m south of the highest mine roads of the Bellekeno Mine.

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Appendix 1

Index to reference localities

These rock exposures are considered the most representative or revealing examples of the stratigraphic units in the map area. Locations are shown on Figure 64, and listed in the following table from youngest to oldest.

Ref.	Latitidue	Longitude	Map	UTM east	UTM north	Elev.	Description
Jones Lake Formation							
TJps	63°58.0'	134°6.5'	M/16	543290	7094290	2300'	Canyon at fork in stream draining southwest
Keno Hill quartzite							
MK1	63°57.0'	135°13.0'	M/14	489600	7090400	5600'	Keno Hill lookout (signpost) and eastward along ridge
MK2	63°54.5'	135°26.0'	M/14	479000	7086800	4300'	Bermingham open pit, crest of Galena Hill
Earn Group							
DME	63°02.6'	135°2.8'	M/3	497500	6990500	4100'	North side Clarke Peak (limestone at base of section)
DMp	63°55.5'	134°15.0'	M/16	536000	7088400	4150'	Ridge 8.3 km north of Tiny Island Lake
Nogold Unit							
PN1	63°11.5'	135°27.6'	M/3	475850	7007250	4950'	Broad, south sloping spur of maroon argillite (Nowakia locality)
PN2	63°18'	134°29'	M/6	326100	7020000	4700	East facing ridge spur (Foraminifera locality 9)
PN3	63°12.5'	135°34.5'	M/4	471200	7009000	4950'	Broad, south sloping spur of maroon argillite (Nowakia locality)
Steel Formation							
Ss	63°07.8'	135°18'	M/3	485690	7001360	4400'	Knoll, southeast end of ridge north of Sideslip Creek
Duo Lake Formation							
OSD	63°05.3'	135°22.0'	M/3	481820	6955700	4700'	Northeast ridge spur, 4 km southwest of Sideslip creek (Fossil locality 5)
Rabbitkettle Formation							
COR	63°07.6'	135°28.0'	M/3	476140	6999900	4700'	East-facing limestone promontory, 3 km southwest of Sideslip Lake
Gull Lake Formation							
COG	63°08.2'	135°4.6'	M/2	511870	7001300	3350'	Forested outcrop 100 m west of pond with north outlet
Hyland Group							
PY1	63°50.2'	135°14'	M/14	488000	7078700	5400'	North side of ridge crest at head of Duncan Creek
PY2	63°44.8'	135°02'	M/11	4983000	7068350	2180	Mayo Lake shoreline 1 km northwest of Anderson Creek mouth
PY3	63°16'	135°36'	M/15	470150	7015140	2600'	East tributary of Nogold Creek, black argillite in gully
PY4	63°18.5'	135°47.5'	M/7	510990	7020420	5300'	Low outcrop at 5 km south of Highland Lake

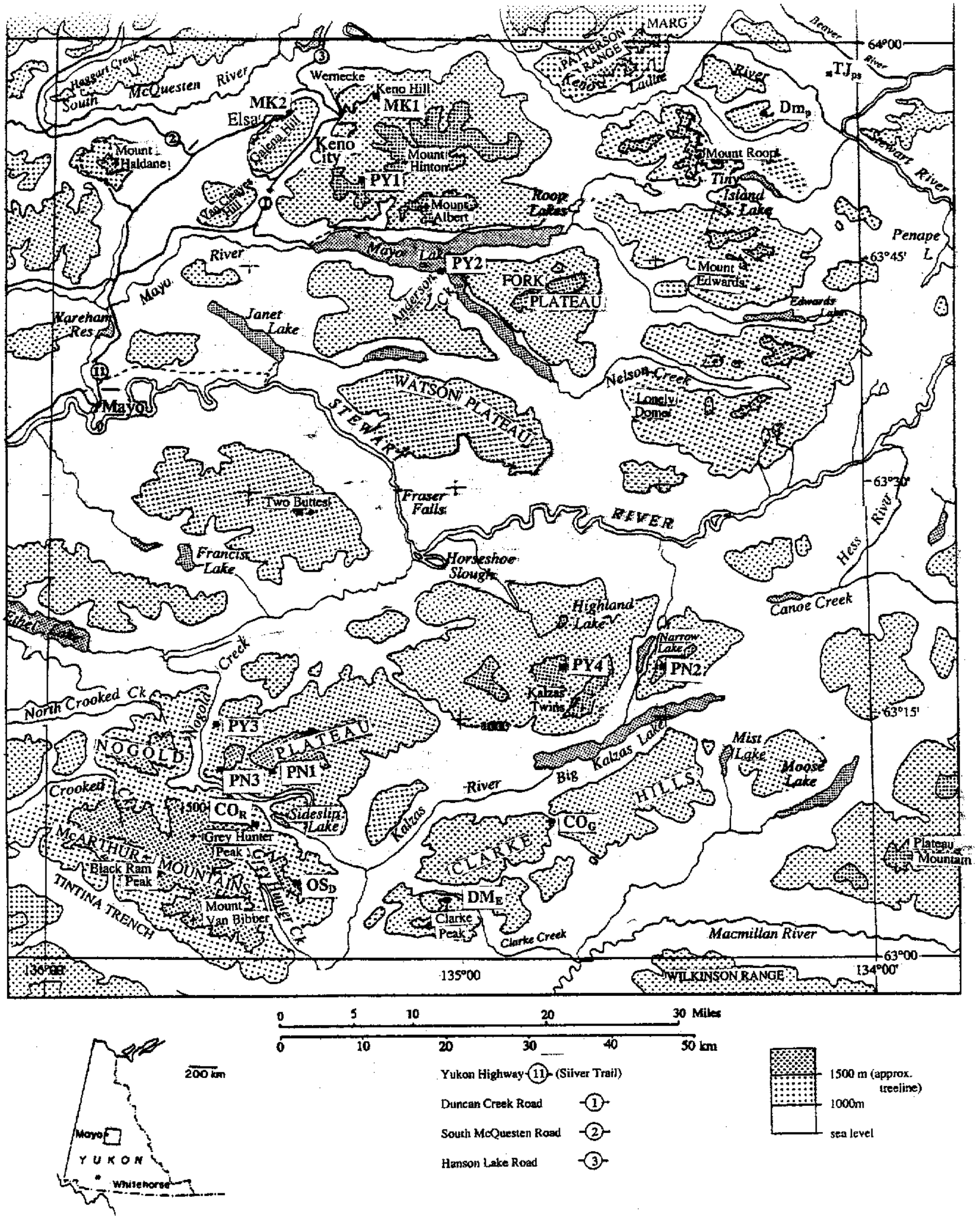


Figure 64. Location of Type Localities of stratigraphic units in the Mayo map area: see text for discussion.

Appendix 2

Index to Yukon geological reports and maps published by the Geological Survey of Canada (GSC). References are indicated for those discussed in the text; serial numbers are given for the rest (O.F. = open files; map numbers with suffix "A" are coloured).

NTS	Name	GSC Report	GSC Map
95D	Coal River	Paper 68-38	11-1968A
95E	Flat River	Memoir 366 (Gabrielse et al., 1973)	1313A
105A	Watson Lake	no report	19-1966
105G	Finlayson Lake	no report	(Tempelman-Kluit, 1984)
105H	Frances Lake	no report	6-1966
105I	Nahanni	Gordey and Anderson, 1993	1762A
105J	Sheldon Lake	Gordey, in prep.	19-1987; in prep.
105K	Tay River	Gordey, in prep.	19-1987; in prep.
105L	Glenlyon	Campbell, 1967	1221A
105M	Mayo	this report	Fig.1
105N	Lansing	no report	Blusson, 1974
105O	Niddery Lake	Cecile, in prep.	Cecile and Abbott, 1992
106A	Mount Eduni	unavailable	O.F. 205 (Blusson, 1974)
106B	Bonnet Plume Lake	unavailable	O.F. 205
106C	Nadaleen River	unavailable	O.F. 205
106D	Nash Creek	Green, 1972	1282A
115I	Carmacks	Memoir 189	O.F. 486
115P	McQuesten	no report	Bostock, 1964
116A	Larsen Creek	Green, 1972	1283A
116B,C	Dawson	Green, 1972	1284A

1:50 000 map areas		Reference	Map #
106D/1	Mount Westman	Abbott, 1990a	Abbott, 1990b
106D/2	no name	Green, 1971	1269A
106D/3	no name	Green, 1971	1268A
105M/13	Mount Haldane	this report; Murphy, 1997	no map
105M/14	Keno Hill	this report; Murphy, 1997	1105A; INAC 1996-5
105M/15	Mayo Lake	Green, 1971	1270A
105M/16	Tiny Island Lake	Gordey, 1990a	Gordey, 1990b
115P/14	Clear Creek	Murphy, 1997	INAC 1996-1
115P/15	Sprague Creek	Murphy, 1997	INAC 1996-2
115P/16	Red Mountain	Murphy, 1997	INAC 1996-3

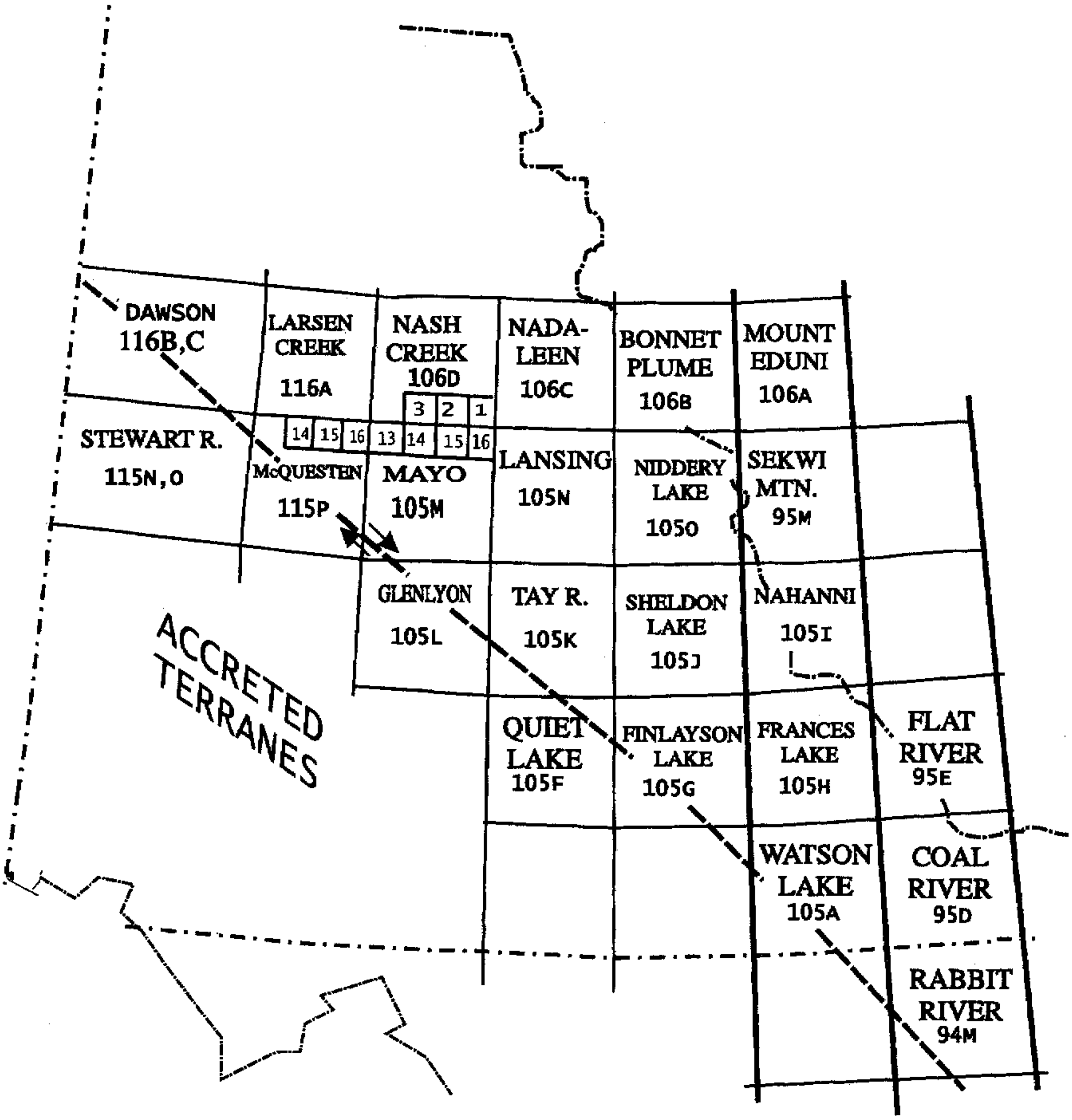


Figure 65. Key to maps: see text for discussion.

Appendix 3

Paleontological Determinations

The paleontologic appendix presents fossil identifications grouped by formation. Only two macrofossils were found and 5 microfossil assemblages discovered from over 100 limestone occurrences sampled (1 kg of small chips). All organic occurrences in the Nogold Formation are listed because further colecting may result in more precise definition of the age range of this unit.

Data on each collection consists of (from left to right):

- GSC locality number,
- latitude/longitude, and
- initials indicate the paleontologist who identified each collection, as follows:

MJO	M. J. Orchard	(conodonts)
AWN	A. W. Norris	(dacryoconarids)
FC	F. Cordey	(radiolarians)

For citation purposes, the GSC locality number should be used.

CAI: Conodont Alteration Index, a relative measure of metamorphic grade.

GULL LAKE FORMATION

C-202221 63°08'00"N 135°47'30"W MJO
coniform elements (12); several morphotypes present
CAI: 4-4.5
AGE: Late Cambrian - Early Ordovician

C-202220 63°02'30"N 135°03'30"W MJO
spicules
AGE: Phanerozoic

C-202232 63°08'30"N 135°23'00"W MJO
shell fragments
AGE: Phanerozoic

RABBITKETTLE FORMATION

C-202229 63°08'00"N 135°28'00"W MJO
spicules
AGE: Phanerozoic

ROAD RIVER GROUP

C-302362 63°11'N 134°15'W FC
sphaeromorphs, remnants of entractinids with non-bladed spines, rare sponge spicules
AGE: Ordovician-Silurian

C-202240 63°05'30"N 135°22'00"W MJO
conodonts, mazuelloids, pellets
CAI: 5
ramiform elements (3)
Carniodus sp. (5)
Panderodus sp. (5)
Pterospathodus pennatus (Walliser 1964) (4)
AGE: Early-Middle Silurian (late Llandovery-early Wenlockian)

NOGOLD UNIT

C-203008 63°11'45"N 135°29'10"W AWN
Nowakia? sp
echinoderm ossicle with single axial canal
AGE: Early Devonian (latest Lochovian) to Late Devonian(mid-Famennian)

C-203013 63°11'45"N 135°29'10"W MJO
sphaeromorphs, tubes, spines, ?crioconarid group
AGE: Paleozoic
Remarks: finely annulated element and several other problematic elements

C-203012 63°12'00"N 135°29'10"W MJO
spine
AGE: Phanerozoic

C-203011 63°12'00"N 135°29'10"W MJO
sphaeromorphs, spines
AGE: ?Phanerozoic

C-202215 63°18'00"N 134°29'00"W MJO
foraminifers
AGE: ?Phanerozoic

C-202216 63°18'30"N 135°31'00"W MJO
foraminifera?
AGE: ? Phanerozoic

C-302223 63°13'09"N 135°24'06"W MJO
ichthyoliths?
AGE: Phanerozoic

C-302229 63°10'56"N 135°27'40"W MJO
sponge spicules
AGE: Phanerozoic

EARN GROUP

C-176364 63°46'08"N 134°04'55"W MJO
ichthyoliths
AGE: Phanerozoic

C-203017 63°02'00"N 135°08'05"W AWN
cf. *Eleutherokomma reidfordi* Crickmay, 1950
Eleutherokomma? sp.- vague impression of a small specimen

Appendix 4

Isotopic Ages

Concordia plots (Figures 66-68), data (Table 2) and sample descriptions are presented for four Tombstone intrusions, metavolcanic units in the Earn Group and Keno Hill quartzite, and two grit samples which may be part of the Nogold Unit. The single grain work is by V. McNicholl of the Geochronology Section, Geological Survey of Canada (GSC). Other determinations were completed by J. Mortensen and M-L Bevier, formerly at the GSC and presently at the Geochronology Laboratory, University of British Columbia (UBC). The author of the age interpretation is in parentheses.

Analytical techniques

Zircon, monazite and titanite were separated from samples weighing from 2-10 kg using conventional crushing, grinding, heavy liquid and magnetic separation methods. The analytical techniques used at the GSC were described by Parrish et al. (1987) and at UBC by Mortensen et al. (1995). Most zircon fractions were abraded prior to analysis to minimize the effects of post-crystallization Pb-loss. Error ellipses on the concordia plots and errors on calculated ages are given at the two-sigma level.

Sample description and age interpretation

Tombstone Intrusions

Two Buttes Stock: RAS-90-25; 15 kg sample

Location:
NTS map area 105 M/6
Lat. 63°29'N, Long. 135°23'W
UTM: Zone 8V 480990E 7039500N
Top of western butte; surveyed point 5094±'; outcrop fractured in large blocks.
Geologic Locale: Main phase of 1 km by 200 m stock, sampled near mid-point.

Rock description: Fresh, medium grained, potassium-feldspar-phyric granite. Biotite > hornblende. Biotite est. 5%, in 3mm books. Some potassium feldspar phenocrysts are 2 cm long, estimated 15% of sample.

This stock was previously K-Ar dated (GSC#81-36: 97.1 ± 3.6 Ma)

Age Interpretation (J. Mortensen)

Five abraded zircon fractions and two titanite fractions were analysed at the GSC laboratory. Four of the zircon analyses define a linear discordia array with calculated lower and upper intercept ages of 92.0+0.5/-0.7 Ma and 1.25 Ga, respectively. The fifth analysis (A) falls below this discordia and appears to have suffered significant post-crystallization Pb-loss that was not completely eliminated by the abrasion. The lower intercept gives a minimum estimate for the crystallization age of the rock. The two titanite analyses give 206Pb/238U ages of **92.5±0.3 Ma**, which is considered the best estimate of the age of the rock.

McArthur Batholith RAS-91-57b; 25 kg sample

Location:
NTS map area105M/4
Lat. 63°10'N, Long. 135°40'W
UTM Zone 8: 466000E 6904250N
Locality: Stumpy tors on broad spur 4 km north-northwest of Grey Hunter Peak. Elevation 5300'.
Geologic locale: 1.5 km south of northern contact of batholith. Typical medium grained phase.

Rock description: Fresh quartz monzanite, biotite > hornblende. Biotite est. 5%, in 2 mm books. Hornblende est. 2%, 1 mm and square. Quartz est. 10% mauve, in 3 mm, sub-equant grains; interstitial plagioclase kaolinized. Potassic feldspar phenocrysts 1 cm by 1.5 cm comprise about 10% of sample.

Age Interpretation: (J. Mortensen)

Three abraded zircon fractions and three unabraded monzonite fractions were analysed in the GSC laboratory. The zircon analyses define a linear array with calculated upper and lower intercept ages of 93.0 +1.6/-3.1 Ma and 1.39 Ga. respectively. The lower intercept age should be close to the crystalline age of the rock. The three monazite analyses yield identical, concordant analyses with a total range of 206Pb/238U ages of **94.0 ±0.3 Ma.**

Roop Lake Stock: sample 284 collected by Greg Lynch in 1985.

Location:
NTS map area 105M/15
Lat. 63°51'N, Long. 134°45'W
Between Graanite Creek and (site of) Wilson's Cabin, elevation about 2620'.
UTM Zone 8: 512500E, 7080500N
Geologic locale: Megacrystic phase (Green, 1971) of 81 sq. km stock

Rock description: Fresh, unaltered, coarse-grained porphyritic granite with 20% coarse euhedral feldspar phenocrysts (alkali feldspar) and 10 to15% black euhedral amphibole, with quartz eyes (30%) and finer feldspars (30 to 40%).

Age Interpretation: (J. Mortensen)

A total of five fractions of abraded zircons and two fractions of titanite were analysed. Four of the analyses were done at the GSC laboratory; the remainder were done in the UBC Geochronological Laboratory. The zircon analyses all fall slightly to the right of concordia, indicating the presence of a significant zircon component. A definite crystallization age for the sample cannot be determined from the zircon data. Two fractions of titanite give overlapping 206Pb/238U ages of **92.8 ±0.5 Ma**, which is considered to be the best estimate for the crystallization age of the Roop Lake stock.

Biotite Felsite: sample VR-7868, collected by T. Heah / R. Hulstein in 1993.

Location:
NTS map area 105M/12
Lat. 63°43.5'N, Long. 135°58'W
UTM Zone 8: 452088E 7066250N
Locality: Vegetated talus and slumped outcrop north of road to Minto Lake.
Geologic locale: Poorly exposed high-level intrusion (or felsic-to intermediate flow rock)

Rock description: Pink to brown siliceous, fine-grained rock. Contains est. 2% mafic phenocrysts 1 mm across; mostly weathered out; and est. 10% transparent, sub-equant quartz phenocrysts to 2 mm across.

This body was K-Ar dated (GSC#87-164) at 85.3 ±2.1 Ma.

Age Interpretation: (J. Mortensen)

Only a very small amount of zircon was recovered from this sample. Three fractions of very strongly abraded zircon were analysed in the UBC laboratory, and define a short linear array that indicates the presence of a minor inherited zircon component in two of the three fractions. Calculated upper and lower intercept ages are **91.7 ± 0.5 Ma** and ~2.5 Ga respectively. The lower intercept is constrained by the concordant analysis for fraction A. The upper intercept age gives an average age for the inherited zircon component,

Keno Hill Quartzite

Felsic metavolcanic sample 91-DM-78 collected by D. Murphy; 15 kg sample.

Location:
NTS map area 105M/15
Lat. 63°57.7'N, Long.134°39.2'W
UTM Zone 8: 516940E 7091960N

Locality: Elevation 5500' high point on southwest spur of the Patterson Range; top of headwall of south-draining cirque.

Geologic locale: From gritty, commonly feldspathic sub-unit 8b (Green, 1971) of Keno Hill quartzite.

Rock description: chloritic feldspathic augen phyllite; augen to 3 mm.

Age Interpretation: (J. Mortensen)

A small amount of zircon was recovered and four abraded fractions were analysed in the GSC laboratory. Three fractions are slightly to moderately discordant and define a Pb-loss line with calculated upper and lower intercept ages of 382 +19/-6 Ma and ~112 Ma, respectively. The fourth fraction (D) appears to have contained a minor inherited zircon component. The upper intercept should be close ro the crystallization age of the rock; however a more precise estimate can be obtained from a weighted 207Pb/206Pb age of the fractions A-C, at **377.9 ± 2.9 Ma**.

Earn Group

Felsic metavolcanic sample# GGA-89-137A collected by S. Gordey in 1989; 14.1 kg

Location:
NTS map area 105M/16
Lat. 63°58.7'N, Long. 134°18.7'W
UTM Zone 8: 533700E 7094545N
Locality: 12.35 km north-northeast of Mount Roop
Geologic locale: Center of 1 km long lens of unit Dmvf mapped by Gordey (1990a,b).

Rock description: Siliceous, green, gritty rock containing 10% quarz phenocrysts to 1.2 mm diameter (some show embayments) in a matrix of interlocking quartz and feldspar grains (0.02 mm) and fine white mica. Foliation is defined by discontinuous seams of kinked muscovite (8% of sample). Interpreted as a felsic, quartz crystal meta-tuff.

Age Interpretation: Four fractions of abraded zircon were analysed in the GSC laboratory, and define a discordia array tht reflects a substantial inherited zircon component in at least two fractions (A and B). The lower calculated intercept age is **373.3 ± 5.4 Ma,** which is in goood agreement with the 206Pb/238U age of fraction CB, at 372.8 ± 1.4 Ma. The upper intercept for the data array is 1.77 Ga, which represents an average age for the inherited zircon component.

Felsic metavolcanic sample GGA-89-157B collected by S. Gordey in 1991; 20 kg

Location:
NTS map area 105M/16
Lat. 63°55.3'N, Long. 134°15.1'W
UTM Zone 8: 536690E 7088300N
Locality 8.85 km northeast of Mount Roop
Geologic locale: Near north end of 8 km-long lens of unit Dmvf, mapped by Gordey (1990a, b)

Rock description: Very weakly foliated quartz porphyry containing 10% phenocrysts of subhedral to euhedral embayed quartz to 2 mm diameter in a matrix of low relief, birefringent minerals. Accessory zircon visible in thin section as isolated equant grains. Clumps of fine white mica visible in hand sample.

Age Interpretation: (J. Mortensen)

Three strongly abraded zircon fractions were analysed in the GSC laboratory. They gave concordant although relatively imprecise analyses. A minimum age for the sample is given by the oldest 206Pb/238U age of the three fractions, at **380.9 ± 1.3 Ma**. Because measured U contents in all zircon fractions are low and Pb-loss from the zircons is likely to have been minimal, this should be very close to the true age of the rock.

Nogold Unit (?)

Chloritic grit sample RAS-92-51A; 10 kg

Location:
NTS map area 105M/4
Lat. 63°14.9'N, Long. 135°32.5'W
UTM Zone 8: 472950E 7013050N
Locality: Knob on northwest side of large hill reaching 4750'; 13.3 km north-northeast of Grey Hunter Peak.
Geologic locale: 25 m wide lens of chloritic grit enclosed in quartz-feldspathic grit.

Rock description: Dark green-grey foliated grit with quartz and feldspar grains to 3 mm across and black argillite chips to 1 cm long.

Analyses: This rock was analysed in an attempt to restrict the age of the Nogold unit by locating grains of mid-Paleozoic age in rock with apparent igneous provenance. Among the rare, well-facetted grains, 11 were analysed and reflect four Pb/Pb age clusters. Two grains are Late Proterozoic (K - 691 Ma; L - 598 Ma), six are Early to Middle Proterozoic (C-1956 Ma; F - 1854 Ma; G - 1924 Ma; H and J - 1837 Ma; and I - 1839 Ma), one is Early Proterozoic (A - 2342 Ma), and two are Archean (D - 2594 Ma; and E - 2685 Ma).

Chloritic grit sample RAS-92-76A; 15 kg

Location:

NTS map area 105M/4

Lat. 63°12.6'N, Long. 135°34.5'W

UTM Zone 8: 471250E 7009000N

Locality: North trending knoll at 4600 elevation, 9.3 km north-northeast of Grey Hunter Peak.

Geologic locale: possible volcanic provenance for grit; Paleozoic igneous or detrital zircon would rule out Hyland Group.

Rock description: Grey-green, foliated, medium grained grit with 20% of grains larger than 2 mm. Most grains are lenticular, transparent quartz; some white euhedral feldspar and flattened chloritic fragments up to 2 cm long.

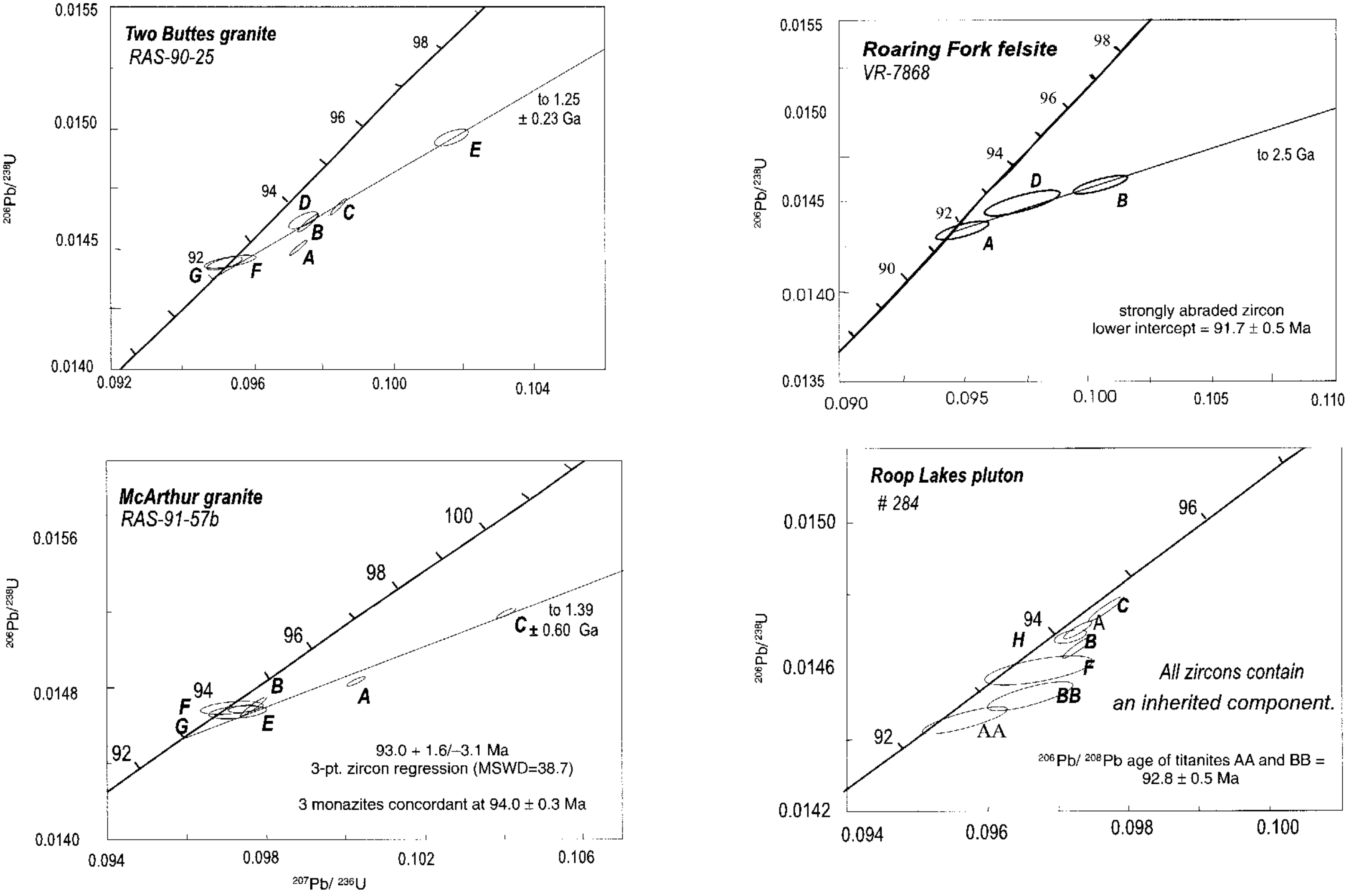
Age Interpretation: (V. McNicoll)

Well-facetted zircon grains comprise a fairly small percentage of the zircons in this sample, but ten were selected. The data is very good and all the zircon analyses are concordant or very slightly discordant. As in the previous sample, four distinct age ranges are apparent. The Pb/Pb ages of the single grain analyses are as follows:

	Morphology	**207Pb/206Pb age**	**% discordance**
A	pink, rounded	2392 ± 1 Ma	0.4
C	light pink, elongate, rounded	1956 ± 35	0
D	light pink, rounded	2594 ± 1	0.2
E	colourless, elongate, rounded	2685 ±2	0.2
F	colourless, rounded	1854 ±3	0.2
G	pink, equant, well-faceted	1924 ±2	0.3
H	light pink, equant, well-faceted	1837 ±6	0
I	light pink, well faceted prism	1839 ±3	0
J	light pink, well faceted prism	1836 ±2	2.0
K	colourless, very well faceted prism	691 ±22	1.6

Most zircon grains well rounded, but well faceted prisms a small proportion of 92-76A.

Figure 66. U-Pb concordia plots for Cretaceous plutons, Mayo map area.



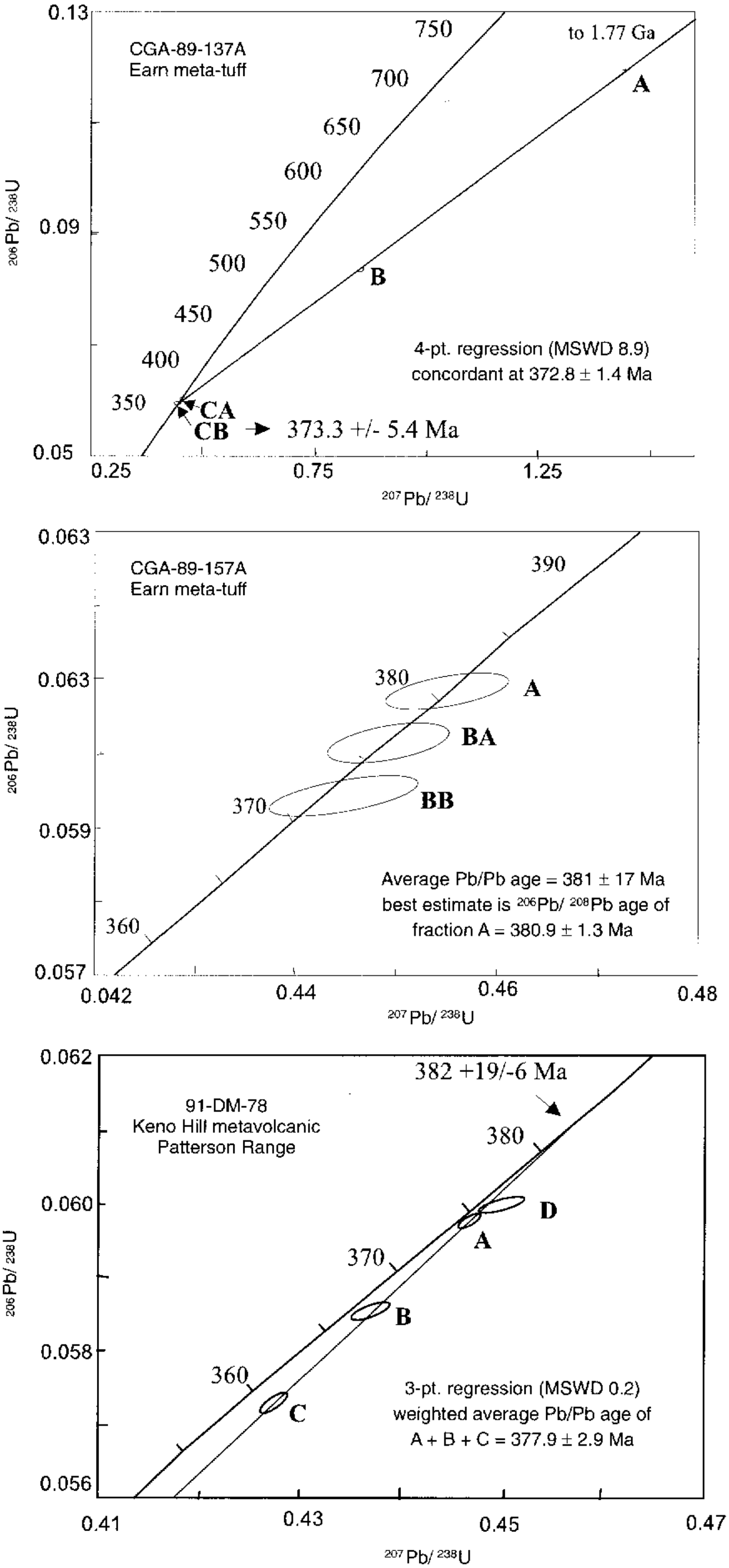
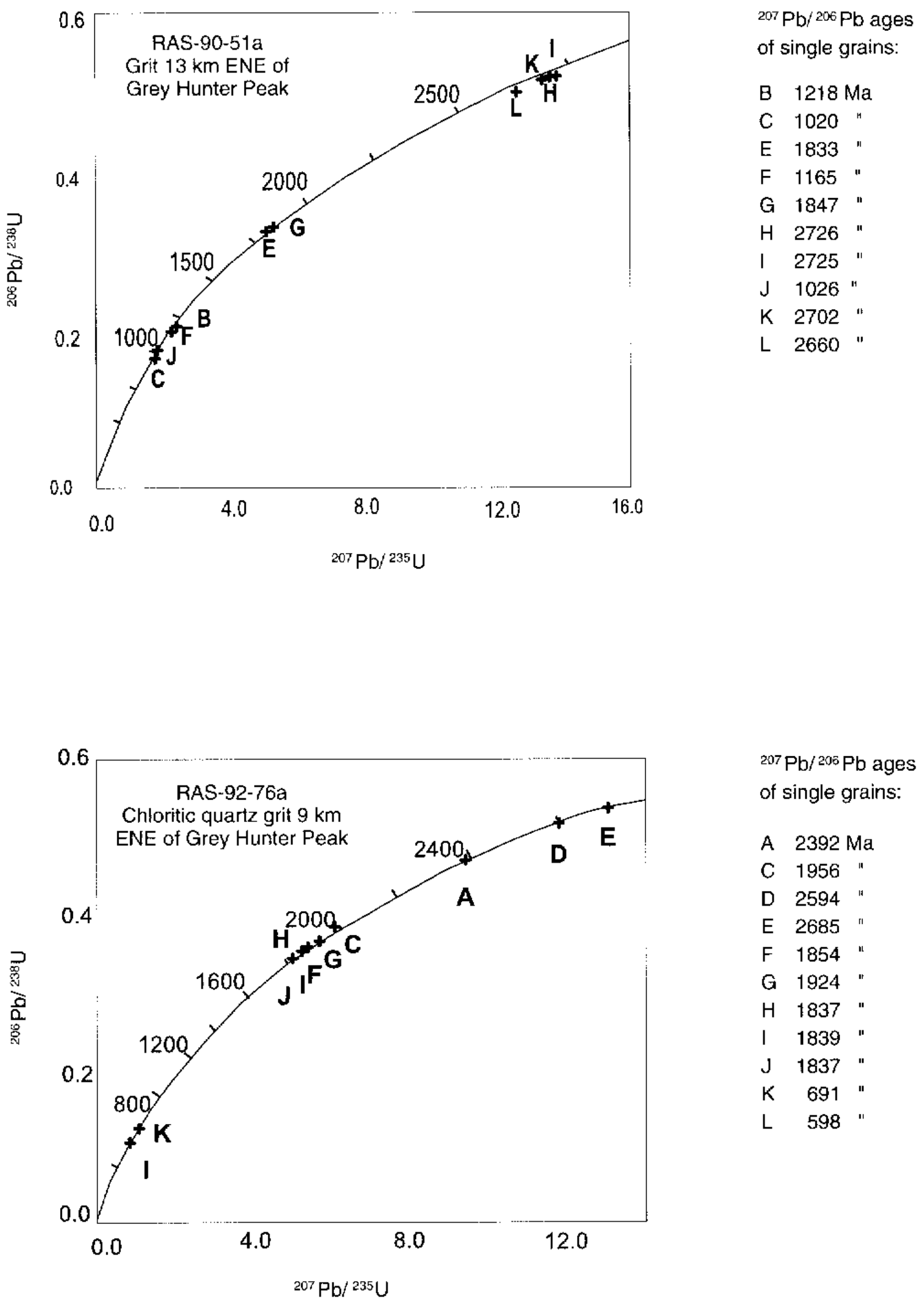


Figure 67. U-Pb concordia plots for Late Paleozoic metavolcanic rocks, Mayo map area.



$^{207}Pb/^{206}Pb$ ages of single grains:

B	1218 Ma
C	1020 "
E	1833 "
F	1165 "
G	1847 "
H	2726 "
I	2725 "
J	1026 "
K	2702 "
L	2660 "

$^{207}Pb/^{206}Pb$ ages of single grains:

A	2392 Ma
C	1956 "
D	2594 "
E	2685 "
F	1854 "
G	1924 "
H	1837 "
I	1839 "
J	1837 "
K	691 "
L	598 "

Figure 68. U-Pb concordia diagram for detrital zircons in Hyland Group, Mayo map area.

U-Pb isotopic data, Tombstone intrusions (1-4) and Late Paleozoic metavolcanic rocks (5-7), Mayo map area

Fraction	Wt. mg a	U ppm a	Pb* ppm a %	206Pb/204Pb c	Pb pg	208Pb %	206Pb/238U	207Pb/235U	207Pb/206Pb	Apparent Age (Ma)	
										206/238	207/206
1. Roop Lake; Sample number 284											
A	0.093	1418	20	7977	15	5.1	0.01470±.10%	0.0973±11%	0.04802±04%	94.1	100.1 +1.9/-1.9
B	0.219	1420	20	9890	29	4.6	0.01466±12%	0.0974±13%	0.04817±.03%	93.8	107.5 +1.6/-1.6
C	0.238	1389	19	8951	35	4.7	0.01476±13%	0.0977±14%	0.04802±.04%	94.5	100.1 +1.9/-1.9
F	0.02	1590	22	562	54	5	0.01459±12%	0.0968±39%	0.04811±.33%	93.4	104.6 +15.6/-15.8
H	0.13	1348	19	4428	36	4.3	0.01468±07%	0.0972±12%	0.04803±.09%	94.0	100.5 +4.2/-4.2
G	0.074	1105	14	1171	63	2	0.01410±73%	0.0859 ±1.2%	0.04419±1.1%	90.2	100.1 +52.2/-53.9
AA	0.55	273	14	216	713	15.7	0.01446±13%	0.0958±35%	0.04804±.25%	92.5	101.1 +11.7/-11.8
BB	0.525	296	5	194	834	16.5	0.01452±11%	0.0966±34%	0.04826±.25%	93.0	112.3 +11.7/-11.8
2. 90-RAS-25											
A	0.063	2989	40	8823	20	2.9	0.01450±11%	0.0973±12%	0.04865±.04%	92.8	130.8 +1.8/-1.9
B	0.156	2176	30	4108	77	3.4	0.01461±13%	0.0976±14%	0.04845±.05%	93.5	121.3 +2.3/-2.3
C	0.156	1431	20	9476	22	4	0.01468±11%	0.0984±12%	0.04864±.04%	93.9	130.7 +1.8/-1.8
F	0.318	266	4	225	386	13.7	0.01445±10%	0.0954±41%	0.04788±.37%	92.5	93.4 +17.2/-17.4
G	0.344	271	4	234	407	13.4	0.01444±11%	0.0952±27%	0.04782±.22%	92.4	90.5 +10.5/-10.6
D	0.012	3037	42	1748	19	4	0.01462±12%	0.0975±21%	0.04835±.16%	93.6	116.4 +7.4/-7.4
E	0.019	1947	27	1202	29	3.5	0.01496±11%	0.1017±24%	0.04927±.20%	95.7	160.7 +9.1/-9.2
3. RAS-91-57B											
A	0.049	1500	21	6000	11	4.2	0.01483±11%	0.1003±12%	0.04902±.06%	94.9	148.7 +2.7/-2.7
B	0.254	1770	25	15052	28	4.4	0.01470±17%	0.0976±17%	0.04817±03%	94.1	107.4 +1.5/-1.6
C	0.147	1243	18	9349	19	5.1	0.01520±10%	0.1041±12%	0.04968±04%	97.2	180.0 +1.8/-1.8
E	0.007	6339	340	970	44	75.2	0.01468±12%	0.0975±32%	0.04814±27%	94	106.2 +12.6/12.7
F	0.007	3775	232	793	31	78.3	0.01471±11%	0.0971±39%	0.04787±33%	94.1	93.1 +15.7/-15.9
G	0.005	6146	345	862	33	76.3	0.01469±11%	0.0972±33%	0.04799±28%	94	98.7 +13.2/-13.3
4. A70VR-7868											
A	0.111	1492	20	427	369	2.7	0.01434±19%	0.0949±58%	0.04803±45%	91.8	100.8 +21.4/-21.6
B	0.168	1700	23	446	615	3.1	0.01458±18%	0.1005±54%	0.04998±42%	93.3	194.1 +19.2/-19.4
D	0.18	1731	23	278	1103	3	0.01448±25%	0.0974±82%	0.04878±66%	92.7	137.1 +30.7/-31.3
5. GGA-89-157-A1											
A	0.017	86	5.5	315	19	14.1	0.060875±17%	0.45540±68%	0.054256±59%	381	381.7±26.5
BA	0.021	133	8.5	236	48	14.9	0.060186±20%	0.44993±74%	0.054218±62%	377	380.1±28.1
BB	0.009	169	11	440	13	13.5	0.059418±24%	0.444333±85%	0.054236±76%	372	380.9±34.1
6. GGA-89-137-A											
A	0.042	93	13	1691	17	21.7	0.119445±09%	1.44141 ±12%	0.087522 ±07%	727	1372.0±2.8
B	0.029	131	13	503	41	20.9	0.083607 ±11%	0.85141 ±29%	0.073858 ±23%	518	1037.6±9.3
CA	0.013	135	8.7	892	8	14.7	0.060318 ±16%	453543 ±32%	0.054534 ±27%	378	393.2±12.0
CB	0.008	135	8.5	308	14	14.6	0.05953±19%	0.44261±80%	0.053925 ±71%	373	367.9±31.8
7. A1491-DM-78											
A	0.128	13	9	2805	23	14	0.05976±10%	0.4468±15%	0.05422±10%	374	380.2 +4.3/-4.4
B	0.184	144	9	869	114	15.1	0.05855±10%	0.4369±21%	0.05413±16%	367	376.4 +7.0/-7.1
C	0.185	156	10	1332	79	15	0.05730±12%	0.4275±17%	0.05411±11%	359	375.8 +4.9/-4.9
D	0.049	146	9	845	32	15	0.05997±10%	0.4501±26%	0.05444±22%	375	389.2 +9.7/-9.8

Errors are 1 std. error of mean in % except 207/206 age errors which are 2 std. errors in Ma; *=Radiogenic Pb
a = Includes sample weight error of±0.001 mg in concentration uncertainty; c = Total Common Pb in analysis.

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