Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

Exploration and Geological Services Division, Yukon Region

BULLETIN 9

Geology of the Upper Hart River Area, Eastern Ogilvie Mountains, Yukon Territory (116A/10, 116A/11)

Grant Abbott

with contributions from M. L. Bevier, W. H. Fritz, H. I. Hormann, B. S. Norford, A. W. Norris, J. K. Mortensen and M. J. Orchard

Canada

Canada/Yukon Economic Development Agreement
To strengthen and diversify the Yukon economy

Yukon
Economic Development

Exploration and Geological Services Division, Yukon Region

BULLETIN 9

Geology of the Upper Hart River Area, Eastern Ogilvie Mountains, Yukon Territory (116A/10, 116A/11)

Grant Abbott

with contributions from M. L. Bevier, W.H. Fritz, H.J. Hofmann, B.S. Norford, A.W. Norris, J.K. Mortensen and M. J. Orchard

1997

Catalogue no. R72-250/1997E

ISBN 0-662-25737-5

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

QS-Y107-000-EF-A1

Recommended citation:
Abbott, Grant, 1997. Geology of the Upper Hart River Area, Eastern Ogilvie Mountains, Yukon Territory (116A/10, 116A/11). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 9, 92 p.

Cover: This view to the west along Rae Creek illustrates the dramatic contrast between the geology of the southern and northern parts of the upper Hart river area. Dark-weathering Paleozoic siliciclastic, chert and carbonate rocks of Selwyn Basin to the south are sharply juxtaposed against light-weathering Proterozoic and Paleozoic platformal carbonate and siliciclastic rocks of the Yukon Block to the north.

Preface

For its small size, the study area includes a remarkable variety of rock types, and records over 1.5 billion years of the geological history of north-central Yukon from the Early Proterozoic through to the Mesozoic. It straddles the Dawson thrust fault, which marks the boundary between predominantly shallow-water sedimentary sequences of Yukon Block on the north, and deep-water sedimentary and volcanic sequences of Selwyn Basin and younger strata on the south. The area contains the Middle Proterozoic Hart River massive sulphide deposit, and several units have the potential to host stratabound sulphide deposits. The significant refinements to structure, stratigraphy, and metallogeny of the Hart River area described in this study are applicable over much of north-central Yukon.

Fieldwork began in 1986 with the examination of the setting of the Hart River massive sulphide deposit as part of a regional study of base metal deposits in the Ogilvie and Wernecke mountains, and continued between 1992 and 1994 as a mapping project funded by the Canada/Yukon Co-operation 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.

Trevor Bremner
Chief Geologist and Regional Manager
Exploration and Geological Services Division
Northern Affairs Program, DIAND

Roderic P. Hill
Manager, Mineral Resources Program
Yukon Department of Economic Development

Préface

Bien que peu étendue, la région d'étude présente une remarquable diversité quant aux types de roches présents et permet la documentation d'un intervalle de l'histoire géologique de plus de 1,5 milliard d'années s'étendant du Protérozoïque précoce au Mésozoïque dans la partie centrale du nord du Yukon. Elle chevauche la faille chevauchante de Dawson, qui marque la limite entre les séquences sédimentaires du Bloc du Yukon principalement déposées en eau peu profonde au nord et les séquences sédimentaires et volcaniques déposées en eau profonde du bassin de Selwyn ainsi que les strates plus jeunes au sud. La région renferme le gisement de sulfures massifs du Protérozoïque moyen Hart River et plusieurs unités pourraient renfermer des gisements de sulfures massifs confinés à des strates. Les importantes améliorations de la description de la structure, de la stratigraphie et de la métallogénie de la région de la rivière Hart décrites dans la présente étude sont applicables à une grande partie du centre du nord du Yukon.

Les travaux sur le terrain ont commencé en 1986 par l'examen du cadre géologique du gisement de sulfures massifs Hart River dans le cadre d'une étude régionale des gisements de métaux communs dans les monts Ogilvie et Wernecke et se sont poursuivis de 1992 à 1994 sous forme d'un projet de cartographie financé en vertu de l'Entente Canada-Yukon de collaboration pour la mise en valeur des ressources minérales. Le soutien logistique a été fourni par le Bureau géoscientifique Canada-Yukon, un projet dirigé conjointement par le ministère des Affaires indiennes et du Nord canadien à titre de responsable scientifique et le ministère de l'Expansion économique du Yukon à titre de responsable de l'administration.

Trevor Bremner
Géologue principal et chef régional
Division des services géologiques et d'exploration
Programme des affaires du Nord, MAIN

Roderic P. Hill
Gestionnaire, Programme des ressources minérales
Ministère de l'Expansion économique du Yukon

Contents

Preface/Préface
Abstract ... 1
Résume ... 2
Introduction
Location, access, topography and glaciation ... 4
Previous and present work ... 5
Acknowledgements ... 5
Regional Setting
Yukon Block ... 6
Selwyn Basin ... 9
Devonian and younger sedimentation ... 10
Structure ... 10
Stratigraphy
Rocks north of the Dawson Fault ... 11
Wernecke Supergroup ... 11
Environment, age and correlation ... 11
Hart River basalts (Pv) ... 14
Age and correlation ... 15
Pinguicula Group (PPA, PPB, PPC, PPD1, PPD2, PPD3) ... 15
PPA ... 15
PPB ... 16
PPC ... 16
PPD1 ... 18
PPD2 ... 19
PPD3 ... 19
Callison Lake dolostone (PCL) ... 21
Age and correlation ... 21
Mount Harper Group (Units PHdi, PHs, and PHv) ... 26
Environment, age and correlation ... 28
Cambrian(?), Ordovician, and Silurian Dolostone (€Sc) ... 30
Age and correlation ... 30
Road River Group (ODp) ... 31
Age and correlation ... 32
Silurian Volcanic Rocks (Sv) ... 32
Age and correlation ... 33
Silurian and (?) Devonian Limestone (SDl) ... 33
Age and correlation ... 34
Ogilvie Formation (DO) ... 34
Age and correlation ... 34
Earn Group (DME) ... 36
Age and correlation ... 36

- Rocks south of the Dawson Fault ... 37
  - Hyland Group (Yusezyu and Narchilla formations) ... 37
    - Age and correlation ... 38
  - Gull Lake Formation (ЄGs, ЄGv, ЄGl, ЄGp) ... 39
    - Sandstone Member (ЄGs) ... 39
    - Volcanic Member (ЄGv) ... 39
    - Limestone Member (ЄGl) ... 41
    - Phyllite Member (ЄGp) ... 42
    - Age and correlation of the Gull Lake Formation ... 42
  - Late Cambrian(?) to Devonian(?) strata ... 43
  - Rabbitkettle Formation ... 44
    - Age and correlation ... 44
  - Road River Group east of Rae Creek (ODp) ... 45
    - Age and correlation ... 45
  - Dempster volcanics (ЄOv) ... 45
    - Age, environment and correlation ... 46
  - Road River Group west of Rae Creek (ЄOu, Ot, OSl, Odpt) ... 47
    - Cambro-Ordovician phyllite and chert (ЄOu) ... 47
      - Age and correlation ... 47
    - Ordovician Chert (ORt) ... 47
      - Age and correlation ... 48
    - Ordovician-Silurian(?) limestone (OSl) ... 48
      - Age and correlation ... 49
    - Ordovician(?), Silurian and Devonian(?) chert and shale (ODpt) ... 49
      - Age and correlation ... 49
  - Keno Hill quartzite (Mq) ... 50
    - Age and correlation ... 50
  - Mesozoic shale and sandstone (ŦJps) ... 51
    - Age and correlation ... 51

Intrusive Rocks

- Hart River sills (Pd) ... 52
  - Age and correlation ... 52
- Cambrian sills (Єd) ... 53
  - Age and correlation ... 54
- Late Paleozoic sills (Pd) ... 56
  - Age and correlation ... 56

Structure

- Racklan orogeny ... 57
- Late Proterozoic reverse(?) faulting ... 57
- Late Proterozoic rifting ... 58
- Paleozoic rifting ... 59
- Mesozoic deformation ... 59
  - Structures north of the Dawson Thrust ... 60
  - Structures south of the Dawson Thrust ... 60
  - Dawson Thrust ... 60
- Paleotectonic significance of the Dawson Thrust ... 61

Economic Geology
Known mineral deposits, occurrences and work targets ... 65
Hart River massive sulphide deposit (Yukon Minfile No. 116A-09) ... 65
Soup Vein (Yukon Minfile No. 116A-05) ... 67
Belcarra Vein (Yukon Minfile No. 116A-10) ... 67
Zebra (Zebra #4) Vein (Yukon Minfile No. 116A-11) ... 67
Hawley Vein (Yukon Minfile No. 116A-34) ... 67
Briden Veins (Yukon Minfile No. 116A-35) ... 67
Holcapek Vein (Yukon Minfile No. 116A-36) ... 67
Reindeer Copper Occurrence (Yukon Minfile No. 116A-07) ... 67
Cloud Skarn(?) (Yukon Minfile No. 116A-26) ... 68
Cinch Work Target (Yukon Minfile No. 116A-06) ... 68
Grace Work Target (Yukon Minfile No. 116A-8) ... 68
Callison Work Target (Yukon Minfile No. 116A-18) ... 68
Rae Work Target (Yukon Minfile No. 116A-19) ... 68
Shine Work Target (Yukon Minfile No. 116A-22) ... 68
Mineral potential ... 68
Hart River basalt ... 68
Pinguicula Group ... 68
Gull Lake and Rabbitkettle formations ... 68
Road River Group ... 69
Mafic sills ... 69
Keno Hill quartzite ... 69
Covered interval in footwall of the Tombstone Thrust ... 69
References ... 70

Figures

Figure 1. Map of north-central Yukon showing location of the project area. ... 3
Figure 2. Traverse locations, spot localities visited, and named geographical features. ... 4
Figure 3. Correlation of Proterozoic sequences. ... 7
Figure 4. Regional map of principal Proterozoic sequences and Proterozoic structures. ... 8
Figure 5. Laminated shale and siltstone near the top of the Quartet Group. ... 11
Figure 6. Thin-bedded, orange-weathering dolostone typical of the Gillespie Lake Group. ... 11
Figure 7. Pillowed flows in the Hart River basalt. ... 15
Figure 8. Nomenclature of Proterozoic strata in the Hart River Inlier. ... 16
Figure 9. Sections 1 and 3 in the Pinguicula Group. Location shown on map 1997-1. ... 17
Figure 10. Basal conglomerate of the Pinguicula Group (Unit PPA). ... 18
Figure 11. Laminated shale and siltstone in unit PPA of the Pinguicula Group. ... 18
Figure 12. Stratigraphic relationships: Pinguicula Group, Hart River sills and Gillespie Lake Group. ... 19
Figure 13. Syneresis cracks in red sandstone near the base of unit PPD1 in the Pinguicula Group. ... 19
Figure 14. Conglomerate in the lower member of unit PPD1 of the Pinguicula Group. ... 20
Figure 15. Thick-bedded quartzite, Pinguicula Group. ... 20
Figure 16. Thin-bedded limestone, Pinguicula Group. ... 20
Figure 17. Laminated dolostone characteristic of the upper member of unit PPD2. ... 21
Figure 18. (a, b, c) Primary sedimentary structures are well preserved in the Callison Lake dolostone. ... 21
Figure 19. Angular unconformity between the Callison Lake dolostone and the Pinguicula Group. ... 22
Figure 20. Correlation of Middle and Early Proterozoic sequencesd. ... 23
Figure 21. Diamictite with a shale matrix in unit PHdi of the Mount Harper Group. ... 27
Figure 22. Diamictite with a carbonate matrix in unit PHdi of the Mount Harper Group. ... 27
Figure 23. Carbonate boulder at the base of a diamictite bed in the Mount Harper Group. ... 28
Figure 24. Striated boulder in diamictite of the Mount Harper Group. ... 29

Figure 25. Coarse-grained, silicified dolostone, typical of unit ЄSc. 30
Figure 26. Schematic cross-section showing stratigraphic relationships of Paleozoic units. 31
Figure 27. Volcanic rocks of unit Sv showing vesicular clasts in an autobreccia. 32
Figure 28. Corals from the base of unit SDl. 33
Figure 29. Proposed facies boundary between Ogilvie Platform and Blackstone Trough. 35
Figure 30. Typical quartz feldspar grit of the Yusezyu Formation. 38
Figure 31. Maroon (dark) and green (light) shale characteristic of the Narchilla Formation. 38
Figure 32. Cast of trace fossils on the base of green sandy beds in the Narchilla Formation. 39
Figure 33. Section 4 measured through the Gull Lake Formation and Road River Group. 40
Figure 34. Sections showing stratigraphic variations in the Gull Lake Formation. 41
Figure 35. Interbedded quartz sandstone and shale, Gull Lake Formation. 42
Figure 36. Limestone member of the Gull Lake Formation. 42
Figure 37. Bioturbated shale typical of the phyllite member of the Gull Lake Formation. 42
Figure 38. Stratigraphic variations in Late Cambrian to Devonian strata south of the Dawson Fault. 44
Figure 39. Exposure of the Dempster volcanics west of Lake Creek. 46
Figure 40. Hyaloclastic breccia typical of the Dempster volcanics. 46
Figure 41. Thick-bedded, resistant chert of unit Ot. 48
Figure 42. Manganese nodules from black-weathering, green shale. 48
Figure 43. Limestone of unit OSl. 49
Figure 44. Interbedded chert and shale characteristic of unit ODpt. 50
Figure 45. A Hart River sill intruding orange-weathering dolostone of the Gillespie Lake Group. 52
Figure 46. U-Pb concordia plot for samples TOA91-26-1 and TOA91-14-4 53
Figure 47. U-Pb concordia plot for sample Blende-1. 54
Figure 48. U-Pb concordia plot for sample TOA91-9-4a. 55
Figure 49. U-Pb concordia plot for sample TOA92-25-3. 55
Figure 50. U-Pb concordia plot for sample TOA92-25-2. 56
Figure 51. View west across Rae Creek to the upper and lower Rae Creek thrust faults. 58
Figure 52. View west across Lake Creek to Road River Group. 61
Figure 53. Restored stratigraphic sections in Late Proterozoic and younger strata. 63
Figure 54. View west to Hart River massive sulphide deposit (gossan). 65
Figure 55. Plan and cross-sections of the Hart River massive sulphide deposit. 66

Tables

Table 1. Table of formations. 12
Table 2. Analysis of manganese nodule from Ordovician chert. 49

Appendices

Appendix 1. Paleontology by H. J. Hoffman, W. H. Fritz, M. J. Orchard, B. S. Norford and A. W. Norris
Appendix 2. Whole rock and trace element geochemical analyses of mafic sills and volcanic rocks
Appendix 3. U-Pb geochronology by J. K. Mortensen and M. L. Bevier

In pocket

Geoscience Map 1997-2 116A/10
Geoscience Map 1997-3 116A/11

Abstract

In the eastern Ogilvie Mountains, geological mapping was undertaken in two map sheets (scale 1:50 000), 116A/10 and 116A/11, which straddle the boundary between the Foreland and Omineca belts of the Cordilleran Orogen. The area is underlain by an unusually diverse assemblage of epicontinental and miogeoclinal sedimentary, and subordinate volcanic and intrusive rocks, ranging in age from Early Proterozoic to Triassic. These rocks represent most of the geological history of the northern Cordilleran miogeocline and its supracrustal basement. Early Devonian and older rocks belong to Yukon Block in the north and Selwyn Basin in the south. In Yukon Block, the Lower Proterozoic Wernecke Supergroup, and the Middle to Late Proterozoic Pinguicula Group and Callison Lake dolostone are epicontinental sedimentary sequences, which represent basement to Cordilleran miogeocline deposits.

The enigmatic Racklan Orogeny, which affected Wernecke Supergroup but no younger rocks, was not recognized in the project area. A younger episode of rifting is recorded by the Hart River sills, which intrude the Wernecke Supergroup and have been dated at about 1.38 Ga, and the coeval(?) Hart River basalts. The sills constrain the maximum age of the Pinguicula Group, which unconformably overlies them. In the Pinguicula Group, an angular unconformity separates a lower upward-shoaling, clastic-carbonate sequence from an upper quartzite-dominated sequence. The upper sequence contains detrital zircons dated at about 1.0 Ga and is interpreted as consisting mainly of debris shed from the Grenville Orogen. An angular unconformity separates the distinctive Callison Lake dolostone from the Pinguicula Group.

Miogeoclinal sedimentation began with Late Proterozoic rifting and deposition of diamictite, siliciclastic rocks and volcanic rocks of the Mount Harper Group in a narrow zone of half grabens(?). Paleozoic strata overlie all Proterozoic strata with profound angular unconformity. They include Late(?) Cambrian to Early Devonian dolostone and limestone belonging to Ogilvie Platform; facies equivalent Ordovician to Devonian shale and chert of the Road River Group; and minor Silurian volcanics rocks belonging primarily to Blackstone Trough. Selwyn Basin represents the deep-water outer portion of the Cordilleran Miogeocline and ranges in age from Latest Proterozoic through Early Devonian.

The oldest exposed strata belong to the Late Proterozoic to Early Cambrian Hyland Group and include siliciclastic turbidites and subordinate carbonate rocks of the Yusezyu Formation, overlying shale and sandstone of the Narchillla Formation. The tremendous thickness of turbidites is related to latest Proterozoic and Earliest Cambrian rifting within the miogeocline. The Gull Lake Formation probably overlies the Hyland Group unconformably and includes shale and siltstone with a thin basal assemblage of conglomerate, sandstone and volcanic rocks. A relatively minor pulse of rifting is represented by the Cambro-Ordovician Dempster volcanics, which unconformably overlie all older units. Mafic sills intruding the Hyland Group have given a loosely constrained Middle Cambrian isotopic age and may be related to either the volcanics at the base of the Gull Lake Formation or the Dempster volcanics. Thin-bedded limestone and shale of the Late Cambrian-Early Ordovician Rabbitkettle Formation overlie the Gull Lake Formation in the eastern part of the map area and are laterally equivalent to the Dempster volcanics and unnamed shale and chert in the west.

Ordovician to Devonian deep-water, starved-basin sedimentation is indicated by thin sequences of shale and chert of the Road River Group. Within the Road River Group, undivided shale and subordinate chert in the east and north give way to an Ordovician chert unit and Ordovician to Devonian(?) chert and shale in the west and south. Locally present Ordovician and/or Silurian limestone is laterally equivalent to the shale and chert. In Middle Devonian to Early Mississippian time, sedimentation patterns changed dramatically when widespread rifting and/or wrench faulting resulted in deposition of siliciclastic rocks of the Earn Group. In the map area, recessive shale, siltstone, grit and chert of the Earn Group unconformably overlie both the carbonate of Ogilvie Platform and the shale of Blackstone Trough in Yukon Block. The Earn Group is not exposed in the area underlain by Selwyn Basin strata, but may underlie an extensive covered interval in the southwestern part of the map area. A mafic sill(s?) intruding the Road River Group in both Yukon Block and Selwyn Basin gives a loosely constrained Late Paleozoic age.

Passive margin sedimentation resumed in the Early Carboniferous and is represented by small, local exposures of Mississipian Keno Hill quartzite, and Triassic and (?) Jurassic sandstone and shale in the southwestern corner of the map area. Strata are folded and imbricated by a series of moderately south-dipping, northerly directed thrust faults of which the Dawson, Tombstone, and Robert Service thrusts are the most significant. The deep-water facies of Selwyn Basin are sharply juxtaposed against the shallow-water facies of Yukon Block across the Dawson Fault, although the amount of shortening along it is estimated to be only a few kilometres. This dramatic contrast is interpreted as indicating that the Dawson Fault reflects an underlying, long-lived, basement structure that had controlled sedimentation patterns along the boundary between Yukon Block and Selwyn Basin since at least Late Proterozoic time. The Hart River massive sulphide deposit is related to the Hart River sills and is interpreted as a replacement deposit that cuts and replaces shale in the Gillespie Lake Group as well as the Hart River basalts. The basalts are thought to be only slightly older than the deposit. The potential for similar mineral deposits in the area is limited, but sediment-hosted base metal deposits could occur in several other underexplored units.

Résumé

Dans la partie orientale des monts Ogilvie, la cartographie géologique a été entreprise pour la région couverte par deux feuilles de la série (à l'échelle de 1/50 000), les cartes 116A/10 et 116A/11, chevauchant la limite entre le Domaine d'Ominéca et le Domaine de l'avant-pays de l'orogène de la Cordillère. La région repose sur un assemblage exceptionnellement diversifié de roches sédimentaires épicontinentales et miogéoclinales et de roches volcaniques et intrusives subordonnées dont l'âge varie du Protérozoïque précoce au Trias. Ces roches représentent la plus grande partie de l'histoire géologique du miogéoclinal de la Cordillère septentrionale et de son socle supracrustal. Les roches du Dévonien précoce et plus anciennes font partie du Bloc du Yukon au nord et du Bassin de Selwyn au sud. Dans le Block du Yukon, le Supergroupe de Wernecke du Protérozoïque inférieur et le Groupe de Pinguicula ainsi que la dolomie de Callison Lake datant du Protérozoïque moyen à tardif sont des séquences sédimentaires épicontinentales constituant le socle des dépôts miogéoclinaux de la Cordillère.

Aucun indice de l'énigmatique orogenèse du Racklan, qui a touché le Supergroupe de Wernecke mais non des roches plus jeunes, n'a été trouvé dans la région du projet. Un épisode plus récent de rifting est repéré dans les filons-couches de Hart River, qui pénètrent le Supergroupe de Wernecke et dont on a établi l'âge à environ 1,38 Ga, ainsi que dans les basaltes contemporains(?) de Hart River. Les filons-couches limitent l'âge maximum du Groupe de Pinguicula qui les recouvre en discordance. Dans le Groupe de Pinguicula, une autre discordance angulaire sépare une séquence inférieure de roches clastiques carbonatées s'amincissant vers le haut d'une séquence supérieure dominée par le quartzite. La séquence supérieure renferme des zircons détritiques datés d'environ 1,0 Ga et est interprétée comme principalement constituée de débris provenant de l'orogène grenvillien. Une discordance angulaire sépare la dolomie particulière de Callison Lake du Groupe de Pinguicula.

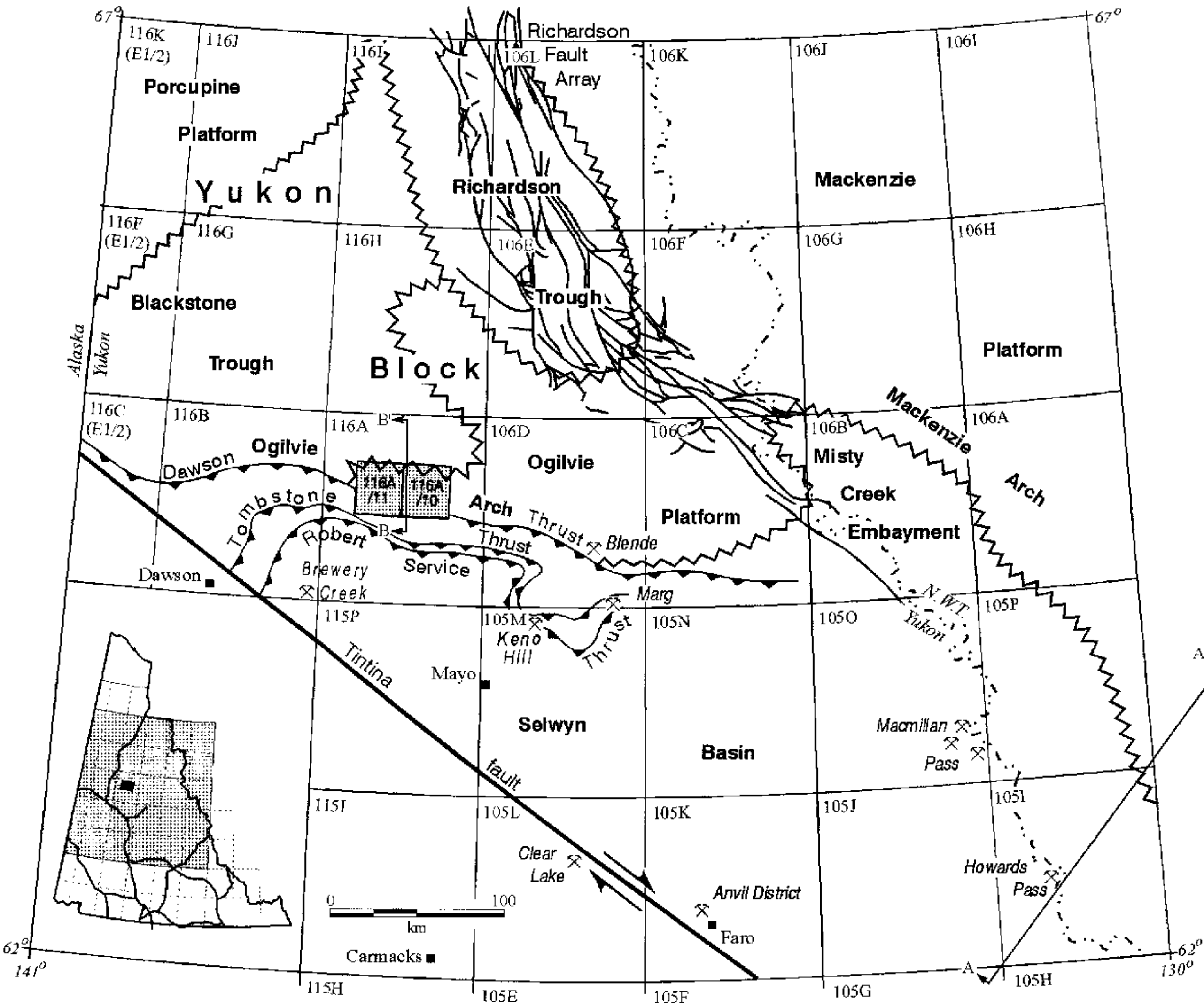
La sédimentation a commencé par le rifting et le dépôt de diamictite, de roches silicoclastiques et de roches volcaniques du Groupe de Mount Harper dans une étroite zone de demi-grabens(?). Les strates paléozoïques recouvrent toutes les strates protérozoïques suivant une discordance angulaire marquée. Elles comprennent de la dolomie et du calcaire de la Plate-forme Ogilvie datant du Cambrien tardif (?) au Dévonien précoce; le shale et le chert ordoviciens à dévoniens du Groupe de Road River de faciès équivalent; et des quantités mineures de roches volcaniques siluriennes, principalement dans la cuvette de Blackstone. Le Bassin de Selwyn représente la partie extérieure en eau profonde du miogéoclinal cordilléran et l'âge des roches qui s'y trouvent s'échelonne du Protérozoïque terminal au Dévonien précoce.

Les plus anciennes strates exposées appartiennent au Groupe de Hyland du Protérozoïque tardif au Cambrien précoce et comprennent les turbidites silicoclastiques et les roches carbonatées de la Formation de Yusezyu recouvrant le shale et le grès de la Formation de Narchilla. L'immense épaisseur de turbidite est reliée au rifting à l'intérieur du miogéoclinal du Protérozoïque terminal au Cambrien initial. La Formation de Gull Lake recouvre probablement en discordance le Groupe de Hyland et comprend du shale et du siltstone avec un mince assemblage basal de conglomérat, de grès et de roches volcaniques. Une pulsation relativement mineure de ce rifting se manifeste dans les roches volcaniques cambro-ordoviciennes de Dempster reposant en discordance sur toutes les unités plus anciennes. Les filons-couches mafiques pénétrant le Groupe de Hyland permettent de lui attribuer l'âge isotopique approximatif du Cambrien moyen et peuvent être reliés aux roches volcaniques à la base de la Formation de Gull Lake ou aux roches volcaniques de Dempster. Le calcaire et le shale finement lités de la Formation de Rabbitkettle du Cambrien tardif à l'Ordovicien précoce recouvrent la Formation de Gull Lake dans la région de la partie est de la carte et sont latéralement équivalents aux roches volcaniques de Dempster ainsi qu'au shale et au chert non nommés à l'ouest.

Les minces séquences de shale et de chert du Groupe de Road River révèlent une sédimentation en bassin sédimentaire à faible remplissage en eau profonde de l'Ordovicien au Dévonien. À l'intérieur du Groupe de Road River, du shale sans distinction et du chert subordonné à l'est et au nord font place à l'ouest et au sud à une unité de chert de l'Ordovicien et à du chert et du shale de l'Ordovicien au Dévonien(?). Par endroits, du calcaire de l'Ordovicien et/ou du Silurien est latéralement équivalent au shale et au chert. Du Dévonien moyen au Mississippien précoce les configurations de la sédimentation ont changé de manière saisissante lorsque le rifting et/ou la formation de failles décrochantes sur une grande échelle ont entraîné le dépôt des roches silicoclastiques du Groupe d'Earn. Dans la région couverte par la carte, du shale récessif, du siltstone, du grès dur et du chert du Groupe d'Earn recouvrent en discordance la roche carbonatée de la Plate-forme Ogilvie et le shale de la cuvette de Blackstone dans le Bloc du Yukon. Le Groupe d'Earn n'affleure pas dans la région constituée des strates du Bassin de Selwyn, mais peut reposer sous un intervalle couvert étendu dans la partie sud-ouest de la région de la carte. Un (des) filon(s)-couche(s?) pénétrant le Groupe de Road River dans le Bloc du Yukon et le Bassin de Selwyn indique(nt) le Paléozoïque tardif comme âge approximatif. La sédimentation sur marge passive a repris au Carbonifère précoce et est représentée par de petits affleurements de «quartzite de Keno Hill» du Mississippien et de grès et de shale du Trias et du (?) Jurassique à l'angle sud-ouest de la région cartographiée. Les strates sont plissées et imbriquées par une succession de failles de chevauchement orientées au nord et modérément inclinées vers le sud, dont les plus importantes sont les chevauchements de Dawson, de Tombstone et de Robert Service. Les faciès en eau profonde du Bassin de Selwyn sont brusquement juxtaposés aux faciès en eau peu profonde du Bloc du Yukon de l'autre côté de la faille de Dawson, bien que le raccourcissement ne soit estimé qu'à quelques kilomètres. Ce contraste saisissant est interprété comme une indication du fait que la Faille de Dawson reflète une structure sous-jacente de longue durée du socle qui a déterminé les configurations de la sédimentation le long de la limite entre le Bloc du Yukon et le Bassin de Selwyn depuis au moins le Protérozoïque tardif. Le gisement de sulfures massifs Hart River est relié aux filons-couches de Hart River et est interprété comme étant un dépôt de substitution qui recoupe et remplace le shale du Groupe de Gillespie Lake ainsi que les basaltes de Hart River. On pense que les basaltes ne sont que légèrement plus anciens que le gisement. Il est peu probable qu'il existe d'autres gîtes minéraux similaires dans la région, mais il pourrait exister des gisements de métaux communs dans les sédiments de plusieurs autres unités encore mal explorées.

Introduction

This report describes the results of recent geological mapping (scale 1:50,000) of NTS areas 116A/10 (unnamed) and 116A/11 (Two Beaver Lake), with emphasis on stratigraphy, structure and mineral potential (Figure 1). The upper Hart River area was selected for study because it contains the Middle Proterozoic Hart River massive sulphide deposit, and is thought to have a high potential for sediment-hosted base metal deposits in several stratigraphic settings. The area is underlain by an unusually diverse stratigraphic assemblage ranging in age from Early Proterozoic through Triassic, and includes sequences of similar age and type to those that contain most sediment-hosted base metal deposits in the northern Cordilleran miogeocline. The area is underexplored and less well understood than many other parts of the northern Cordilleran miogeocline. The refined interpretation of the stratigraphic and tectonic



105E - Lake Lebarge
105F - Quiet Lake
105G - Finlayson Lake
105H - Frances Lake
105I - Little Nahanni
105J - Sheldon Lake
105K - Tay River
105L - Glenlyon
105M - Mayo
105N - Lansing Range
105O - Niddery Lake
105P - Sekwi Mountain
106A - Mount Eduni
106B - Bonnet Plume Lake
106C - Nadaleen River
106D - Nash Creek
106E - Wind River
106F - Snake River
106G - Ramparts River
106H - Sans Sault Rapids
106I - Fort Good Hope
106J - Ontaratue River
106K - Martin House
106L - Trail River
115H - Aishihik Lake
115I - Carmacks
115P - McQuesten
116A - Larsen Creek
116B/C(E1/2) - Dawson
116F(E1/2)/G - Ogilvie River
116H - Hart River
116I - Eagle River
116J/K(E1/2) - Porcupine River

⚒ Significant mineral deposit

Figure 1. Map of north-central Yukon showing location of the project area, principal Paleozoic and Mesozoic geological elements and significant mineral deposits. Section lines A-A' and B-B' are the location of restored sections in Figure 53.

history of the area presented here may lead to more refined exploration models for sediment-hosted base metal deposits in the central Yukon.

Location, access, topography and glaciation

The project area is located in the eastern Ogilvie Mountains, at the headwaters of the Hart River, about 120 km east-northeast of Dawson City and 120 km north-northwest of Mayo (Figure 1). The nearest road is the Dempster Highway, located 60 km to the west, and access is primarily by helicopter. A short airstrip on Marc Creek near the Hart River massive sulphide deposit is not maintained, but was used in 1994. Small fixed-wing aircraft can land on Callison and Two Beaver lakes.

In order to allow adequate description of the geology, the informal names Marc Creek, Callison Creek and Twin Lakes are used here to supplement the few official geographic names in the area (Figure 2).

The eastern Ogilvie Mountains are more rounded and gentle than many of the glaciated parts of the Yukon. Peaks reach elevations of 2000 m and range from 700 to 1000 m in relief. Bedrock or felsenmeer are generally well exposed at higher elevations and locally down to valley bottoms. Intense solifluction and downslope movement of colluvium and talus are characteristic on most slopes, even below the treeline (about 1100–1200 m). Higher peaks have been shaped by young alpine glaciation and are rugged and clearly scalloped. A few have tarns at their base.

The glacial history of the Ogilvie Mountains is very complex. The glacial history of the northern Ogilvie Mountains is sketchy compared to the southern Ogilvie Mountains, where a record of several pre-Illinoian (pre-Reid) glaciations starting in the late Pliocene is preserved (Duk-Rodkin, pers. comm.). Pre-Reid glaciations are recorded in the Tintina Trench area and along the northern slopes of the southern Ogilvie Mountains (Duk-Rodkin, 1996). Evidence of the two youngest glaciations — Illinoian-Reid Glaciation (circa 200k) and Late Wisconsinian-McConnell Glaciation (circa 23k) — is found in mountain valleys throughout the southern Ogilvie Mountains (Duk-Rodkin, 1996). The eastern part of the southern Ogilvie Mountains that includes the study area was affected by two types of glaciers: 1) cordilleran valley glaciers, which extended westward into the area; and 2) glaciers from local peaks. During the Reid Glaciation, main and local valley glaciers merged and local ice caps may have been present. Cordilleran glaciers during the McConnell Glaciation did not reach the study area, and only local glaciers

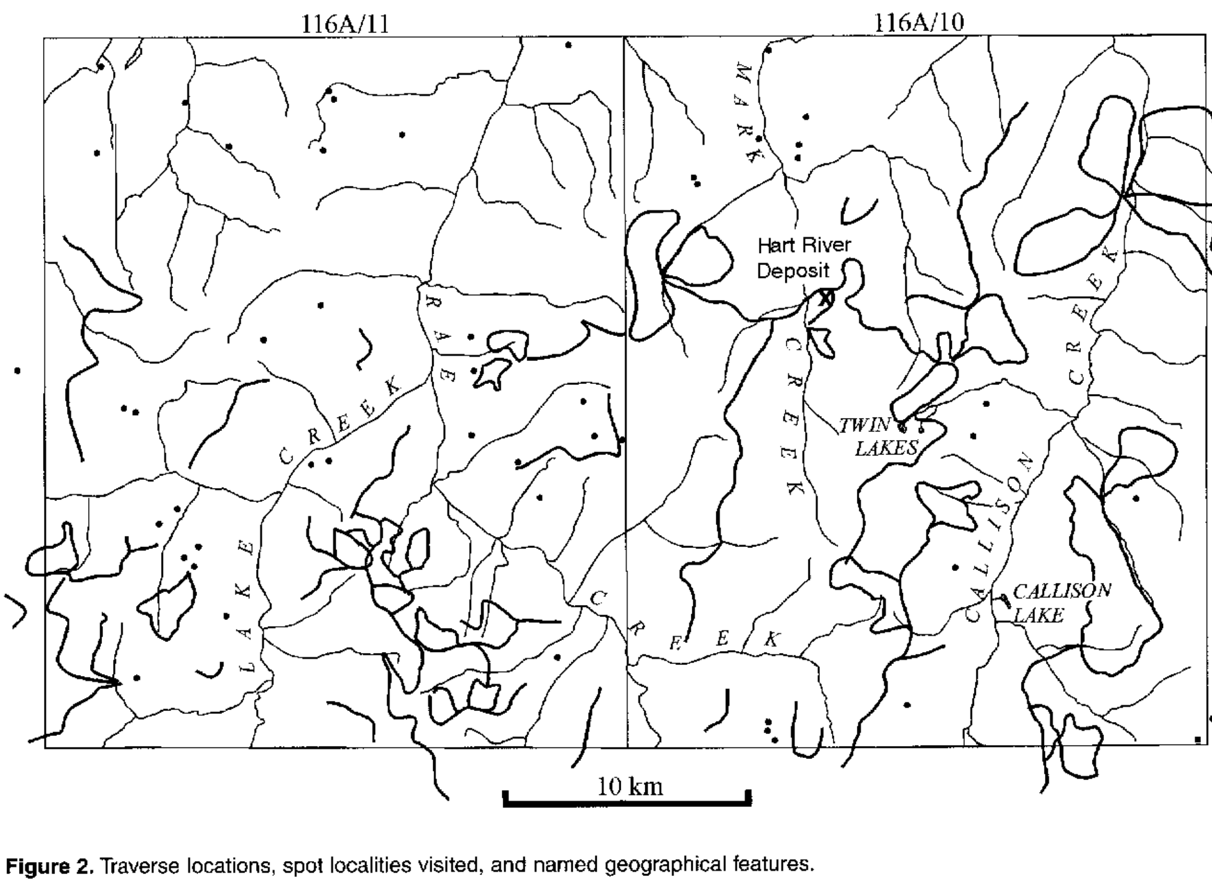


Figure 2. Traverse locations, spot localities visited, and named geographical features.

were present. Evidence of glaciation in the study area (116A, 10 and 11) is widespread and is mainly related to the last two glacial periods (Vernon and Hughes, 1966). Reid-age features are subdued in comparison to the distinct, well-preserved features of McConnell Glaciation (e.g., the upper reaches of Lake Creek).

Previous and present work

Green (1972) established the regional stratigraphic and structural framework of the Ogilvie Mountains when he completed mapping (scale 1:250,000) of the Dawson (116B and C), Larsen Creek (116A) and Nash Creek (106D) map areas in 1966. The Dawson map area (116B and C), which is located west of sheet 116A, was recently remapped (Thompson and Roots, 1982; Thompson, Roots and Mustard, 1992; Thompson, 1995). Morin (1979) studied the Hart River massive sulphide deposit.

The writer began geological mapping of sheets 116A 10 and 11 (scale 1:50,000) during four weeks in 1986, with funding from the Exploration and Geological Services Division of Indian and Northern Affairs Canada (Figure 2). Work resumed with funding from the Canada/Yukon Mineral Development Agreement in 1991 (two weeks), and continued in 1992 (five weeks), 1993 (four weeks), and 1995 (one week). C. F. Roots mapped in both sheets for one month in 1987, and his data have been incorporated (Abbott and Roots, 1992; 1993a,b).

Acknowledgements

Chuck Gregerson and Natalie Nachey provided able assistance in the field. This paper benefited from discussions with C. Roots, S. Gordey and D. Thorkelson, from constructive criticism by D. Murphy, M. Cecile and D. Cook, and thorough editing by L. Reynolds.

Regional Setting

Most strata in the study area are part of either Yukon Block or Selwyn Basin, two of the main geological subdivisions of the northern Cordilleran miogeocline. They are sharply separated by the Dawson Fault, a Mesozoic thrust fault with a Proterozoic and Paleozoic history (Figure 1). North of the Dawson Fault, Yukon Block includes a complex assemblage, more than six km thick, of shallow-marine clastic and carbonate rocks, and minor volcanic rocks ranging in age from Lower Proterozoic through Middle Paleozoic. South of the Dawson Fault, Selwyn Basin includes deeper water or basinal siliciclastic rocks, shale, chert, limestone, and volcanic rocks of Late Proterozoic to Devonian age. Locally preserved, poorly exposed, but regionally extensive Devonian through Triassic marine siliciclastic and carbonate strata overlie both Yukon Block and Selwyn Basin. Mafic sills and dikes are widespread and are of Middle Proterozoic, Cambro-Ordovician, Middle or Late Paleozoic, and possibly other, ages.

Yukon Block

Yukon Block (see Yukon Stable Block of Jeletsky, 1962; and Lenz, 1972) is here interpreted as representing an isostatically independent crustal block that has remained persistently high standing since at least Late Proterozoic time. It is bounded to the south by Selwyn Basin and to the east by Richardson Trough, but its northern and western boundaries are unclear (Figure 1). The Richardson Fault array and Dawson Fault coincide with Richardson Trough and the northern margin of Selwyn Basin, and are thought to reflect long-lived basement structures that 1) mark the eastern and southern margin of Yukon Block; 2) have been periodically active since at least Late Proterozoic time; and 3) controlled deposition of the deeper-water sedimentary rocks in Richardson Trough and along the northern margin of Selwyn Basin. Middle and Lower Proterozoic strata in Yukon Block are also distinct. The Middle Proterozoic strata in Yukon Block, for reasons that are not yet clear but that might reflect Late Proterozoic strike-slip faulting, are sharply juxtaposed across the Richardson Fault array against different, but genetically related, time-equivalent strata. The oldest exposed rocks in Yukon Block are Early Proterozoic, and are far older than the oldest exposures in adjacent areas.

Proterozoic successions of the northern Cordillera and western Arctic were first divided by Young et al. (1979) into three unconformity-bounded sequences: A (about 1.7 to about 1.2 Ga.); B (1.2 to about 0.8 Ga.); and C (about 0.8 to 0.7 Ga.) (Figures 3, 4). In Yukon Block, the Wernecke Supergroup belongs to Sequence A; the Pinguicula Group, Callison Lake dolostone, upper and lower Fifteenmile, and lower Tindir groups belong to Sequence B; and the Mount Harper Group, upper Tindir Group, and Windermere Supergroup belong to Sequence C.

Sequences A and B were deposited under mainly shallow-marine epicontinental conditions. The Racklan Orogeny, an enigmatic regional tectonic event, affected Sequence A and preceded deposition of Sequence B. Evidence for Racklan deformation is primarily exposed in the Wernecke Mountains, where the Pinguicula Group unconformably overlies folded and cleaved Wernecke Supergroup (Gabrielse, 1967; Eisbacher, 1978; Young et al., 1979; Thorkelson and Wallace, 1993a, b). Timing of Racklan deformation is constrained by cross-cutting relationships between foliated Wernecke Supergroup strata and the Wernecke breccias. Until recently, the breccias were thought to be 1.27 Ga (Parrish and Bell, 1987). Recent U/Pb ages of circa 1.6 Ga were obtained by R. Creaser (Abbott et al., 1997) from sphene from the Wernecke breccias. U/Pb ages of circa 1.71 Ga were obtained by J. Mortensen (pers. comm., 1995) from zircon in mafic dikes cutting the Wernecke Supergroup. The relationship between deformation and the dikes is unclear (D. Thorkelson, pers comm., 1995). Thus the Racklan Orogeny is at least 1.6 Ga, and possibly older than about 1.71 Ga. East of the Mackenzie Mountains, near Great Bear Lake, Cook and MacLean (1992, 1995) identified a similar Proterozoic deformational event on the surface and in seismic sections, which they called the Forward Orogeny and which correlated with the Racklan Orogeny. A 1.27 Ga rift event, but not the Racklan Orogeny, is recorded in the Coppermine area of the eastern Arctic where the 1.27 Ga Coppermine lavas overlie older strata with angular unconformity (Cook and McLean, 1995).

In Yukon Block, the lower Fifteenmile and Pinguicula Groups are now known to be correlative (Abbott et al., 1997; this paper). They include a lower upward-shoaling clastic carbonate sequence and an upper sequence of quartzite, shale, siltstone and carbonate. In the Ogilvie Mountains an angular unconformity clearly separates the two sequences (Abbott et al., 1997; this paper). The maximum age of the lower sequence is most tightly constrained in the Hart River area, where it unconformably overlies the Hart River sills. These intrude the Wernecke Supergroup and have been dated by M. L. Bevier at 1.38 Ga (Abbott, 1993; this paper). The upper sequence has yielded detrital zircons as young as about 1.0 Ga (Rainbird et al., in press). Thus it is unclear whether the lower sequences in the Pinguicula and lower Fifteenmile groups are younger than 1.27 Ga, as originally thought, or if they are as old as 1.38 Ga. The possibility that the unconformity

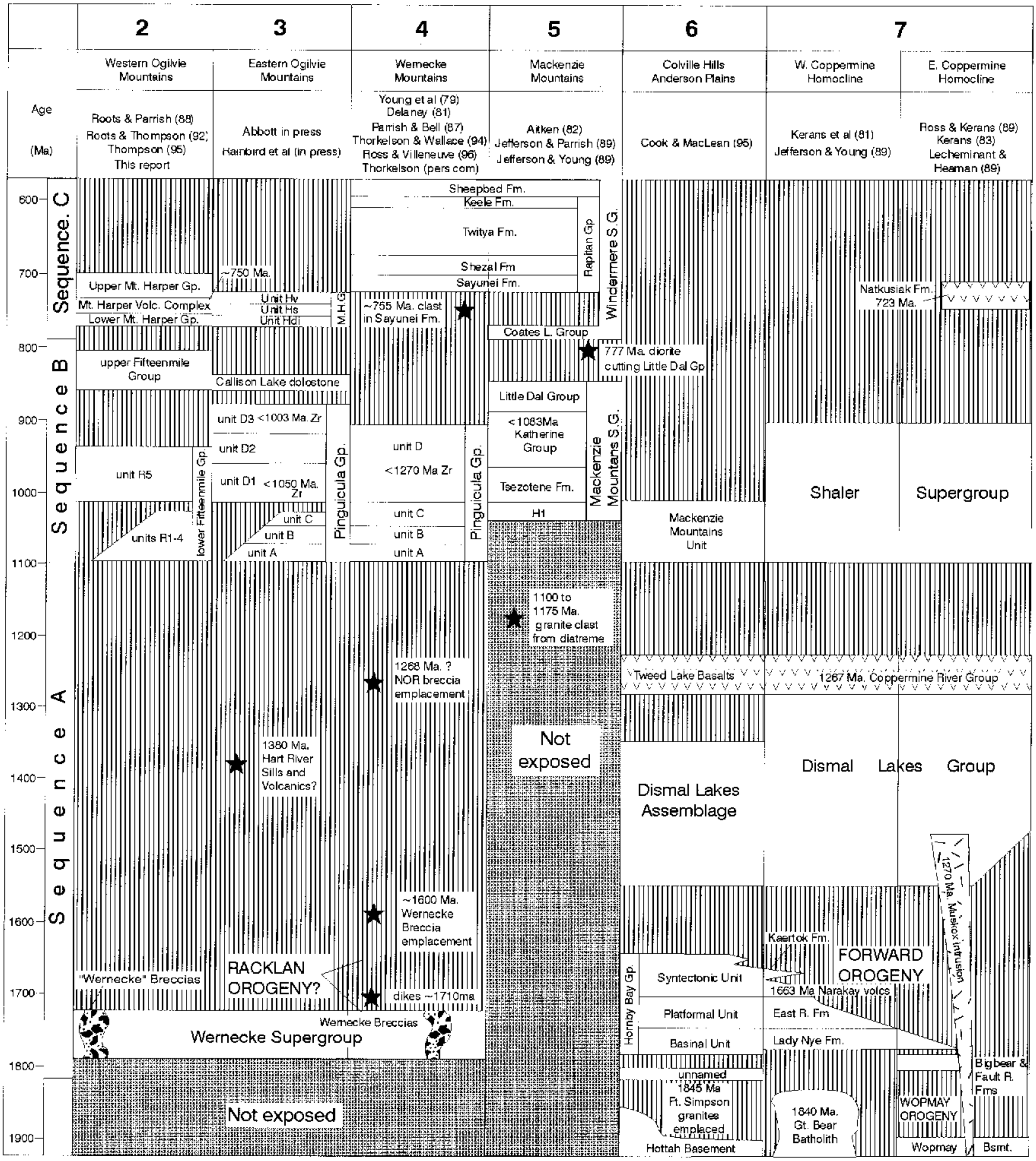


Figure 3. Correlation of Proterozoic sequences in the Ogilvie, Wernecke and Mackenzie mountains, and the western Arctic (modified from diagram by Cook and MacLean, 1995).

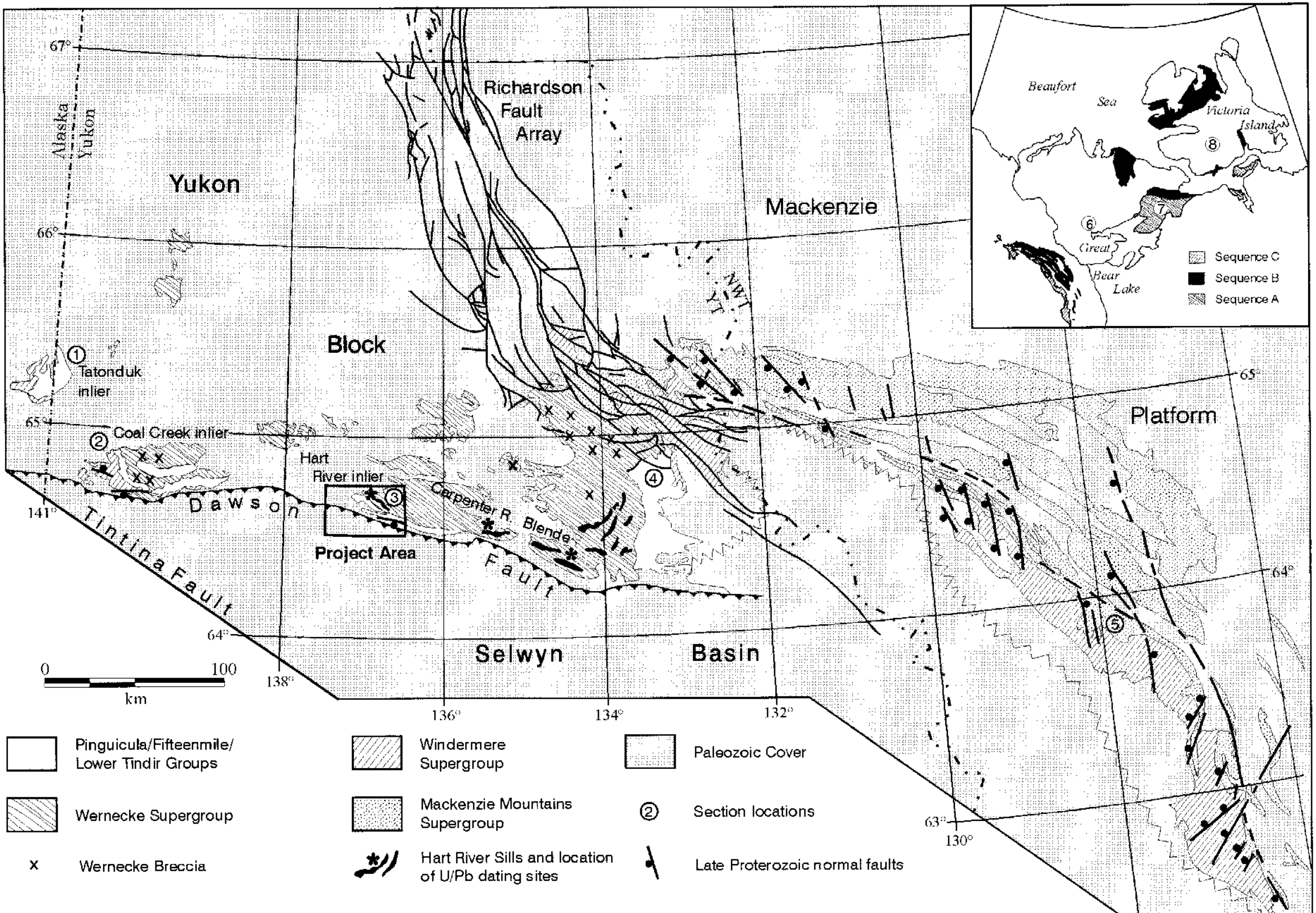


Figure 4. Regional map of principal Proterozoic sequences and Proterozoic structures in the Ogilvie, Wernecke and Mackenzie mountains, and location of sections in Fig. 20. Modified from Wheeler and McFeely (1991) with additions from Eisbacher, 1981; Thompson, 1995; Young, 1982; and Thorkelson and Wallace, 1993b, 1994b, 1995b. Insert from Cook and McLean, 1995.

between the upper and lower sequences represents the 1.27 Ga rift event cannot be discounted.

Deposition of Sequence C marked the onset of sedimentation within the Cordilleran miogeocline, and began with widespread Late Proterozoic continental rifting and, possibly, strike-slip faulting along the ancestral Richardson Fault array. Sequence C, although widespread in the Mackenzie Mountains as the Windermere Supergroup, is confined to three localities in Yukon Block. Coarse diamictite, siltstone, and volcanic rocks of the Mount Harper Group occur on the southern margins of the Coal Creek and Hart River inliers in the Ogilvie Mountains, and diamictite, conglomerate, siltstone, shale and carbonate of the Windermere Supergroup are confined to the eastern flanks of the Wernecke Mountains.

Paleozoic and Mesozoic strata within Yukon Block define several troughs and platforms to which a number of names have been applied (Gabrielse and Yorath, 1992). In this study, Ogilvie Platform, Porcupine Platform and Blackstone Trough are used (Figure 1). Lower Cambrian to Devonian carbonate-dominated strata of Ogilvie Platform (Figure 1) unconformably overlie all older units with marked angularity. The unconformity probably represents several erosional events in many places, and includes two Paleozoic events. Lower Cambrian siliciclastic and carbonate rocks are preserved along the Richardson Trough and in exposures along the Alaska-Yukon border. Elsewhere, the oldest Paleozoic rocks belong to the rift-related Middle Cambrian Slats Creek Formation and are confined to syndepositional fault-bounded grabens. A monotonous sequence of dolostone and limestone characterizes the Late(?) Cambrian to Middle Devonian succession. Black carbonaceous shale and chert of the Road River Group are primarily of Late Ordovician and Silurian age, and form troughs and tongues within the carbonate shelf. Blackstone Trough, which trends east across the northern Ogilvie Mountains, is the best defined. In the southern Ogilvie Mountains, the distribution of the Road River Group is not well understood, as it has been removed in many places by erosion, so the age of the carbonate sequence is only loosely constrained.

Ogilvie Arch (Gabrielse, 1967) is an important structural element within Yukon Block. It is located (Figure 1) north of the Dawson Fault along the Coal Creek and Hart River inliers (Figure 4) — two structural culminations that expose Proterozoic strata in windows beneath Lower Paleozoic carbonate rocks. Lower Paleozoic carbonate rocks along Ogilvie Arch are thinner than they are farther north, and latest Proterozoic and Lower and Middle Cambrian strata are absent, in contrast to the thick sequences of that age to the south in Selwyn Basin. Ogilvie Arch thus represents a hingeline along the north side of Selwyn Basin that was tectonically high from Late Proterozoic through Early Paleozoic time. Mackenzie Arch (Douglas et al., 1970), in the Mackenzie Mountains is a similar feature along the eastern margin of Selwyn Basin (Figure 1).

Selwyn Basin

South of the Dawson Fault, Selwyn Basin comprises Late Proterozoic to Middle Devonian strata that represent the outer, deeper water, part of the Cordilleran miogeocline. The oldest exposed rocks are thick, widespread, coarse-grained siliciclastic rocks of the latest Proterozoic and earliest Cambrian Hyland Group. They represent a period of rifting and probable continental separation along the western margin of North America (Bond and Kominz, 1984). Cambrian to Middle Devonian strata in Selwyn Basin comprise a relatively thin, laterally consistent sequence of shale, chert, and limestone. Formations represented in this sequence are Gull Lake, Rabbitkettle and various units of the Road River Group. Local accumulations of mafic volcanic rocks are widespread both in time and space, but those of Early Cambrian and late Early to Middle Ordovician age are the most voluminous and extensive (Goodfellow et al., 1995). They attest to episodic tectonic instability and relatively minor extension along the otherwise passive continental margin. The widespread Late Cambrian unconformity mapped in the area may reflect thermal uplift related to rifting.

The abrupt contrast in sedimentary facies and the concentration of mafic igneous rocks of several different ages along the Dawson Fault indicate that it reflects an old basement structure that has controlled sedimentation patterns at least since Late Proterozoic time and possibly longer (Roots and Thompson, 1992). Along the eastern margin of Selwyn Basin, facies transitions with equivalent shelf strata of Mackenzie Platform are gradual and well documented (Gordey and Anderson, 1993). In contrast, thin Lower and Middle Paleozoic shelf strata of Ogilvie Platform are sharply juxtaposed across the Dawson Fault against quite different deep-water facies in Selwyn Basin. The thick wedge of sediments that normally separates these facies and forms the bulk of the miogeocline elsewhere in the Cordillera is absent. Only black shale and chert of the Road River Group occurs on both sides of the fault. Latest Proterozoic through Middle Cambrian strata, which form much of the sequence south of the fault, are absent beneath Lower Paleozoic carbonates on the north side due to erosion or nondeposition. Also, many of the Proterozoic units in Yukon Block are older than any in Selwyn Basin.

Devonian and younger sedimentation

Devonian rifting and/or wrench faulting along the outer margin of the Cordilleran miogeocline dramatically altered sedimentation patterns. This tectonic activity is reflected in the Middle Devonian marine transgression and deposition of relatively deep-water siliceous shales onto Ogilvie Platform, and deposition of Devonian to Early Carboniferous coarse clastic rocks of the Earn Group (Abbott et al., 1986) into fault-controlled basins on Selwyn Basin. A return to passive margin sedimentation is marked by locally preserved Carboniferous through Jurassic strata consisting primarily of a variety of shallow-marine siliciclastic and carbonate rocks. On Ogilvie Platform, one exception consists of clastic rocks derived from the Ellesmerian Orogen, which flooded south over much of what is now northern Yukon in Late Devonian through Lower Carboniferous time.

Structure

The study area straddles the boundary between the Foreland and Omineca belts of the Cordilleran Orogen. Strata are folded and imbricated by a series of moderately south-dipping, northerly directed thrust faults. Three principal faults (Figure 1) — from north to south, the Dawson, Tombstone, and the Robert Service thrusts — are more than 200 km long and juxtapose laterally continuous, distinct sequences of rocks. The juxtaposition of Selwyn Basin sequence against Ogilvie Platform and younger strata along the Dawson Thrust is the most dramatic. However, this contrast in part reflects differences in the Paleozoic and Proterozoic history of sequences on either side of the fault rather than a significantly greater amount of shortening on the adjacent thrust faults on either side. The Tombstone Thrust places the Mississippian Keno Hill quartzite on the Jurassic and older Lower Schist. The Robert Service Thrust, immediately south of the map areas, places the Latest Proterozoic and Early Cambrian Hyland Group on the Keno Hill quartzite. Both of these faults have offsets in the order of tens of kilometres (Gordey and Thompson, 1991). Other faults are spaced one to three km apart, and most have a stratigraphic throw of less than one km. All units are cleaved and folded, and metamorphosed to sub- to lower greenschist facies. Intensity of deformation and grade of metamorphism increases gradually from north to south.

The leading edge of post-orogenic, mid-Cretaceous magmatism lies well south of the map area.

Stratigraphy

The project area contains 39 map units (Table 1). In the following section the rocks in the project area are described under three main headings: sedimentary and volcanic rocks north of the Dawson Fault, sedimentary and volcanic rocks south of the Dawson Fault, and intrusive rocks. Given the small size of the project area, the short time committed to fieldwork, and to maintain continuity, the only new name introduced here is the informal Callison Lake dolostone (see Table 1). Wherever possible, formation names from other areas were retained; if that was not possible, informal unit designations were used.

Rocks north of the Dawson Fault

Wernecke Supergroup (Quartet and Gillespie Lake groups)

The oldest exposed rocks in the Ogilvie and Wernecke mountains belong to the Wernecke Supergroup, which includes the Fairchild Lake, Quartet, and Gillespie Lake groups (Delaney, 1981, 1985). Only the Quartet and Gillespie Lake groups are exposed in the map area.

The Quartet Group (PQ) is uniform throughout the area and comprises mainly dark grey to black phyllite and slate with irregularly distributed laminations and rare beds of siltstone and quartz sandstone up to five cm thick. Rhythmically bedded, tan- and grey-weathering, thinly laminated shale and silty shale about 50 m thick mark the top of the unit (Figure 5). Structural complexity and lack of marker units prevent an accurate estimation of thickness. A minimum thickness of 2000 m is likely as the unit is exposed in mountains with a vertical relief of 1000 m and occupies large areas both within the map area and beyond, to the north and northeast.

The Gillespie Lake Group (PG) is characterized by resistant orange- to buff-weathering, platy, thin- to medium-bedded ferroan dolostone (Figure 6). The dolostone is well bedded, variably shaly, silty and, locally, sandy. Stromatolites and algal laminations are common. The contact with the Quartet Group, in the few places where it is not a fault, is gradational with buff-weathering, thin-bedded, shaly dolostone about 50 m thick comprising the base of the unit.

A unit of recessive, black to dark grey shale between 10 and 100 m thick is tentatively included in the Gillespie Lake Group (PG1). Alternatively, the shale is part of a younger sequence that also includes the Hart River basalts. The shale hosts the Hart River massive sulphide deposit in map sheet 116A/10. It has been traced west of the deposit for about four km, but to the east appears to have been removed by erosion beneath the Pinguicula Group. Along the western boundary of sheet 116A/10, the same(?) thin interval of shale and siltstone is thought to be overlain by orange-weathering stromatolitic dolostone. This is the only locality where there is evidence that dolostone of the Gillespie Lake Group overlies the shale. Because the area is poorly exposed and structurally complicated, this interpretation is tentative. A small erosional remnant of hornfels-rich black shale located five km east-northeast of the Hart River deposit has also been included in the unit. The presence of hornfels is thought to be related to a mafic sill (unit Pd), which is exposed nearby and projects above the shale.

Widespread faulting, abundant mafic sills, and lack of distinctive markers make it difficult to precisely define the internal stratigraphy and thickness of the Gillespie Lake Group. No complete section is exposed, but a minimum thickness of 1000 m is probable.

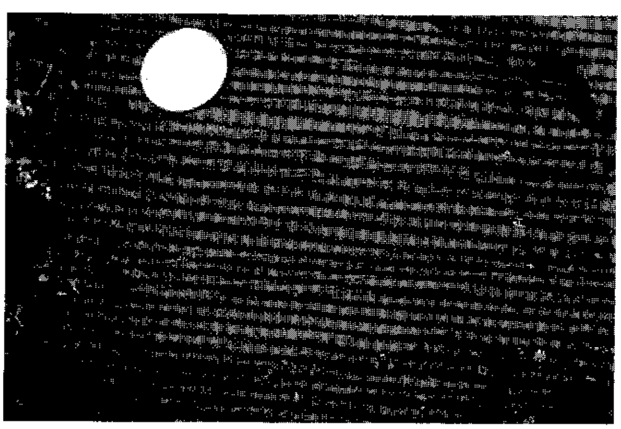


Figure 5. Laminated shale and siltstone near the top of the Quartet Group.

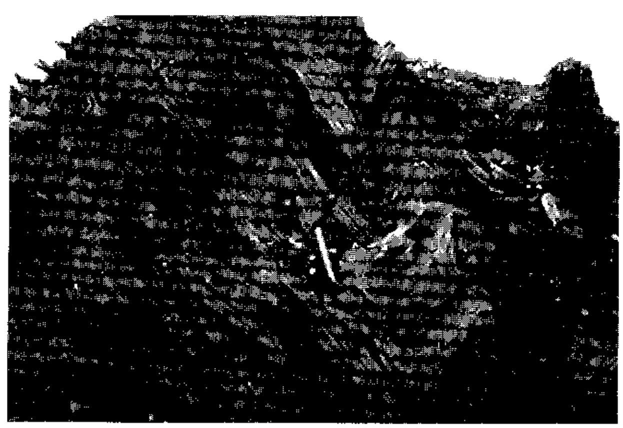


Figure 6. Thin-bedded, orange-weathering dolostone typical of the Gillespie Lake Group.

Table 1. Table of formations.

Period or Epoch	Formation/ Map Unit	Lithology	Thickness (m)
Pleistocene to recent	Quaternary Q		
North of Dawson Fault			
Earn Group (DME)			
Devonian and Carboniferous	DME	shale, siltstone, sandstone	>500
disconformable on Ogilvie Formation, SDI, Sv and ЄSc			
Devonian	Ogilvie Formation (DO)	limestone	~200
Silurian and ?Devonian	SDI	limestone	~100
disconformable? on ЄSc and Ov; facies equivalent to ODR1,2			
Silurian	Sv	mafic volcanics	~20-50
conformable? on ODRp, ЄSc			
Road River Group (ODp)			
Ordovician, Silurian, and Devonian	ODp	shale, chert	~20-500
conformable on ЄSc, facies equivalent to ЄSc, and SDI			
Cambrian(?) Ordovician, and Silurian	ЄSc	dolostone	~500
unconformable on all older units			
Mount Harper Group (PHdi, PHs, PHv)			
Upper Proterozoic	PHv	mafic volcanics	~100
conformable?			
Upper Proterozoic	PHs	siltstone, shale	~200
conformable			
Upper Proterozoic	PHdi	diamictite, limestone, shale	~100-500
unconformable on PCc, PP			
Upper Proterozoic	Callison L. dolostone (PCL)	dolostone	~500
unconformable on PD3			
Pinguicula Group (PPA,B,C,D1,D2,D3)			
Upper Proterozoic	PPD3	sandstone, siltstone, quartz arenite, shale	210
conformable			
Upper Proterozoic	PPD2	dolostone, limestone	180
conformable			
Upper Proterozoic	PPD1	quartz arenite, shale, siltstone, conglomerate	780
unconformable on PPA,B,C, PG? and PQ?			
Middle? and Upper Proterozoic	PPC	dolostone	~250
conformable			
Middle? and Upper Proterozoic	PPB	silty dolostone, dolostone	498
conformable			
Middle? and Upper Proterozoic	PPA	shale, siltstone, sandstone	~350
unconformable on Pd, Pv, PG			
Middle Proterozoic	Hart River volcanics Pv	mafic volcanics	75
unconformable(?) on PG1			
Wernecke Supergroup (Quartet Group, Gillespie Lake Group)			
Lower Proterozoic	Gillespie Lake Group Units PG, PG1	PG, silty dolostone, dolostone; PG, black shale	>1000
conformable			
Lower Proterozoic	Quartet Group (PQ)	shale, siltstone, sandstone	>2000
base not exposed			

South of Dawson Fault

Jurassic, Triassic, and older?	TJps	Shale, siltstone, sandstone	
base not exposed			
Mississippian	Keno Hill quartzite Mq	quartz arenite, shale	
base not exposed			
Road River Group (ЄOu, ODp, OSl, Ot, ODpt)			
Ordovician, Silurian and (?)Devonian	ODpt	chert, shale	>100
conformable on Ot			
Ordovician	Ot	chert	~50-70
unconformable on ЄOv, ЄGs, PЄN; facies equivalent to parts of ODp			
(?)Ordovician and (?)Silurian	OSl	limestone	~1-100
unconformable on ЄOv, ЄGs, PЄN; facies equivalent to parts of Ot			
Ordovician, Silurian and Devonian	ODp	shale, chert	365
conformable on Rabbitkettle Formation; facies equivalent to ODpt, Ot, OSl, parts of ЄOu			
Cambrian and Ordovician	Dempster volcanics ЄOu	shale, chert	~25-100
unconformable on ЄG, PЄN; facies equivalent to Rabbitkettle Formation and part or ODRp			
Cambrian and Ordovician	ЄOv	mafic volcanic rocks	~10-100
unconformable? on ЄGs, PЄN, PY			
Upper Cambrian and Lower Ordovician	Rabbitkettle Formation ЄOR	silty limestone, shale	~50
unconformable? on Gull Lake Formation			
Lower and (?)Middle Cambrian	Gull Lake Formation	ЄGp: shale, siltstone ЄGl: limestone, diamictite ЄGv: mafic volcanic rocks ЄGs: quartz arenite, mafic volcanic rocks, shale	~300
unconformable? on PЄN			
Hyland Group			
Lower Cambrian and Upper Proterozoic	Narchilla Formation PЄN	shale, sandstone, grit	~500
conformable			
Upper Proterozoic	Yusezyu Formation PY;PY1	PY: sandstone, grit, siltstone, limestone, shale PY1: limestone, sandy	>1000
base not exposed			

Intrusive Rocks

Late Paleozoic	Pd	diorite, gabbro sills and dikes	
intrudes Road River Group on both sides of the Dawson Fault			

Cambrian	Єd	diorite, gabbro sills and dikes	
intrudes Hyland Group south of Dawson Fault			

Middle Proterozoic	Hart River sills Pd	diorite, gabbro sills and dikes	250
intrudes Wernecke Supergroup			

Environment, age and correlation

The Wernecke Supergroup is only exposed in Yukon Block in inliers beneath younger Proterozoic and Paleozoic strata (Wheeler and McFeely, 1991; Aitken and McMechan, 1992; Figure 4). Studies in the Wernecke Mountains by Delaney (1981) provided the only detailed descriptions. Delaney divided the Wernecke Supergroup, from oldest to youngest, into the Fairchild Lake, Quartet, and Gillespie Lake groups. The base is not exposed and its total thickness according to Delaney is more than 15 km. The Wernecke Supergroup has been traced across Yukon Block and the threefold subdivision and distinct lithological character of each group in the Dawson map area (Thompson, 1995) are essentially the same as in the Wernecke Mountains. Delaney interpreted the Wernecke Supergroup as an upward-shoaling miogeoclinal sequence, and Aitken and McMechan (1992) concurred. An alternative interpretation — from the widespread distribution of the Wernecke Supergroup, with no clear polarity of facies or thickness — is that it was deposited in an intracratonic basin rather than a continental margin.

In the Hart River area, the Fairchild Lake Group is not exposed. The Quartet Group appears to be comparable in thickness and lithostratigraphy to Wernecke Mountain strata, although sandstone and siltstone appear to be much less abundant, perhaps indicating a more distal, deeper water environment. The Quartet Group gives the appearance of a deep-water sequence, with its black colour, monotonous stratigraphy, and great thickness. Also, the rhythmic siliciclastic interbeds strongly suggest deposition in deep water as turbidites. However, in the Wernecke Mountains, Delaney (1981) reported sedimentary structures indicating deposition under shallow-marine conditions.

The Gillespie Lake Group in the Wernecke Mountains closely resembles that in the Hart River area. Delaney identified seven formations that indicate a gradual upward transition from siliciclastic-dominated rocks (G-TR) at the base through carbonate-siliciclastic admixtures (G-2-6) to shallow-marine platform carbonates (G-7) at the top. The basal transition in the Wernecke Mountains is up to 700 m thick in contrast to 50 m at Hart River. The middle part of the Gillespie Lake Group in the Wernecke Mountains resembles the rest of the sequence at Hart River, but no specific correlations to the five formations in that part of the sequence are possible. Thorkelson and Wallace (1993a) reported thin intervals of black shale and siltstone in the Gillespie Lake Group similar to unit G1, but did not consider them to be reliable stratigraphic markers. Delaney (1981) concluded that deposition occurred in a shallow-marine environment and that clastic detritus was derived from the north. The Hart River strata were deposited in a similar environment, but the paleogeographic relationship to the Wernecke strata is unknown. The Gillespie Lake Group in the Wernecke Mountains is at least 4 km thick (Delaney, 1981). The relatively thin (about 1 km) sequence in the Hart River area may reflect the original thickness, or could have been eroded before deposition of the overlying Pinguicula Group, or both. The last alternative is the most likely given the difference in thickness of the basal transition and the absence of the upper carbonate unit at Hart River.

The Wernecke Supergroup belongs to Sequence A (Young et al., 1979) and until recently was thought to be Middle Proterozoic in age. Recent isotopic ages obtained by J. Mortensen for zircons in mafic dikes cutting the Fairchild Lake Group indicate that the Wernecke Supergroup in the Wernecke Mountains is Early Proterozoic and was deposited before about 1.71 Ga (D. Thorkelson pers. comm., 1995).

A noteworthy difference between the Wernecke Supergroup in the eastern Ogilvie Mountains and other areas is the absence of Wernecke breccia. This unusual breccia cuts the Wernecke Supergroup both to the northeast in the Wernecke Mountains (Thorkelson and Wallace 1993a, b, 1994a, b) and to the west in the Coal Creek Inlier (Lane and Godwin, 1992). However, none were seen in the area mapped and none have been reported from the surrounding Hart River Inlier. The minimum age of the breccia is critical in interpreting the minimum age of the unconformably overlying Pinguicula Group in the Werencke Mountains. A U-Pb date of 1.27±0.04 Ga for monazite was obtained from an outlying breccia zone in the Richardson Mountains (Parrish and Bell, 1987). Recently, R. Creaser (Abbott et al., 1997) obtained a preliminary U-Pb (sphene) date of about 1.6 Ga on one of the main breccia zones in the Wernecke Mountains, at the Slab mineral occurrence. Breccia formation and initial metasomatism was postulated as having occurred at 1.6 Ga, followed at 1.27 Ga by hydrothermal activity, possibly related to emplacement of the Mackenzie dyke swarm.

Hart River basalts (Pv)

In the central part of map sheet 116A/10, the Hart River basalts are exposed in a west-plunging anticline along the crest and dip slope of a single ridge stratigraphically above the Hart River massive sulphide deposit. The volcanic rocks overlie black slate of unit PG1 with apparent concordance, although poor exposure and complex small-scale faulting precludes precise determination of the relationship. Faults and poor exposure also make stratigraphic relationships with overlying rocks unclear.

The volcanic rocks are about 75 m thick and consist of amygdaloidal pillow lavas (Figure 7) grading downward into massive aphanitic greenstone. Morin (1979) and Guardia (1971) reported columnar structures in the lower parts of the unit. A few thin shale layers within the greenstone bodies suggest more than one flow unit. Thin sections show that the volcanic rocks consist of a felted aphanitic groundmass of chlorite, epidote and minor carbonate replacing fine-grained laths of plagioclase and phenocrysts of clinopyroxene.

The unit continues north along the crest of the ridge above the Hart River sulphide deposit, where the contact with underlying shale remains generally concordant, although narrow apophyses of the main body clearly cross-cut and intrude the underlying shales. The upper contact of the northern exposures is not exposed and it is unclear whether they are intrusive or extrusive in origin. They are aphanitic greenstone and closely resemble the volcanic rocks in hand specimen, but contain no structures to clearly identify them as volcanic. Thin sections reveal that they are coarser grained than the pillowed rocks, but much finer grained than the nearby coarse-grained diorite and gabbro intrusions of unit Pd.

The Hart River basalts appear to be restricted to one exposure in the map area. Along strike to the east and west, Abbott and Roots (1993a) interpreted clastic rocks in the same approximate stratigraphic position as distal tuffs. Subsequent study indicated that they are, at least in part, unconformable on the Hart River sills and therefore probably younger than the volcanic rocks. Some of these rocks could still be distal equivalents of the volcanics, but this seems unlikely.

Age and correlation

The age and correlation of the Hart River basalts remain uncertain. Most probably, they are the extrusive equivalents of the Hart River sills, which are 1380 Ma (see U/Pb geochronometry). Although there is no isotopic evidence to support this, the close spatial relationship and geochemical similarity of the intrusive and extrusive rocks makes this the most likely possibility.

Figure 7. Pillowed flows in the Hart River basalt.

The only known correlatives of the Hart River basalts are located near Carpenter Ridge, about 75 km east of the map area, where the writer (unpublished data) recognized previously unmapped lava flows and spatially associated mafic sills in the same stratigraphic position as those in the Hart River area. Other exposures may occur between the map area and Carpenter Ridge, where there has been no recent mapping. Roots (1990a,b) showed that the volcanic rocks probably do not continue east of Carpenter Ridge. Eisbacher (1981) described the "Kohse Creek volcanics" at the base of the Pinguicula Group and unconformably overlying the Gillespie Lake Group in the Wernecke Mountains. However, Thorkelson and Wallace (1995a) were unable to locate those volcanic rocks and believed that the mafic sills were misidentified.

Pinguicula Group (PPA, PPB, PPC, PPD1, PPD2, PPD3)

Strata correlated with the Pinguicula Group include six provisional units. Strata assigned to units PPA, PPB, and PPC were previously included in the Gillespie Lake Group and those now included in units PPD1, PPD2, and PPD3 were correlated with the Fifteenmile Group (Abbott, 1993) (Figure 8). Units PPA, PPB, and PPC form an upward-shallowing sequence, which includes basal siliciclastic rocks (unit PPA), silty carbonate rocks (unit PPB) and massive to thick-bedded dolostone (unit PPC). They closely resemble their counterparts in the Wernecke Mountains. Unit PPA overlies the Gillespie Lake Group, the Hart River sills and Hart River basalts with angular unconformity and is overlain with angular unconformity by unit PPD1, the basal unit of a sequence of clastic and carbonate rocks comprising units PPD1, PPD2, and PPD3, which correlate loosely with unit D in the Wernecke Mountains.

The best exposures of the Pinguicula Group are in sheet 116A/10 where they form a colourful, resistant belt that cuts northwest across the centre of the map area. The most complete sequence is located immediately west of Marc Creek, where a measured section (Figure 9) gives a minimum thickness of 1984 m. It does not include unit PPC, which has an estimated minimum thickness of 250 m.

Unit PPA

In its reference section, unit PPA consists of recessive, dark-brown-weathering clastic rocks about 350 m thick. The lower half of the unit comprises

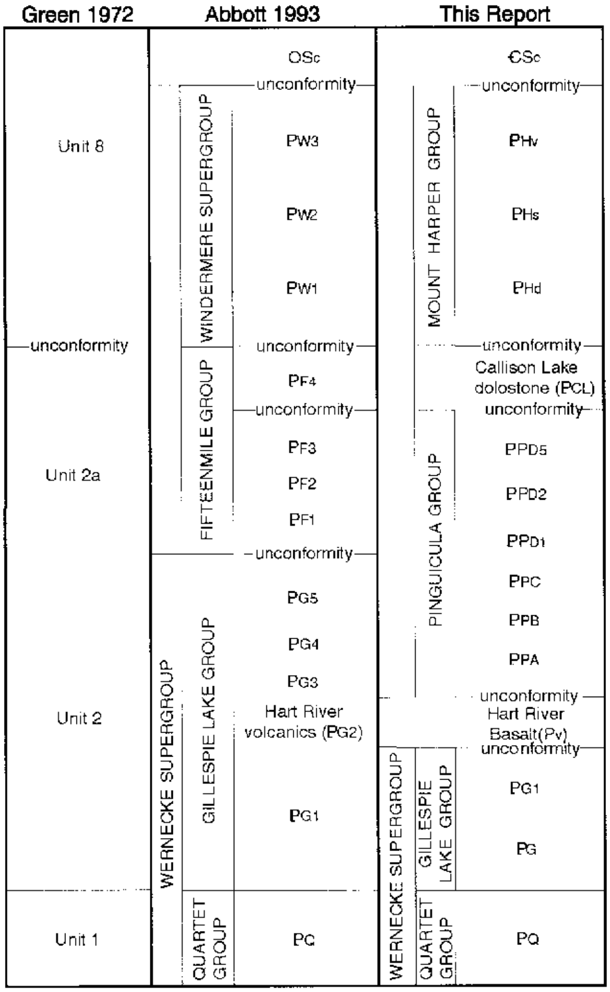


Figure 8. Nomenclature of Proterozoic strata in the Hart River Inlier.

finely laminated to massive greywacke and siltstone, and local conglomerate (Figure 10) and lesser amounts of phyllite. Thinly laminated grey, green, and maroon phyllite and silty phyllite dominate the upper half (Figure 11). The coarse clastic lower part of the unit is generally less than 100 m thick. The unusual thickness in the reference section may reflect structural repetition. Although the dark green colour and well indurated character of the sandstone and siltstone suggest that they are distal epiclastic or volcaniclastic or tuff equivalents of the Hart River basalts, as was proposed by Abbott (1993), information from thin sections suggests otherwise. They are composed primarily of angular grains of monocrystalline quartz, very fine-grained quartzite, and sericitic phyllite in a matrix of sericite and chlorite. Likewise, the conglomerate contains angular to rounded pebbles of quartz, quartzite, greenstone, grey and green phyllite and minor carbonate. The most likely source for most of this detritus is the Quartet Group, with only a minor amount from the Hart River sills, volcanics and the Gillespie Lake Group.

Figure 12 illustrates the stratigraphic relationships between unit PPA and older strata. East of the Hart River basalt, the coarse clastic rocks unconformably overlie one of the Hart River sills and the Gillespie Lake dolostone. The contact between unit PPA and the sill is well exposed in at least two localities, and the coarse clastic rocks are clearly in depositional contact with the sill. Near the Hart River basalts, poor exposure and structural complications make stratigraphic relationships unclear. Next to the volcanics, a few metres of dark green greywacke appear to mark the base of unit PPA and overlie black shale assigned to the Gillespie Lake Group (unit PG1). Maroon and grey shale appears to overlie the volcanics. Farther west past Marc Creek, the sandstone and conglomerate overlie black shales correlated with the Gillespie Lake Group (PG1). These shales resemble those in the upper part of unit PPA. Abbott (1993) interpreted all of the shales as one unit in the Gillespie Lake Group. In this interpretation, the coarse clastic rocks were considered distal equivalents to the Hart River basalts and formed a member within the unit. However, if the correlation of the Hart River basalts with the Hart River sills is correct, the composition of the clastic rocks and unconformable relationship with the Hart River sills dictate that the coarse clastic rocks of unit A must be younger than the volcanics.

Unit PPB

Unit PPB resembles the Gillespie Lake Group, with which it was previously correlated by Abbott (1993). It sharply overlies unit PPA, and is 498 m thick in the reference section. It consists of thinly laminated to thinly bedded tan- to orange-weathering, pale green calcareous phyllite and argillaceous, calcareous dolostone. Unit PPB becomes slightly more resistant and carbonate rich upsection, but is otherwise uniform throughout the map area.

Unit PPC

Unit PPC consists primarily of massive to thick-bedded cream to light-grey dolostone. Near Twin Lakes the dolostone contains quartzite in beds up to 30 cm thick. The upper part of the unit is intensely brecciated, with red-weathering ferroan carbonate cementing angular clasts and forming veinlets throughout. The breccias are thought to reflect karstification related to uplift and erosion before deposition of unit D1. The dolostone is gradational with the underlying well bedded argillaceous carbonate of unit PPB. It is estimated to be 250 m thick east of Callison Creek, thins to the west, and is absent

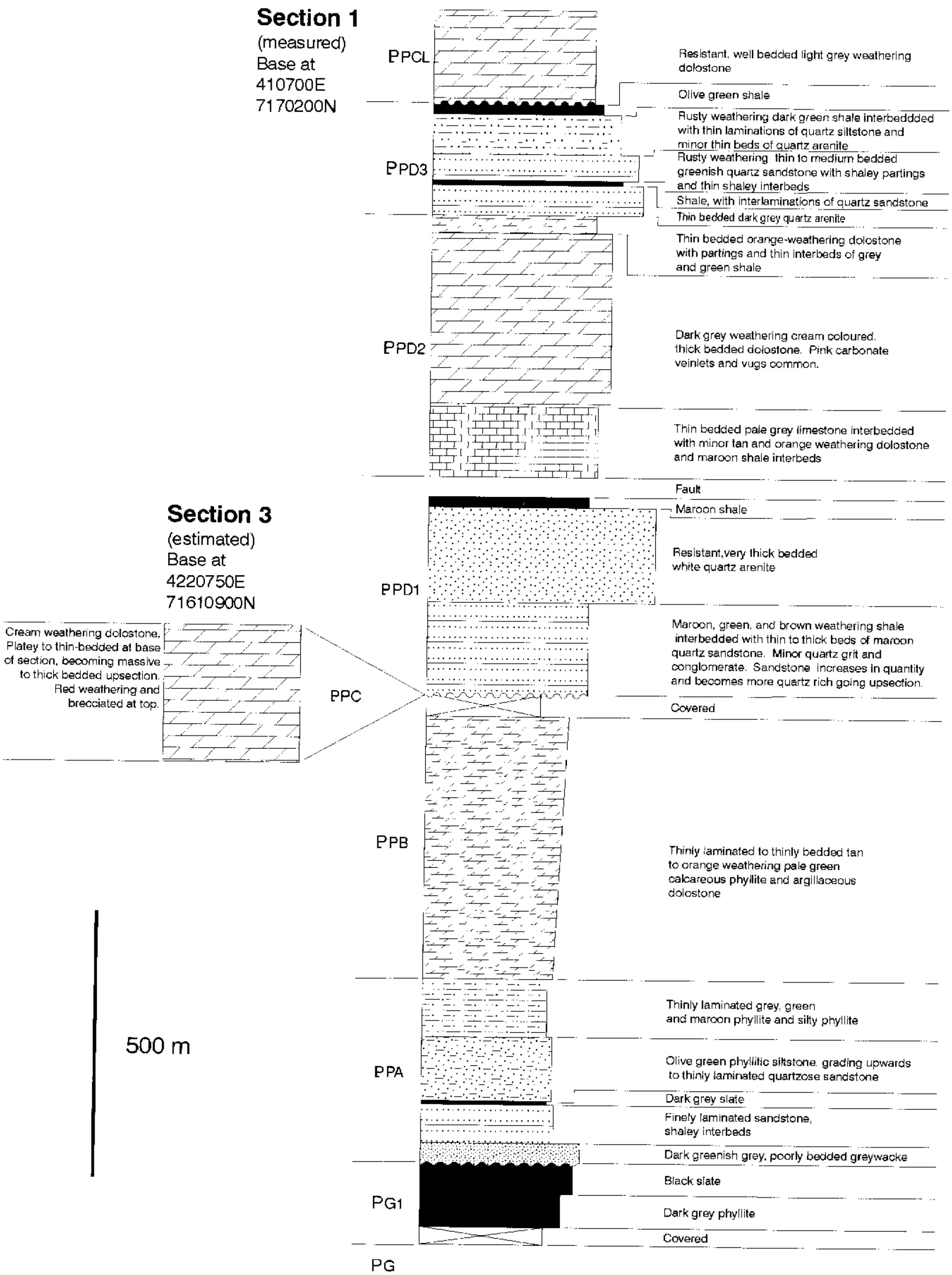


Figure 9. Sections 1 and 3 in the Pinguicula Group. Location shown on map 1997-2.

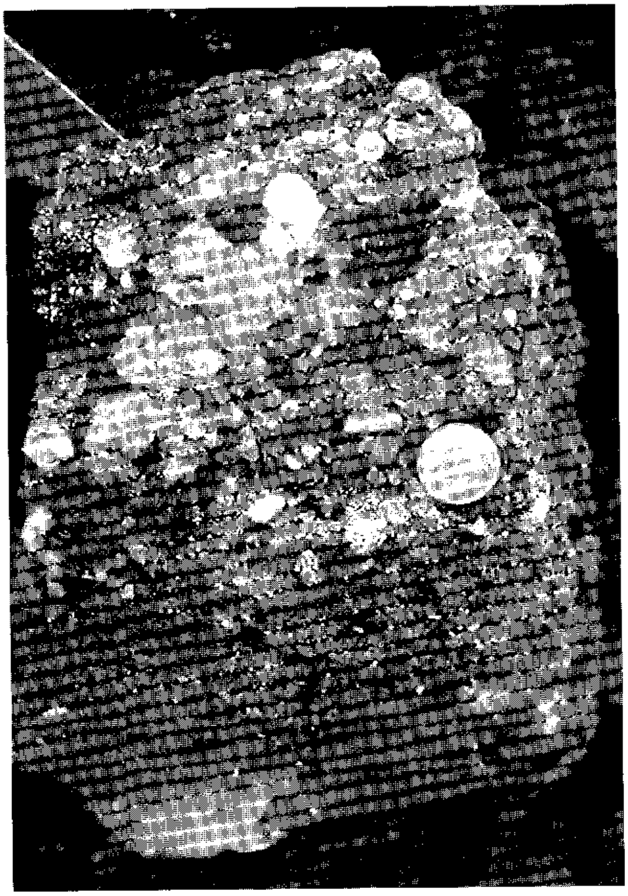


Figure 10. Basal conglomerate of the Pinguicula Group (Unit PPA) consisting of angular clasts of green phyllite, greenstone, vein quartz and quartzite. The conglomerate overlies the Hart River sills and the Gillespie Lake Group with angular unconformity.

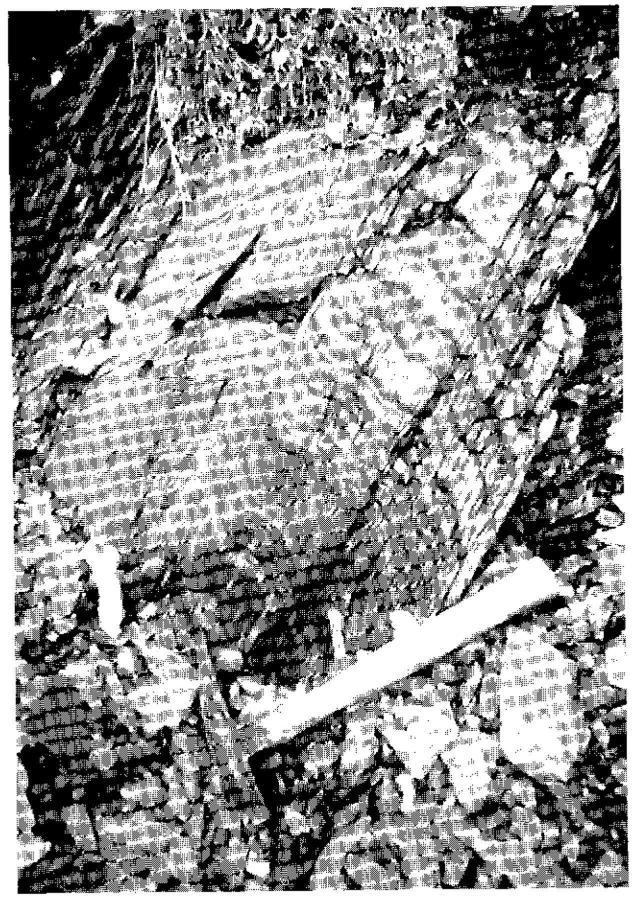


Figure 11. Laminated shale and siltstone in unit PPA of the Pinguicula Group.

west of Marc Creek. An unconformity at the base of unit PPD1 appears to account for the removal of unit PPC.

Unit PPD1

Unit PPD1 has three members and a total thickness of about 780 m in the reference section. The lower member is highly variable and in the reference section is about 170 m thick and includes maroon, green, and brown shale interbedded with thin to thick beds of maroon quartz sandstone (Figure 13) and conglomerate (Figure 14). It consists of about 50 m of olive-green and maroon shale three km farther west. Near Twin Lakes, it is about 150 m thick and includes orange- and brown-weathering orange and maroon shale interbedded with thin beds of orange-weathering dolostone and sandstone, with the upper 50 m comprising poorly bedded, maroon-, green-, and orange-brown-weathering sandstone. East of Callison Creek, it consists of about 30 m of buff-weathering, olive-green slate and black slate, with minor sandstone.

The middle member of unit PPD1 consists primarily of resistant, thick-bedded to massive, grey-weathering quartzite (Figure 15). The quartzite is 180 m thick in the reference section, sharply overlies the lower member, and is fairly uniform in thickness and character throughout the map area. Near Twin Lakes, the upper part of the member consists of thin- to medium-bedded quartzite interbedded with maroon and grey shale. In the western part of the map area, conspicuous orange gossans in the quartzite are derived from disseminated pyrite. The quartzite displays few obvious sedimentary structures in outcrop but fresh surfaces locally display faint bedding laminations defined by concentrations of heavy detrital minerals. In thin section, quartzite consists of well sorted, monocrystalline, equant, rounded to sub-angular quartz grains (90%) 0.1-0.2 mm across. Pressure solution and secondary overgrowths have mostly destroyed the original grain shape, which was probably equant and well rounded. Other constituents include fine grains of shale and siltstone (about 8%), and euhedral diagenetic pyrite (about 1%).

An upper shale member about 30 m thick sharply overlies the quartzite. It is brown weathering from a

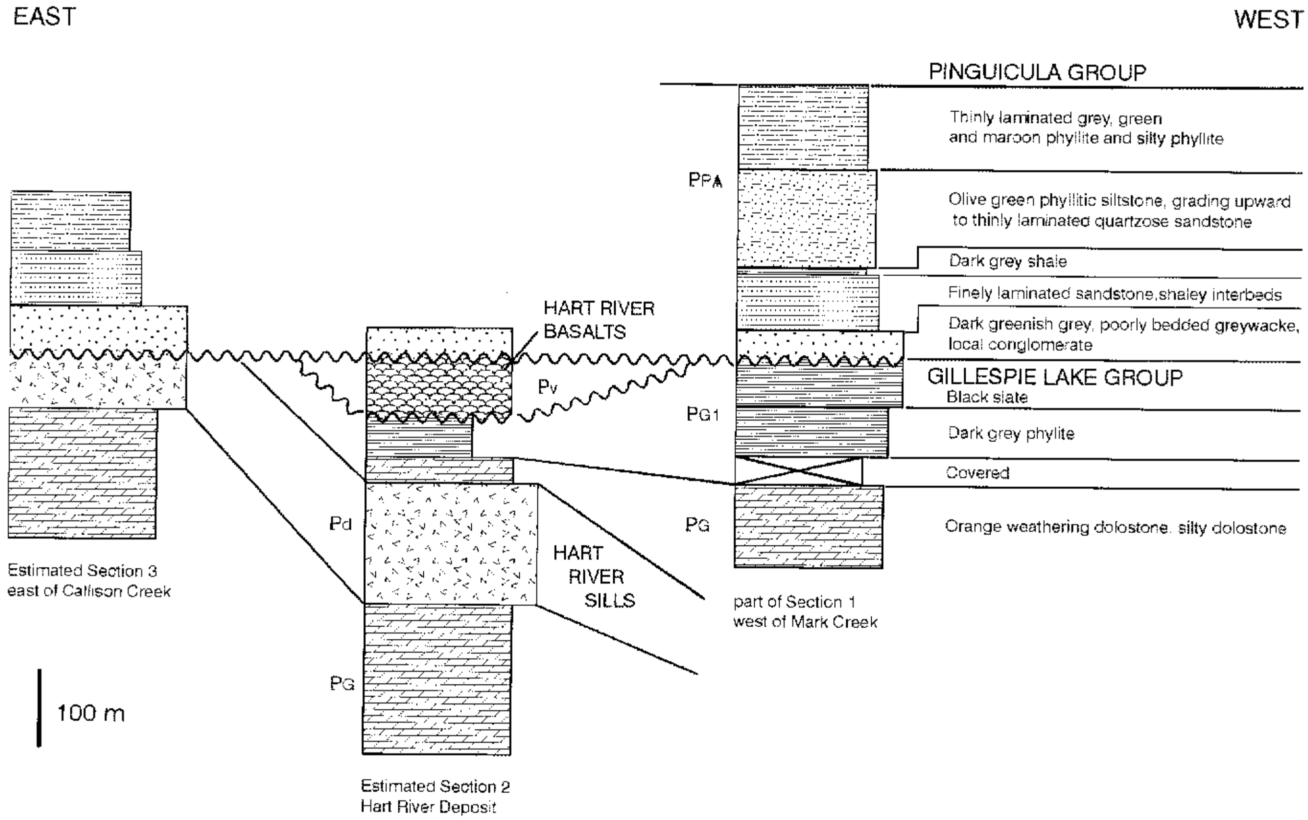


Figure 12. Stratigraphic relationships between the base of the Pinguicula Group and the Hart River sills, and shale and dolostone of the Gillespie Lake Group.

distance and consists mainly of maroon shale with lesser amounts of olive-green shale, mainly in the upper part. The shale is variably calcareous and locally contains some thin beds of pale dolostone and dolomitic siltstone. For reasons that are unclear, the member is absent east of Callison Creek.

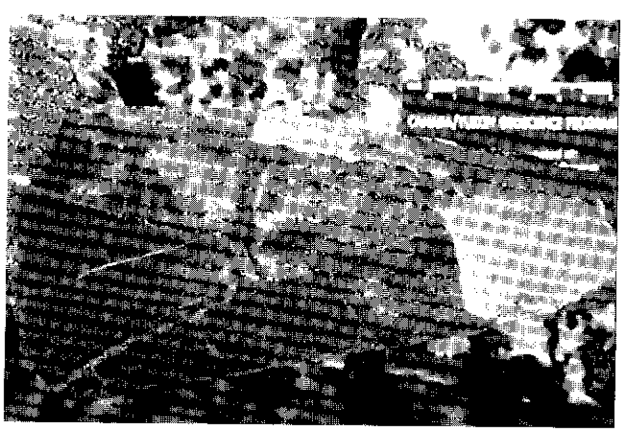


Figure 13. Syneresis cracks in red sandstone near the base of unit PPD1 in the Pinguicula Group, suggesting subaerial deposition for the lower parts of the unit.

Unit PPD2

Unit PPD2 includes lower and upper members with a combined thickness of 489 m in the reference section. The lower member is 132 m thick and consists of recessive, thin-bedded, pale grey limestone (Figure 16). Bedding is typically well developed and wavy. Maroon and green shale of unit PPD1 gradually pass upsection over a few metres into the limestone of unit PPD2. The limestone member passes gradationally upward into 548 m of more resistant, grey- to cream-weathering dolostone of the upper member. The dolostone weathers into prominent medium to thick beds, which display well defined laminations (Figure 17). Vugs and randomly oriented veinlets of pink to red carbonate are characteristic. Unit D2 is fairly consistent in lithology and thickness throughout most of the map area, although the lower limestone member is absent east of Callison Creek.

Unit PPD3

Unit PPD3 sharply overlies unit PPD2 and is 210 m thick in the reference section. Its thickness varies considerably, primarily as a result of removal by erosion beneath unconformities at the base of Lower Paleozoic strata and possibly beneath the Callison

Figure 14. Conglomerate containing angular to rounded clasts of vein quartz and greenstone in the lower member of unit PPD1 of the Pinguicula Group. The conglomerate is part of a basal sequence containing mainly maroon sandstone, siltstone and shale.

Lake dolostone. Its internal stratigraphy is highly variable and not yet precisely defined. Typically, dark-brown- to rusty-weathering, thinly laminated to thick-bedded quartzite and sandstone are interbedded with varying amounts of dark grey to greenish grey shale and micaceous siltstone. Finer grained rocks predominate in the upper half of the unit. Maroon shale and thin beds of orange dolostone are minor components, mainly near the top of the unit. Gossans are widespread and most likely formed from weathering of iron carbonate cement in the sandstones. Massive to thick bedded quartzite similar to that in unit PPD1 occurs mainly in the southernmost thrust panel containing unit PPD3, and east of Callison Lake. Beds of thin- to medium-bedded sandstone are generally separated by partings and laminations of siltstone and shale. Clastic grains are mainly monocrystalline quartz with minor chert. The matrix includes overgrowths of silica in the most pure beds, but in most specimens iron oxide and chlorite(?)

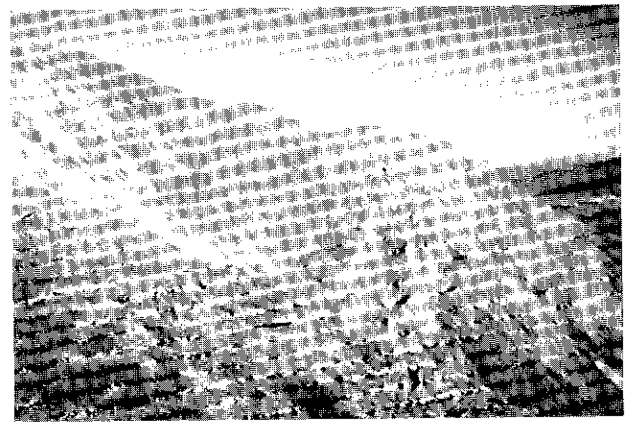


Figure 15. Thick-bedded quartzite characteristic of the middle member of unit PPD1 of the Pinguicula Group.

dominate. In some, rounded quartz grains are suspended in a matrix of iron oxide and very fine-grained chlorite(?). Locally, primary iron carbonate matrix is preserved and thought to be the source of the iron oxide. Diagenetic pyrite is also a possibility.

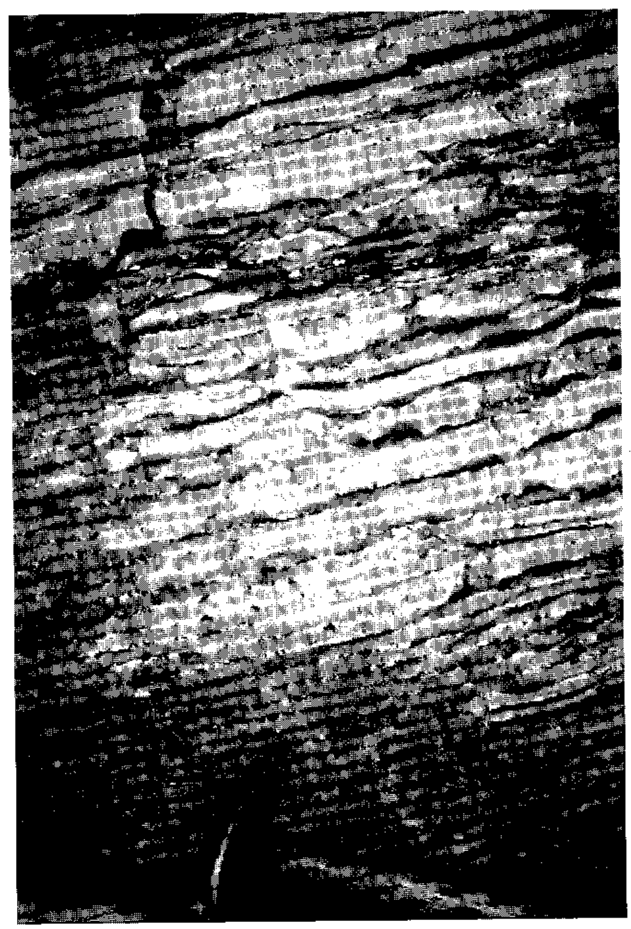


Figure 16. Thin-bedded limestone characteristic of the lower member of unit PPD2 of the Pinguicula Group.

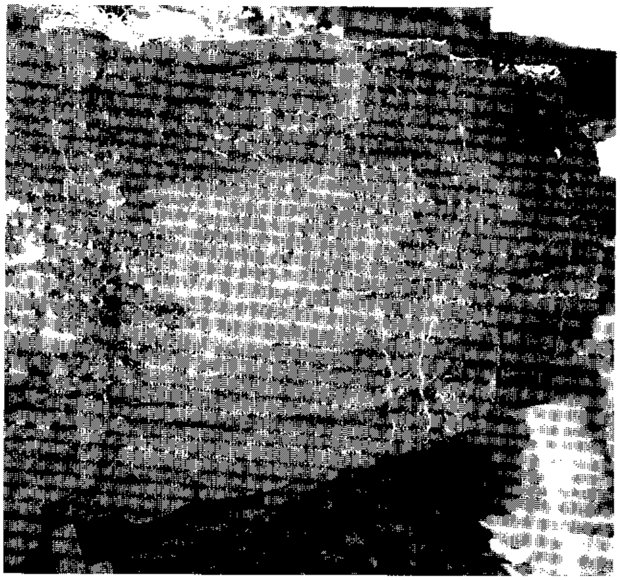


Figure 17. Laminated dolostone characteristic of the upper member of unit PPD2.

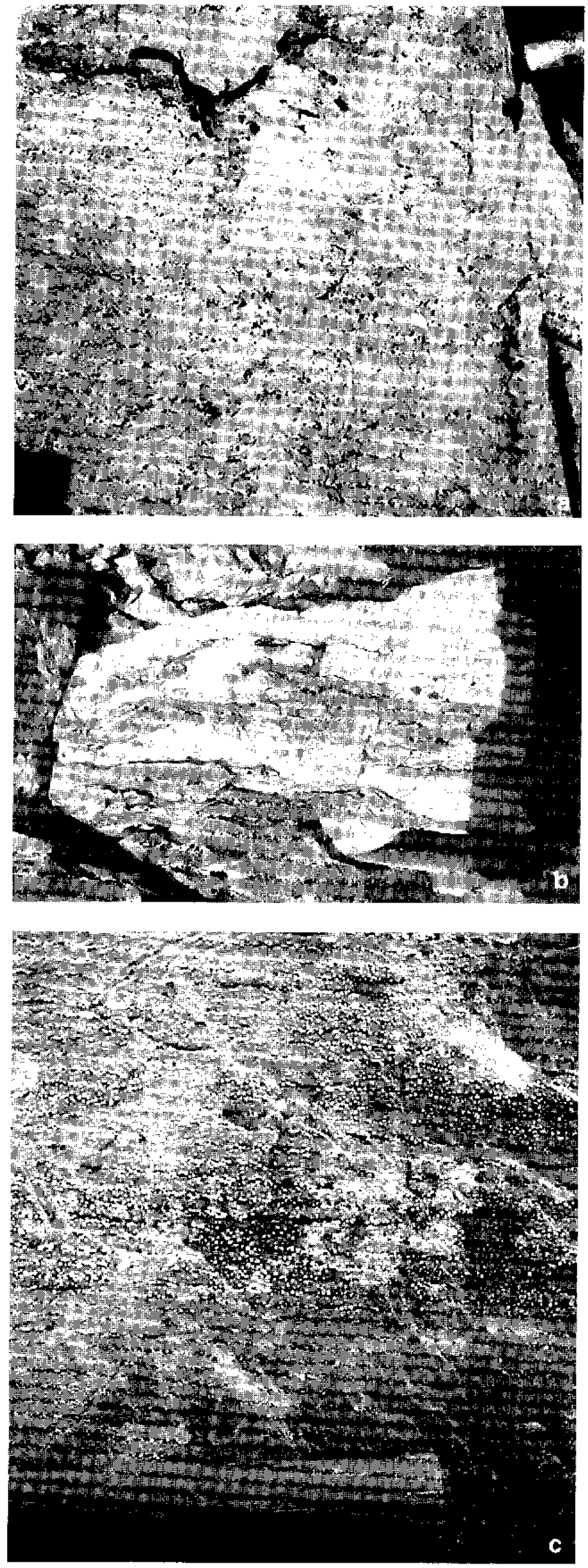


Figure 18. Primary sedimentary structures are well preserved in the Callison Lake dolostone. These include: a) stromatolites; b); oncolites; and c) chert lenses.

Callison Lake dolostone (PCL)

The Callison Lake dolostone is well bedded, light-grey-weathering and forms resistant craggy bluffs. Sedimentary structures are well preserved in eastern exposures and include delicate algal laminations, stromatolites, pisoliths, and intraformational breccias (Figure 18). Lenses of grey to black chert up to 10 cm thick are common and characteristic. These features serve to distinguish the Proterozoic dolostone from talus-forming, massive, coarse-grained and featureless Paleozoic dolostone, which in places directly overlies the older carbonate. Farther west, in sheet 116A/11, the dolostone is structureless and cannot always be distinguished from the Paleozoic carbonate.

The thickness of the dolostone is estimated at about 500 m, but varies widely because of erosion beneath unconformities at the base of the overlying Upper Proterozoic and Lower Paleozoic strata. The dolostone overlies unit PPD3 at least locally with angular unconformity (Figure 19), but the internal stratigraphy of the unit is not well enough known to allow the amount of erosional relief to be estimated.

Age and correlation

Sequence B of Young et al. (1979) includes five isolated Middle to Late Proterozoic sequences spread across the northern Cordillera and western Arctic (Figures 4, 20). These are the Shaler Supergroup in the western Arctic (Rainbird et al., 1994), the Mackenzie Mountains Supergroup in the Mackenzie Mountains (Aitken and McMechan, 1992), the Pinguicula Group (Eisbacher, 1981) in the Wernecke Mountains and eastern Ogilvie Mountains (this

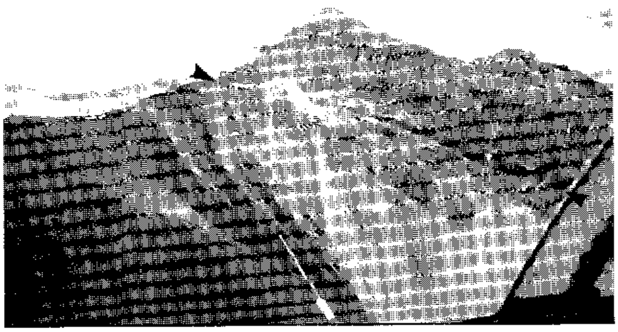


Figure 19. Angular unconformity between the Callison Lake dolostone and underlying unit PPD3 of the Pinguicula Group at the headwaters of Marc Creek.

paper), the Fifteenmile Group (Roots and Thompson, 1992) in the Coal Creek Inlier of the western Ogilvie Mountains, and the lower Tindir Group in the Tatonduk Inlier along the Alaska-Yukon border (Young, 1982). The Shaler Supergroup and the Mackenzie Mountains Supergroup can be correlated with confidence formation by formation (Rainbird et al., 1996a), although the Great Bear Arch, a northwest-trending area of nondeposition, separated the two. On the other hand, the Cordilleran sequences differ significantly, and a lack of detailed stratigraphic information and age control have made correlations tenuous. Recent correlations by Rainbird et al. (1996a, in press) and Cook and MacLean (1995) are mostly based on studies undertaken in the western Arctic. The alternative correlations presented below are based on more recent Cordilleran work, including this and other studies in the Wernecke Mountains by Abbott et al., 1997, Thorkelson and Wallace (1995a, b), Thorkelson and Creaser (unpubl.), and Thorkelson and Mortensen (unpubl.).

Previous correlations of Proterozoic strata in the Hart River Inlier by Rainbird et al. (1996a, in press), and Cook and MacLean (1995) are based on Abbott's (1993) assignment of strata to the Gillespie Lake Group (units PG3, PG4, and PG5), and the Fifteenmile Group (units PF1, PF2, PF3, and PF4). The Gillespie Lake Group is now correlated with the Pinguicula Group (units PPA, PPB, PPC, PPD1, PPD2, and PPD3) and the Fifteenmile Group is correlated with the Callison Lake dolostone (Figure 8). This reassignment is based on the recent recognition of an angular unconformity beneath strata overlying the Hart River sills and volcanics. The unconformity makes the correlation of overlying strata with the Gillespie Lake Group impossible, as the Hart River sills have been dated at 1380 Ma (Abbott, 1993, this paper) and mafic dikes cutting the Wernecke Supergroup give U/Pb (zircon) ages of circa 1710 Ma (D. Thorkelson and J. Mortensen, pers. comm., 1995).

Strata assigned to the Pinguicula Group in the Hart River Inlier are clearly correlative with parts or all of the type Pinguicula Group (Eisbacher, 1981) in the Wernecke Mountains. These correlations have become evident, in part, through redescription and reinterpretation of the Pinguicula Group by Thorkelson and Wallace (1995a). In both areas, units PPA, PPB, and PPC define a remarkably similar upward-shoaling sequence. In both sequences, dark basal siliciclastic rocks of unit PPA unconformably overlie the Gillespie Lake Group and pass upward into well bedded, orange-weathering, silty, ferroan carbonate of unit PPB, which in turn grades upward into the more massive, grey to buff, platformal carbonate of unit PPC. Thicknesses of units PPA and PPB are similar, but unit PPC is much thicker in the Wernecke Mountains. This difference can be explained by removal of parts of unit PPC beneath the unconformity at the base of unit PPD1 in the Hart River Inlier. The succession PPD (PPD1, PPD2, PPD3) in the eastern Ogilvie Mountains is less similar to unit PPD (units D, E, and F of Eisbacher) in the Wernecke Mountains and no one-to-one correlation of units is possible. Thorkelson and Wallace (1995a) suggested that the three divisions of Eisbacher (units D, E and F) are really lithofacies of a single diverse unit (unit PPD) up to 1050 m thick. Thick-bedded quartzite of the Corn Creek quartzite (unit E) was assigned to several stratigraphic intervals in unit PPD. The finely laminated nodular limestone of unit F, which was originally mapped at the top of the sequence in one syncline, may correlate with limestone between quartzite units in another locality. Thorkelson and Wallace (1995a) described unit PPD in the Wernecke Mountains as highly variable with a basal sequence about 100 m thick of interbedded black shale and dolostone overlain by interbedded thin- to very thick-bedded, buff-, grey- and orange-weathering dolostone; black-weathering shale; thin- to medium-bedded, black, maroon, and buff-weathering, locally muscovite-bearing siltstone; finely laminated, grey- to maroon-weathering, nodular limestone; and thick-bedded, grey-weathering quartzite. Carbonate predominates in the lower parts of the sequence; quartzite predominates in the upper part, where it includes mappable units up to 200 m thick in more than one stratigraphic position.

No carbonate rocks in unit PPD in the Wernecke Mountains resemble the distinctive Callison Lake dolostone in the Hart River Inlier. If equivalent strata ever were deposited, they are presumed to have been removed by erosion before deposition of the Windermere Supergroup.

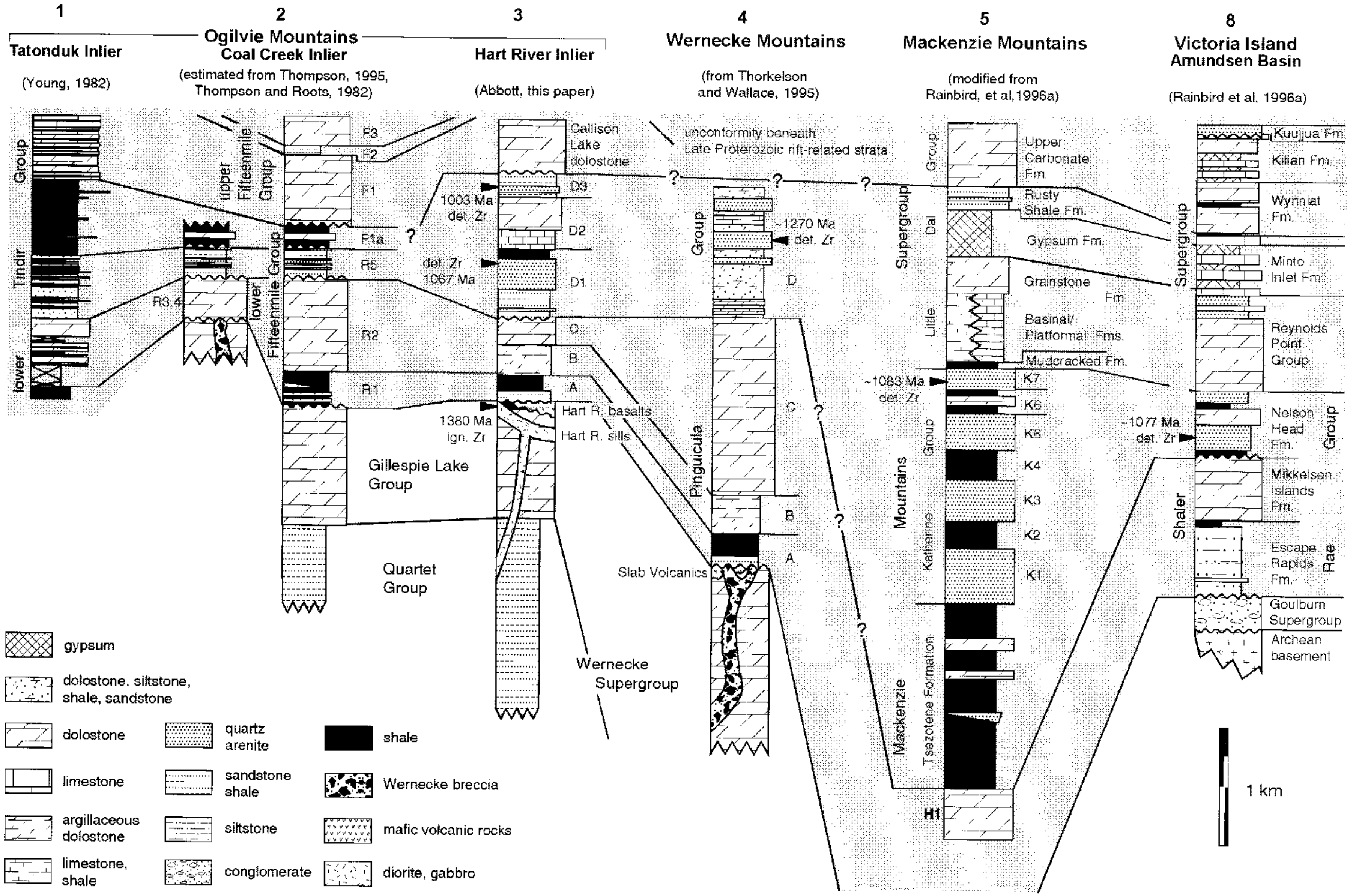


Figure 20. Correlation of Middle and Early Proterozoic sequences in the Ogilvie, Wernecke and Mackenzie mountains, and Victoria Island. Shaded area denotes strata belonging to Sequence B of Young et al. (1979). Location of sections shown in Figure 4.

The diverse and discontinuous lithofacies of unit PPD in the Wernecke Mountains contrast with the thick, continuous and relatively homogeneous units of succession PPD in the eastern Ogilvie Mountains, although the lithologies in both are similar. One of three explanations could account for this difference:

1) Lateral facies variations might occur regionally, but the area of exposure in the Ogilvie Mountains may be too small for regional variations to be expressed.
2) Unit PPD in the Wernecke Mountains might be older than succession D in the Ogilvie Mountains. In the Ogilvie Mountains, succession D is separated from the lower part of the Pinguicula Group by an angular unconformity. No unconformity has yet been recognized in the Wernecke sequence, where the equivalent contact, between units PPD and PPC, appears to be conformable and gradational (Thorkelson and Wallace, 1995a). Detrital zircons from the Corn Creek quartzite (unit E of Eisbacher) are only as young as 1271±10 Ma (Rainbird et al., in press), unlike all other sequence B quartzites, which contain zircons at least as young as about 1100 Ma.
3) Units D2 and D3 in the Ogilvie Mountains might be younger than unit PPD in the Wernecke Mountains.

Until now, correlation of the Pinguicula Group with the Fifteenmile Group in the western Ogilvie Mountains has been unclear. Although the two sequences occupy the same stratigraphic position and are broadly similar, the Wernecke breccias were thought to crosscut the lower Fifteenmile Group (Thompson and Roots, 1982; Thompson, 1995), making it much older than the Pinguicula Group. Critical localities in the Coal Creek Inlier were recently examined by the writer and D. Thorkelson (Abbott et al., 1997), however, and both units PR1 and PR5 of the lower Fifteenmile Group were observed to unconformably overlie Wernecke breccia. Available descriptions of the lower Fifteenmile Group (Thompson and Roots, 1982; Thompson et al., 1992, Thompson, 1995) and brief examinations by the writer and D. Thorkelson indicate that the lower Fifteenmile Group resembles and is equivalent to the Pinguicula Group. The lower Fifteenmile Group, like the Pinguicula Group in the Hart River Inlier, overlies the Wernecke Supergroup with angular unconformity and includes a clastic-carbonate succession (units PR1-PR4), unconformably overlain by a clastic succession (units PR5, PR5a).

The clastic-carbonate succession of the lower Fifteenmile Group forms two dissimilar belts. In the northern belt, dark shale and siltstone 300 to 1800 m thick and interbedded with dolostone and dolostone olistoliths (unit PR1) are overlain by orange-weathering dolomitic mudstone, lesser dolostone breccia and massive dolostone (unit PR2), containing grey stromatolitic dolostone lenses (unit PR2a). The southern belt consists of shallow-water carbonate (units PR3 and PR4). Grey dolostone (unit PR3), whose stratigraphic relationships with older rocks are not exposed, occurs in one locality. Grey dolostone containing breccia, oolitic packstone and stromatolites (unit PR4) disconformably overlies the Wernecke Supergroup and the one exposure of unit PR3, but is nowhere mapped in contact with units PR1 and PR2. It remains unclear whether unit PR4 is a facies equivalent of units PR1 and/or PR2, or if it is younger and separated from them by an unconformity. Abrupt variations in thickness of units PR1 and PR2 have been attributed by Roots and Thompson (1992) to syndepositional listric normal faulting. Perhaps these units represent relatively deep-water sedimentation confined to downthrown blocks, whereas unit PR4 represents concurrent shallow-water deposition on upthrown blocks.

In the clastic succession, unit PR5 consists primarily of black, maroon and olive shale, interbedded with micaceous siltstone, quartz sandstone, and lesser stromatolitic limestone, pebbly mudstone, diamictite, and, near the base, thin pebble conglomerate. Unit PR5a consists of thin, discontinuous lenses of light-grey dolostone in unit PR5. Thicknesses are highly variable, but one section was measured by Thompson and Roots (1982) at 294 m. Unit PR5 overlies units PR4, PR3, and PR2 as well as the Wernecke Supergroup and Wernecke breccias in different places, suggesting a profound angular unconformity. These different stratigraphic relationships occur over short distances, commonly across thrust faults, which might represent reactivated normal faults predating deposition of unit PR5.

The clastic carbonate succession (units PR1-PR4) in the lower Fifteenmile Group resembles the upward-shoaling sequence defined by units PPA, PPB, and PPC of the Pinguicula Group, although litholo-gical similarities are not as close as those between the Pinguicula sequences in the eastern Ogilvie and Wernecke mountains. Also, the evidence of tectonic instability within the lower Fifteenmile Group, as indicated by dramatic changes in thickness and litho-facies, has not been observed in the lower part of the Pinguicula Group.

Unit PR5 is broadly similar to unit PPD of the Pinguicula Group in both the eastern Ogilvie and Wernecke mountains. It contains similar lithofacies and its internal stratigraphy varies laterally like that of Pinguicula D. The unconformity at the base of unit PR5 correlates with that at the base of Pinguicula unit PPD1 in the eastern Ogilvie Mountains.

The Callison Lake dolostone most closely resembles and probably correlates with unit PF1 of the upper Fifteenmile Group. The upper Fifteenmile Group overlies the lower Fifteenmile Group disconformably, locally with angular unconformity, and includes four units with a total thickness of at least 1200 m (Thompson and Roots, 1982; Thompson et al., 1992, Thompson 1995). Unit PF1a occurs only locally beneath unit PF1 and consists of interbedded argillite and dolostone (Thompson, 1995). Unit PF1a was not seen by the writer, but map relationships and the lithologies of the unit suggest that it correlates with the Pinguicula Group. The craggy dolostone (unit PF1) consists of resistant, medium to dark grey, crystalline, stromatolitic dolostone with variable thickness in the order of 600 m. The craggy dolostone is overlain by a marker unit about 60 m thick (unit PF2) of black- and brown-weathering shale and siltstone with thin interbeds of red-weathering quartzite. It is overlain by the cryptalgal dolostone (unit PF3), a heterogeneous unit of laminated to thinly bedded dolostone up to 250 m thick. The dolostone is locally stromatolitic and includes chert and dolomitic breccia. Mercier and Chauval (1987) obtained microfossils from shale, chert and black dolostone at an unspecified location in the Fifteenmile Group. They interpreted the assemblage as indicating a maximum depositional age of about 1 Ga and a minimum age of 0.6 Ga. This age range is compatible with other constraints on the age of the upper Fifteenmile group and the Callison Lake dolostone. These constraints are the 1 Ga age of detrital zircon in quartzite underlying the Callison Lake dolostone and the maximum age of about 750 Ma for the Mount Harper Group (Roots and Parrish, 1989), which overlies the upper Fifteenmile Group.

The lower Tindir Group (Young, 1982), located 45 km northwest of the Fifteenmile Group, is likely equivalent to the Fifteenmile Group (Figure 20). The base is not exposed, and it is unconformably overlain by the Late Proterozoic upper Tindir Group, which includes basalt flows and glacially derived diamictites that are considered equivalent to the Neoproterozoic Mount Harper Group (Mustard and Roots, 1997). The lower Tindir Group includes a basal shale unit with minor conglomerate (PR1 equivalent?), overlain by a sequence of stromatolitic dolostone with shale intervals (PR2-4 equivalent?). The dolostone-shale sequence is overlain by a clastic sequence containing quartzite interbedded with shale and siltstone (PR5 equivalent?). The quartzite-shale unit is overlain by a recessive sequence of black shale containing some beds of conglomerate and diamictite (PF1a equivalent?) and the uppermost unit consists of well bedded dolostone and limestone (PF1 equivalent?).

The Mackenzie Mountain Supergroup probably contains correlative strata to all or most of the Pinguicula, Fifteenmile, and lower Tindir groups, but with significant dissimilarities in thickness, lithology and stratigraphic detail (Figure 20). The Pinguicula Group and Mackenzie Mountains Supergroup are juxtaposed over a few kilometres across the Snake River Fault (part of the Richarson Fault array). The lithological differences between the two sequences are so great that proposed correlations have always been controversial (Eisbacher, 1981; Aitken and McMechan, 1992).

The Mackenzie Mountains Supergroup is at least six km thick and includes four main units: H1; Tsezotene Formation; Katherine Group; and Little Dal Group (Aitken and McMechan, 1992). Some workers (Young et al., 1979; Rainbird et al., 1996a) have correlated Units PPB(?) and PPC of the Pinguicula Group with unit H1 at the base of the Mackenzie Mountains Supergroup, and assumed that unit PPA represents unexposed parts of the Mackenzie Mountains Supergroup. Units D, E, and F of Eisbacher (1981) have been correlated with the Tsezotene, Katherine and basal parts of the Little Dal Group, respectively. The recent interpretation of Pinguicula stratigraphy has discounted the correlation of unit F with the Little Dal Group, but the other correlations are still possible.

One alternative correlation is suggested by the sequence exposed in the Hart River Inlier, where the stratigraphic sequence defined by the upper part of unit PPD1, units PPD2, PPD3 and the Callison Lake dolostone resembles the Little Dal Group. In this interpretation, Units PPA, PPB and PPC would still be equivalent to unit H1 and older unexposed strata of the Mackenzie Mountains Supergroup. Unit PPD1 to the top of the quartzite member could include the Tsezotene Formation and Katherine Group, and the upper shale member of unit PPD1 and units PPD2, PPD3 and the Callison Lake dolostone could represent the Little Dal Group. The lower Little Dal Group (Aitken, 1981) includes mudstone and subordinate sandstone of the Mudcracked Formation (equivalent to the upper shale member of unit PPD1(?)); nodular limestone, rhythmically interbedded clastic and carbonate rocks and stromatolitic reefs of the basinal assemblage; laterally equivalent limestone-dominated platformal assemblage (equivalent to the lower limestone member of unit PPD2(?)); and overlying dolostone of the Grainstone Formation (equivalent to the dolostone member of unit PPD2(?)). The platformal assemblage is located in the southern Mackenzie Mountains and the Basinal assemblage is located in the north. A north-north-east-trending facies boundary coinciding with a stromatolitic biostrome complex separate the two. The upper Little Dal Group includes gypsum and minor anhydrite, shale siltstone and local carbonate of the Gypsum Formation; shale, sandstone, quartzite, and carbonate of the Rusty Shale Formation (equivalent to unit PPD3(?)); and resistant stromatolite-rich dolostone of the Upper Carbonate formation (equivalent to the Callison Lake dolostone(?)).

Significant differences between the two successions include the following. The unconformity beneath unit PPD1 has not been recognized at the top of unit H1. In the Shaler Supergroup, however, Rainbird et al. (1994) reported a local paleokarst unconformity at the equivalent stratigraphic position at the top of the easternmost exposures of the Mikkelsen Islands Formation. They interpreted the unconformity as indicating emergent conditions along the eastern margin of the depositional basin. Another significant difference between the Pinguicula Group and Mackenzie Mountains Supergroup is the great difference in thickness between unit PPD1 of the Pinguicula Group and the Tsezotene Formation and Katherine Group. The last two range from 1450 m to 2800 m in thickness (Aitken and McMechan, 1992) and include four mappable quartzite units of formational rank, whereas unit PPD1 is about 400 m thick and includes one quartzite horizon.

The Little Dal Group is about 2000 m thick, almost twice as thick as units PPD1-3, and the Callison Lake dolostone; no equivalent of the Gypsum Formation has been recognized in the Pinguicula Group; and no unconformity has been recognized beneath the Upper Carbonate formation, but the similarities between the two sequences seem to outweigh the differences. Alternatively units PPD2 and PPD3 might correlate with the Katherine Group, but other than the presence of quartzite in unit PPD3, they bear little resemblance to any part of the Katherine Group. In this correlation, the Callison Lake dolostone could only correlate with the limestone of the Platformal assemblage and there is little similarity between the two. Now that the Wernecke Supergroup, the Wernecke breccias and the Racklan Orogeny are known to be much older than 1270 Ma, the significance of the 1270 Ma unconformity separating sequences A and B is unclear. Currently the unconformity separating sequences A and B is clearly documented only in the Coppermine area north of Great Bear Lake at the base of the Shaler Supergroup, where it truncates the 1267 Ma mafic volcanic rocks of the Coppermine River Group. The unconformities at the base of unit PPD1 in the Hart River Inlier and at the base of unit PR5 in the Coal Creek Inlier are possible correlatives. Although the upper part of the Pinguicula Group contains 1270 Ma detrital zircons, the lower part is constrained only by the age of the underlying Hart River sills, and could be older than 1270 Ma. If so, the lower part of the Pinguicula Group might correlate with the Dismal Lakes Group, which is exposed in the Coppermine area beneath the Coppermine River Group, and is thought to be farther west in the subsurface of the Colville Hills (Cook and MacLean, 1995).

Eisbacher (1981) suggested, and Bell (1982), Yeo (1984) and Aitken and McMechan (1991) proposed that if the Pinguicula Group and Mackenzie Mountains Supergroup are the same age, their stratigraphic differences are so great that they must be juxtaposed along a strike-slip fault ancestral to the Richardson Fault array. Their hypothesis is supported by subsequent age determinations of detrital zircons from quartzites in both sequences (Rainbird et al., in press), which indicate that the siliciclastic rocks are approximately coeval and were derived from the Grenville Orogen. Abbott (1996) presented evidence that this postulated fault could be Late Proterozoic in age and have significant right-lateral offset.

Not only is there no compelling reason for the Pinguicula Group to have been deposited in its present location, there is other evidence to support the strike-slip hypothesis. Unlike the Pinguicula, lower Fifteen-mile and lower Tindir groups, the Mackenzie Mountains Supergroup is a relatively thick sequence, and is characterized by consistent stratigraphy over great distances. Most formations and units in the Katherine and Little Dal groups thicken significantly to the southwest (Aitken and McMechan, 1991) indicating that the depocentre of the basin was to the west of existing exposures and that the margin was to the east and southeast. In sharp contrast, the Pinguicula, Fifteenmile and lower Tindir groups, which lie west of the Mackenzie Mountains Supergroup, are relatively thin, shallow-water sequences, which differ significantly from one another and are characterized by internal unconformities not seen in the Mackenzie Mountains Supergroup. These characteristics suggest a basin-margin setting. In order for the facies differences between the Pinguicula Group and the Mackenzie Mountains Supergroup to be explained, the Pinguicula Group must be restored to some point south of the most southerly exposure of the Mackenzie Mountains Supergroup, a minimum distance of 450 km.

Mount Harper Group (PHdi, PHs, *and* PHv)

Diamictite (unit PHdi), shale and siltstone (unit PHs) and mafic volcanic rocks (unit PHv) between the Callison Lake dolostone and Paleozoic carbonates of unit €Sc are tentatively correlated with the Mount Harper Group (Roots, 1987; Mustard, 1991;

Roots and Thompson, 1992; Mustard and Roots, 1997). Unit PHdi consists almost entirely of distinctive diamictite containing mainly angular to rounded clasts of quartzite and grey dolostone that are lithologically like the Pinguicula Group and the Callison Lake dolostone. Most are pebble-sized or smaller, but some are as large as 30 cm across. Most are supported in a matrix of orange-weathering dolostone (Figure 21), silty dolostone, and lesser amounts of grey shale (Figure 22) and black argillite. Internal stratification and sorting is generally absent.

Clast-supported conglomerate was observed west of Callison Lake in a few exposures, intercalated with matrix-supported diamictite nearby in different beds. Orange-weathering, rhythmically laminated, silty dolostone or dolomitic mudstone in intervals less than 10 m thick forms a minor component of the unit. East of Callison Lake, the diamictite appears to be about 500 m thick and includes a lower part with an orange-weathering dolomitic matrix and an upper part with a dark-grey shale matrix. The top of the unit contains two light-grey bands of dolostone, each about 20 m thick, separated by shale and diamictite. The unit might be repeated by a thrust fault in this area; the precise stratigraphy is unknown. West of Callison Lake, the upper shaly interval is absent and the unit is orange- or black-weathering and up to

Figure 21. Diamictite with a shale matrix in unit PHdi of the Mount Harper Group. The steep-dipping fabric is cleavage.

Figure 22. Diamictite with a carbonate matrix in unit PHdi of the Mount Harper Group.

about 100 m thick. In most places the unit is much thinner as a result of erosion beneath the unconformity at the base of unit €Sc. The diamictite forms a distinctive and invaluable marker that separates similar dolostones of the Callison Lake dolostone and unit €Sc.

Unit PHdi sharply overlies Callison Lake dolostone in most places, and the contact is interpreted as a disconformity. In one thrust panel west of Callison Lake, diamictite (subunit PHdi1) unconformably overlies greywacke and silty dolostone of units A and B of the Pinguicula Group and a Hart River sill at an angle of more than 30–40° to bedding. Correlation of the diamictite at this locality with similar diamictites nearby implies an abrupt stratigraphic omission of at least 1500 m. Alternatively, the diamictite could represent an isolated exposure of an older or younger unit that does not occur elsewhere. The tectonic implications of the different possible correlations are discussed under "Structure".

West of Callison Lake, the recessive, orange-brown- to dark-brown-weathering, platy siltstone, sandstone, and dark grey shale of unit PHs sharply overly the diamictite. The unit is about 200 m thick and is only exposed in one thrust panel for a strike length of six km. Elsewhere it appears to have been removed by erosion beneath the unconformity at the base of unit ЄSc.

Recessive, dark-green-weathering, mafic lapilli tuff, hyaloclastic breccias, and finely laminated epiclastic(?) rocks of unit PHv overlie the shales and siltstones of unit PHs. The volcanic rocks are less than 100 m thick and, like unit PHs, have been removed in most places by erosion beneath the unconformity at the base of unit ЄSc.

Environment, age and correlation

The Mount Harper Group in its type area, 120 km to the west in the Coal Creek Inlier (Roots, 1987; Mustard, 1991; Roots and Thompson, 1992: Mustard and Roots, 1997), includes alluvial fan conglomerate and sandstone of the Lower Mount Harper Group; mafic volcanic flows and breccias and subordinate andesite and rhyolite of the Mount Harper Volcanic Complex; and submarine debris apron and fan complexes of the Upper Mount Harper Group (Mustard and Roots, 1997). A U-Pb age of 751+26/-18 Ma was obtained from zircon in rhyolite near the top of the volcanic sequence (Roots and Parrish, 1989). The Mount Harper Group was deposited in east-trending half grabens that formed during incipient Late Proterozoic rifting (Mustard and Roots, 1997).

The general character of the Mount Harper Group in the Hart River Inlier indicates that the diamictite and siltstone units correlate with the Lower Mount Harper Group, and the volcanic unit correlates with the Mount Harper Volcanic Complex. In the Hart River Inlier, however, the upper age limit of the sequence is only constrained by the overlying Lower Paleozoic carbonate. The possibility that some or all of the sequence could be Cambrian, and therefore younger than the Mount Harper Group, is unlikely, but cannot be precluded.

Diamictites in the Hart River Inlier were originally interpreted by Abbott (1993) as glaciogenic on the basis of poor sorting, ubiquitous matrix-supported clasts, and the presence of 'dropstones'. A more likely explanation is that they were deposited as submarine sediment gravity flows, although a glaciogenic origin cannot be ruled out. The poor sorting and matrix support of clasts, which characterize the diamictites, typify both depositional models. In the western Ogilvie Mountains, the Late Proterozoic Upper Mount Harper Group contains similar matrix-supported conglomerate, which Mustard and Roots (1997) attributed to subaqueous debris flow from syndepositional fault scarps. There the coarse clastic rocks are interbedded with, and laterally equivalent to, lithofacies with features indicative of deposition from sediment gravity flows in subaqueous clastic fans. Matrix-supported diamictites are uncommon, and were thought to have formed along slopes steeper than those required for deposition of turbidity currents (Mustard and Roots after Walker, 1984, p. 177). The dropstone reported by Abbott (1993) is a large boulder that depresses the top of an underlying shale bed (Figure 23). Such a structure could have formed by depositional loading. One grooved cobble was observed in the diamictite (Figure 24), but also fails to provide conclusive evidence of a glaciogenic origin. The apparent lack of exotic clasts and well-defined sedimentological features indicative of glaciation make a glaciogenic interpretation of the diamictites in the Hart River area suspect.

The alluvial facies of the lower Mount Harper Group in the Coal Creek inlier differs from the deep water facies of the Hart River diamictite, but both suggest the same tectonic setting. The lower Mount Harper Group in the Coal Creek inlier was deposited along fault scarps in east-trending half grabens. In the Hart River area, half grabens are not clearly evident, but reverse movement during Mesozoic deformation may have masked them. The diamictites form a narrow east-trending belt and all Mesozoic thrust faults trend east. Therefore the postulated syndepositional faults also must have trended east.

In the Mackenzie Mountains, most workers (Eisbacher, 1981; Aitken, 1991) considered Late Proterozoic rifting began with deposition of the highly variable shallow-water carbonates, evaporites and clastic rocks of the Coates Lake Group, although Jefferson and Parrish (1989) proposed that tectonism began about midway through deposition of the older Little Dal Group. Sedimentary facies and thickness changes in the Coates Lake Group were controlled by

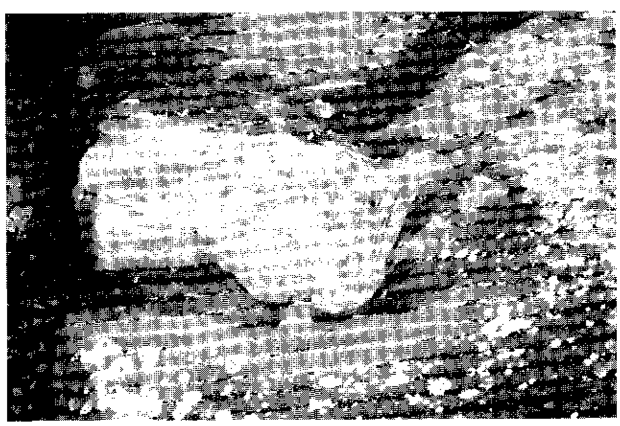


Figure 23. Carbonate boulder at the base of a diamictite bed in the Mount Harper Group. The boulder indents underlying bedding. It is unclear whether this effect reflects deposition of the boulder as a dropstone or as part of a gravity flow.

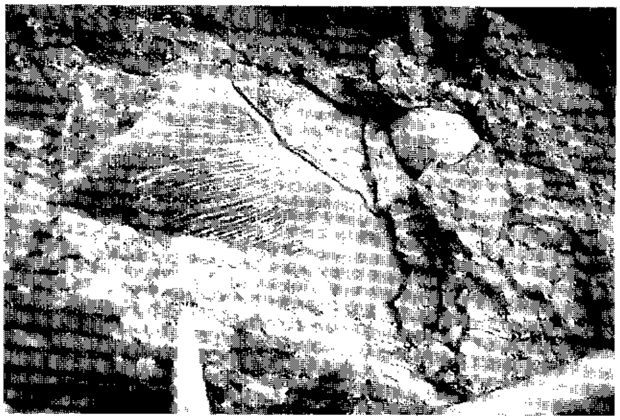


Figure 24. Striated boulder in diamictite of the Mount Harper Group. These deep regular grooves are only on the surface of the rock and could be glacial striae, but their form is unusual.

normal faults with orientations ranging from northeast-trending in the southern Mackenzie mountains to northwest-trending in the northern Mackenzie Mountains (Eisbacher, 1981). The most intense tectonism followed Coates Lake Group deposition, as indicated by differential erosion across truncated normal faults and local preservation of subaerial orthoconglomerates beneath the unconformably overlying strata of the Rapitan Group (Jefferson and Parrish, 1989). Rifting continued with deposition of the glaciomarine siliciclastic rocks of the Sayunei Formation (basal Rapitan Group) in fault-bounded troughs and with more widespread, but still unconformable deposition of overlying glacial diamictites of the Shezal Formation.

Assignment of the Coates Lake Group to the Windermere Supergroup has been a matter of debate. Eisbacher (1981), Jefferson and Ruelle (1986), Jefferson and Parrish (1989), and Rainbird et al. (1996a) considered the base of the Windermere Supergroup to be the base of the Rapitan Group, which corresponds to the end of carbonate-dominated sedimentation in a tropical environment and the onset of siliciclastic-dominated sedimentation with associated glaciogenic deposits. Aitken (1981, 1991) included the Coates Lake Group in the Windermere Supergroup for tectonic reasons. By doing so, the onset of Late Proterozoic rifting corresponds to the onset of Windermere sedimentation, thus removing confusion about the correlation of what he considered to be essentially one rift event with two stratigraphic sequences. Ross (1991) accepted this view.

Mustard and Roots (1997) favoured correlation of the Mount Harper Group with the Rapitan Group, but did not discount correlation with the Coates Lake Group. They argued that correlation with the Rapitan Group is more likely because the Mount Harper Group is lithologically unlike the Coates Lake Group and because the main period of extension in the Mackenzie Mountains occurred after deposition of the Coates Lake Group and before or during initial Rapitan deposition (Jefferson and Parrish, 1989). Evidence for climatic conditions during deposition of the Mount Harper Group is inconclusive, and Mustard and Roots (1997) attributed the absence of glaciogenic deposits in the Mount Harper Group to diachronous rifting and/or localization of glaciers in mountainous areas. They suggested that a similar sedimentary and tectonic environment is represented by unnamed orthoconglomerate and breccia up to 200 m thick, which are correlated with the Rapitan Group, but which are older than glaciogenic deposits of the Sayunei Formation (Jefferson and Parrish, 1989). They also cited rare tuffs and locally abundant volcanic clasts reported by Yeo (1984) as evidence of volcanism associated with Rapitan deposition.

Radiometric dating of igneous rocks in the Mackenzie Mountains has provided some constraints on possible correlations of the Mount Harper Group. A small diorite stock cutting the Little Dal Group beneath the Coates Lake Group gives a U/Pb age of 777 +2.5/−1.8 Ma (Jefferson and Parrish, 1989) providing a minimum age for the Little Dal Group. The stock is chemically similar to diabase sills, which have yielded a Rb-Sr age of 766–769±27 Ma (Armstrong et al., 1982). They are chemically similar to, and might be equivalent to, the Little Dal lavas at the top of the Little Dal Group. The lavas conformably overlie Little Dal carbonate and are unconformably overlain by the basal Coates Lake strata of the Thundercloud Formation, and therefore slightly predate the onset of Coates Lake deposition. An alternative interpretation was provided by Jefferson and Parrish (1989), citing the absence of dikes and intrusions in the upper part of the Little Dal Group as evidence that the dikes are unrelated to the lavas, thereby implying that they are older. A U/Pb age of 755±18 Ma was recently obtained by single-grain zircon analysis of an igneous dropstone from the Sayunei Formation (Ross and Villeneuve, 1996). The leucogranite clast was exhumed and eroded before deposition in the Sayunei Formation. Therefore, the Lower Mount Harper Group and the Mount Harper Volcanic Complex are probably, but not certainly, older than the Sayunei Formation. Locally preserved orthoconglomerates beneath the Sayunei Formation, at the base of the Rapitan Group, could correlate with the Lower Mount Harper Group. If so, the Mount Harper Volcanic Complex would be a stratigraphic interval that is mostly absent in the Mackenzie Mountains either because of nondeposition, or removal by erosion beneath the angular unconformity separating the Coates Lake and Rapitan groups. The

Upper Mount Harper Group might then correspond to the Sayunei Formation. This correlation, although only one of several possible, is preferred because it is the only one to explain most of the lithological similarities and differences between the Mount Harper Group and the Windermere Supergroup in the Mackenzie Mountains, and to equate the intense normal faulting that accompanied deposition of the Mount Harper Group with the most intense phase of Late Proterozoic rifting in the Mackenzie Mountains.

Cambrian(?), Ordovician and Silurian dolostone (ЄSc)

Massive, light bluish-grey-weathering, coarse-grained dolostone is the most prominent unit in the map area and characterizes Ogilvie Platform. Dolomitization and net-like zones of silica replacement have obliterated most sedimentary structures (Figure 25), and the most distinctive feature of the unit is its monotonous homogeneity. Coarse-grained limestone immediately east of the lower reaches of Marc Creek has also been included in the unit. The dolostone forms smooth talus slopes, a characteristic that helps to distinguish it from the uppermost dolostone in the Callison Lake dolostone. The dolostone is about 500 m thick near the Dawson Fault, and is likely thicker along the northern margins of the map area.

Unit ЄSc overlies all older strata in the map area with profound angular unconformity. From south to north, over a lateral distance of 20 km, the dolomite rests on progressively older strata ranging in age from Early Paleozoic to Early Proterozoic. At least four km of strata are absent beneath the unconformity in the north. This amount of erosion is accounted for by the cumulative effect of erosion beneath at least four unconformities ranging in age from Middle Proterozoic to Early Paleozoic. Black shale and chert of the Road River Group sharply overlie the carbonate rocks and are lateral facies of it.

Figure 25. Coarse-grained, silicified dolostone, typical of unit ЄSc.

Age and correlation

Carbonate rocks equivalent to unit ЄSc occur throughout Yukon Block. In the Wernecke Mountains and southern Ogilvie Mountains they belong to Ogilvie Platform, and were assigned to unit 8 by Green (1972). Fossils are scarce but range in age from Early Ordovician to Late Silurian. North of latitude 65°, Norris (1984) assigned a Late Cambrian to Early Devonian age to equivalent and similar dolostone of unit CDb. Northwest of Ogilvie Platform, the carbonates are covered by, and in part equivalent to, the Middle Ordovician to Early Devonian black shale of Blackstone Trough (Cecile and Norford, and Morrow and Geldsetzer in Fritz et al., 1992). Throughout much of the central Yukon Block, units 8 and CDb unconformably overlie a variety of strata as old as the Early Proterozoic Wernecke Supergroup. In a broad area that extends from the northern flank of the Hart River Inlier northeast to the Richardson Trough, the carbonates overlie grabens filled with marine and alluvial clastic deposits of the Middle Cambrian Slats Creek Formation and disconformably overlie locally preserved buff-weathering limestone and dolostone of the Late Cambrian Taiga Formation (Fritz et al., 1992). The Middle Cambrian record, at least in the southeast portion of Yukon Block, is one of uplift, erosion and graben formation related to rifting and crustal extension. Lower Cambrian strata were therefore either never deposited over most of Yukon Block or were removed by Middle and Late Cambrian erosion.

Cambrian sequences are relatively well preserved on the eastern and western flanks of Yukon Block. In the Richardson Trough, the Slats Creek Formation overlies the thick Lower Cambrian limestone of the Illtyd Formation. Along the Alaska border, another more complete sequence of Cambrian and Ordovician carbonate rocks of the Jones Ridge Formation undergoes a westward transition to more basinal facies (Fritz et al., 1992). In the western part of the Dawson map area, Mustard et al. (1988) reported archeocyathids from the base of the CDb (unit 8) dolostone.

In the project area, only one collection of fossils was obtained from the carbonates and the precise age is uncertain. Regional evidence described above suggests that they are younger than Middle Cambrian. Conodonts obtained from the uppermost limestone beds in the unit along the lower reaches of Marc Creek are Late Ordovician in age. Elsewhere, upper age limits are constrained by fossils from the base of the overlying Road River Group. These range in age from Middle to Late Ordovician to Early Silurian. The Silurian fossils are confined to the extreme southeastern corner of the map area. In most areas, a Late Cambrian and Ordovician age is likely.

The Dawson Fault juxtaposes time-equivalent basinal strata against the shelf sequence and marks the southern margin of Ogilvie Platform. A remarkable feature of unit ЄSc in the project area, and apparently in equivalent strata elsewhere along the Dawson Fault, is the fact that there is no evidence of a transition from shelf to basin. Unit ЄSc is no thicker and probably even thinner than equivalent strata in other parts of Ogilvie Platform and no different in sedimentary facies. Equivalent strata south of the fault contain no coarse clastic debris or other sedimentary facies indicating deposition near a shelf margin. A transition facies might be buried beneath the Dawson Fault. However, structural arguments suggest that the amount of shortening is not exceptional and that no great distance separated the two very different facies. Certainly, no relatively thick and extensive miogeoclinal wedge like that seen elsewhere in the Canadian Cordillera separates platform from basin. Therefore, in Lower Paleozoic time, the southern margin of Ogilvie Platform was probably an abrupt and sharp escarpment.

Road River Group (ODp)

"Road River Group" is a general term that has superceded "Road River Formation", which was originally defined by Jackson and Lenz (1962) from a type section on the Road River in the northern Richardson Trough. The type Road River Formation includes basinal strata ranging in age from Early Cambrian through Early Devonian. Since 1962, black graptolitic shale and chert of similar age throughout Ogilvie Platform, Richardson Trough and Selwyn Basin were assigned to or correlated with the Road River Formation. With the subdivision of these strata into new formations in eastern Selwyn Basin (Gordey and Anderson, 1993), the Road River Formation was elevated to Road River Group.

In the map area, the Road River Group north of the Dawson Fault consists primarily of recessive, blue-grey-weathering, noncalcareous shale interbedded with variable amounts of thin-bedded, black to dark grey chert and argillaceous chert. Younger parts of the unit consist of calcareous black shale, but are locally preserved only along the lower reaches of Marc Creek and in the extreme western parts of the map area.

The black shales sharply overlie carbonate of unit ЄSc and flank both sides of an east-trending high defined by Silurian and (?)Devonian limestone. These stratigraphic relationships are shown schematically in Figure 26. Exposures on the north side of the high are confined to the lower reaches of Marc Creek. There, the shales are poorly exposed, but their upper and lower contacts are well defined, and a complete sequence of about 100 m thick is preserved. The shales appear to be gradational with the overly-

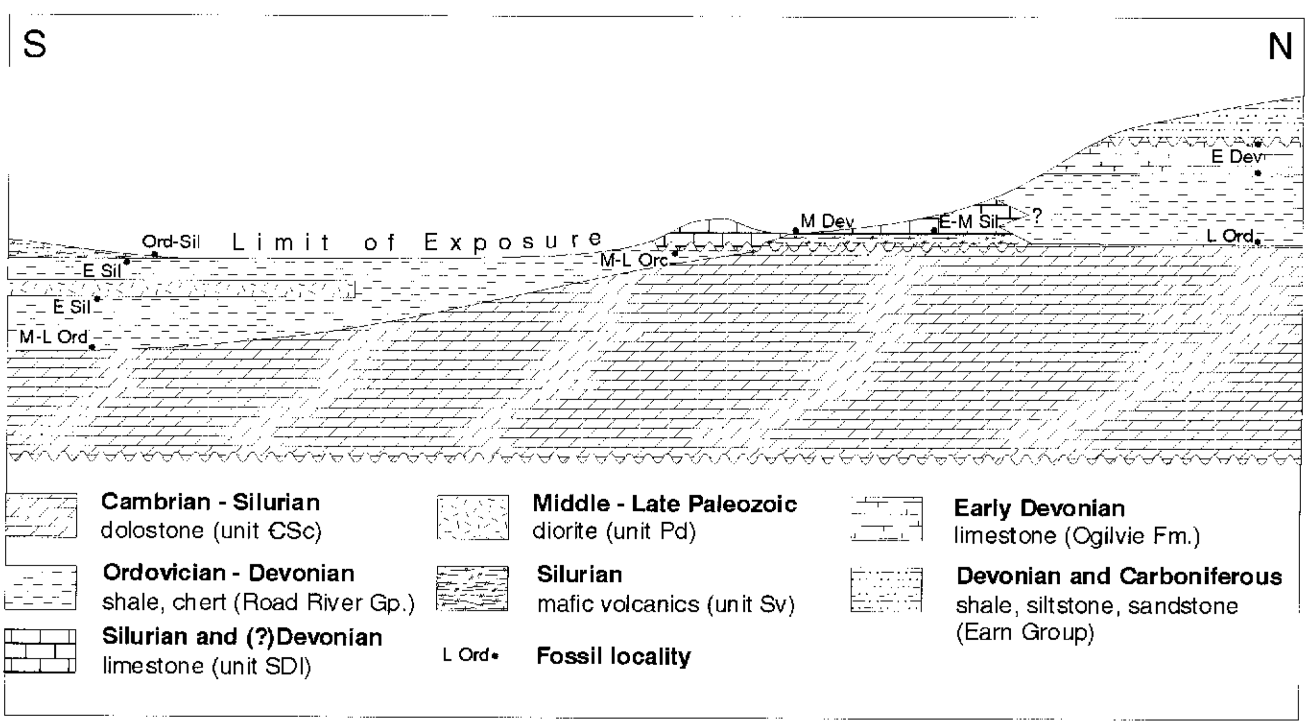


Figure 26. Schematic cross-section showing stratigraphic relationships of Paleozoic units within the project area north of the Dawson Fault.

ing limestone assigned to the Ogilvie Formation, and there is no evidence of an unconformity. Within the central high, the shales are either absent or about 20 m thick, and are in sharp contact with the overlying carbonate. South of the high, the shales thicken southward and may reach 500 m thick along the Dawson Fault. Calcareous shale is gradational with the Ogilvie Formation in the extreme western part of the map area. Elsewhere, the upper parts of the unit have been removed by erosion.

Age and correlation

Graptolites are widespread in the unit and range in age from Middle or Late Ordovician to Early Devonian (Appendix 1). The lower contact is diachronous and youngs from west to east, and from south to north. Immediately west of Callison Creek, graptolites from the lower contact are Middle to Late Ordovician, but they are Early Silurian only 11 km to the east. This diachronous relationship might continue east beyond the map area. Carbonate rocks of Green's (1972) unit 8, located 27 km east of the Early Silurian localities, contain Silurian or Devonian fossils in a section measured by Green (1972). Along Marc Creek, Late Ordovician conodonts were obtained from the uppermost beds of underlying unit **ЄSc**, indicating that shale deposition on the north side of the carbonate high began later than in the centre and to the south.

Western exposures of the unit, at the contact with the overlying Ogilvie Formation, contain tentaculitids and graptolites that are Early Devonian (late Lochkovian through Pragian). A similar upper age limit is likely for the exposures beneath the Ogilvie Formation along Marc Creek. Within the central high, the shales contain Middle to Late Ordovician graptolites, and are overlain by limestone containing Early to Middle Silurian conodonts. Along the eastern end of the Dawson Fault, Early Silurian graptolites were obtained beneath volcanic rocks of unit **Sv** (Appendix 1). The volcanic rocks are only locally preserved and most of the Road River Group north of the Dawson Fault is probably Early Silurian and older.

The black shales reflect starved sedimentation in relatively deep, restricted anoxic basins bounded at least in part by carbonate shelves.

Elsewhere within Yukon Block, the Road River Group overlies Ordovician carbonate rocks, ranges in age from Middle Ordovician to Early Devonian (Lenz, 1972; Cecile and Norford, 1992), and is laterally equivalent to carbonate rocks of similar age. The Road River Group is thickest and spans the greatest time range in Blackstone Trough along the northwestern margin of Ogilvie Platform. The precise distribution and age of the shales is not clear in many areas because they are either not exposed or have been removed by erosion. In the Larsen Creek and Nash Creek map areas, the Road River Group is preserved only in a narrow belt along the northern boundary of the Hart River Inlier where it was mapped by Green (1972) as unit 9. Farther east, the shale and chert are absent and equivalent carbonate rocks mapped by Green as units 8 and 10 range in age from Early Ordovician through Early Devonian. Along the carbonate-shale boundary, transitional Silurian and Early Devonian shale and silty limestone mapped by Green as unit 12 were included in the Road River Formation by Lenz and Pedder (1972).

Silurian volcanic rocks (Sv)

Between Rae and Marc creeks, poorly exposed mafic volcanic rocks sharply overlie the Cambro-Silurian dolostone (**ЄSc**). Most exposures are between 20 and 50 m thick and consist of dark green, highly altered flow breccias (Figure 27) and hyaloclastic breccias. Most of the breccia matrix consists of carbonate. Massive flows occur in one exposure immediately east of Rae Creek. The northernmost

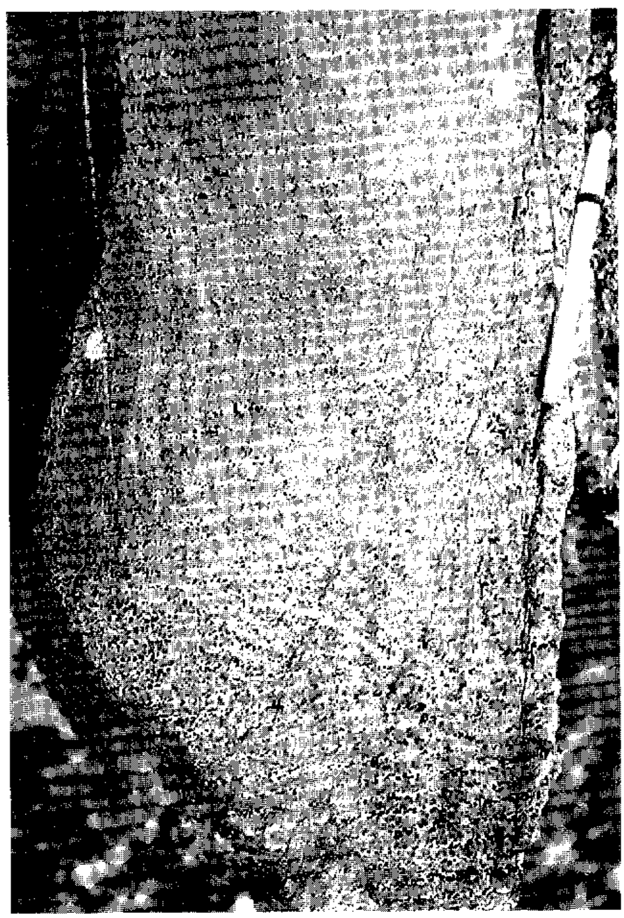


Figure 27. Volcanic rocks of unit Sv showing vesicular clasts in an autobreccia.

exposures near Marc Creek consist of well bedded epiclastic(?) rocks. The stratigraphic level occupied by the volcanic rocks has been eroded in most places and it is unclear if they were originally laterally continuous or formed localized, discontinuous lenses.

In the southeast corner of the map area, along the Dawson Fault, mafic flows, hyaloclastic breccias, and thin-bedded, epiclastic(?) rocks about 50 m thick overlie graptolitic shales of the Road River Group. No coherent internal stratigraphy has been recognized. The volcanic rocks are exposed in two parallel bands, which could either represent one structurally repeated stratigraphic unit or two separate units.

The volcanic rocks along the Dawson Fault might be laterally equivalent to those overlying the Cambro-Silurian dolostone farther west. If so, a disconformity might separate the volcanic rocks from the carbonates (Figure 26). Alternatively, the Road River shales could be diachronous, with at least 200 m of black shale in the south correlating with dolostone 15 km to the north; or the volcanic rocks might include two units with slightly different ages. As a widespread disconformity has been documented in the northern Cordillera at the Ordovician-Silurian boundary (Lenz and McCracken, 1982), the first alternative is preferred.

Age and correlation

If all of the volcanic rocks are the same age, they must be Early or Middle Silurian. This is because volcanic rocks along the Dawson Fault contain Ordovician or Silurian conodonts and overlie shale containing Early Silurian graptolites, whereas in another locality farther north, limestone overlying volcanic rocks contains Early to Middle Silurian conodonts. More than one age is also possible. Where the volcanic rocks overlie carbonate rocks of unit **ЄSc** and are overlain by Early Silurian limestone, they could be as old as Middle Ordovician and as young as Middle Silurian. In the footwall of a thrust fault east of Rae Creek, a thin sliver of black shale overlies the volcanic rocks. Middle Devonian conodonts were obtained from a thin bed of limestone in the shale and there is a remote chance that the underlying volcanic rocks are Devonian in age. No volcanic rocks of that age were seen elsewhere, however.

Silurian volcanic rocks are not known elsewhere on Ogilvie Platform. Along the headwaters of the Beaver River 60 km to the east of the map area, much thicker and more extensive volcanic rocks are interstratified with Ordovician and Silurian carbonate rocks of unit 8 (Green, 1972). Middle Ordovician graptolites from strata beneath the volcanics, Middle to Late Ordovician fossils from tuffs, and Late Ordovician fossils from strata overlying the volcanics constrain their age to Middle to Late Ordovician. The presence of Ordovician volcanic rocks so close to the map area reinforces the possibility that the northern belt of volcanic rocks included in unit **Sv** could also be Ordovician. In adjacent Selwyn Basin, local accumulations of Lower and Middle Paleozoic mafic alkaline lavas of different ages are common (Goodfellow et al., 1995), and examples of volcanic rocks of different ages being so close together are not uncommon.

Silurian and (?)Devonian limestone (Unit **SDl***)*

Fossiliferous grey limestone mapped as unit **SDl** is exposed between Rae and Marc creeks. The limestone is at least 100 m thick and the top of the unit is not exposed. The northernmost exposure consists of poorly bedded, coarse-grained limestone with abundant corals, brachiopods and crinoids scattered throughout. The two southern exposures consist entirely of fossil debris (Figure 28). The abundance of corals and crinoids suggest that the limestone formed as a reef complex. The limestone is separated from

Figure 28. Corals from the base of unit SDl. This fossil debris is characteristic of the unit, indicating that it formed as a reef complex.

Cambro-Silurian dolostone by a few metres of volcanic rocks in the northern exposure and by about ten m of black shale in the southern exposures. The sharp contact with these rocks and the thinness or absence of the black shales suggest a disconformity.

Age and correlation

Conodonts obtained from the base of the limestone where it overlies volcanic rocks of unit **Sv** are Early to Middle Silurian in age. The upper age limit is constrained only by the age of the Ogilvie Formation, which is late Early Devonian.

Silurian and Early Devonian shelf carbonate rocks are widespread to the east in the Nash Creek map area (Green, 1972), but are uncommon elsewhere on Ogilvie Platform. In the Nash Creek map area, unit 8 ranges in age from Early Ordovician to Late Silurian. In the same area, the unfossiliferous dolostone of unit 10 overlies unit 8 and is constrained to a Late Silurian through Early Devonian age by the overlying Ogilvie Formation. Unit 8 is also known to be as young as Late Silurian in one small locality along the northern margin of the Larsen Creek map area and farther north in the Hart River map area, where unit **CDb** is as young as Early Devonian and is conformably(?) overlain by the late Early to Middle Devonian Ogilvie Formation (D. Morrow, pers. comm., 1996).

The facies boundary between Silurian and Devonian carbonates and shales of the Road River Group is poorly defined due to lack of preservation and poor exposure. In the Larsen Creek map area and the western Nash Creek map area, Silurian and Devonian(?) carbonates almost certainly formed a narrow east-trending tongue just north of the Dawson Fault, bounded on both sides by black shale and chert (Figure 29). The western limit of the carbonates is unclear. The carbonate-shale boundary swings north in the central Nash Creek map area, where it is well defined by the sharp boundary between the shales and shaly limestone of unit 12 and the carbonate of unit 8. Farther north, the boundary could have either swung to the east into Richardson Trough or west across the northern Larsen Creek map area to the isolated patch of Late Silurian and Early Devonian carbonates in the northern Larsen Creek map area and the southern Hart River map area. As these carbonates are clearly bounded by shale to the northeast and to the southwest (D. Morrow, pers. comm., 1996) they quite possibly formed a small isolated patch surrounded by black shale.

Ogilvie Formation (DO)

Recessive, fossiliferous Early Devonian limestone assigned to the Ogilvie Formation is exposed in three localities. Near Marc Creek, the limestone might be as thick as 200 m, and consists mainly of thick-bedded, light-grey, argillaceous limestone with minor black shale partings. The base of the unit is gradational with calcareous, black, sooty shale of the Road River Group over several metres, and becomes thicker bedded and more resistant upsection. Well-defined bedding laminations are common throughout, and crinoid hash and other fossil debris are scattered throughout. In exposures along Marc Creek, the upper two m of the unit consist of thick-bedded, fetid, medium-grey, bioclastic limestone interbedded with black chert and calcareous shale. The central portions of the unit were only observed from a distance, but they appear to be more massive and less shaly than the lower and upper parts. Along the western boundary of the map area, limestone is interbedded with a greater proportion of black chert and calcareous shale, and is probably less than 100 m thick. An isolated exposure of massive black limestone about four km west of Rae Creek is overlain by blue siliceous shale of the Earn Group.

The sporadic exposures of the Ogilvie Formation are attributable in part to its recessive nature, but also to an unconformity at the base of the overlying Devono-Mississippian Earn Group. This relationship is apparent west of Rae Creek, where fairly well exposed siltstone and shale of the Earn Group overlie graptolitic shale of the Road River Group less than two km east along strike from the Ogilvie Formation.

Age and correlation

Late Early Devonian (Emsian) conodonts and/or macrofossils were obtained from the Ogilvie Formation in all three localities. The most precise ages come from exposures along Marc Creek where the base of the unit is early Emsian and the top is late Emsian to early Eifelian (late Early to early Middle Devonian). Echinoderm ossicles with twin axial canals ('two-hole' crinoids), which were obtained from the top of the unit, are characteristic of the Ogilvie Formation (Norris, 1968; Green, 1972). In northwestern Canada, they have an age range that corresponds approximately with the Emsian stage (Norris in Appendix 1).

The Ogilvie Formation was originally assigned a late Early (Late Zlichovian) to Middle Devonian (Givetian) age (Norris, 1968), but is now known to range from the earliest Emsian to earliest Middle Devonian (Morrow and Geldsetzer, in Fritz et al., 1992).

North of latitude 65°, the Ogilvie Formation is widely exposed and laterally continuous over most of the Yukon Platform (Morrow and Geldsetzer, in Fritz et al., 1992), but south of latitude 65° the paleogeography is poorly understood. Only one small exposure in the Nash Creek map area and another in the

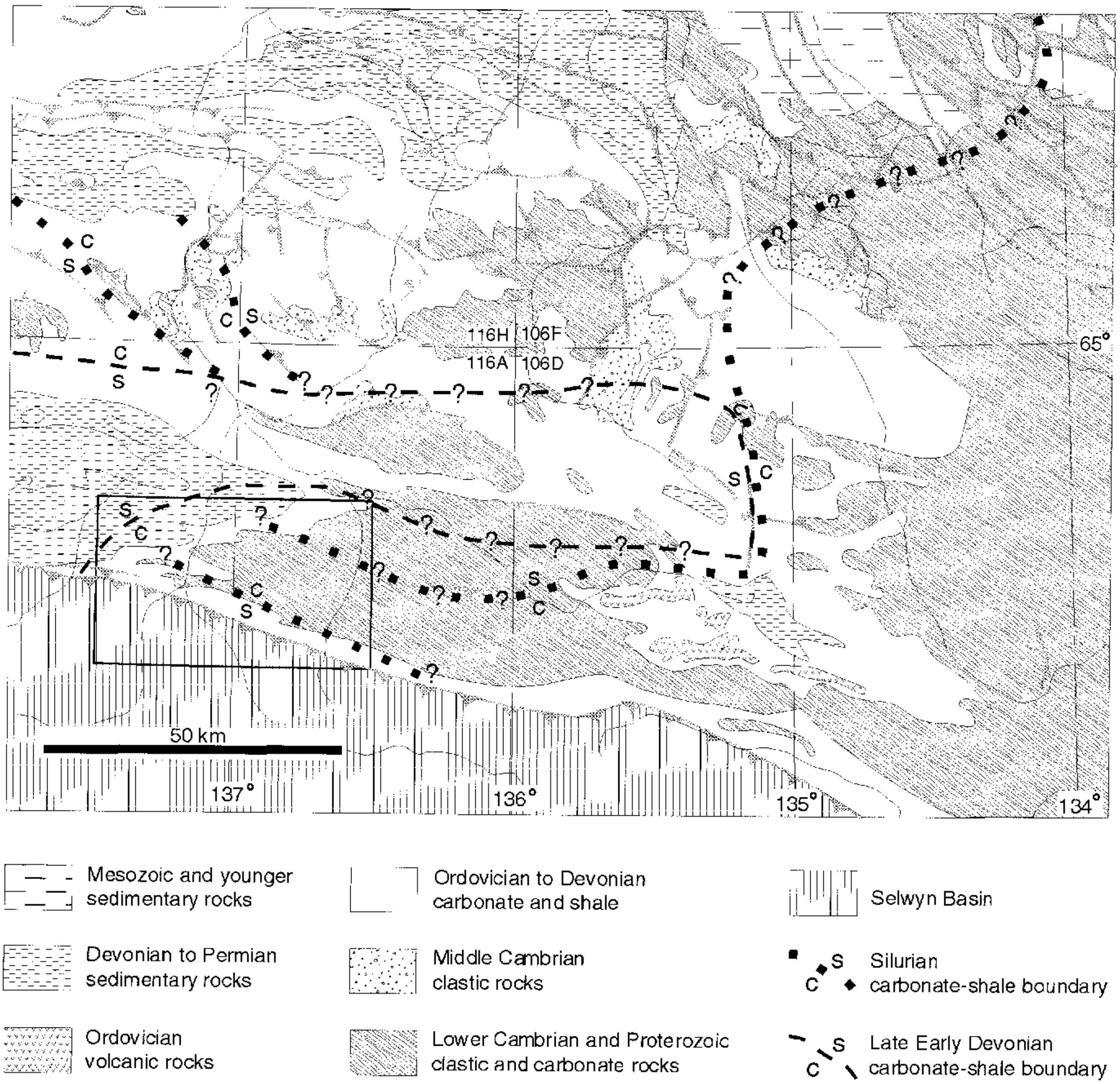


Figure 29. Proposed facies boundary between Ogilvie Platform and Blackstone Trough during the Late Ordovician to Early Silurian, and shale boundary of the late Early Devonian Ogilvie Formation. Base map from Wheeler and McFeely (1991).

northern Larsen Creek map area were previously known (Green, 1972). This study extends the known distribution of the Ogilvie Formation much farther south. Sparse fossil evidence suggests that time-equivalent shale underlies areas to the west and northwest of the project area (Figure 29).

Morrow and Geldsetzer (in Fritz et al., 1992) suggested that shale separated the Ogilvie Formation in the Nash Creek map area from other exposures to the northwest, and assigned it to a separate local tectonic element called the Royal Mountain Platform. This interpretation is apparently based on the presence of time-equivalent calcareous shale, limestone and shelly limestone in the upper part of Green's unit 12. The presence of a separate, isolated Early Devonian platform is not certain, however, because no Early Devonian strata are preserved in most localities between the Royal Mountain Platform and the Ogilvie Formation north of latitude 65°. Although the Ogilvie Formation (unit 11) in the Nash Creek map area is not laterally continuous, it appears to have been locally removed beneath an unconformity at the base of the Carboniferous shales (Green, 1972), rather than being originally discontinuous.

In the northwest corner of the Larsen Creek map area, and farther west in the Dawson map area, black slate with minor thin beds of black limestone were assigned to unit 13 (Green, 1972) of Devonian to Carboniferous age. Unit 13 overlies the Ordovician-Silurian dolostone of unit 8 and contains diagnostic two-hole crinoid ossicles and is therefore in part time-equivalent to the Ogilvie Formation and probably the Road River Group. About 13 km west of the project area along the Dawson Fault, unit 13 contains tentaculitids of Devonian age (Green, 1972). Although these fossils do not tightly constrain the age of unit 13, all tentaculitid collections made by Green and the writer (Appendix) in nearby areas come from the Ogilvie Formation, unit 12, or the Road River Group and are Early Devonian in age. Thus unit 13 in this area also probably includes Early Devonian and older strata and contains shales that are time equivalent to the Ogilvie Formation. This suggests that the late Early Devonian shale-carbonate facies boundary trended north-south along the western margin of the project area and swung west along the northern margin of the Larsen Creek map area (Figure 29). It also might have formed a narrow embayment far to the east into the Nash Creek map area.

Earn Group (DME)

Recessive, poorly exposed light-brown- to blue-weathering chert, silver-blue siliceous shale, black shale, sandstone and minor chert grit correlated with the Earn Group (Gordey et al., 1982) underlie much of the northern portion of the Two Beaver Lake map area and the northwestern corner of sheet 116A/10. The sequence is estimated to be at least 500 m thick, but lack of exposure precludes detailed definition of internal stratigraphy. Blue-weathering siliceous rocks predominate in the lower part of the sequence, but likely occur throughout. Siltstone and sandstone occur thoughout most of the sequence as thin, platy beds in variable amounts that are generally subordinate to shale and cherty argillite. A 100-to 200-m-thick sequence of thin-bedded, cherty argillite and shale lacking interbedded siliciclastic rocks is exposed in the footwall of the Dawson Fault along the western edge of the Two Beaver Lake map area. It overlies graptolitic shale of the Road River Group and is tentatively correlated with the Earn Group, but might also be part of the Road River Group. That possibility is unlikely, however, given that no graptolites could be found within it. One isolated exposure west of Rae Creek consists of black, fetid, coarse-grained limestone containing distinctive, very large pelecypods. Condonts from the limestone are Early Carboniferous in age, indicating that the limestone belongs to the upper parts of the sequence. However, the top of the Earn Group is not exposed in the map area.

The Earn Group is thought to unconformably overlie older strata. West of Rae Creek, the Ogilvie Formation is preserved in one locality, but along strike, less than two km to the east, poorly exposed siltstone and shale of the Earn Group appear to overlie graptolitic black shale of the Road River Group. The occurrence of Earn Group black shales lying on Silurian volcanic rocks in the thrust panel east of Rae Creek indicates that a significant thickness of strata is locally absent beneath an unconformity. The lithological similarity between the black shale and chert of the Road River Group and the Earn Group make mapping of the contact difficult. The Earn Group might overlie Ordovician dolostone in places, and the basal parts of the strata mapped as the Earn Group might belong to the Road River Group.

Many streams draining the Earn Group are orange coloured and acidic. Ferricrete gossans locally accompany acid springs. The acidity apparently reflects oxidation of finely disseminated pyrite in the shales, although no pyrite was observed in hand specimen. Similar ferricrete gossans are common in most areas underlain by the Earn Group in Selwyn Basin and in time-equivalent black shales, which cover most other parts of Ogilvie Platform.

Age and correlation

A Middle Devonian to Early Carboniferous age for the Earn Group is indicated by fossils obtained during this study (see Appendix 1). Middle Devonian (Givetian) conodonts were obtained west of Rae Creek from a 2-m-thick bed of limestone interbedded with siliceous shale and chert near the base of the unit. Middle Devonian conodonts were also obtained from a thin limestone bed in black shale overlying Silurian volcanic rocks along the footwall of a thrust fault east of Rae Creek (Figure 28). An isolated exposure of limestone, assigned to unit DME1, west of Rae Creek yielded Early Carboniferous (Late Tournesian) conodonts. At 137°15', one km north of the map area, the Earn Group strata are overlain by an overturned(?) sequence of tan- to brown-weathering silty limestone, black shale, and shaly and silty limestone, which contain Late Carboniferous conodonts. Although mapped by Green (1972) as unit 13, they actually belong to his unit 14, which is well exposed farther west on the other side of the West Hart River, where it overlies unit 13 and contains macrofossils as old as Late Carboniferous.

In the Dawson, Larsen Creek, and Nash Creek map areas, equivalent strata are included in unit 13 of Green (1972). Lower and Middle Devonian carbonate rocks are absent in the Dawson and western Larsen Creek map areas, unlike other parts of Ogilvie and Mackenzie platforms, and unit 13 includes strata as old as late Early Devonian and overlies black shale of the Road River Group (unit 9). The division between the two is in places arbitrary. In the Dawson map area, where chert pebble conglomerate is widespread, Thompson (1995) recently subdivided unit 13 into the Road River and Earn groups and included strata as young as Middle Devonian in the Road River Group. North of latitude 65°, Late Devonian and Early Mississippian strata include northerly derived turbidites related to the Ellesmerian Orogeny. The southern depositional limit of the "Imperial Assemblage" (Gordey et al., 1992) is unknown. Parts of the sequence included in the Earn Group in this study might be related to the Imperial Assemblage. However, the presence of chert grit suggests that most or all of the clastic debris was locally derived from the Road River Group and other, older, local units.

The Earn Group (Gordey et al., 1982, 1987; Gordey and Anderson, 1993) reflects a poorly understood episode of rifting and/or wrench faulting within the outer part of the Cordilleran miogeocline that marks the end of Late Proterozoic to Middle Paleozoic passive margin sedimentation in Selwyn Basin and Ogilvie and Mackenzie platforms. The Earn Group was mostly deposited in Selwyn Basin and is characterized by fault-controlled troughs filled with coarse, clastic, gravity-flow deposits, dramatic thickness changes and minor volcanism. Carbonate sedimentation ended on Ogilvie and Mackenzie platforms with widespread emergence and erosion followed by Middle to Late Devonian marine transgression and deposition of black siliceous shale represented primarily by the Canol Formation over much of the northern Yukon, and the northern Mackenzie Mountains (Gordey et al., 1992).

The extent of Devonian tectonism related to Earn Group sedimentation (i.e., not Ellesmerian), although poorly documented, is generally considered to have been confined to the area underlain by Selwyn Basin. In the project area, the apparent abrupt changes in stratigraphic level preserved beneath the Earn Group suggest that it underwent Devonian faulting with associated differential uplift and erosion. To the west in the Dawson map area, the presence of chert-pebble conglomerate and bedded barite in the Earn Group far north of the Dawson Fault (Green, 1972) suggests that Devonian tectonism extended beyond Selwyn Basin into the carbonate platform. This was not the case in other areas.

Rocks south of the Dawson Fault

Strata south of the Dawson Fault range in age from Late Proterozoic to Triassic and include the Upper Proterozoic to Lower Cambrian Hyland Group, Lower and Middle Cambrian Gull Lake Formation, Upper Cambrian and Lower Ordovician Rabbitkettle Formation, Cambro-Ordovician volcanic rocks, the Ordovician to Devonian Road River Group, Mississippian Keno Hill quartzite, and Triassic and Jurassic lower schist. Most of these units are remarkably uniform and consistent across the Yukon. The reader is referred to recent studies in the Nahanni and Niddery map areas by Gordey and Anderson (1993) and Cecile (in press) for exhaustive descriptions, interpretations and correlations of most units. This study is restricted primarily to documenting differences between these units in the study area and in their type areas to the east.

Hyland Group (Yusezyu PY, PY1 *and Narchilla* PN *formations)*

The oldest rocks south of the Dawson Fault are assigned to the Upper Proterozoic and Lower Cambrian Hyland Group (Gordey and Anderson, 1993). Both of Gordey and Anderson's subdivisions, the Yusezyu and Narchilla formations, are represented. The Yusezyu Formation is a massive, resistant, dark-brown-weathering sequence of medium- to coarse-grained turbiditic clastic rocks at least 1000 m thick in the map area. It displays no obvious internal stratigraphy, but includes mainly dull grey-brown quartzo-feldspathic grit, quartz sandstone and arenite, lesser amounts of interbedded dark grey phyllite, and some maroon and green shale. The coarse clastic rocks are thick- to very-thick-bedded, lack internal structure or grading and are poorly sorted. Composition varies from quartzite to greywacke. Greywacke consists of dark grey opalescent quartz grains in a fine-grained green matrix. Pebbly grits consisting of quartz and feldspar with little matrix are also common (Figure 30). Thin beds and laminations of dark-grey siltstone and shale separate the coarse clastic beds. Thin sections show that the coarse grits consist primarily of monocrystalline quartz with lesser polycrystalline quartz, microcline, plagioclase and muscovite. The grains vary in shape from well rounded to angular. Brown-weathering, sandy limestone a few metres thick is interbedded with the coarse clastic rocks fairly low in the sequence east of Rae Creek. Near the top of the sequence west of Rae Creek, at least two light-grey limestone bands between 1 and 30 m thick are interbedded with the grits.

The Narchilla Formation consists of maroon, green and grey shale with lesser amounts of thin- to medium-bedded quartz sandstone, quartzite and less common quartzo-feldspathic grit. The contact with the underlying Yusezyu Formation is gradational. Although the shales are highly deformed, and no complete sections are preserved, the thickness is estimated at about 500 m. The internal stratigraphy

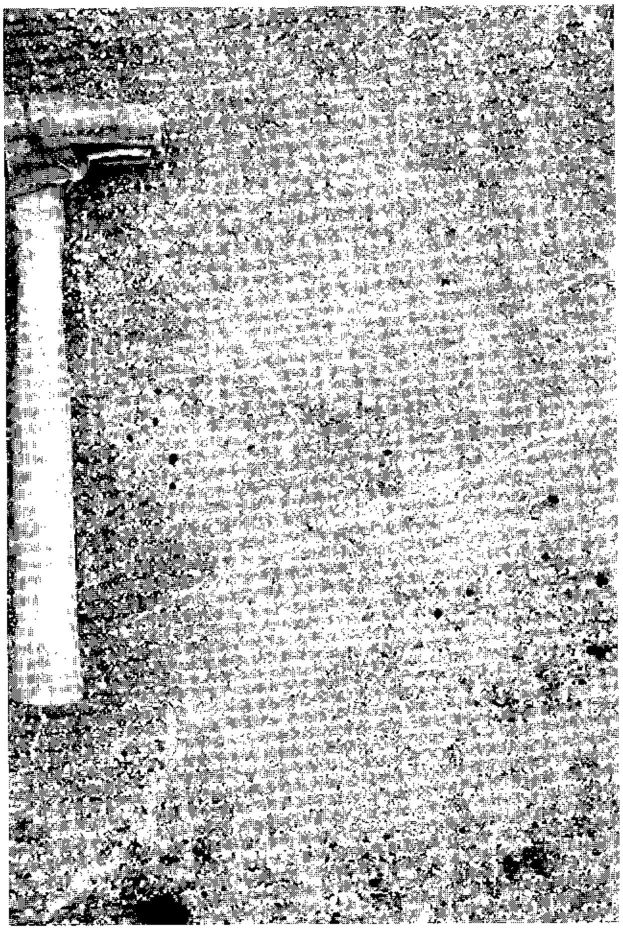


Figure 30. Typical quartz feldspar grit of the Yusezyu Formation.

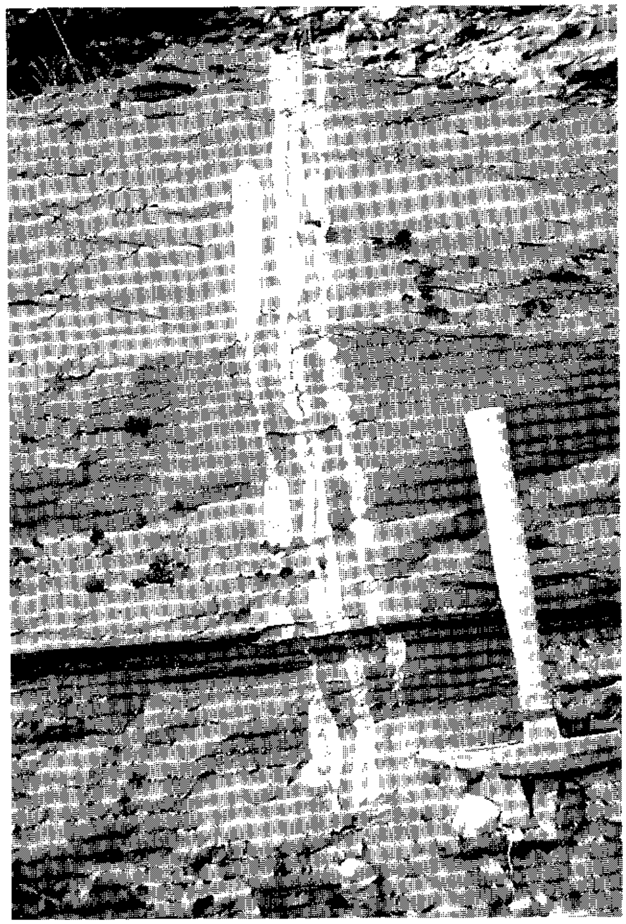


Figure 31. Maroon (dark) and green (light) shale characteristic of the Narchilla Formation. The green colour follows silt and sand laminae, which continue into the red rock. The irregular contact between the two colours is thought to indicate diagenetic replacement of reduced fluids in the green sandy beds by oxidizing fluids in the red shale beds.

of the Narchilla Formation is also unclear. In places, contacts between maroon and green shales can be seen to clearly cut bedding, and are therefore alteration fronts (Figure 31). Cecile (pers. comm., 1997) considers both the maroon and green colours to represent diagenetic alteration of a blackish, hematite-rich protolith. He considers the green colour to represent a reduced counterpart to the maroon parent. Variably spaced beds of quartz sandstone about 2–10 cm thick are characteristic of the unit. The beds — particularly their lower surfaces — are highly contorted and irregular, possibly indicating deposition as turbidites. Trace fossils are abundant on the lower surfaces of the beds (Figure 32).

Age and correlation

The type section for the Hyland Group is located far to the east in the Nahanni map area (Gordey and Anderson, 1993). In the Dawson, Larsen Creek, and Nash Creek map areas, equivalent strata were originally mapped by Green (1972) as unit 3 and, as everywhere in Selwyn Basin, were informally called the Grit Unit. The usage of Hyland Group is now generally accepted for the distinctive Late Proterozoic and Early Cambrian siliciclastic rocks that form the oldest exposed stratigraphic sequence throughout Selwyn Basin (Wheeler and McFeely, 1991). Within Selwyn Basin, wherever detailed descriptions are available, the Hyland Group is remarkably consistent, with thick, coarse, siliciclastic gravity-flow deposits forming the basal part of the sequence, maroon and green shale-dominated strata forming the top, and limestone occurring near the boundary between the two. Stratigraphic details vary from place to place. In the Nahanni map area, the Narchilla Formation includes a sandstone member. In the Niddery Lake map area, Cecile (in press) has further subdivided the Hyland Group. Limestone of the Algae Lake Formation overlies the Yusezyu Formation, which locally includes an unnamed maroon and green shale and quartzite succession. The Narchilla Formation overlies the limestone, and includes the grey, green and buff shale with minor quartzite and conglomerate of the Senoah Member and the overlying maroon and

Figure 32. Cast of trace fossils on the base of green sandy beds in the Narchilla Formation.

green shale of the Arrowhead Member. Gordey and Anderson (1993) considered the Algae Lake Formation carbonate to be time equivalent to the discontinuous limestone at the top of the Yusezyu Formation in the Nahanni map area, and concluded that coarse clastic-dominated sedimentation ended at different times in different places.

Within the project area, trace fossils, including Early Cambrian *Oldhamia*, were collected from the Narchilla Formation in three localities and were observed in many others (Appendix 1). No trace fossils were observed in the Yusezyu Formation. Fritz et al. (1984), on the basis of trace fossils, placed the Cambrian-Precambrian boundary near the base of the Narchilla Formation in the Nahanni map area. In the Niddery map area, Hoffman and Cecile (1981), Cecile and Abbott (1992), and Cecile (in press) reported *Oldhamia* from the maroon and green shales of the Arrowhead Member and other less definitive(?) trace fossils from the Senoah Member, but none from the Algae Lake Formation or older strata. In the project area, it is not certain that the Early Cambrian trace fossils are present throughout the Narchilla Formation, but the Cambrian-Precambrian boundary probably lies near the base.

Gull Lake Formation (ЄGs, ЄGv, ЄGl, ЄGp)

A recessive shale-argillite-dominated sequence overlying the Hyland Group is here correlated with the Cambrian Gull Lake Formation (Gordey and Anderson, 1993). In the project area, the Gull Lake Formation (Figures 33, 34) includes four members with a total thickness of about 750 m. The base of the formation is characterized by complex internal stratigraphic relationships between thin but generally mappable members of sandstone, volcanic rocks, and a distinctive limestone diamictite. The greater part of the sequence, however, consists of monotonous shale and argillite of the phyllite member.

Sandstone Member (ЄGs)

The base of the Gull Lake Formation is only exposed west of Rae Creek. It consists in most places of dark-weathering sandstone and quartz sandstone, rhythmically interbedded with grey and greenish grey phyllite (Figure 35). The sandstone unit is approximately 30 to 80 m thick. It sharply overlies the Narchilla Formation and, locally, the volcanic member of the Gull Lake Formation. The sandstone and arenite are regularly interbedded with shale and siltstone in widely varying proportions, giving outcrops a characteristic ribbed appearance. Bed thickness varies greatly from 2 cm to 50 cm, with the thicker beds tending to be the most pure. The variability of bed thickness and purity is irregular within the sequence. Most beds are massive and structureless, although some sandstone displays crosslaminations. Thin sections of quartzite show that detrital grains are angular and intergrown, with little or none of their original shape having been preserved. Thus, internal sedimentary structures might have been destroyed by pressure solution and silicification.

Volcanic Member (ЄGv)

Between Lake and Rae creeks, mafic volcanic flows and tuffs of the volcanic member overlie the Narchilla Formation or are locally interstratified with the sandstone member. The volcanic rocks are 1 to 30 m thick, and only the thicker portions are mapped separately. The volcanic rocks include dark green to purple, vesicular and amygdaloidal flows, and hyaloclastic breccias cemented by carbonate. In one locality, epiclastic rocks containing rounded carbonate and other exotic clasts, as well as volcanic fragments, occur at the base of the sandstone member.

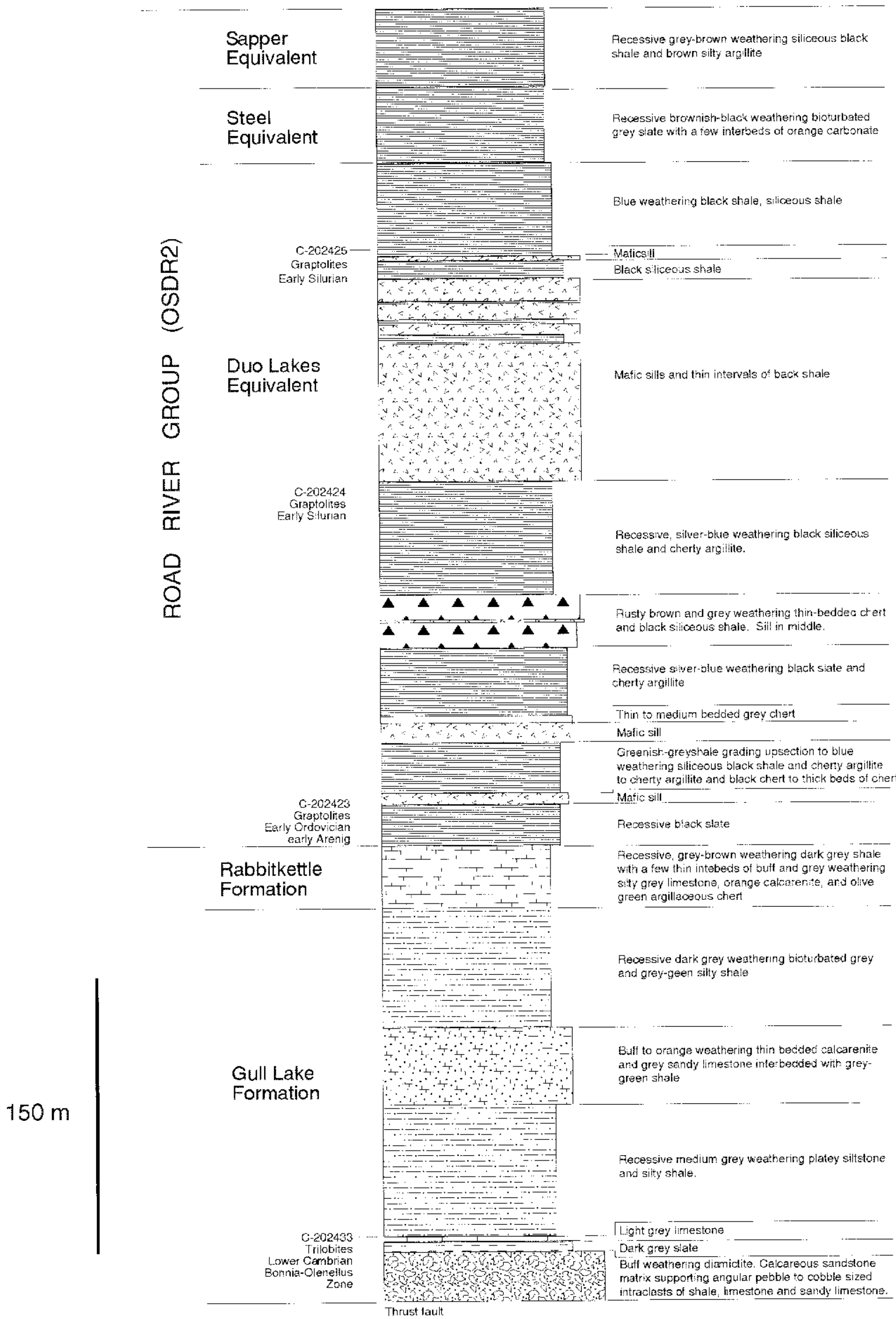


Figure 33. Section 4 measured through the Gull Lake Formation and Road River Group. Location shown on map 1997-2.

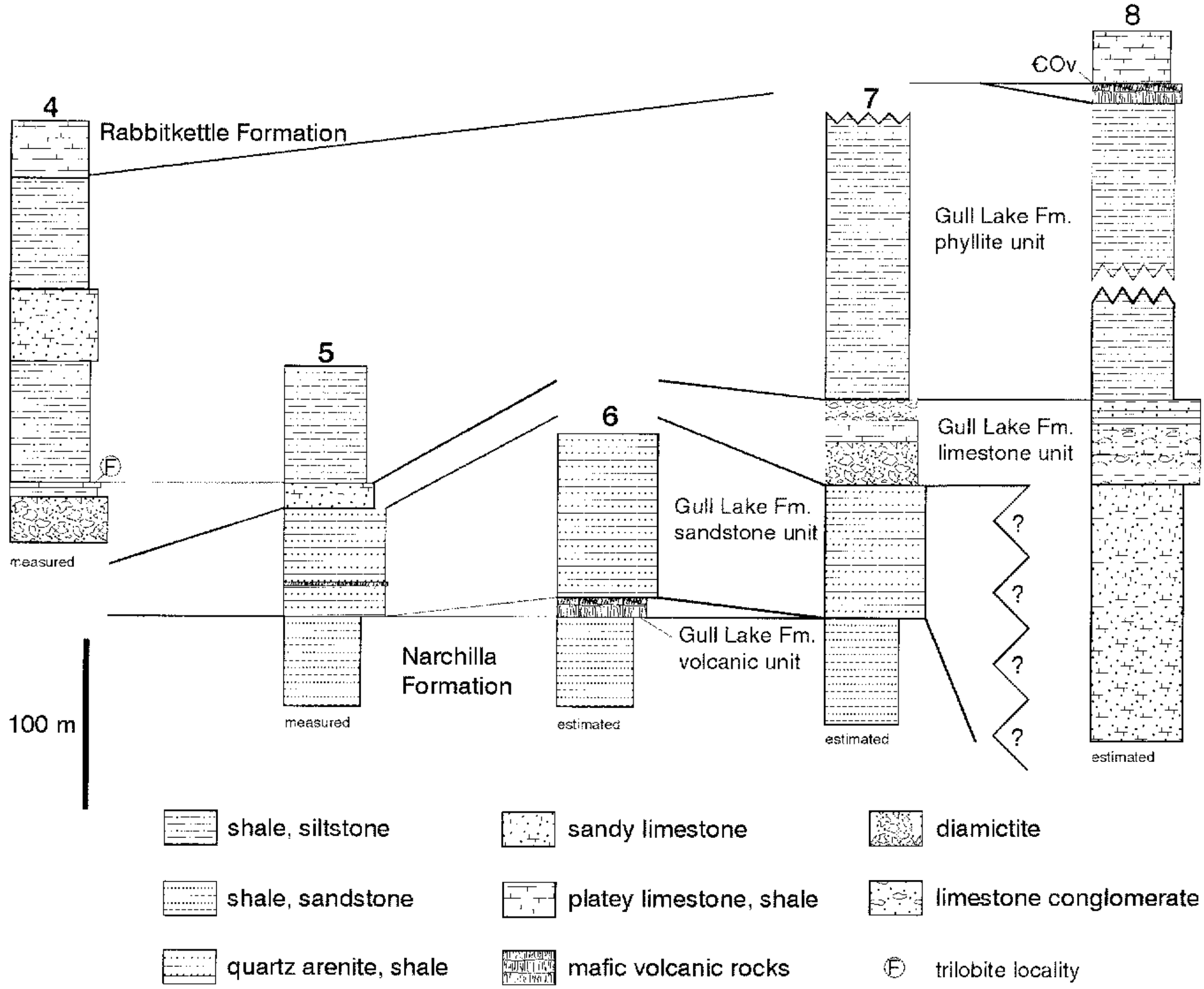


Figure 34. Sections showing stratigraphic variations in the Gull Lake Formation. Locations shown on maps 1997-2, 3.

Limestone member (€Gl)

A thin, heterogeneous, but distinctive and continuous limestone member overlies, and might be laterally equivalent to, the basal sandstone member. Distinctive limestone conglomerate and/or diamictite occurs at, or near the top of, the member. The limestone member varies from about 10-200 m thick and includes yellowish-brown-weathering calcareous siltstone, calcareous sandstone, sandy limestone, dark grey-brown shale and limestone conglomerate. The member is thickest and most varied in one thrust panel between Rae and Callison creeks, where it consists mainly of thin-bedded, buff-weathering sandy limestone overlain by a few metres of buff-weathering shale interbedded with calcareous quartz sandstone and limestone conglomerate. The conglomerate consists of recessive limestone clasts in a sandy carbonate matrix (Figure 36). Elsewhere, the limestone member is much thinner. In Section 4 east of Callison Creek, only the upper part is preserved above a thrust fault. It consists primarily of diamictite containing angular pebble- to cobble-sized clasts of greenish grey shale, grey limestone, and sandy limestone supported in a matrix of calcareous sandstone. The diamictite is capped by four m of dark grey slate overlain by three m of fossiliferous light-grey limestone. West of Rae Creek, the unit thins and overlies the sandstone unit. Between Rae and Lake creeks it consists of about ten m of buff-weathering, thin-bedded calcareous sandstone and sandy limestone, and cannot be mapped separately from the sandstone member. Some beds display pure limestone nodules in the sandy matrix. This texture is reminiscent of the 'Swiss cheese limestone' that forms the base of the Lower Cambrian Sekwi Formation in eastern Yukon (Blusson, 1968). West of Lake Creek, along the Dawson Fault, the unit includes about 30 m of typical rounded to angular, pebble- to boulder-sized clasts of

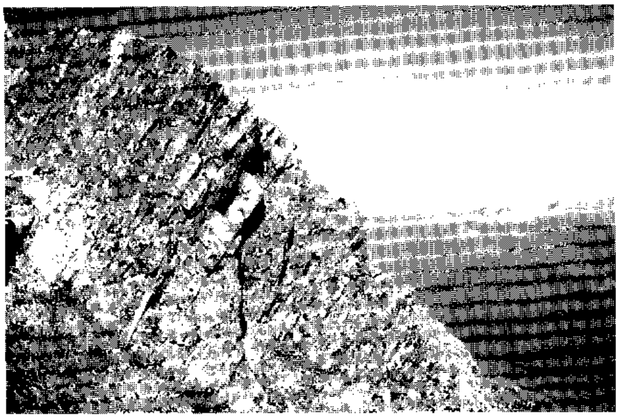


Figure 35. Interbedded quartz sandstone and shale typical of the sandstone member of the Gull Lake Formation.

greenish- to buff-weathering limestone, with lesser amounts of dark-grey slate, and minor black chert suspended in a matrix of yellowish-brown-weathering calcareous siltstone and sandstone. The diamictite is overlain by about 20 m of thinly laminated calcareous siltstone. In one locality, clast-supported conglomerate about 10 m thick caps the unit.

The diamictite appears to have been deposited by gravity-flow processes and possibly reflects tectonic instability. Although a glacial origin cannot be discounted, this possibility is unlikely. No record of Lower Cambrian glaciation is known in the northern Cordillera, and no sedimentological evidence of glaciation was observed.

Phyllite member (€Gp)

Most of the Gull Lake Formation consists of recessive dull grey to greenish grey phyllite and siltstone. The phyllite unit sharply overlies the limestone member and is 178 m thick in Section 4, but is estimated to be about 500 m thick north of Rae Creek in Section 8. The phyllite is characteristically thinly laminated and bioturbated (Figure 37), but between Lake and Rae creeks consists mainly of massive, unbedded olive-green argillite. Beds of sandstone and quartzite are uncommon. In Section 4, the member includes an unusual interval, 47 m thick, of buff- to orange-weathering, thin-bedded calcarenite and grey sandy limestone interbedded with lesser amounts of grey-green shale. The absence of the calcarenite elsewhere could be accounted for either by removal from erosion beneath unconformities or by a facies change.

Age and correlation of the Gull Lake Formation

Trilobites from the top of the limestone member and from a 30-cm-thick bed of clastic limestone — interbedded with noncalcareous phyllite and a few thin beds of quartz sandstone in an isolated outcrop near the base of the phyllite member — are upper Lower Cambrian and belong to the *Bonnia-Olenellus* Zone in the upper part of the Waucoban series (Fritz, Appendix 1). The trilobite collections are not far above, and probably not much younger than, the base of the Gull Lake Formation. The Gull Lake Formation is overlain unconformably(?) by the Rabbitkettle Formation in Section 4, unconformably by Cambro-Ordovician volcanic rocks in Section 8 and in many localities west of Rae Creek, and by Ordovician chert west of Rae Creek. Although no fossils were obtained from any of the overlying units mentioned above, similar strata in other parts of Selwyn Basin have been determined as being Upper Cambrian and Ordovician. The Gull Lake Formation therefore ranges in age from late Early to possibly Late Cambrian in age.

The Gull Lake Formation is widespread in eastern Selwyn Basin, where it was first named in the Nahanni map area by Gordey and Anderson (1993). In its type section, the Gull Lake Formation is 1052 m thick and conformably overlies the Narchilla Formation. It consists of an intermittent basal lime-

Figure 36. Limestone member of the Gull Lake Formation. Clasts of limestone and shale supported in a silty carbonate matrix characterize the unit.

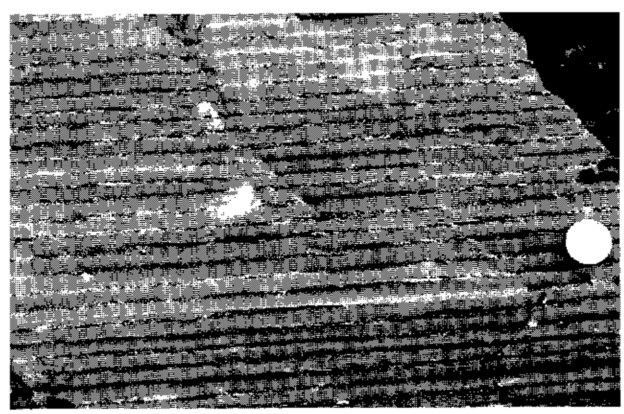


Figure 37. Bioturbated shale typical of the phyllite member of the Gull Lake Formation.

stone conglomerate less than 1 m thick with archeocyathid-bearing clasts; a middle shale member of slate, siltstone and very fine-grained sandstone; and an upper member of siltstone and mudstone. The Late Cambrian and Early Ordovician Rabbitkettle Formation overlies the Gull Lake Formation with angular unconformity.

Northwest of the Nahanni map area, in the Niddery Lake map area (Cecile, in press), the Gull Lake Formation is broadly similar to its type area. Basal strata overlying the Narchilla Formation in the southeastern corner include about 10 to 40 m of basal limestone and limestone conglomerate named the North Keele Member. Limestone conglomerate is also found at the base of the Gull Lake Formation in the northwesternmost Niddery Lake and adjacent Lansing map areas (Cecile, pers. comm., 1997). Elsewhere limestone is absent, and the basal contact is defined by a colour change. In many localities, the Gull Lake Formation is intertongued with volcaniclastic rocks of the Old Cabin Formation. The Gull Lake Formation in this area is overlain with apparent conformity by Early Ordovician shale and chert of the Elmer Creek Formation. Cecile considered most of the Cambrian system to be represented within the Gull Lake Formation, although the lower age can only be placed as accurately as the Lower Cambrian.

Originally the Gull Lake Formation likely extended across Selwyn Basin. It has been recognized west of the Niddery Lake map area in the eastern Lansing map area (Roots et al., 1995), west of the Nahanni map area in the Tay River map area by Gordey and Irwin (1987), and south of the project area in the northern McQuesten map area by Murphy (1996). In the McQuesten map area, the Gull Lake Formation closely resembles the Hart River sequence in that it includes mafic volcanic rocks and quartzite at the base. The absence of the unit in some areas, such as the Sheldon Lake (Gordey and Irwin, 1987) and Flat River map areas (Gabrielse et al., 1973), can be attributed to removal beneath the unconformity at the base of the overlying Rabbitkettle Formation.

In Yukon Block (Yukon Platform of Fritz et al., 1992), Lower Cambrian limestone unconformably overlies Proterozoic strata. Illtyd Formation limestone is preserved on the eastern margin, and Jones Ridge Formation limestone is preserved on the western margin. The limestone is as old as the *Bonnia-Olenellus* Zone, and time equivalent to at least the lower parts of the Gull Lake Formation in the project area. Fritz (1991) thought the carbonate rocks originally covered Yukon Platform (Yukon Block). The sandstone and coarse carbonate debris within the basal members of the Gull Lake Formation were probably shed from it, and onset of deposition probably coincided with onset of deposition of the Illtyd-Jones Ridge carbonates. The unconformity at the base of these formations is widespread and profound, and so might also be present beneath the Gull Lake Formation in the project area.

Fritz et al. (1984, 1992), Gordey and Anderson (1993) and Cecile (in press) correlated the Gull Lake Formation with platformal carbonate strata of the Lower Cambrian Sekwi Formation and possibly the Middle Cambrian Rockslide and Avalanche formations, which are located along the eastern margin of Selwyn Basin in Mackenzie Platform. They correlated the basal contact of the Gull Lake Formation with the base of the Sekwi Formation, such that the underlying Narchilla Formation correlated with the Backbone Ranges Formation and the transitional Vampire Formation. This correlation implies that the base of the Gull Lake Formation is near the boundary between the Placentian and Waucoban stages of the Lower Cambrian (Fritz et al., 1992), and is significantly older than the *Bonnia-Olenellus* Zone. In the eastern Niddery map area, Cecile (in press) demonstrated that the Gull Lake Formation forms a mappable tongue between the Sekwi and Backbone Ranges formations. Farther east, however, but still within the Niddery map area, Fritz (1976) measured an area (Section 6) in which the Sekwi Formation contains a tongue of calcareous brown shale and siltstone, which is probably equivalent to the Gull Lake Formation, and which is in the *Bonnia-Olenellus* Zone. No other evidence constrains the age of the base of the Gull Lake Formation more closely than Lower Cambrian, and a *Bonnia-Olenellus* age is possible everywhere. If this age is correct, then either the Gull Lake Formation disconformably overlies the Narchilla Formation, or the Narchilla Formation is younger than previously thought, and its upper part is a facies equivalent of the lower part of the Sekwi Formation. Fritz (Appendix 1) identified a local disconformity beneath a thin quartzite member within the Sekwi Formation, and stated that "Lowermost *Bonnia-Olenellus* Zone fossils have not been found in or above the quartzite, suggesting that the quartzite overlies a disconformity of moderate magnitude". Thus the possibility exists that a widespread unconformity of late Early Cambrian age not only extended across Yukon Platform, but also across Selwyn Basin and into Mackenzie Platform.

Late Cambrian(?) to Devonian(?) strata

Lower and Middle(?) Paleozoic strata overlying the Gull Lake Formation south of the Dawson Fault undergo dramatic facies changes from east to west and from north to south (Figure 38). East of Rae Creek, a consistent shale-dominated sequence with reasonable fossil control is correlated with the Rabbitkettle Formation and the Road River Group. West of Rae

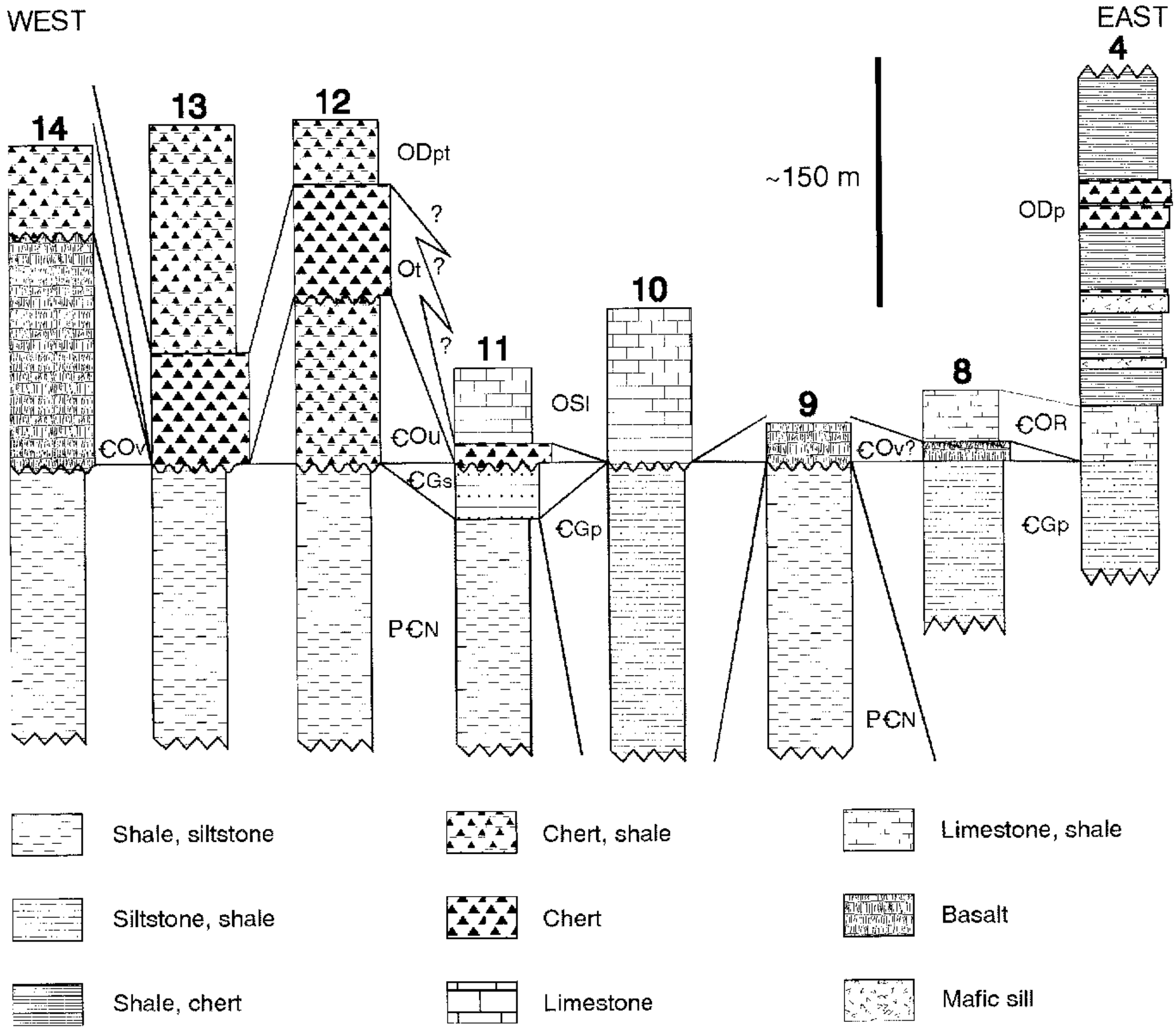


Figure 38. Stratigraphic variations in Late Cambrian to Devonian strata south of the Dawson Fault; location of sections shown on maps 1997-2, 3.

Creek, equivalent strata overlie all older strata with angular unconformity and include volcanic rocks, shale and chert. In this area, particularly in the lower parts of the sequence, stratigraphic relationships between units and with older units vary drastically over short distances (Figure 38). Although fossil control is limited, these changes are interpreted as evidence of Cambro-Ordovician rifting and crustal extension, primarily in the western part of the area.

Rabbitkettle Formation (ꞒOR)

East of Rae Creek, a unit of recessive, dark grey shale interbedded with thin-bedded, platy grey limestone and minor thin beds of grey-green chert overlying the Gull Lake Formation is correlated with the Rabbitkettle Formation (Gabrielse et al., 1973). The unit is laterally continuous, but only up to about 50 m thick, and could only be mapped discontinuously. Stratigraphic relationships with the Gull Lake Formation are uncertain, given the similarity of shales in both units, but the base of the formation was established at the first occurrence of limestone. Similarly, the upper contact with the overlying shale of the Road River Group was placed at the uppermost occurrence of limestone.

Age and correlation

No definitive fossil collections were made from the Rabbitkettle Formation within the project area, but graptolites collected five m above its top in the Road River Group are Early Ordovician in age.

West of Rae Creek, the Rabbitkettle Formation is absent, and equivalent strata are probably shale and chert of unit **€Ou**, which probably also includes younger strata. Unit **€Ou** rests unconformably on rocks as old as the Yusezyu Formation. The unconformity may continue east and separate the Rabbitkettle and Gull Lake formations, but cannot be recognized in outcrop.

Distinctive silty limestone of Late Cambrian and Early to Middle Ordovician age extends across much of Selwyn Basin and has been assigned by recent workers (Gordey and Irwin, 1987; Gordey and Anderson, 1993; Cecile (in press) to the Rabbitkettle Formation. In most localities, and particularly on the eastern margin of Selwyn Basin, the Rabbitkettle Formation is much thicker and less shaly than in the project area. Near the type section in the Flat River map area, (Gabrielse et al., 1973) much of the formation contains distinctive, recessive, grey limestone nodules in a buff, silty matrix. Despite the detailed differences in lithology and thickness between strata in the map area and in the type area, the name Rabbitkettle Formation is retained here because of the broad lithological similarity with strata included in the formation in other areas, and the consistent stratigraphic position. In most localities, the Rabbitkettle Formation rests with angular unconformity on the Gull Lake Formation and older strata, and is overlain conformably by chert and black graptolitic shale of the Road River Group.

Road River Group east of Rae Creek (ODp)

The Road River Group east of Rae Creek locally includes three subtle divisions, which can be roughly correlated with strata in eastern Selwyn Basin. The sequence is well exposed in a section (Section 4; Figure 33) that straddles the southern boundary of the map area east of Callison Creek and has a measured thickness of 365 m. Sills with a total thickness of 135 m intrude the unit, giving it a substantially greater apparent thickness. The top of the unit is not exposed. Only the lower division is preserved in most parts of the area, however, and the divisions are too indistinct, and deformation too intense, to allow them to be mapped. The lower division consists primarily of blue-weathering shale, siliceous shale, thin-bedded argillaceous chert and minor chert. Thin- to thick-bedded grey chert forms a resistant interval about 25 m thick near the middle part of the division. The middle division is about 46 m thick and consists of recessive, brownish-black-weathering, bioturbated, grey slate interbedded with a few resistant beds of orange-weathering carbonate. The upper member is also about 46m thick and consists of very recessive, grey-brown-weathering, black siliceous shale and brown, silty argillite.

The lower division is very similar to unit **ODp** on the north side of the Dawson Fault. It sharply overlies the Rabbitkettle Formation and not Ordovician dolostone, as it does on the north side.

Age and correlation

Graptolites collected from unit **ODp** range in age from Early Ordovician to Early Silurian. No fossils were collected from the upper two divisions. The Early Ordovician age contrasts with the Middle or Late Ordovician age of graptolites collected from the base of the unit on the north side of the Dawson Fault. The shales on the south side are therefore facies equivalents of Ordovician dolostone on the north side.

Black graptolitic shale and chert of Ordovician and Silurian age occur throughout Selwyn Basin. In the Nahanni (Gordey and Anderson, 1993) and Niddery (Cecile, in press) map areas along the eastern margin of Selwyn Basin, they have been assigned to the Duo Lakes Formation. In the central parts of Selwyn Basin, where deposition occurred in deeper water with less detrital influx, grey-weathering, thick-bedded Ordovician chert was assigned to the Elmer Creek Formation in the Niddery map area and elsewhere remains unnamed (Gordey and Irwin, 1987; Roots et al., 1995). In the Nahanni and Niddery map areas, orange-weathering, bioturbated, wispy-laminated siltstone of the Silurian Steel Formation overlies the Duo Lakes Formation and is in turn overlain by calcareous shale and silty limestone of the Early Devonian Sapper Formation. The two upper members of unit **ODp** resemble these formations, but are much more shaly and less distinct. The Steel Formation was traced across Selwyn Basin by Gordey and Irwin (1987) and Roots et al. (1995), and was mapped south of the project area in the northern McQuesten map area by Murphy (1996). The Sapper Formation is only known on the eastern side of Selwyn Basin; farther west it has either been removed beneath the unconformity at the base of the Earn Group or has undergone a facies change to black shale and chert, which have been included in the Earn Group.

Dempster volcanics (€Ov)

This unit includes mafic alkalic volcanic rocks with imprecise age constraints and probably at least two different ages. The volcanic rocks form dark-weathering resistant sequences 10 to 100 m thick (Figure 39), consisting mainly of flow breccias, hyaloclastic breccias, agglomerates, and massive or pillowed flows. Breccias grade laterally and vertically into massive and pillowed flows with no clear definition of individual flow units. No clear stratigraphic sequence or regional facies zonation could be determined.

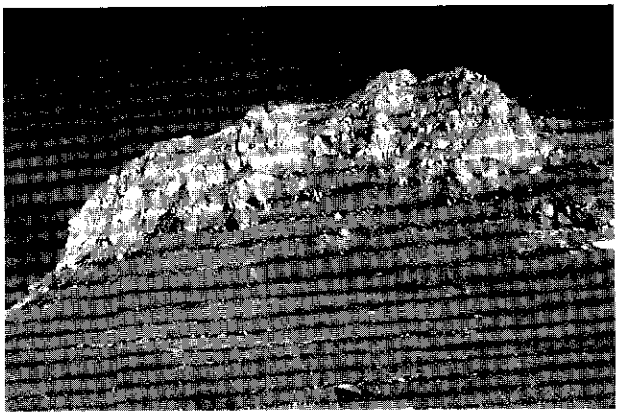


Figure 39. This exposure of the Dempster volcanics west of Lake Creek is on one of the thickest in the map area at about 100 m. It consists entirely of hyaloclastic breccia.

Most breccia fragments are lapilli to cobble-sized (Figure 40) and are locally boulder-sized. The breccia matrix includes carbonate and crystalline flow material. Most of the flows are fine to medium grained. Some are porphyritic and contain large augite phenocrysts. Amygdules and vesicles are common in both fragments and flow material.

Stratigraphic relationships between the volcanic rocks and the underlying strata are not well understood, but the possibility exists for a significant angular unconformity. Most of the volcanic rocks sharply overlie the Narchilla Formation and some may actually be equivalent to unit ЄGv. That correlation cannot be proven, however, because their upper contacts are with Ordovician limestone or chert. Some of the volcanic rocks are clearly not unit ЄGv as they overlie green argillite in the upper part of the Gull Lake Formation. In one locality north of Rae Creek, a thin flow overlies Gull Lake shales and is overlain by the Rabbitkettle Formation. Other volcanic rocks overlie the Narchilla Formation but are interbedded with green shale and, locally, chert, which resembles the undivided Cambro-Ordovician shale unit. The absence of the Gull Lake Formation beneath the volcanics indicates that an angular unconformity separates them from the Narchilla Formation. Along the far western boundary of the Two Beaver Lake map area, one flow overlies Ordovician(?) chert.

Age, environment and correlation

No fossils were collected from the volcanic rocks, but stratigraphic relationships constrain most of them to a Middle Cambrian to Early Ordovician age, and indicate that a few are younger.

Mafic volcanic rocks continue west into the Dawson map area where they form thick, extensive accumulations above the Hyland Group south of the

Figure 40. Hyaloclastic breccia typical of the Dempster volcanics.

Dawson Fault (Roots, 1988; Thompson, 1995). Goodfellow et al. (1995) introduced the name "Dempster volcanics" for this assemblage, but it has never been formally defined. One Early Ordovician conodont was recovered from interbedded(?) limestone (Cecile, pers. comm., in Roots, 1988). The Dawson area volcanic rocks as described by Roots resemble those in the project area, but also include minor rhyolite. Roots inferred that the basal portions of the volcanic piles were deposited in a relatively deep marine environment, whereas the upper portions were deposited, at least in part, in a shallow-water to subaerial environment. Roots interpreted the volcanic rocks as overlying the Hyland Group conformably, but also reported that quartzite and wispy-laminated, olive-coloured shale and siltstone, much like the Gull Lake Formation, lay above the Hyland Group in places where the volcanics were absent. Although the volcanic rocks might be a facies equivalent of these strata, the possibility of an unconformity beneath the volcanic rocks cannot be discounted. The volcanic rocks have not been observed east of the project area.

Restoration of about 450 km of Late Cretaceous(?) and Early Tertiary right-lateral offset on the Tintina Fault brings two east-northeast-trending belts of mafic igneous rocks in the Livengood area of Alaska (Weber et al., 1992) close to the volcanic rocks in Dawson map area. A northern belt, including peridotite, dunite, gabbro, metabasalt and metatuff, was assigned an Early Cambrian or Late Proterozoic age, and an assemblage of gabbro, diorite, basalt, shale, chert, argillite, quartzite and greywacke was mapped as Paleozoic and (?)Proterozoic. The basal contacts of both assemblages are not exposed. The Cambrian assemblage appears to be overlain by Silurian and Devonian strata, and K/Ar ages of 518 to 643 Ma have been obtained from diorite within it. The age of the Paleozoic and older assemblage is unconstrained.

The southern belt, comprising the Fossil Creek volcanics, is located about 40 km to the southeast, in the hanging wall of the White Mountains Fault, the equivalent of the Robert Service Thrust (Murphy and Abbott, 1995). The Fossil Creek volcanics contain Early, Middle(?) and Late Ordovician fauna (Blodgett et al., 1987; Weber et al., 1994). An Early Ordovician basal sequence is dominated by shale, siltstone, lime mudstone and chert with interbedded aquagene tuffs and basalt flows, and an upper sequence consists primarily of basalt, tuff, and agglomerate. The Fossil Creek volcanics unconformably overlie *Oldhamia*-bearing maroon and green shale of the "Wickersham unit" (Weber et al., 1985), a direct equivalent of the Narchilla Formation.

The Fossil Creek volcanics are too young to correlate with the Dempster volcanics, and more likely correlate with strata located south of the Robert Service Thrust near Brewery Creek (D. Murphy, pers. comm., 1996). The volcanic portion of the northern belt, although undated, is a more likely correlative. If so, the volcanic rocks originally formed a continuous belt at least 200 km long, and in one locality, at least 40 km wide.

Two volcanic assemblages along the western margin of Selwyn Basin appear to be the same age as the Dempster volcanics. The Menzie Creek volcanics, at the northwestern end of Cassiar Platform, overlie the Gull Lake Formation and are overlain by graptolitic, Early Ordovician shales (Pigage, 1990). South of the Tintina Fault, in Cassiar Platform, the 'groundhog volcanics' (Goodfellow et al., 1995) are also considered to be Late Cambrian to Early Ordovician (Gordey, 1981).

Other Late Cambrian and Early Ordovician volcanic rocks include parts of the Late Cambrian to Late Ordovician Marmot Formation and the Early Cambrian to Late Ordovician Niddery volcanics in the Misty Creek Embayment and the northeast corner of Selwyn Basin. These long-lived volcanic assemblages are part of a discontinuous north-trending belt, which roughly follows the carbonate-shale boundary along the eastern margin of Selwyn Basin (Goodfellow et al., 1995). This belt also includes Lower Cambrian, Middle to Late Ordovician, Early Silurian and Early Devonian volcanic rocks.

Road River Group west of Rae Creek (€Ou, Ot, OSl, ODpt)

Cambro-Ordovician phyllite and chert (€Ou)

West of Rae Creek, an unnamed unit of shale interbedded with chert and minor limestone is inferred to unconformably overlie the Narchilla Formation and, in one locality, the Yusezyu Formation. The shales also overlie the Cambro-Ordovician volcanics, and appear to be interbedded with them in one locality west of Lake Creek, on the margin of the map area. The shales are generally siliceous and olive-green to grey in colour. They contain variable amounts of similarly coloured chert and a few thin beds of sandstone and grey or buff limestone. The southernmost belt of rocks included with this unit on both sides of Lake Creek contain up to 25% chert, which is a greater proportion than that found elsewhere. The green shales by themselves are indistinguishable from green shales in the Narchilla and Gull Lake formations, but the combination of shale, chert and limestone and absence of maroon shales, quartz sandstone, or limestone diamictite distinguishes these rocks from the Narchilla and Gull Lake formations. No accurate estimate of thickness is possible, but it probably varies from 25 to 200 m.

Age and correlation

The Cambro-Ordovician shale unit is interpreted as being laterally equivalent to the Rabbitkettle Formation and the lowermost part of unit **ODp** of the Road River Group. Two conodonts were obtained from a limestone bed ten cm thick at the locality where the shales overlie the Yusezyu Formation. The conodonts could range in age from Ordovician to Triassic, but the general character and stratigraphic position beneath thick-bedded chert of unit **Ot** strongly suggests that the shale unit is Ordovician. The fossil locality, combined with the absence of Gull Lake Formation and Narchilla Formation beneath the shales, demonstrates the presence of a Middle to Late Cambrian unconformity beneath the unit. This unconformity would correspond to the one postulated beneath the Dempster volcanics.

Ordovician chert (ORt)

West of Rae Creek, a prominent chert unit about 50-70 m thick unconformably overlies strata as old as the Narchilla Formation. The chert is medium- to thick-bedded, light-grey to olive-green in colour, and locally bioturbated (Figure 41). Commonly, only thin partings or very thin beds of olive-green- and blue-weathering siliceous shale separate the chert beds. Along the western boundary of the map area, the unit might include two chert intervals, both of which are capped by a few metres of olive-green, siliceous shale. Alternatively, given the tectonic complexity in this area, one interval could be repeated by thrust faults. Between Rae and Lake creeks, the chert is interbedded with limestone of unit **OSl**.

The green shale weathers black and is highly manganiferous. In one locality, manganese nodules are embedded in the shale (Figure 42). The nodules are 1 to 6 cm long and appear to have grown around a siliceous shale nucleus. The nodule-bearing horizon has been traced west out of the map area for six km and appears to be a continuous, distinctive stratigraphic marker. The manganiferous unit was recognized near the end of the mapping program and could be more widespread within the map area than presently documented. Analysis of one nodule gave the composition shown in Table 2.

John Wiltshire of the University of Hawaii examined some specimens and considered them to be analogous to modern sea floor nodules found in continental borderlands (pers. comm. 1997). If so, this is one of the first recorded examples of preserved ancient sea floor nodules. Wiltshire estimates a minimum depth of formation of 1000 m, and possibly 3000 m, based on the depths of formation of modern sea floor nodules with a similar composition and high Mn/Fe ratio. In places the chert is interbedded with limestone, indicating that deposition occurred above the carbonate compensation depth of about 4000 m. Evidence of deposition in such deep water contrasts dramatically with the coeval shallow-water depositional environment on Ogilvie Platform. The chert and carbonate are now nine km apart; even with an estimate of 100% shortening during Mesozoic deformation, the original distance was less than 20 km.

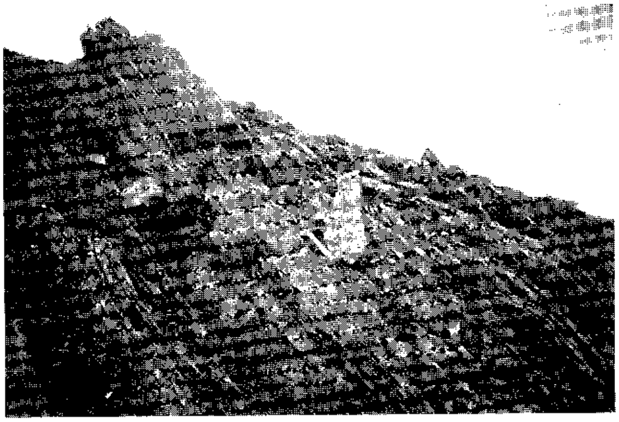


Figure 41. Thick-bedded, resistant chert of unit Ot.

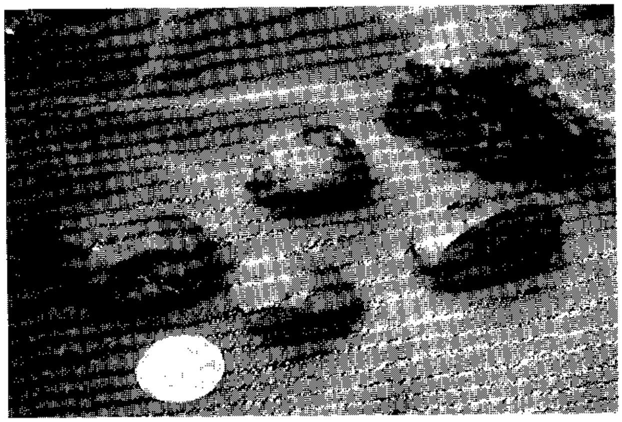


Figure 42. Manganese nodules from black-weathering, green shale interbedded with Ordovician chert (unit Ot).

Strata beneath the Ordovician chert seem to form a broad arch over which the chert unconformably overlies the Narchilla Formation in the centre, Cambro-Ordovician volcanics to the north and a thick sequence of undivided shale and chert of unit **ЄOu** to the south. In one thrust panel on the south side of the arch, interbedded shale and thin-bedded quartz sandstone correlated with the Gull Lake Formation underlies the chert.

Age and correlation

No fossils were obtained from the chert unit, but it is probably equivalent to the resistant, chert-rich interval in unit **ODp** east of Rae Creek (Figure 33). Graptolites about 90 m stratigraphically beneath the chert are Early Ordovician in age, and about 60 m above the chert are Early Silurian. In the Niddery map area, similar, thick-bedded grey chert of the Elmer Creek Formation is Middle Ordovician in age (Cecile, in press), and Ordovician in the Lansing map area, (Roots et al., 1995). The unconformity beneath the chert unit is profound, but has not been documented in other parts of Selwyn Basin. It might be present in the Lansing map area, where chert equivalent to the Elmer Creek Formation overlies the Gull Lake Formation (Roots et al., 1995). In the Dawson map area, the shallow water and subaerial deposition of the upper part of the Cambro-Ordovician volcanic sequence (Roots, 1988) suggests the possibility of an equivalent unconformity.

Ordovician-Silurian(?) limestone (OSl)

An unusual limestone unit between one m and about 200 m thick only occurs east of Lake Creek. Structural complexity precludes precise definition of the internal stratigraphy, but the limestone is inferred

Table 2. Analysis of manganese nodule from Ordovician chert.

Ag	Cu	Pb	Zn	As	Sb	Mo	Tl	Bi	Cd	Co	Ni	Ba	W	Cr
—	—	29	34	537	—	13	—	7	—	14	68	352	5	100
V	La	Sr	Zr	Sc	Mn	Ti	Al	Ca	Fe	Mg	K	Na	P	
					(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
28	3	73	—	4	39	0.03	0.395	0.63	1.83	0.36	0.06	0.03	0.01	

Measurements in ppm, unless % indicated.

to grade both laterally and vertically from a fine-grained, massive, white variety to one which is fetid, black and platy (Figure 43). In several localities, the base of the unit consists of 1 to 10 m of medium- to thick-bedded grey to black chert. Similar chert also forms uncommon bands less than a metre or two thick within the limestone and possibly, at the top of the limestone. The limestone might be, in part, a facies equivalent of the Ordovician chert unit. Northern- and easternmost exposures consist primarily of pale-grey, thin-bedded limestone. The easternmost exposure in map area 116A/10 differs in that it contains sandy intervals. This exposure is complexly interleaved with the Narchilla Formation and the possibility exists that it is Proterozoic in age and part of the Hyland Group.

The same broad arch defined by strata beneath the Ordovician chert unit seems to continue east beneath the limestone, at least as far as Rae Creek. In the centre, the limestone unconformably overlies the Narchilla Formation and, locally, the Gull Lake Formation. On the north limb, it unconformably overlies Cambro-Ordovician volcanics and the Gull Lake Formation, and on the south limb, the Ordovician chert unit. The abrupt changes in stratigraphic level beneath both the Ordovician chert and the limestone suggest that normal faulting accompanied the development of the unconformity. The top of the unit is exposed in only one locality, where it is overlain by thin to medium beds of grey and black chert interbedded with dark grey shale, platy blue siliceous shale, and olive-green shale correlated with unit ODpt.

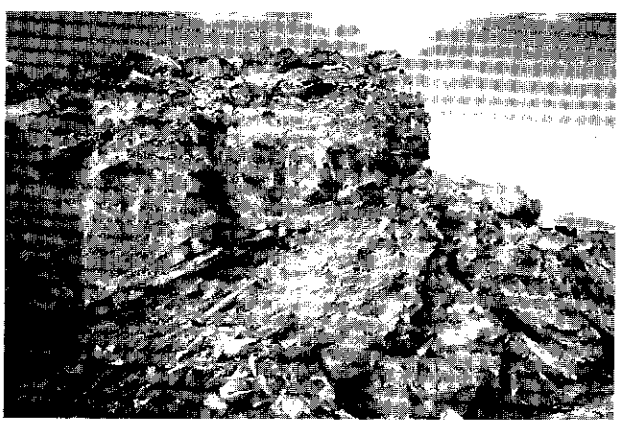


Figure 43. Limestone of unit OSl.

Age and correlation

Two collections of conodonts were obtained from the limestone, both with an Ordovician to Devonian age assignment. Within Selwyn Basin, limestone of that age range is uncommon. Thin limestone lenses reported within(?) Cambro-Ordovician volcanics of the Dawson map area yielded one conodont of Early Ordovician age (Roots, 1988). In Alaska, the Tolovana limestone, which unconformably overlies the Fossil Creek volcanics (Blodgett et al., 1987), is earliest Silurian to Early Devonian in age, and was deposited in shallow water. The limestone shows no evidence of shallow-water deposition, and its association with chert suggests that it was deposited in deep water, perhaps as gravity flows derived from the carbonate platform to the north.

Ordovician(?), Silurian and Devonian(?) chert and shale (ODpt)

Rusty-brown-weathering chert and shale sharply overly the Ordovician chert unit. The unit consists mainly of olive-green, siliceous shale regularly interbedded with thin- to medium-bedded, grey to olive-green chert (Figure 44). Blue-weathering chert and shale are minor components. No consistent variations in internal stratigraphy were recognized. The sequence resembles that of unit ЄOu and the two can only be distinguished by their stratigraphic position. No accurate estimate of thickness is possible, but a minimum of 100 m is likely. The top of the unit is not exposed.

Age and correlation

No fossils could be found in unit ODpt. It is probably equivalent to the upper two members of unit ODp east of Rae Creek, but might include strata as old as Ordovician and as young as Early Devonian.

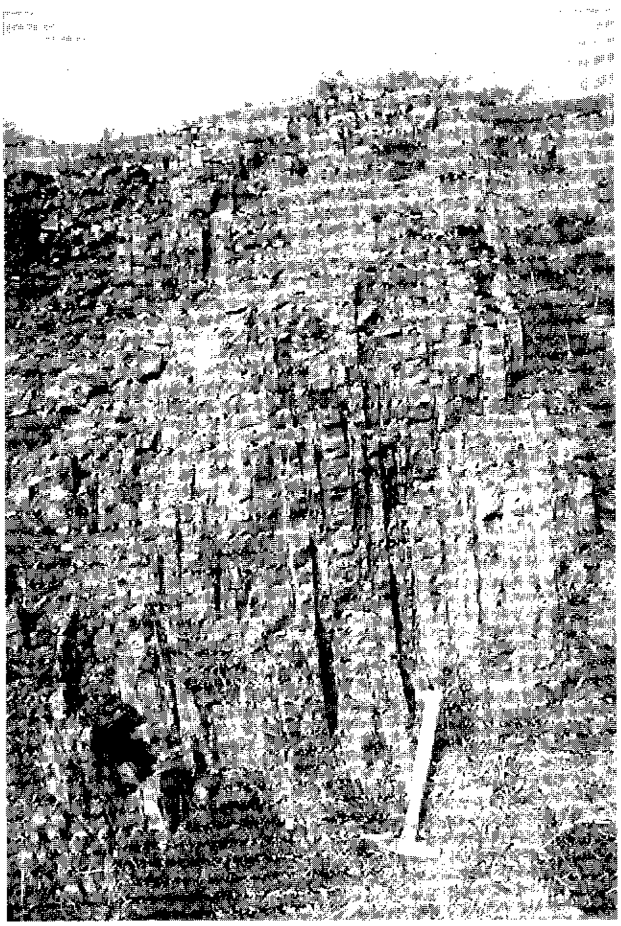


Figure 44. Interbedded chert and shale characteristic of unit ODpt.

Keno Hill quartzite (Mq)

Keno Hill quartzite (**Mq**) (Tempelman-Kluit, 1970; Green, 1972) is exposed in the hanging wall of the Tombstone Thrust, in the extreme southwest corner of sheet 116A/11. The unit primarily consists of dark-grey-weathering, massive to very thick-bedded, vitreous quartzite, and a few thin intervals of jet black slate. These rocks are intensely deformed and their true thickness and internal stratigraphy is not known. A subunit of thin-bedded, phyllitic quartzite, and graphitic and chloritic phyllite, mapped by Green (1972) just south of the map area, was not seen by the writer.

Age and correlation

No fossils were obtained from the Keno Hill quartzite in the map area, but the quartzite is considered to be Carboniferous in age on the basis of Mississippian (Viséan-Namurian) conodonts recently collected from interbedded limestone and shale in the Dawson area by R. Thompson (Mortensen and Thompson, 1989; Orchard, 1991).

The Keno Hill quartzite consists mostly of the panel of rocks between the Tombstone Thrust below and the Robert Service Thrust above. At the western end, in the Dawson map area, it is about 550 m thick and consists primarily of massive members of quartzite interbedded with lesser amounts of black siliceous shale and minor limestone (Tempelman-Kluit, 1970). Within the thrust belt, stratigraphic relationships are mostly unknown, but at the eastern end, latest Devonian felsic metavolcanic rocks are tectonically interleaved with the Keno Hill quartzite and are inferred to underlie it (Abbott, 1990a,b).

In the southeastern Nash Creek map area, in the footwall of the eastern end of the Tombstone Thrust and in the footwall of the Dawson Thrust, strata originally mapped by Green (1972) as the "Lower Schist" includes a sequence of black shale and siltstone containing a single quartzite horizon. Abbott (1990) correlated the quartzite with the Keno Hill quartzite, and underlying strata with the Devono-Mississippian Earn Group, although they are indistinguishable from strata above the quartzite.

The Keno Hill quartzite continues east across Lansing map area (Roots et al., 1995) into eastern Selwyn Basin where, in the Nahanni map area, Gordey and Anderson (1993) included equivalent Mississippian quartzite in the Tsichu Formation. Cecile (in press), working in the adjacent Niddery map area, has since elevated the Tsichu Formation to the Tsichu Group and divided it into five formations. These are, from oldest to youngest: shale with minor quartzite; overlain by black shale and interbedded limestone of the Hawthorne Formation; massive, thick-bedded quartzite of the Heritage Trail Formation; bioclastic limestone of the Caribou Pass Formation; laterally equivalent shale interbedded with crinoidal limestone of the Keele Creek Formation; and limestone of the Fourway Formation. South of its type area, strata equivalent to the Heritage Trail Formation near Macmillan Pass (Abbott, 1983) and in the Nahanni map area (Gordey and Anderson, 1993) include three or more quartzite horizons interbedded with shale and siltstone. The lowest quartzite unconformably overlies the Earn Group and defines the base of the Tsichu Formation (Group). The age of the Heritage Trail Formation and equivalent strata ranges from Early (Viséan) to Late Mississippian. Gordey and Anderson (1993) inferred that the quartzites in the Tsichu Group were probably deposited as bar finger sands on a shallow-marine shelf.

Mesozoic shale and sandstone (TRJps)

A small area of talus immediately beneath the Tombstone Thrust consists mainly of grey-brown-weathering black slate with some weakly calcareous, micaceous siltstone, silty shale, and minor, crosslaminated, micaceous quartz sandstone. The fragments appear to be weakly metamorphosed to hornfels, probably by the buried extension of a mafic sill mapped by Green (1972), 2 km to the west. These rocks are thought to underlie a large portion of an extensive, mostly covered interval along the footwall of the Tombstone Thrust.

Age and correlation

Unit TRJps is part of an extensive, mostly covered sequence of black shale, sandstone, and siltstone that occupies the footwall of the Tombstone Thrust for its entire length. The sequence was originally mapped by Green (1972) as the Lower Schist and was considered to be Jurassic in age. Before the Tombstone Thrust was recognized, workers coined the name "Lower Schist" for strata thought to underlie the Keno Hill quartzite in the Keno Hill District. Now that the Keno Hill quartzite is known to be older than the Lower Schist, the name is no longer applicable. The Jurassic age is based on fossils collected at the extreme western and eastern ends of the belt (Poulton and Tempelman-Kluit, 1982). Recent work along the east end in the Mount Westman area by Abbott (1990a, b) has shown that the basal strata in the Lower Schist are black shale interbedded with distinctive chert grit and bedded barite, which are probably Devonian in age and correlative with the Earn Group. These rocks unconformably overlie the Hyland Group. In the same area, Triassic strata were also recognized in the Lower Schist on the basis of lithology. At the western end, chert-pebble conglomerate and black shale of the Earn Group, limestone of the Permian Tahkandit Formation and Triassic siltstone and shale occur sporadically beneath the fossiliferous Jurassic strata (Green, 1972; Thompson, 1995). Thus, the covered interval in the project area might include strata ranging in age from Devonian through Jurassic.

The micaceous, calcareous siltstones in the map area are unfossiliferous, but resemble the Triassic strata that underlie Jurassic shales along strike to the west in the Dawson map area (Green, 1972), and which are widespread in other parts of Selwyn Basin (Tempelman-Kluit, 1970; Gordey, 1981; Cecile and Abbott, 1989). In addition, Mortensen and Thompson (1990) obtained a Middle Triassic age (232.2+1.5/-1.2 Ma) from a mafic sill intruding the Keno Hill quartzite in the hanging wall of the Tombstone Thrust, 50 km to the west. Similar sills continue intermittently eastward past the map area, primarily in the hanging wall of the Tombstone Thrust, but also in the footwall sequence (Abbott, 1990a, b). The lone sill intruding shales in the footwall of the thrust near the map area probably belongs to the same suite. These two lines of evidence suggest that unit TRJps in the map area is, at least in part, Middle Triassic or older.

Intrusive Rocks

At least three ages of diabase sills and dikes are known to occur in the map area. The Middle Proterozoic Hart River sills intrude the Wernecke Supergroup north of the Dawson Fault; unnamed Cambro-Ordovician sills intrude the Hyland Group south of the Dawson Fault; and an unnamed Late Paleozoic sill or sills intrude the Road River Group on both sides of the Dawson Fault. The intrusions are remarkably similar in spite of their diverse ages. Most locally crosscut bedding, but are essentially tabular and sheet-like bodies, which are roughly concordant with bedding. All form dark, resistant outcrops, and are laterally continuous for great distances. Most are coarse- to very coarse-grained, except along chilled margins and in smaller bodies. Clinopyroxene and plagioclase are the dominant primary minerals, and all are variably altered to a variety of secondary minerals. Thicker sills are differentiated to varying degrees, with pyroxene and opaque minerals more abundant at the base, and feldspar and small amounts of quartz concentrated at the top. Trace element contents of the Hart River sills also indicate enrichment toward the top (Appendix 2). The Hart River and Cambro-Ordovician sills are spatially associated with basaltic lavas, to which they are probably feeders.

Hart River sills (Pd)

The dark, resistant, craggy outcrops of the Hart River sills contrast sharply with the orange-weathering dolostone of the Gillespie Lake Group, but blend with the black Quartet Group. In the Gillespie Lake Group, aureoles of de-dolomitized white marble, rarely thicker than several metres, further emphasize the intrusions (Figure 45). The intrusions appear widely, but probably as few as one or two sills and a few relatively thin dikes are structurally repeated.

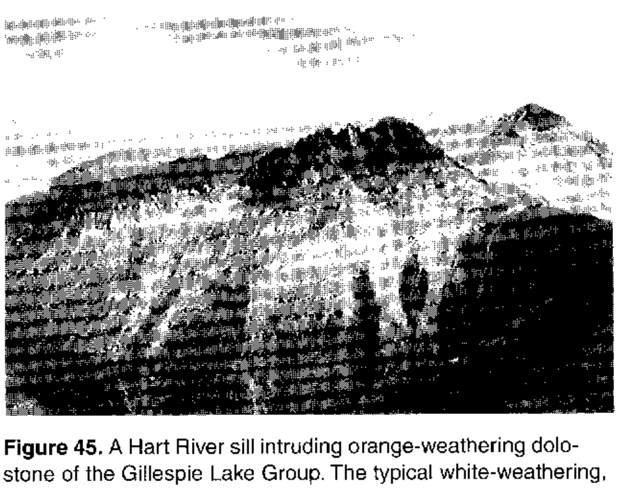


Figure 45. A Hart River sill intruding orange-weathering dolostone of the Gillespie Lake Group. The typical white-weathering, dedolomitized alteration selvage can be seen beneath the sill.

The largest sill is exposed over a strike length of at least 23 km. It reaches a thickness of 250 m beneath the Hart River volcanics and thins to less than 30 m at the eastern margin of the map area, where it is inferred to have been dismembered into three or more bodies by thrust faults. The sill intrudes the Gillespie Lake Group and reaches a stratigraphic level about 400 m below the Hart River volcanics, suggesting a shallow level of emplacement. In the northeast corner of the map area, the other main body is a sill at least 200 m thick, synclinally folded with the upper part of the Quartet Group and the base of the Gillespie Lake Group. A thinner sill occupies the same strati-graphic position at the western limit of exposure, 15 km to the west. The sills could originally have been continuous, both with each other and with the larger body to the south.

The Hart River sills are more altered than the Paleozoic sills. Secondary minerals are pervasive, although relict textures are preserved. Thin sections show corroded and dismembered clinopyroxene in a matrix of relict feldspar laths. The feldspars are completely altered to a felted matrix of sericite, amphibole, chlorite and minor carbonate.

Age and correlation

Until this study, the age of numerous mafic sills and dikes intruding Proterozoic strata in the Ogilvie and Wernecke mountains was essentially unknown. Green (1972) and Blusson (1974) tentatively considered them to be Cretaceous, but suspected that they were older. Roots (1990) mapped them as Triassic on the basis of recent dating of similar sills on the south side of the Dawson Fault (Mortensen and Thompson, 1990).

Samples of mafic sills intruding the Wernecke Supergroup were collected from four sites in the southern Ogilvie Mountains (Figure 4). One sample was from the Hart River Inlier, in the project area; two were from Carpenter Ridge; and one was near the Blende Pb-Zn deposit (Figure 1) on Mount Williams. All yielded zircons. The Blende sample gave an age of 1380.2 +4.0/–3.8 Ma; one Carpenter Ridge sample gave an age of 1385.8±1.9 Ma; and a combined set of fractions from the second Carpenter Ridge sample and the Hart River sample gave an age of 1383.0 +5.9/–5.2 Ma (Appendix 3; Figures 46, 47, 48).

The Hart River sills occur in a narrow east-trending belt at least 175 km long that follows the north side of the Dawson Fault from the Hart River Inlier to Kathleen Lakes, where it veers north in a broad arc that ends near the Bonnet Plume River (Figure 4). Mapping by the writer near Carpenter Ridge (unpublished) and by Roots (1990a, b) near Mount Williams indicates that the sills are everywhere similar in nature and setting to those in the

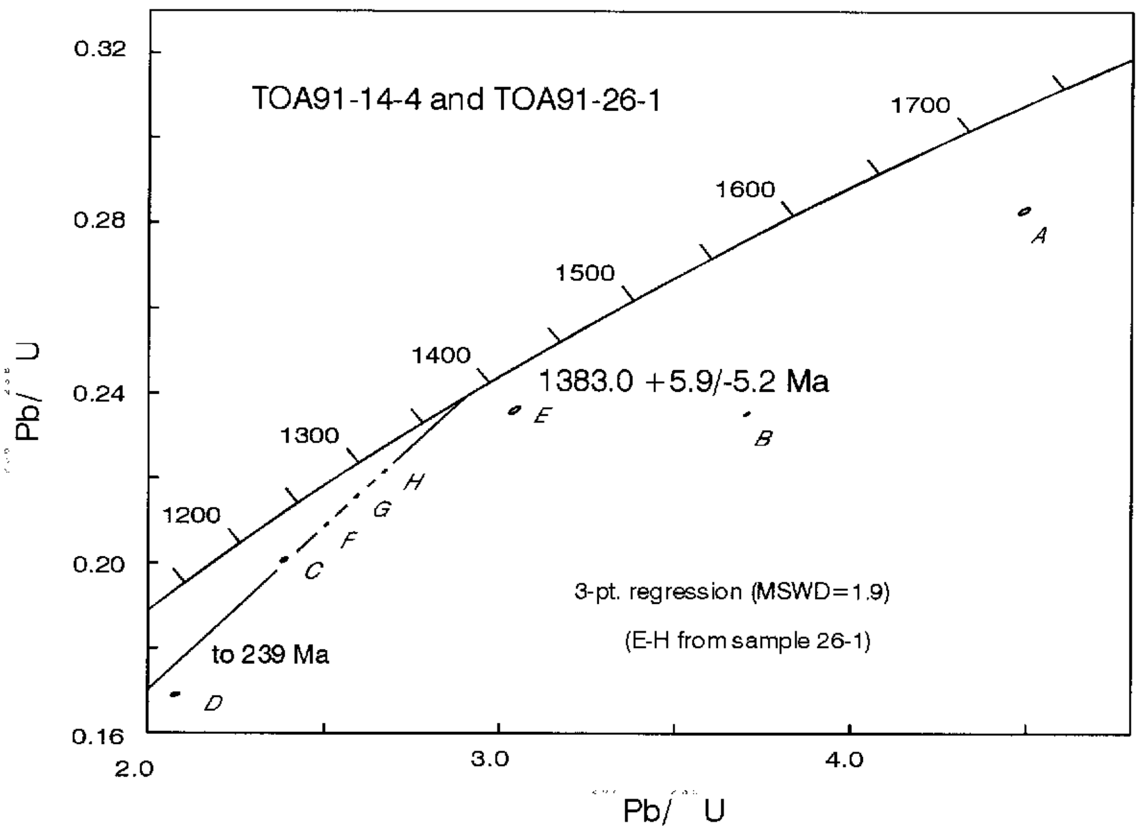


Figure 46. U-Pb concordia plot for samples TOA91-26-1 and TOA91-14-4.

project area. Although highly visible in the orange-weathering Gillespie Lake Group, the sills are difficult to see in the dark-weathering Quartet Group and might be more extensive and continue north of the exposures shown on maps by Green (1972) and Blusson (1974).

Mafic dikes and a few sills also intrude the Wernecke Supergroup in the Coal Creek Inlier (Thompson et al., 1992) and northern Wernecke Mountains (Thorkelson and Wallace, 1993b, 1994b, 1995b). All are significantly smaller and less extensive than the Hart River sills. Several dikes in the northern Wernecke Mountains have been dated by U/Pb methods and none are the same age as the Hart River sills (D. Thorkelson, pers. comm., 1996).

The nearest known igneous rocks with ages close to 1380 Ma are in central Idaho, where a U/Pb age of 1378.7±1.2 Ma was recently obtained from a diabase sill intruding the lower parts of the Middle Proterozoic Belt-Purcell Group (Doughty and Chamberlain, 1996). The sill is part of a swarm 5–8 km thick that is thought to mark the onset of the East Kootenay Orogeny, which is manifested primarily by bimodal plutonism (about 1370 Ma). The East Kootenay Orogeny is generally thought to mark the abrupt end of Belt-Purcell sedimentation, but its tectonic significance remains controversial. McMechan and Price (1982) proposed that it was a compressional event involving gentle folding and low-grade regional metamorphism followed by granitic intrusion. Doughty and Chamberlain (1996) propose that the East Kootenay Orogeny was mostly "a pulse of bimodal magmatism, basin rifting, and renewed subsidence and sedimentation that shortly preceded the end of deposition in the Belt basin".

The similarity in age between the Hart River sills and diabase in the southern Cordillera suggests that the "East Kootenay Orogeny" as defined by Doughty and Chamberlain might have been more extensive than previously thought. Ties with the East Kootenay Orogeny remain tenuous, however. No associated deformation or metamorphism has yet been recognized. In addition, no felsic intrusions are associated with the Hart River sills, and their mafic composition so far suggests that they are associated with rifting.

Cambrian sills (Ꞓd)

Cambrian sills are most abundant between Lake and Rae creeks, where they reach a thickness of about 150 m, but they cross the map area for a strike length of at least 40 km. Like the Hart River sills, they appear to be numerous, but might actually consist of one or two tectonically dismembered bodies. The sills intrude the Narchilla Formation and come within

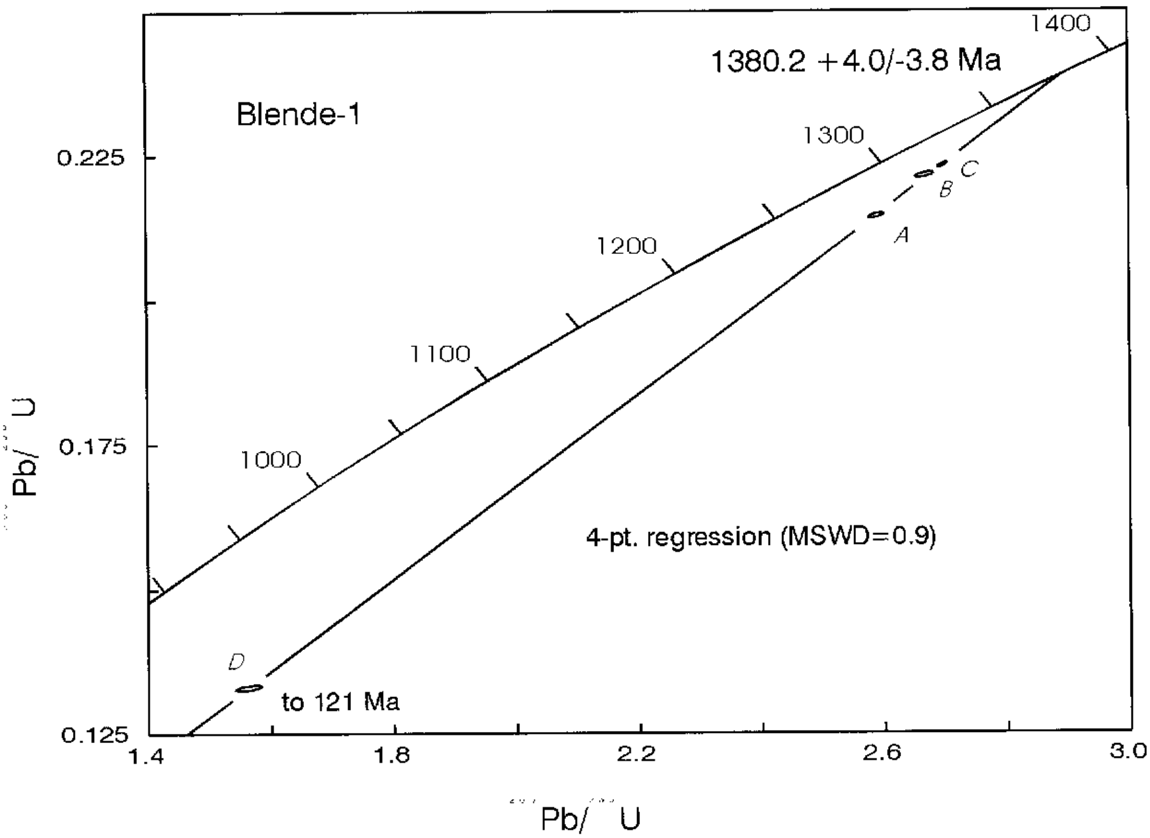


Figure 47. U-Pb concordia plot for sample Blende-1.

200 m of overlying Cambro-Ordovician volcanic rocks. The sills appear to be the most differentiated of the three groups. The thicker bodies consist of pyroxenite at the base and monzogabbro at the top. The basal parts are highly serpentinized, but primary minerals appear to have been augite with lesser amounts of hypersthene and possibly olivine.

Age and correlation

Baddeleyites obtained from one sample taken from the top of a thick sill between Rae and Lake creeks have yielded a Middle Cambrian age of 518.2±2.9 Ma (Mortensen, Appendix 3, Figure 49). This is the first isotopic age obtained for Lower Paleozoic igneous rocks in Selwyn Basin. Other age assignments for volcanic rocks are relatively imprecise and based on stratigraphic relationships and on fossil determinations, primarily from conodonts in overlying strata (Goodfellow et al., 1995). The Middle Cambrian age suggests a genetic link between the sill and the overlying Cambro-Ordovician volcanic rocks, which is implied by their spatial association. However, the absolute age range of the Middle Cambrian epoch remains only loosely constrained.

The most recent estimate of the isotopic age for the Early-Middle Cambrian boundary is 520±10 Ma, and for the Middle-Late Cambrian boundary is 515±10 Ma (Okulitch, 1995). Thus it is still unclear whether the sill was a feeder to the late Early Cambrian volcanic rocks at the base of the Gull Lake Formation, or to the volcanic rocks that overlie the Gull Lake Formation, which are probably Late Cambrian or younger. The Middle Cambrian age also corresponds to rifting associated with the Middle Cambrian Slats Creek Formation in Yukon Block.

To the west in the Dawson map area, similar sills intrude the Hyland Group and are spatially associated with Cambro-Ordovician rolcanic rocks (Thompson et al., 1992). Elsewhere in Selwyn Basin, sills are known to be associated with volcanic rocks at two localities. Metabasites in the Mount Mye and Vangorda formations in the Anvil Range are interpreted as sills and dikes that were feeders to the Early Ordovician or older Menzie Creek volcanics (Pigage, 1990). Near Macmillan Pass, sills are spatially associated with Devonian volcanic rocks (Abbott, 1983; Cecile and Abbott, 1992).

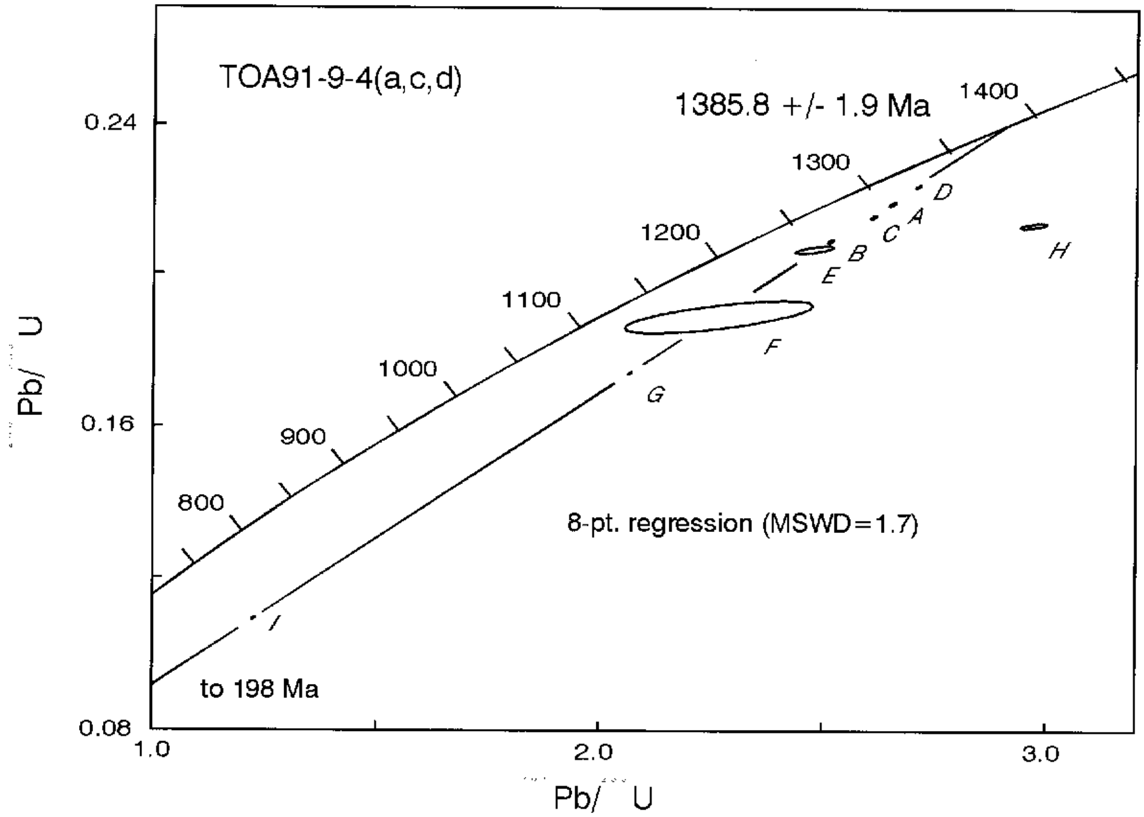


Figure 48. U-Pb concordia plot for sample TOA91-9-4a.

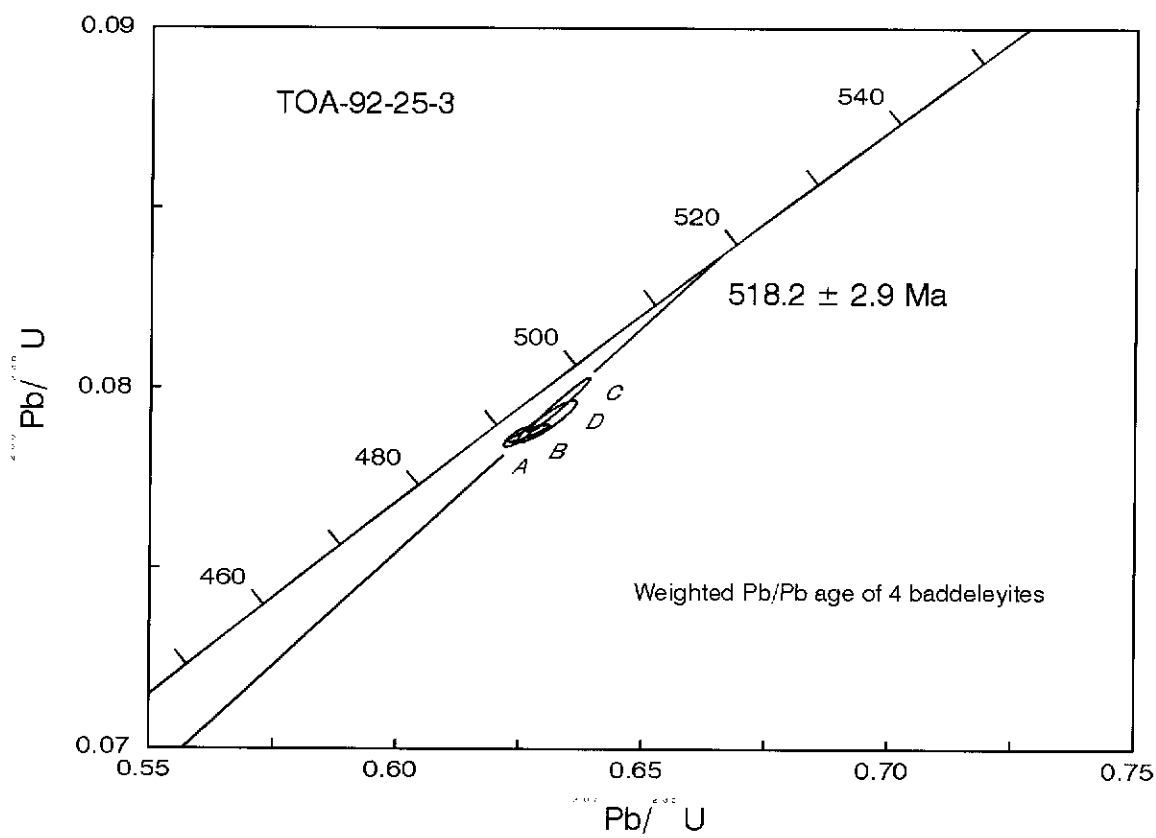


Figure 49. U-Pb concordia plot for sample TOA92-25-3.

Late Paleozoic sills (Pd)

One, and possibly more, diabase sills up to 60 m thick intrude strata as young as the Road River Group in the footwall and hanging wall of the Dawson Fault for a length of at least 50 km. The sills intrude shales as young as Early Silurian and come within about 300 m of overlying Silurian or younger volcanic rocks near Callison Creek. The sill(s) consists mainly of relict coarse-grained laths of plagioclase intergrown with clinopyroxene, and are variably altered to antigorite, chlorite and talc(?).

Age and correlation

Zircons obtained from a sample collected from the top of a sill immediately west of the map area yielded an Early Permian age of 275±34 Ma (Figure 50). Although very imprecise, this age determination appears to indicate a previously unrecognized magmatic event. There is evidence for Silurian, Devonian, and Triassic mafic magmatism in this region, and it was anticipated that the sill would yield an age consistent with one of these periods of magmatism. A Silurian age was suggested by the spatial association with Silurian volcanic rocks. A Devonian age was possible both because of the presence of Devonian volcanic rocks along the Dawson Fault about 140 km to the east in the Mount Westman map area (Abbott, 1990; unpublished fossil data), and evidence for extensive rifting associated with deposition of the Earn Group throughout the outer part of the northern Cordilleran miogeocline. A Triassic age was also possible in view of the nearby occurrence of mafic sills, which in the Dawson map area yielded a Middle Triassic U/Pb age of 232.2+1.5/-1.2 Ma (Mortensen and Thompson, 1990). The Triassic sills occur primarily south of the Tombstone Thrust Fault in the Dawson and Larsen Creek map areas, but are widespread in the footwall of the Tombstone thrust farther to the east in the Nash Creek map area.

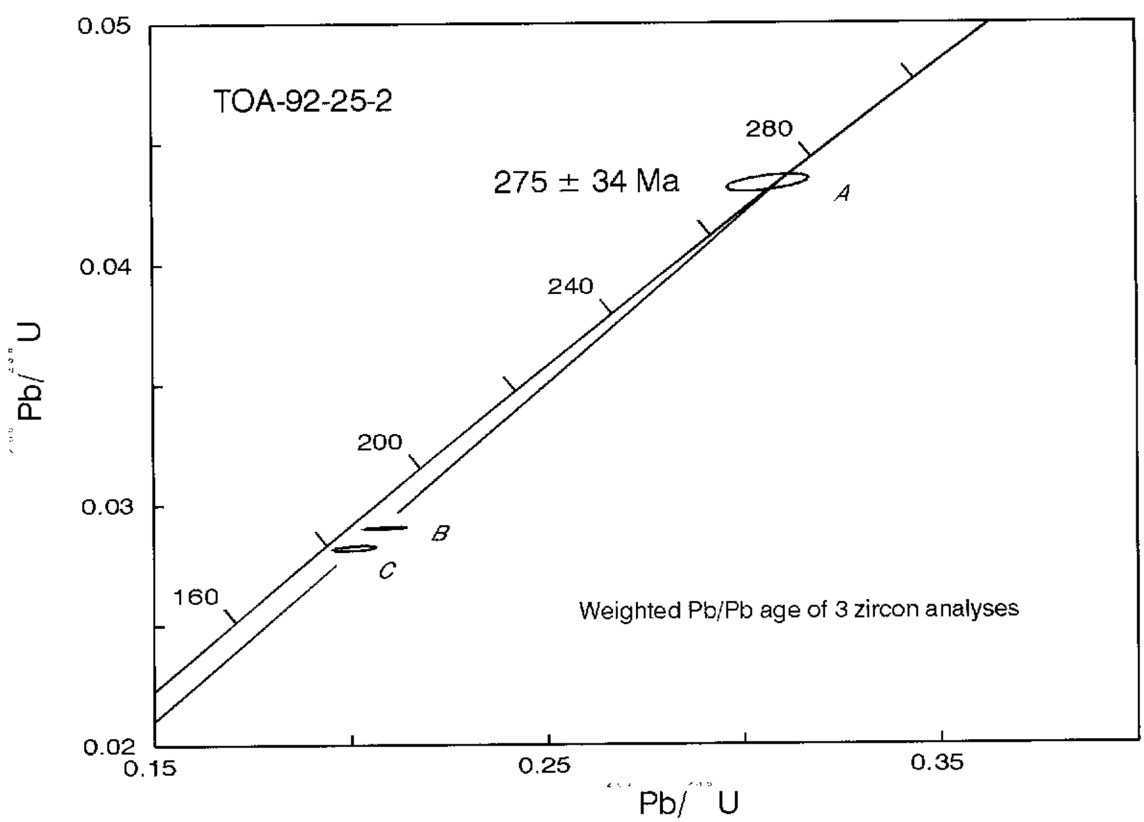


Figure 50. U-Pb concordia plot for sample TOA92-25-2.

Structure

The Hart River area records a variety of tectonic events ranging in age from Late Proterozoic through Mesozoic. Deformation is primarily Mesozoic in age and is manifested in north-directed thrust faults with associated folds and axial-plane cleavage. Older, more cryptic events include Late Proterozoic thrust(?) faulting and rifting, and Early and Middle Paleozoic rifting. Other events as old as the Early(?) Proterozoic Racklan Orogeny may also have affected the area but have not yet been recognized. Evidence for some of these events is circumstantial or comes from other areas. An important structural element is the ancestral Dawson Fault, which strongly influenced sedimentary facies and the emplacement of igneous rocks through much of the Paleozoic, Late Proterozoic and possibly earlier.

Racklan orogeny

Evidence for the Racklan Orogeny (Gabrielse, 1967) comes primarily from the Wernecke Mountains, where an early phase of folding and cleavage development and a second phase of kinking in sedimentary rocks of the Wernecke Supergroup predate emplacement of the Wernecke breccias (Thorkelson and Wallace, 1993a) at about 1.6 Ga.

In the Hart River area, Racklan deformation might have affected the Wernecke Supergroup, but has not yet been recognized. Not only was the Wernecke Supergroup mapped in a small part of one 1: 50 000 scale map sheet, but it is intruded by the voluminous Hart River sills, which might mask older structures.The one phase of folds and axial plane cleavage in the Gillespie Lake Group is similar in trend (east-west) and style as Mesozoic structures in younger rocks. Although the Pinguicula overlies the Gillespie Lake Group with angular unconformity, the Gillespie Lake Group dips south beneath it in a monocline that has the same strike as overlying strata. Weakly developed, widely spaced fractures, which predate folding and cleavage development in the Gillespie Lake Group, might reflect Racklan deformation, but the effect is subtle.

The nature of Racklan deformation is not well known, but maps by Thorkelson and Wallace (1993b, 1994b, 1995b) indicate that Racklan structures are sporadically distributed and not present everywhere. This sporadic pattern resembles that proposed by Cook and MacLean (1995) for the Forward Orogeny. The Forward Orogeny, which was documented by analysis of seismic records from the Colville Hills east of the Mackenzie River, is constrained to the same approximate age as the Racklan Orogeny, and might be equivalent. Cook and MacLean showed that Forward structures consist mainly of discontinuous, widely spaced, high-angle reverse faults and related folds, with a variety of orientations and inconsistent vergences. They included an early phase indicating northwest-southeast compression and a later phase indicating east-west compression. Cook and MacLean likened the Forward structures to those that characterize thick-skinned deformation in some intracratonic mobile belts, such as the Rocky Mountain Foreland of the United States, but emphasized the relatively small size of the Forward structures. Thus in the Hart River area, the Wernecke Supergroup may have undergone Racklan deformation, but structures may be too widely spaced to appear in the small area mapped.

Late Proterozoic reverse(?) faulting

Significant differences in levels of erosion beneath Paleozoic dolostone, and, locally, the Mount Harper Group across four Mesozoic thrust faults, suggest that they may be reactivated Late Proterozoic thrust faults. The Callison Lake, upper Rae Creek and lower Rae Creek thrust panels (Figure 51) form an en echelon belt where much greater thicknesses of Upper Proterozoic strata have been removed than elsewhere. North of these panels, uppermost strata of the Pinguicula Group (unit PPD3) and, locally, the Callison Lake dolostone, are preserved beneath Paleozoic dolostone. On the south side beneath the Paleozoic dolostone, the Mount Harper Group unconformably overlies the Callison Lake dolostone, and older strata are not exposed. Within the anomalous thrust belt, each thrust panel displays different stratigraphic relationships. In a small inlier along Rae Creek, in the lower Rae Creek thrust panel, Paleozoic dolostone unconformably overlies strata as old as the Quartet Group and the Hart River sills, indicating removal of at least one kilometre of strata, which are preserved in the footwall of the fault. These include all of the Pinguicula Group and the Callison Lake dolostone. In the upper Rae Creek thrust panel, Paleozoic dolostone unconformably overlies Pinguicula Group quartzite (unit PPD1), indicating removal of the Callison Lake dolostone and units PPD2 and PPD3 of the Pinguicula Group. In the Callison Lake thrust panel, west of Callison Lake, in a small block bounded on the south by the Marc Creek Fault, diamictite (unit PHdi1) tentatively correlated with the Mount Harper Group unconformably overlies a Hart River sill and units PPA and PPB of the Pinguicula Group at an angle of at least 30 degrees. Along the northern margin of map sheet 116A/10, Lower Paleozoic carbonate overlies strata as old as the Quartet Group in the hanging wall of the Noname thrust, but only as old as the Gillespie Lake Group in the footwall. Unlike the other faults, the age of movement on the fault is not constrained by

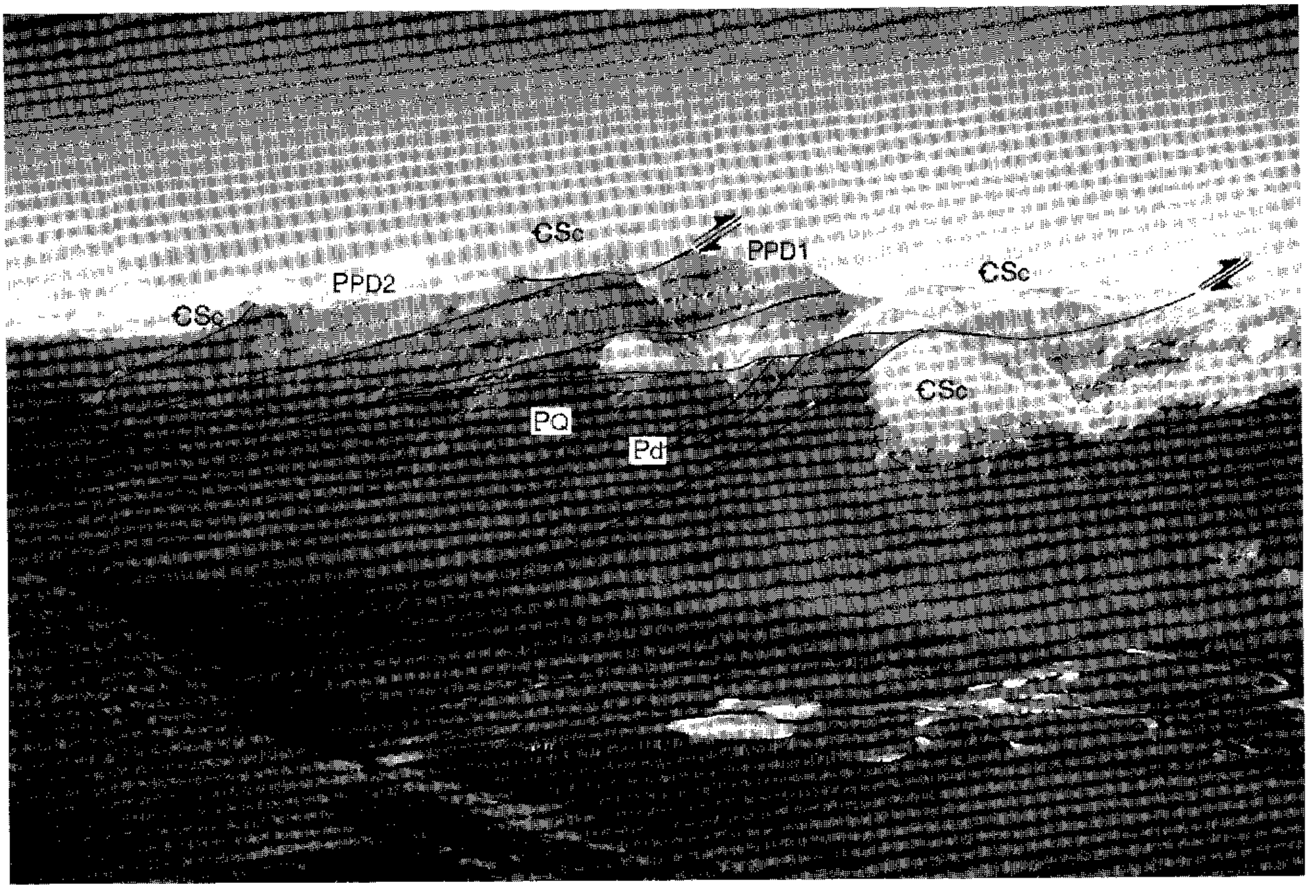


Figure 51. View west across Rae Creek to the upper and lower Rae Creek thrust faults. In the hanging wall panel of the upper Rae Creek thrust fault, Paleozoic carbonate unconformably overlies unit D1 of the Pinguicula Group. In the footwall of the Lower Rae Creek thrust fault, the dolostone overlies unit D3 of the Pinguicula Group (not shown in picture). In the thrust panel between the two faults, the dolostone unconformably overlies the Quartet Group, indicating pre-Paleozoic erosion of at least 1000 m more strata than in the adjacent thrust panels. This discrepancy is interpreted as reflecting uplift and erosion related to Late Proterozoic rifting.

the presence of the Pinguicula Group or Mount Harper Group and could therefore be older.

The southern dip of the faults and of strata in their hanging walls makes it impossible to attribute the discordance in erosional levels to normal faulting. Reverse faulting, and by implication, compressional deformation is the only alternative. Deformation must post-date the Callison Lake dolostone and pre-date the Mount Harper Group, and is therefore late Middle or early Late Proterozoic in age.

In the Wernecke Mountains, Eisbacher (1980) and Thorkelson and Wallace (1995a) described west- to southwest-verging thrust faults that involve the Pinguicula Group but not the overlying Windermere Supergroup. No others are reported from the northern Canadian Cordillera and their regional tectonic significance remains unclear.

Late Proterozoic rifting

The coarse diamictites of the Mount Harper Group strongly suggest rifting and sedimentation along syndepositional fault scarps. Potential candidates are the Callison Lake thrust and the Marc Creek fault. The Callison Lake thrust is a possibility because all of the Mount Harper Group occurs in a narrow belt in several thrust panels located structurally above and south of it. There is no direct evidence of early normal movement on the thrust, however. The Marc Creek fault marks the southern boundary of an anomalous block in the hanging wall of the Callison Lake thrust. Within it, diamictite (unit PHdi1) tentatively correlated with the Mount Harper Group unconformably overlies a Hart River sill and units PPA and PPB of the Pinguicula Group of at least 30°. On the south side of the block in the hanging wall of the fault, the upper parts of the Pinguicula Group (unit PPD3?) and the Callison Lake dolostone are preserved beneath diamictite. Normal movement on the fault may have removed as much as part of unit PPB and all of units PPC, PPD1 and PPD2 before deposition of unit PPDi1. The age of unit PHdi1 is critical in determining the age of uplift and erosion. If it is the same age as the other diamictites (Lower Mount Harper Group), uplift and erosion must have occurred before deposition of the Mount Harper Group. Alternatively, unit PHdi1 might be younger, and equivalent to the Upper Mount Harper Group.

In Yukon Block, Late Proterozoic rifting is manifested primarily by the Mount Harper Group and coeval structures near the Dawson Fault in the Coal Creek inlier and the Hart River area. Other less well developed Late Proterozoic faults have been documented in the Wernecke Mountains, where Eisbacher (1980) and Thorkelson and Wallace (1995a) described west- to northwest-trending normal faults that controlled deposition of coarse clastic rocks assigned to the Sayunei Formation at the base of the Windermere Supergroup.

In contrast to the east-west trend of most structures in Yukon Block, synsedimentary faults associated with deposition of the Windermere Supergroup in the Mackenzie Mountains (Eisbacher, 1981: Figure 4) trend north to northeast. The difference between the orientation of these structures and those in Yukon Block has not yet been explained. One possibility is that they reflect the orientation of underlying basement structures.

Paleozoic rifting

In the Hart River area, the Dempster volcanics are associated with tectonism. Lower Cambrian and Silurian volcanics also indicate more subtle rifting. The abrupt changes in stratigraphic relationships between the Dempster volcanics and both underlying and overlying strata indicate uplift, erosion and block faulting before, during, and possibly after deposition of the volcanics. Syndepositional faults have not yet been mapped, and have probably been masked by Mesozoic thrusting and folding. The Middle Cambrian age of a sill associated with the volcanic rocks suggests that rifting began at that time.

The Dempster volcanics might reflect a widespread rift event. If there is, as seems likely, a widespread unconformity at the base of the Dempster volcanics in the Hart River area, in the Dawson map area, and beneath the Fossil Creek volcanics in Alaska, it might represent thermal uplift and erosion caused by rifting, and crustal attenuation followed by crustal cooling accompanied by subsidence and volcanism. 'Breakup unconformities' such as this are characteristic of continental rift environments (Bond and Kominz, 1984). Elsewhere in Selwyn Basin, the widespread Late Cambrian unconformity, which has been documented at the base of the Rabbitkettle Formation and equivalent Late Cambrian and Ordovician strata, might be correlative and a further indicator of widespread Middle to Late Cambrian rifting. Certainly, in the northeast corner of Selwyn Basin, Cecile (1982) documented Middle Cambrian rifting, subsidence, and deposition of a thick flysch sequence (Hess River Formation) within Misty Creek Embayment, all of which occurred while the flanks underwent uplift and erosion. The Dempster volcanics are similar in age to the voluminous Menzie Creek volcanics in the Anvil Range and the groundhog volcanics in the Pelly Mountains. On Ogilvie Platform, widespread Middle Cambrian uplift, erosion, block faulting, and volcanism is documented by alluvial and marine siltstone, sandstone, conglomerate and greenstone of the Slats Creek Formation, which is preserved in grabens beneath the angular unconformity at the base of the overlying Ordovician carbonates (Green, 1972; Fritz et al., 1992). In northern British Columbia, Middle Cambrian block faulting has also been documented in the Kechika Trough (Fritz et al., 1992).

The coincidence of mafic volcanic rocks at the base of the Gull Lake Formation both in the Hart River area and the McQuesten map area (Murphy, 1996), and the possibility of a disconformity at that stratigraphic level, suggest a similar but less pronounced rift event in late Early Cambrian time.

The Silurian volcanic rocks also occur above a widespread disconformity at the Ordovician-Silurian boundary. Silurian volcanic rocks occur locally along the eastern margin of Selwyn Basin, but no other evidence for rifting at that time has been documented.

The possibility of the volcanic rocks being associated with specific, widespread rift events, as proposed above, is clouded by a lack of precise age control on many of the widespread accumulations of alkalic volcanic rocks that occur throughout Selwyn Basin and elsewhere in the outer portions of the Cordilleran miogeocline (Goodfellow et al., 1995). Although some closely correlate in time to those in the project area, most are loosely constrained to a Late Cambrian through Ordovician age, and a few are Early Cambrian, Early Silurian or Devonian. The hypothesis that volcanism within Selwyn Basin and Cassiar Platform reflects widespread, short-lived pulses of rifting can only be verified with more precise age control than that presently available.

Mesozoic deformation

West-northwest-trending, moderately south-dipping thrust faults typify Mesozoic deformation in the map area. The intensity of deformation, amount of shortening and grade of metamorphism all increase from north to south. Two phases of faulting and cleavage development have been recognized locally south of the Dawson Fault, but only one is present on the north side. The faults generally display a flat and ramp geometry typical of the Cordilleran foreland thrust and fold belt. The complicated and incompletely understood Proterozoic stratigraphic and structural history make construction of complete, balanced cross-sections impossible, however. There is enough evidence to suggest that all thrust faults in the area may root in the same detachment, and that the amount of displacement on the Dawson Fault, in spite of the great dissimilarity of strata juxtaposed across it, is not significantly greater than the amount of displacement on adjacent thrust faults.

Structures north of the Dawson Thrust

North of the Dawson Thrust, thrust faults appear to root in the Quartet Group along a single, flat-to-gently-south-dipping detachment (see map cross-sections). It is not certain, however, whether the detachment stays in the Quartet Group as it approaches the Dawson Fault. The tremendous thickness of Middle to Late Proterozoic strata in the south and their complete absence in the north, combined with the fact that overlying Paleozoic carbonate remains at roughly the same elevation in the south and north, requires that the detachment steepen to the south or climb upsection to the south, contrary to common patterns of thrust fault development. The second alternative was arbitrarily chosen. A further complication is the presence of normal faults of uncertain age and origin. These include the Callison Lake normal fault and other normal faults to the north, which cut Proterozoic strata but have a poorly constrained age. These faults could be either younger or older than the thrusting. They have been portrayed in cross-sections as listric and being rooted in the same detachment as the thrusts, although there is no direct evidence for this relationship.

Only rough estimates of the amount of shortening are possible. North of the Dawson Fault, stratigraphic throw ranges approximately from 500 m to 2 km, and displacements appear to be about the same or slightly greater. In map sheet 116A/10, where the faults are best exposed, about eight faults with minor splays are exposed in any given cross-section. An estimate of an average one km of displacement per thrust gives a total of eight km of shortening across 25 km, or 25% shortening.

Structures south of the Dawson Thrust

All of the thrust faults south of and including the Dawson Thrust are inferred to root in a single detachment in the Yusezyu Formation of the Hyland Group, with faults cutting progressively deeper in the section from north to south. The Lake Creek thrust is the largest and includes an upper and lower splay. Combined displacement is estimated to be at least four km. Displacement on other faults is significantly less, but accurate estimates of displacement are not possible.

Within each thrust panel, tight to isoclinal folds with steeply south-dipping axial planes accommodate a significant portion of the shortening. The intensity of folding increases to the south, and in southernmost exposures west of Lake Creek (Figure 52), Ordovician chert clearly defines upright isoclinal folds with a wavelength of about 700 m and an amplitude of about 700 m, indicating about 50% shortening. The style of deformation resembles that documented in eastern Selwyn Basin by Cecile (in press) in equivalent Ordovician chert.

Two phases of deformation are apparent in one locality between Lake and Rae creeks, where the basal quartzite of the Gull Lake Formation forms a marker that defines two splays of an early north- or northwest-directed thrust fault. The two splays have been folded about west-plunging folds (see Section A-A' on map sheet 116A/11). The quartzite also defines interference patterns in which a first-phase syncline is arched around a west-plunging second phase anticline. Beneath the anticline, displacement appears to have been taken up by reactivation of the early thrust fault. Two superimposed sets of cleavage are also prominent in the area, but a detailed structural analysis was not undertaken.

It is unclear whether the two superimposed phases of deformation correlate with the dominant regional phase or if they represent two separate phases of deformation. A locally developed second phase of reverse faulting is most easily explained as a late, out-of-sequence phenomenon, and is the preferred alternative.

Elsewhere west of Rae Creek, complex map patterns, such as those defined by repetitions of Ordovician and Silurian limestone south of the Lake Creek thrust, suggest that more than one phase of deformation is present at least locally in other areas.

East of Callison Creek, in the hanging wall of the Dawson Thrust Fault, two phases of minor structures are strongly developed in a fault-bounded panel containing Cambro-Ordovician volcanic rocks, and shale and quartzite of the Gull Lake Formation. Also in the panel is an unusual normal fault, the significance of which is unclear. The two phases of penetrative fabrics and minor folds in this block contrast with the less weakly deformed shales of the Road River Group on either side. This second phase of structures might reflect local deformation confined to one fault block, and might not correlate with the second-phase structures seen farther west.

Dawson Thrust

Estimating the amount of displacement on the Dawson Fault is especially difficult because bedding in rock units in both the hanging wall and footwall generally parallel the fault. Although this relationship

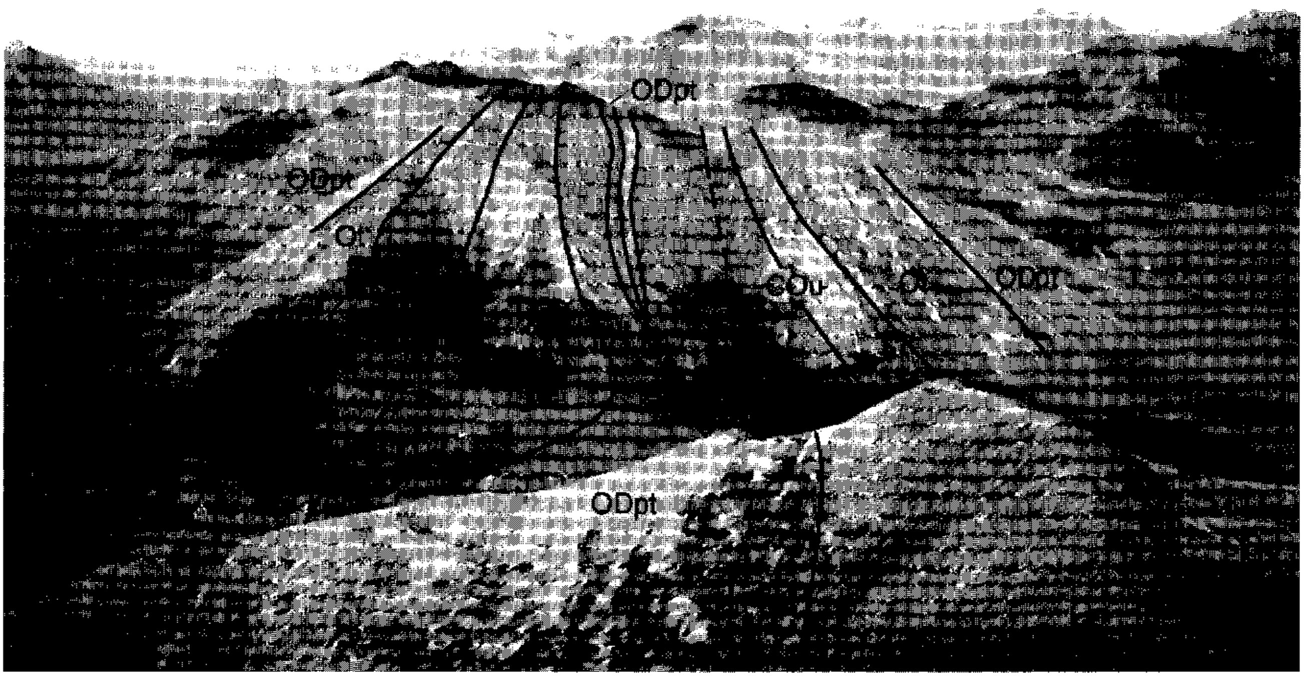


Figure 52. View west across Lake Creek to large-scale, upright isoclinal folds in chert and shale of the Road River Group. Deformation this intense is only seen south of the Lake Creek thrust fault, and contrasts with the small amount of internal deformation in thrust sheets in the northern portions of the project area (see Figure 51).

suggests that a significant amount of shortening is possible, sections can be constructed across the fault that suggest offset could be as little as two to four km. For almost its entire length within the map area, the Dawson Fault places the Gull Lake Formation on the Road River Group. If the base of Cambro-Ordovician carbonate is used as a datum on the north side of the fault, and the base of the Road River Group is used on the south side, the stratigraphic offset is only about 500 m, which further supports a small amount of displacement. Support is also provided by the lithological similarity of the Road River Group on both sides of the fault, particularly at the eastern end where the same(?) sill intrudes black shales of the same age on both sides.

The moderate dip, the spacing with respect to adjacent faults to the north and south, and the amount of stratigraphic offset on the Dawson Fault are similar to other thrust faults in the area. Certainly there is no evidence that the Dawson Fault records displacements in the order of tens of kilometres, like the Tombstone and Robert Service thrusts, which are structurally higher detachment surfaces located about 30 and 40 km to the south.

Paleotectonic significance of the Dawson Thrust

The Dawson Fault is a remarkably linear Mesozoic thrust fault more than 200 km long, which has a moderate amount of shortening, and two very different assemblages of rocks sharply juxtaposed for its entire length. Not only do the basinal sedimentary sequences on the south side differ from the mostly shallow-water sequences on the north, but many of their ages also differ. Mafic volcanic and intrusive rocks ranging in age from Middle Proterozoic through Upper Paleozoic are in much greater abundance near the fault than in equivalent sequences elsewhere. The fault trends generally west across the northwest grain of the Canadian Cordillera. These characteristics infer that the fault reflects an ancient underlying basement structure, which repeatedly influenced patterns of sedimentation, igneous activity, and faulting. The following aspects of the regional geology might reflect influence by the basement fault:

1. The Hart River sills are confined to a broad band that follows the north side of the fault.

2. The level of exposure of Proterozoic rocks changes abruptly across the fault from the Lower, Middle and Late Proterozoic Wernecke Supergroup, Pinguicula Group and Mount Harper Group on the north, to the younger rift-related sediments of the Hyland Group on the south, indicating a major basement fault or flexure during the Late Proterozoic. The fault is the northern limit of the Hyland Group. Either the north side of the ancient Dawson Fault was high-standing during latest Proterozoic rifting and the Hyland Group was never deposited, or Hyland Group strata were eroded during Middle Cambrian uplift and erosion. In either case the ancient Dawson Fault controlled the northern boundary of the Hyland Group.
3. Late Proterozoic reverse faulting and rifting, manifested by the Mount Harper Group, was focused near the fault.
4. The fault is the northern limit of the Gull Lake Formation. Either the north side of the ancient Dawson Fault was high standing during Early and Middle Cambrian time and the Gull Lake Formation was never deposited, or Gull Lake equivalent strata were eroded during Middle Cambrian uplift and erosion. Coarse clastic rocks present at the base of the Gull Lake Formation on the south side of the fault could have been shed from a high-standing Yukon Platform on the north side, which would suggest the first alternative.
5. Late Early Cambrian Gull Lake volcanics, the Cambro-Ordovician Dempster volcanics, Middle Ordovician volcanics (Green, 1972), Early Silurian, and Devonian volcanics (Abbott, 1990a, b; unpublished data) and Upper Paleozoic sills are concentrated near the fault.
6. The southern boundary of the Lower Paleozoic shelf-carbonate rocks coincides with the fault.

Figure 53 illustrates these abrupt stratigraphic changes across the Dawson Fault in a schematic, restored cross-section and compares them with the gradual changes seen in a more typical cross-section from Abbott et al. (1986) through the Cordilleran miogeocline in eastern Selwyn Basin. On the north side of the Dawson Fault, the Lower Proterozoic through Upper Paleozoic age range of exposed strata, the predominant shallow-water environment of deposition, and the relatively thin Late Proterozoic and Paleozoic sequence, indicate that Yukon Block underwent little subsidence and crustal attenuation after the Early Proterozoic. On the south side, in contrast, the tremendous thickness of coarse clastic rocks of the Hyland Group, the absence of older exposed strata, and deep-water environment of deposition of most strata indicate significant subsidence and crustal attenuation, most of which must have accompanied deposition of the Hyland Group. The ancestral Dawson Fault acted as a remarkably sharp rift boundary during deposition of the Hyland Group. The absence of a broad zone of crustal attenuation and subsidence prevented the accumulation of the thick wedge of Late Proterozoic and Paleozoic sedimentary rocks that separate platform and basin throughout most of the Cordilleran miogeocline (Abbott et al., 1986; Gordey and Anderson, 1993). An older structural history is indicated by the Hart River sills (Middle Proterozoic) and Mount Harper Group (Late Proterozoic). This older history — coupled with the peculiar sharpness of the boundary, its consistency over a length of 200 km, and its unusual orientation — suggest that the ancestral Dawson Fault could have been a very old basement structure, the earliest history of which predates deposition of Early Proterozoic supracrustal strata.

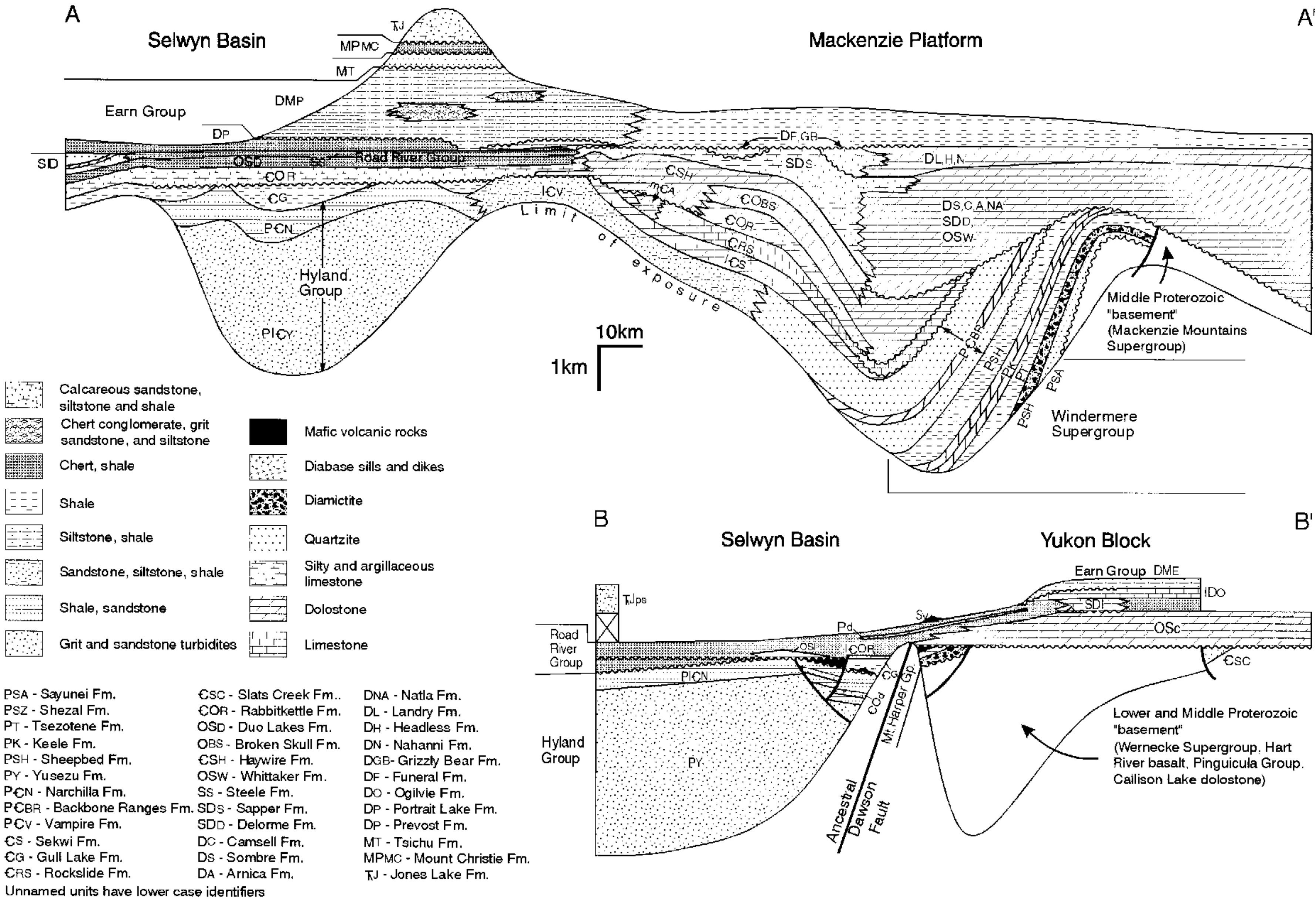


Figure 53. Restored stratigraphic sections in Late Proterozoic and younger strata across Selwyn Basin and Mackenzie Arch (A-A') in eastern Yukon, and across Selwyn Basin and Yukon Block in the project area (B-B'). The location of sections is shown in Figure 1. Section A-A' is modified from Abbott et al., 1986 and was generated from maps and sections by Gordey, 1981, 1982; Gordey and Anderson, 1993; and by Gabrielse, Blusson, and Roddick, 1973.

Economic Geology

Known mineral deposits and occurrences in the project area all appear to be related to the Hart River sills. They include the Hart River massive sulphide deposit and several copper-bearing quartz veins. All were discovered by prospecting and were explored in the 1950s and 1960s. Advanced exploration was done only on the Hart River deposit, where surface and underground drilling defined the deposit. Other occurrences were explored with geochemical surveys, sampling and hand trenching. Most of the more recent exploration occurred during the 1970s, when companies undertook extensive regional geochemical and radiometric surveys across Selwyn Basin and Ogilvie and Mackenzie platforms. These programs focused on the potential for sedimentary exhalative base metal deposits in black shales of the Road River and Earn groups, carbonate-hosted lead and zinc deposits, and uranium related primarily to the Wernecke breccias. In the project area, these efforts resulted in only two weak-stream geochemical anomalies with no known lode sources. Recent exploration has only been undertaken on the Hart River deposit, which was explored in 1994 and 1995 with geophysical surveys and diamond drilling.

The Hart River area is underexplored relative to other areas with similar geology in the northern Cordillera. This study has revealed several sedimentary units with underevaluated potential, which are discussed in the section on exploration potential.

Known mineral deposits, occurrences and work targets

The following descriptions include information from Yukon Minfile, assessment reports, Department of Indian Affairs and Northern Development (DIAND) reports, and the writer's examination of some occurrences. Only geological information is included here. Work history, ownership and other information is provided in Yukon Minfile. Locations are shown on the 1:50 000 map accompanying this report.

Hart River massive sulphide deposit (Yukon Minfile No. 116A-09)

The Hart River massive sulphide deposit includes two en echelon, steeply south-dipping, west-plunging, lens-shaped bodies. In 1969, total proven reserves were calculated to be 523 849 t with an average grade of 3.65% Zn, 1.45% Cu, 0.87% Pb, 49.7 g/t Ag, and 1.41 g/t Au (Hart River Mines Ltd., Annual Report). The No. 1 zone is up to 119 m in strike length, between 4.6 and 15 m wide and has a plunge length of at least 183 m. Proven reserves are 462 728 t grading 3.6% Zn, 1.45% Cu, 0.9% Pb, 49.7 g/t Ag and 1.41 g/t Au. In the No. 2 zone, proven reserves are 61 122 t grading 3.65% Zn, 0.96% Cu, 0.7% Pb, 40.8 g/t Ag and 1.03 g/t Au. Both zones are open to depth, and probable tonnage was estimated at about 544 000 t of a similar grade.

The only surface exposure is near the crest of a north-trending ridge and consists of a narrow, bright-orange gossan in which all sulphides are oxidized (Figure 54). Most of the information about the deposit comes from diamond drill core, which is now lost, and from underground workings at the 3880 level, which are accessible but difficult to map because no water is available to wash the walls. A second adit at the 3680 level does not reach the deposit. The following description is derived from reports by Usher and MacDonald (1968, unpubl.), Guardia (1971, unpubl.), Olsson (1973, unpubl.) and Morin (1979), and from a brief examination by the writer.

The deposit is located in a west-plunging anticline, primarily beneath the Hart River volcanics in shales assigned to unit Gl of the Gillespie Lake Group (Figure 55). The two zones are oriented roughly parallel to the axial plane and cleavage of the fold, and rake down the fold axis. The No. 2 zone is about 15-30 m above the No. 1 zone, but is not exposed at the surface. Guardia described four sets of faults, all of which cut the deposit. West-trending, high-angle reverse faults are associated with the anticline and three sets of younger faults have the following orientations: northwest-trending and moderately southwest-dipping; west-trending and moderately to shallowly north-dipping; and north-trending and moderately west dipping. Replacement of shear zones by sulphides attests to poorly understood pre- or synmineralization faulting.

Three types of mineralization are reported: banded ore; massive ore; and mineralized andesite. Banded ore is described by Guardia as having preserved bedding in which sulphides selectively replaced certain layers, and which grade from unmineralized argillite to totally replaced argillite over several feet. The banded mineralization appears to mantle the massive sulphide core of the No. 1 zone, and makes up most of the No. 2 zone. Massive ore consists of at least 90% sulphide with quartz and dolomite gangue as cavities and irregular veins and patches. Geological relationships suggest that massive sulphides replaced both argillite and andesite. Mineralized andesite is developed locally in the No. 1 zone, where sulphides preferentially replace shear zones and margins of fractures, and fill cavities in intense breccias.

The sulphide minerals are mainly pyrite and pyrrhotite, with lesser amounts of sphalerite, galena, and chalcopyrite, and traces of tetrahedrite, tennantite and the argyrodite-canfieldite sulphosalt series

Figure 54. View west to the west-plunging anticline containing the Hart River massive sulphide deposit (gossan). The deposit cuts both shale of the Gillespie Lake Group (unit PG1) and the Hart River basalt. The deposit is probably related to the mafic sill in the core of the anticline. Both the sill and the deposit are interpreted as having been emplaced shortly after deposition of the Hart River basalts.

(Olsson). Morin described a crude metal zonation in the No. 1 zone, where copper and gold are concentrated in the eastern portion and lead and zinc in the west.

Petrological studies by Zentilli (in Usher and MacDonald) and Olsson, as well as mesoscopic textures observed by Usher and MacDonald, and by Guardia indicate that primary textures were mostly destroyed by later deformation and annealing. Foliation and cataclastic textures are locally prominent in the deposit.

Early workers (Usher, MacDonald and Guardia) strongly argued that the deposit was epigenetic. Later workers (Zentilli, Olsson and Morin) suggested a syngenetic origin. Zentilli, whose work was mostly petrographic, interpreted spherulitic pyrite seen in one specimen as being primary and suggested the possibility of a syngenetic origin. Olsson, whose work was also mostly petrographic, cited preservation of bedding in the banded ore as evidence for syngenesis. Usher and Macdonald, however, while acknowledging Zentilli's evidence for syngenesis, described macroscopic evidence for selective replacement along bedding. Morin also argued that the sulphide-bearing breccias were synsedimentary, that a vein stockwork and silicified zone on the northern margin of the No. 1 zone represented a feeder zone, and that the metal zonation within the deposit was typical of a volcanogenic deposit. Given the intense deformation of the deposit, however, it is unlikely that the breccias conclusively demonstrate a synsedimentary origin. The other features cited by Morin are equally likely to be features of epigenesis. After recent re-examination of the deposit, Morin (pers. comm., 1996) considered it to be epigenetic. Certainly there is no conclusive evidence for a syngenetic origin. The deposit is most likely epigenetic, given its position beneath the Hart River volcanics (or sill), its overall orientation across the general trend of bedding, and the evidence for replacement cited by early workers.

Lead isotope ratios from galena indicate a Middle Proterozoic age for the Hart River deposit (Godwin et al., 1988) roughly the same as the U/Pb age of the Hart River sills; the two are almost certainly re-lated. Replacement of andesite indicates that mineralization postdates volcanism. Perhaps the thick, coarse-grained sill beneath the deposit was emplaced shortly after volcanism, and is related to mineralization.

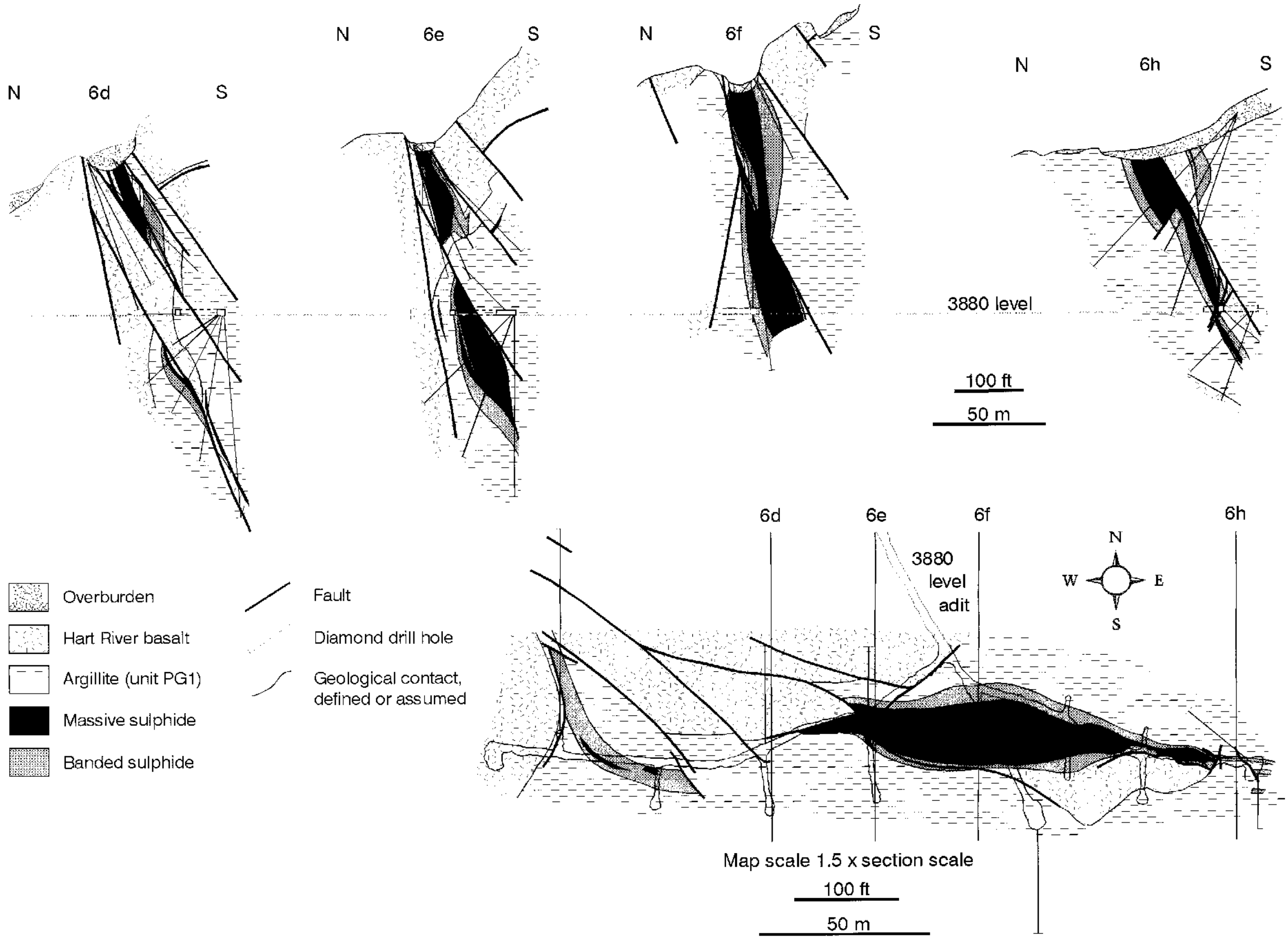


Figure 55. Plan and cross-sections of the Hart River massive sulphide deposit (from illustrations by Alrae Engineering in BSc thesis by Olsson (1973). These diagrams indicate that the deposit cuts and replaces shale of unit PG1 and the Hart River basalt.

The Hart River deposit, although probably epigenetic, formed close to the surface and should be classified as a volcanogenic massive sulphide deposit. It could represent a feeder to a syngenetic deposit which was deposited above the volcanic rocks and which has since been eroded away.

Soup Vein (Yukon Minfile No. 116A-05)
(From Yukon Minfile 1995)

Quartz veins containing chalcopyrite were found near mafic sills cutting the Gillespie Lake and Quartet groups in two areas about three km apart.

Belcarra Vein (Yukon Minfile No. 116A-10)
(From an unpublished report by P. Holcapek)

A few small occurrences of chalcopyrite, galena and sphalerite are in hornfels-rich siltstone and shale of the Quartet Group and dedolomitized white marble of the Gillespie Lake Group along the southern margin of a mafic intrusion. Trenching indicated that mineralization is erratic over a length of 250 m.

Zebra (Zebra #4) Vein (Yukon Minfile No. 116A-11)
(From examination by the writer and assessment report No. 019103 by R. G. Hawley and R. Philp)

A vertical, north-trending, quartz-carbonate vein containing erratically distributed clots of chalcopyrite is oriented parallel to, and about 40 m east of, a narrow mafic dike (examination by the writer). Both vein and dyke cut the Quartet Group and emanate from a thick, west-trending mafic sill, which is located about 70 m north of the nearest vein exposure. The vein is almost two m wide at its northern end, and gradually narrows to the south, where it is exposed on a series of hand trenches over a strike length of about 200 m. The vein cuts shale of the Quartet Group, which is altered and silicified for about 1 m on either side. A chip sample across the north end of the vein is reported to have returned assays of 0.14 g/t Au, 249 g/t Ag, and 6.85% Cu across 1.2 m (Assessment Report No. 019103 by H. Briden).

Hawley Vein (Yukon Minfile No. 116A-34)
(Formerly Zebra No. 3, 10: Part of Yukon Minfile No. 116A-11; from examination by the writer and assessment report No. 019103 by R. G Hawley and R. Philp)

A creek cut exposes a concordant lens of massive chalcopyrite with minor pyrite and quartz in steeply south-dipping shale in the Gillespie Lake Group(?). The occurrence is up to 30 cm across and at least ten m long, with knife-sharp contacts. Both ends of the lens grade to narrow stringers of quartz and siderite. The sulphide lens is associated with nearby quartz-carbonate veins and stringers with minor chalcopyrite and pyrite.

Sulphide-rich float boulders up to 50 cm wide are fairly abundant in the main creek about 200 m upstream from the main showing. The boulders consist of massive and brecciated vein quartz with up to 60% pyrite and small amounts of arsenopyrite. An arsenopyrite-bearing specimen is reported to have assayed 5.14 g/t Au and 5.14 g/t Ag.

Briden Veins (Yukon Minfile No. 116A-35)
(Formerly Zebra No. l, 2; Part of Yukon Minfile No. 116A-11; from assessment report No. 019103 by R. G. Hawley and R. Philp)

Showing No. 1 is a very irregular quartz vein or series of en echelon pods cutting a serpentinized sill. The vein strikes roughly north and dips vertically to steeply to the east. It is exposed for a length of 25 m and varies from 30 cm to 2 m wide. Malachite and minor chalcopyrite occur mainly at cross-shears in the vein. The maximum possible length of the vein is about 300 m, with most of the potential to the north of the exposure. Three chip samples across the zone are reported to have assayed: 0.47% Cu across three m; 1.67% Cu across 60 cm; trace Cu across 60 cm; and all with trace Au and Ag.

Showing No. 2 is exposed about 75 m upstream from showing No. 1 over an area about three m by two m, on the same slope. It consists of a steeply dipping, northwest-trending shear zone in a mafic sill, which, from southwest to northeast, contains malachite and minor chalcopyrite over 60 cm; minor chalcopyrite in fractures over 60 cm; and 45 cm of massive chalco-pyrite. The maximum possible length of the zone is 20 m. A two-m chip sample across the widest part of the zone assayed 12.55% Cu, 95.3 g/t Ag and trace Au.

Holcapek Vein (Yukon Minfile No. 116A-36)
(Formerly part of Belcarra: Yukon Minfile No. 116A-10; from examination by the writer and an unpublished report by P. Holcapek)

A hand trench about ten m long in talus of Gillespie dolostone exposed a few pieces of chalcopyrite-bearing white bull quartz, up to 20 cm across. About 100 m to the northeast across a northwest-trending normal fault, similar, malachite-stained vein quartz occurs in talus of black shale of the Quartet Group.

Reindeer Copper Occurrence
(Yukon Minfile No. 116A-07)
(From assessment report No. 019107 by R. Philp)

Minor chalcopyrite is reported from grey limestone. Farther southeast, several boulders containing pyrite and minor galena were found in Marc Creek, the main creek crossing the area. Both the Gillespie Lake and Pinguicula Groups underlie the area.

Cloud Skarn(?) (Yukon Minfile No. 116A-26)

Claims were staked by a mineral dealer over the contact between dolostone of the Gillespie Lake Group and a mafic sill. It is rumoured that axinite crystals in the alteration zone were collected, although none were seen by the writer during a brief examination.

Cinch Work Target (Yukon Minfile No. 116A-06)
(From assessment report No. 060636 by G. Trowsdale)

One soil geochemical anomaly in lead and another in copper were obtained from two areas on the east side of Marc Creek. The copper anomaly was at the base of a steep north-facing slope near a diorite-shale contact. The lead anomaly was in a cirque about 600 m south of the copper anomaly, at the base of a steep talus slope of Paleozoic(?) dolostone.

Grace Work Target (Yukon Minfile No. 116A-8)
(From assessment report No. 060635 by B. C. Fulcher)

The original claims were underlain by mafic sills, and by the Gillespie Lake and Quartet groups. Copper, zinc and lead stream-sediment anomalies were outlined in the southeast and northern portions of the claim group. Mineralized float included a small amount of argillite containing disseminated pyrite with minor chalcopyrite, and one galena-rich specimen, which assayed 59.7% Pb, 0.07% Cu, 143 g/t Ag, and trace Zn and Au.

Callison Work Target (Yukon Minfile No. 116A-18)
(From assessment report No. 090121 by A. A. Burgoyne)

A geochemical anomaly with values greater than 300 ppm zinc was obtained from stream sediments derived from black shale and chert of the Road River Group (unit **ODp**). Zinc anomalies such as this are not uncommon in the Road River Group and do not reflect significant mineralization.

Rae Work Target (Yukon Minfile No. 116A-19)
(From assessment report No. 090121 by A. A. Burgoyne)

A geochemical soil anomaly with values greater than 250 ppm zinc was obtained from an area underlain by the contact between a mafic sill (unit **Ꞓd**) and shale and chert of the Road River Group (unit **ODp**). The anomaly was interpreted as reflecting low grade, noneconomic, erratic zinc mineralization in host rocks along the sill margin.

Shine Work Target (Yukon Minfile No. 116A-22)
(From Yukon Minfile 1995)

Claims were staked over black shale of the Devono-Mississippian Earn Group following an airborne radiometric survey.

Mineral potential

The revised stratigraphy presented here provides a more accurate framework in which the exploration geologist can assess the mineral potential of the southern Ogilvie Mountains, and focus on specific targets for detailed exploration. In the writer's opinion, the following units offer the most potential, both within the project area and in surrounding areas. They are listed in order of age (from older to younger), not importance.

Hart River basalt

Volcanogenic massive sulphide deposits related to unmapped mafic lavas equivalent to the Hart River basalt possibly occur unmapped in a 70-km interval between the project area and Carpenter Ridge to the east.

Pinguicula Group

The Pinguicula Group belongs to the same general stratigraphic sequence, and broadly resembles the lower part of the Shaler Group in the Arctic Islands. Pyritic sediment-hosted copper deposits were recently discovered in the Glenelg Formation of the Shaler Group. The Fifteenmile Group has probably never been explored for sediment-hosted copper deposits.

Gull Lake and Rabbitkettle formations

Pyritic massive sulphide deposits in the Anvil District are associated with black shale in a transitional interval between the Gull Lake (Mount Mye) and Rabbitkettle (Vangorda) formations. The Late Cambrian sub-Rabbitkettle unconformity reflects a rift event accompanied by high heat flow. The Anvil deposits could have formed and been preserved in a graben related to this rift event. The stratiform, pyritic massive sulphide deposits are associated with the margins of a discontinuous, black shale facies, and occupy a 150-m-thick stratigraphic interval in the transition zone between the Gull Lake Formation (locally Mount Mye Formation) and the overlying Rabbitkettle Formation (locally Vangorda Formation) (Pigage, 1990).

The Gull Lake Formation has only recently been recognized as a locally preserved but regional unit. Thus, past exploration for sediment-hosted Pb-Zn deposits of the same age as the Anvil deposits might have been hampered in many parts of Selwyn Basin. The Gull Lake Formation along the Dawson Fault is an underexplored target.

Road River Group

Black shale and chert of the Road River Group contains the Howard's Pass zinc-lead deposit. Large areas shown as Hyland Group on early maps are underlain by the Road River Group.

Mafic sills

Magmatic sulphide deposits could be associated with Middle Proterozoic (Hart River), Cambro-Ordovician and Middle Paleozoic or younger mafic sills. Differentiation is apparent in all three, and most pronounced in those of Cambro-Ordovician age.

Keno Hill quartzite

The Marg volcanogenic massive sulphide deposit and associated felsic volcanic rocks of Devono-Mississippian age were recently discovered east of Mayo. They are overlain by, and tectonically interleaved with, the Keno Hill quartzite. The volcanic rocks were traced westward by recent mapping as far as the Keno Hill Mining District, but their presence farther northwest remains unknown. The panel of rocks containing the Keno Hill quartzite, and bounded by the Tombstone and Robert Service thrusts, is an exploration target from the Keno Hill District to Dawson City.

Covered interval in footwall of the Tombstone Thrust

The footwall of the Tombstone Thrust is mostly covered and might include the Devono-Mississippian Earn Group. The Earn Group contains sediment-hosted zinc, lead, and silver deposits at Macmillan Pass and elsewhere in Selwyn Basin.

References

Abbott, J. G., 1983. Geology, Macmillan Fold Belt. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File Maps.

Abbott, J. G., 1990a. Preliminary results of the stratigraphy and structure of the Mt. Westman map area, central Yukon. In Current Research, Part E, Geological Survey of Canada, Paper 90-1E, p. 15-22.

Abbott, J. G., 1990b. Geological map of Mt. Westman map area (106D/1). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada, Open File 1990-1.

Abbott, J. G., 1993. Revised stratigraphy and new exploration targets in the Hart River Area (NTS 116A/10, 116A/11), southeastern Yukon. In Yukon Exploration and Geology, 1992, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 13-23.

Abbott, J. G., 1996. Implications of probable Late Proterozoic dextral strike-slip movement on the Snake River fault. In Lithoprobe Report No. 50, p.138-140.

Abbott, J. G. and Roots, C. F., 1992. Geological map of part of map sheets 116A/10 and 116A/11. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada, Open File 1992-2.

Abbott, J. G. and Roots, C. F., 1993a. Geological map of sheet 116A/10. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada, Open File 1993-7.

Abbott, J. G. and Roots, C. F., 1993b. Geological map of Two Beaver Lake map area (116A/11). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada, Open File 1993-8.

Abbott, J. G. and Turner, R., 1991. Character and paleotectonic setting of Devonian stratiform sediment-hosted Zn, Pb, Ba deposits, Macmillan Fold Belt, Yukon. In J. G. Abbott and R. J. W. Turner (eds.), Mineral Deposits of the northern Canadian Cordillera, Yukon-Northeastern British Columbia (Field trip 14); Geological Survey of Canada, Open File 2169, p. 99-136.

Abbott, J. G., Gordey, S. P., and Tempelman-Kluit, D. J., 1986. Setting of stratiform, sediment-hosted lead-zinc deposits in Yukon and northeastern British Columbia. In J. Morin (ed.), Mineral Deposits of Northern Cordillera, Canadian Institute of Mining and Metallurgy, Special Volume 37, p. 1-18.

Abbott, G., Thorkelson, D., Creaser, R., Bevier, M. L., and Mortensen, J., 1997. New correlations among Proterozoic successions and intrusive breccias in the Ogilvie and Wernecke Mountains, Yukon. In Lithoprobe Report No. 56, p. 188-197.

Aitken, J. D., 1981. Stratigraphy and sedimentology of the upper Proterozoic Little Dal Group, Mackenzie Mountains, Northwest Territories. In F. H. A. Campbell (ed.), Proterozoic Basins of Canada, Geological Survey of Canada, Paper 81-10, p. 47-71.

Aitken, J. D., 1991. The Ice Brook Formation and Post-Rapitan, Late Proterozoic Glaciation, Mackenzie Mountains, Northwest Territories. Geological Survey of Canada, Bulletin 404, 43 p.

Aitken, J. D. and McMechan, M. E., 1992. Middle Proterozoic assemblages, Chapter 5. In H. Gabrielse and C. J. Yorath (eds.), Geology of the Cordilleran Orogen in Canada, Geological Survey of Canada, Geology of Canada, no. 4, p. 97-124 (also Geological Society of America, The Geology of North America, v. G-2.)

Armstrong, R. L., Eisbacher, G. H., and Evans, P. D., 1982. Age and stratigraphic-tectonic significance of Proterozoic diabase sheets, Mackenzie Mountains, northwestern Canada. Canadian Journal of Earth Sciences, v.19, no. 2, p. 316-323.

Bell, R. T., 1982. Comments on the geology and uraniferous mineral occurrences of the Wernecke Mountains, Yukon and District of Mackenzie. In Current Research, Part B, Geological Survey of Canada, Paper 1982-1B, p. 279-284.

Blodgett, R. B., Wheeler, K. L., Rohr, D. M., Harris, A. G., and Weber, F. R., 1987. A Late Ordovician age reappraisal for the upper Fossil Creek volcanics, and possible significance for glacio-eustacy. United States Geological Survey, Circular 998, p. 54-58.

Blusson, S. L., 1968. Geology and tungsten deposits near the headwaters of Flat River, Yukon Territory and southwestern District of Mackenzie, Canada. Geological Survey of Canada, Paper 67-22, 77 p.

Blusson, S. L., 1974. Operation Stewart (northern Selwyn Basin): Mount Eduni (106A), Bonnet Plume Lake (106B), Nadaleen River (106C), Lansing (105N) and Niddery Lake (105O). Geological Survey of Canada, Open File 205.

Bond, G. C. and Kominz, M. A., 1984. Construction of tectonic subsidence curves for the early Paleozoic miogeocline, southern Canadian Rocky Mountains. Implications for subsidence mechanisms, age of breakup, and crustal thinning; Geological Society of America, Bulletin, v. 95, p. 155-173.

Boucek, B., 1964. The tentaculites of Bohemia: their morphology, taxonomy, ecology, phylogeny, and biostratigraphy. Czechoslovak Academy of Science, 215 p.

Cecile, M. P., 1982. The Lower Paleozoic Misty Creek Embayment, Selwyn Basin, Yukon and Northwest Territories. Geological Survey of Canada, Bulletin 335, 78 p.

Cecile, M. P. (in press). Geology of the northeastern Niddery Lake map area (NTS-105O/7N2/3,8N2/3,9,10,15,16). Geological Survey of Canada, Bulletin.

Cecile, M. P. and J. G. Abbott, 1989. Geology of the Niddery Lake Map Area (NTS 105-O) Yukon, scale 1:125 000. Geological Survey of Canada, Open File 2076.

Cecile, M. P. and J. G. Abbott, 1992. Geology of the Niddery Lake Map Area (NTS 105-O), Yukon, scale 1:250 000. Geological Survey of Canada, Open File 2465.

Cecile, M. P and Norford, B. S., 1992. Ordovician and Silurian assemblages. In H. Gabrielse and C. J. Yorath (eds.), Cambrian to Middle Devonian Assemblages, Chapter 7, Geology of the Cordilleran Orogen in Canada, Geological Survey of Canada, Geology of Canada, no. 4, p.184-196 (also Geological Society of America, The Geology of North America, v. G-2.)

Cook, D. G. and MacLean, B. C., 1992. Proterozoic thick-skinned intracratonic deformation, Colville Hills region, Northwest Territories Canada. Geology, v.20, p. 67-60.

Cook, D. G. and MacLean, B. C., 1995. The intracratonic Forward orogeny, and implications for regional correlations, Northwest Territories, Canada. Canadian Journal of Earth Sciences,v. 32, p. 1991-2008.

Delaney, G. D., 1981. The mid-Proterozoic Wernecke Supergroup, Wernecke Mountains, Yukon Territory. In F. H. A. Campbell (ed.), Proterozoic Basins of Canada, Geological Survey of Canada, Paper 81-10, p. 1-24.

Delaney, G. D., 1985. The Middle Proterozoic Wernecke Supergroup, Wernecke Mountains, Yukon Territory. University of Western Ontario, unpublished Ph.D thesis.

Doughty, P. T. and Chamberlain, K. R., 1996. Salmon River Arch: new evidence for 1370 Ma rifting near the end of deposition in the Middle Proterozoic Belt basin; Canadian Journal of Earth Sciences, v. 33, p. 1037-1052.

Douglas, R. J. W., Gabrielse, H., Wheeler, J. O., Stott, D. F., and Belyea, H. R., 1970. Geology of western Canada. In R. J. W. Douglas (ed.), Geology and Economic Minerals of Canada, Geological Survey of Canada, Economic Geology Report No. 1, p. 367-488.

Duk-Rodkin, A., 1996. Surficial Geology, Dawson, Yukon Territory, map, scale 1:250 000. Geological Survey of Canada, Open File 3288.

Eisbacher, G. H., 1978. Two major Proterozoic unconformities, northern Cordillera. In Current Research, Part A, Geological Survey of Canada, Paper 78-1A, p. 53-58.

Eisbacher, G. H., 1981. Sedimentary tectonics and glacial record in the Windermere Supergroup, Mackenzie Mountains, northwestern Canada. Geological Survey of Canada, Paper 80-27, 40 p.

Fritz, W. H., 1972. Lower Cambrian trilobites from the Sekwi Formation type section, Mackenzie Mountains, northwestern Canada. Geological Survey of Canada, Bulletin 212, 90 p.

Fritz, W. H., 1974. Cambrian biostratigraphy, northern Yukon Territory and adjacent areas. In Report of Activities, Part A, Geological Survey of Canada, Paper 74-1, Part A, p. 309-313.

Fritz, W. H., 1975. Broad correlations of some Lower and Middle Cambrian strata in the North American Cordillera. In Report of Activities, Geological Survey of Canada, Paper 75-1A, p. 533-540.

Fritz, W. H., 1976. Ten stratigraphic sections from the Lower Cambrian Sekwi Formation, Mackenzie Mountains, northwestern Canada. Geological Survey of Canada, Paper 76-22, 19 p.

Fritz, W. H., 1978a. Fifteen stratigraphic sections from the Lower Cambrian of the Mackenzie Mountains, northwestern Canada. Geological Survey of Canada, Paper 77-33, 19 p.

Fritz, W. H., 1978b. Upper (carbonate) part of Atan Group, Lower Cambrian, north-central British Columbia. In Current Research, Part A, Geological Survey of Canada, Paper 78-1A, p. 7-16.

Fritz, W. H., 1979. Eleven stratigraphic sections from the Lower Cambrian of the Mackenzie Mountains, northwestern Canada. Geological Survey of Canada, Paper 78-23, 19 p.

Fritz, W. H., 1982. Vampire Formation, a new upper Precambrian(?)/Lower Cambrian formation, Mackenzie Mountains, Yukon and Northwest Territories. In Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p.83-92.

Fritz, W. H., 1985. The basal contact of the Road River Group - a proposal for its location in the type area and in other selected areas in the northern Cordillera. In Current Research, Part B, Geological Survey of Canada, Paper 85-1B, p. 201-215.

Fritz, W. H., 1991. Lower Cambrian trilobites from the Illtyd Formation, Wernecke Mountains, Yukon Territory. Geological Survey of Canada, Bulletin 409, 77 p.

Fritz, W. H., Narbonne, G. M., and Gordey, S. P., 1984. Strata and trace fossils near the Precambrian-Cambrian boundary, Mackenzie, Selwyn and Wernecke mountains, Yukon and Northwest Territories. In Current Research, Part B, Geological Survey of Canada, Paper 84-1B, p. 409-412.

Fritz, W. H., Cecile, M. P., Norford, B. S., Morrow, D., and Geldsetzer, H. H. J., 1992. Cambrian to Middle Devonian Assemblages. In H. Gabrielse and C. J. Yorath (eds.), Geology of the Cordilleran Orogen in Canada, Geological Survey of Canada, Geology of Canada, no. 4, p. 153-218 (also Geological Society of America, The Geology of North America, v. G-2.)

Gabrielse, H., 1967. Tectonic evolution of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, v. 29, p. 271-298.

Gabrielse, H. and Yorath, C. J. (eds.), 1992. Geology of the Cordilleran Orogen in Canada. Geological Survey of Canada, Geology of Canada, no. 4, 844 p. (also Geological Society of America, The Geology of North America, v. G-2.)

Gabrielse, H., Blusson, S. L., and Roddick, J. A., 1973. Geology of Flat River, Glacier Lake, and Wrigley Lake map areas, District of Mackenzie and Yukon Territory. Geological Survey of Canada, Memoir 366, 153 p.

Godwin, C. I., Gabites, J. E., and Andrew, A., 1988. Leadtable: a galena lead isotope data base for the Canadian Cordillera. British Columbia Geological Survey Branch Paper 1988-4, 188 p.

Goodfellow, W. D., Cecile, M. P., and Leybourne, M. I, 1995. Geochemistry, petrogenesis and tectonic setting of Lower Paleozoic alkalic and potassic volcanic rocks, northern Canadian Cordilleran Miogeocline. Canadian Journal of Earth Sciences, v. 32, p. 1236-1254.

Gordey, S. P., 1981. Structural and tectonic evolution of southern Pelly Mountains in the Indigo Lake area, Yukon Territory. Geological Survey of Canada, Bulletin 318, 44 p.

Gordey, S. P., 1982. Structure section, south-central Mackenzie Mountains, NWT., Geological Survey of Canada, Open File 809.

Gordey, S. P., 1990a. Geological map of the Tiny Island Lake map area (106D/1). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada, Open File 1990-2.

Gordey, S. P., 1990b. Geology and mineral potential, Tiny Island Lake map area (105M/16), Yukon Territory. In Current Research, Geological Survey of Canada, Paper 1990-1E, p. 23-29.

Gordey, S. P. and Anderson, R. G., 1993. Evolution of the northern Cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428, 214 p.

Gordey, S. P. and Irwin, S. E. B., 1987. Geology, Sheldon and Tay River map areas Yukon Territory. Geological Survey of Canada, map 19-1987 (3 sheets), scale 1:250 000.

Gordey, S. P. and Thompson, R. I., 1992. Ancestral North America, Selwyn Basin. In H. Gabrielse and C. J. Yorath (eds.), Structural Styles, Chapter 17, Geology of the Cordilleran Orogen in Canada, Geological Survey of Canada, Geology of Canada, no. 4, p. 625-634 (also Geological Society of America, The Geology of North America, v. G-2.).

Gordey, S. P., J. G. Abbott, and M. J. Orchard, 1982. Devono-Mississippian (Earn Group) and younger strata in east-central Yukon. In Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 93-100.

Gordey, S. P., Abbott, J. G., Tempelman-Kluit, D. J., and Gabrielse, H., 1987. "Antler" clastics in the Canadian Cordillera. Geology, v. 15, p. 103-107.

Gordey, S. P., Geldsetzer, H. H. J., Morrow, D. W., Bamber, E. W., Henderson, C. M., Richards, B. C., McGugan, A., Gibson, D. W., and Poulton, T. P., 1992. Part A. Ancestral North America. In H. Gabrielse and C. J. Yorath (eds.), Upper Devonian to Middle Jurassic Assemblages. Chapter 8, Geology of the Cordilleran Orogen in Canada, Geological Survey of Canada, Geology of Canada, no. 4, p. 219-327 (also Geological Society of America, The Geology of North America, v. G-2.)

Green, L. H., 1972. Geology of Nash Creek, Larsen Creek and Dawson map-areas, Yukon. Geological Survey of Canada, Memoir 364, 157 p.

Guardia, F. J. L., 1971. Report on Mark Group Claims, Hart River, Yukon Territory. Unpublished report for Hart River Mines Limited, 34 p.

Helmstaedt, H., Eisbacher, G. H., and McGregor, H., 1979. Precambrian copper mineralization at the Nite Claims, Mackenzie Mountains. Canadian Journal of Earth Sciences, v. 16, p. 50-59.

Hofmann, H. J. and Aitken, J. D., 1979. Precambrian biota from the Little Dal Group, Mackenzie Mountains, northwestern Canada. Canadian Journal of Earth Sciences, v. 16, no. 1, p. 150-166.

Hofmann, H. J. and Cecile, M. P., 1981. Occurrence of *Oldhamia* and other trace fossils in Lower Cambrian(?) argillites, Niddery map area, Selwyn Mountains, Yukon Territory. In Current Research, Part A, Geological Survey of Canada, Paper 81-1A, p. 281-289.

I.N.A.C., 1992. Occurrence 116A/(9), Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada.

Jackson, D. E. and Lenz, A. C., 1962. Zonaton of Ordovician and Silurian graptolites of northern Yukon, Canada. American Association of Petroleum Geologists, Bulletin v. 46, no. 1, p. 30-45.

Jackson, D. E., Lenz, A. C., and Pedder, A. E. H., 1978. Late Silurian and Early Devonian graptolite, brachiopod and coral faunas from northwestern and Arctic Canada. Geological Association of Canada, Special Paper no. 17, 159 p.

Jefferson, C. W. and Parrish, R. R., 1989. Late Proterozoic stratigraphy, U-Pb zircon ages, and rift tectonics, Mackenzie Mountains, northwestern Canada. Canadian Journal of Earth Sciences, v. 26, p. 1784-1801.

Jefferson, C. W. and Ruelle, J. C. L., 1986. The Late Proterozoic Redstone Copper Belt, Mackenzie Mountains Northwest Territories. In J. A. Morin (ed.), Mineral Deposits of Northern Cordillera, Canadian Institute of Mining and Metallurgy, Special Volume 37, p. 154-168.

Jefferson, C. W. and Young, G. M., 1989. Late Proterozoic orange-weathering stromatolite biostrome, Mackenzie Mountains and western Arctic Canada. In H. Geldsetzer, N. P. James and G. E. Tebutt (eds.), Reefs in Canada and adjacent areas, Canadian Society of Petroleum Geologists, Memoir 13, p. 72-80.

Jeletsky, J. A., 1962. Pre-Cretaceous Richardson Mountains Trough — its place in the tectonic framework of Arctic Canada and its bearing on some geosynclinal concepts. Transactions of the Royal Society of Canada. 3rd ser., v. 56, sec. 3, pt. 1, p. 55-84.

Johnson, J. G. and Lane, N. G., 1969. Two new Devonian crinoids from central Nevada. Journal of Paleontology, v. 43, no. 1, p. 69-73.

Lane, R. A. and Godwin, C. I., 1992. Geology of the Ogilvie Mountains breccias, Coal Creek Inlier (NTS 116B/11, 13, and 14), Yukon Territory, map, scale 1:50 000, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1992-5.

Lardeux, H., 1969. Tentaculitids of central Europe and north Africa. 238p.

Lenz, A. C., 1966. Upper Silurian and Lower Devonian paleontology and correlations, Royal Creek, Yukon Territory: a preliminary report. Bulletin of Canadian Petroleum Geology, v. 14, no. 4, p. 604-612.

Lenz, A. C., 1968. Upper Silurian and Lower Devonian biostratigraphy, Royal Creek, Yukon Territory, Canada. In International Symposium on the Devonian System, v. 2, p. 587-599. Alberta Society of Petroleum Geologists, p. 587-599.

Lenz. A. C., 1972. Ordovician to Devonian history of northern Yukon and adjacent District of Mackenzie. Bulletin of Canadian Society of Petroleum Geologists, v. 20, no. 2, p. 321-361.

Lenz, A. C., 1981. New data on Late Silurian and Early Devonian brachiopods from the Royal Creek area, Yukon Territory. Canadian Journal of Earth Sciences, v. 19, no. 2, p. 364-375.

Lenz, A. C. and McCracken, A. D., 1982. The Ordovician-Silurian boundary, northern Cordillera: graptolite and conodont correlation. Canadian Journal of Earth Sciences, v. 19, no. 6, p. 1308-1322.

Lenz, A. C. and Pedder, A. E. H., 1972. Lower and Middle Paleozoic sediments and paleontology of Royal Creek and Peel River, Yukon and Powell Creek, N. W.T. 24th International Geological Congress; Field Excursion Guidebook A-14, 43 p.

McMechan, M. E. and Price, R. A., 1982. Superimposed low-grade metamorphism in the Mount Fisher area, southeastern British Columbia — implications for the east Kootenay Orogeny. Canadian Journal of Earth Sciences, v. 19, p. 476-489.

Mercier, E. and Chauval, J. J., 1987. Micropaléontologie du Proterozoique des montagnes Ogilvie (Yukon, Canada). Bulletin de la Société Geologique de France, Huitième Série, p. 743-747.

Morin, J., 1979. A preliminary report on Hart River — a Proterozoic massive sulphide deposit, Yukon Territory. In Marchand et al. (ed.) Mineral Industry Report, 1977 Yukon Territory. Indian and Northern Affairs, Canada, Report EGS 1978-9, p. 22-24.

Morris, W. A. and Aitken, J. D., 1982. Paleomagnetism of the Little Dal lavas, Mackenzie Mountains, Northwest Territories, Canada. Canadian Journal of Earth Sciences, v. 19, p. 2020-2027.

Mortensen, J. K. and Thompson, R. I., 1990. A U-Pb zircon-baddelyite age for a differentiated mafic sill in the Ogilvie Mountains, west-central Yukon. In Radiogenic Age and Isotopic Studies: Report 3. Geological Survey of Canada, Paper 89-2, in press.

Mortensen, J. K., Ghosh, D., and Ferri, F., 1995. U-Pb age constraints of intrusive rocks associated with copper-gold porphyry deposits in the Canadian Cordillera. In T. G. Schroeter (ed.), Porphyry Deposits of the Northwestern Cordillera of North America, CIM special volume 46, p. 142-158.

Murphy, D. C. (1997). Geology of the McQuesten River region, northern McQuesten and Mayo Map areas, Yukon Territory (115P/ 14,15,16; 105M/13,14). Exploration and Geological Services Division, Indian and Northern Affairs Canada, Bulletin.

Murphy, D. C. and Abbott, J. G., 1995. Northern Yukon-Tanana Terrane: the equivalent of Yukon's western Selwyn Basin offset along the Tintina Fault? Geological Association of America, Cordilleran Section Annual Meeting, Abstracts with Programs, p. 66.

Murphy, D. M. and Roots, C. F., 1992. Geology of Keno Hill map area. Exploration and Geological Services Division, Indian and Northern Affairs Canada, Open File 1992-3.

Mustard, P. S., 1990. Sedimentology and tectonic evolution of the upper Proterozoic Mount Harper group sedimentary rocks, Yukon Territory, Canada. Unpubl. Ph.D thesis, Carleton University, 330 p.

Mustard, P. S., 1991. Normal faulting and alluvial-fan deposition, basal Windermere Tectonic Assemblage, Yukon, Canada. Geological Society of America Bulletin, v. 103, no. 10, p. 1346-1364.

Mustard, P. S. and Roots, C. F., 1997. Rift-related volcanism, sedimentation and tectonic setting of the Mount Harper Group, Ogilvie Mountains, Yukon. Geological Survey of Canada, Bulletin 492, 92 p.

Mustard, P. S., Donaldson, J. A., and Thompson, R. I., 1988. Trace fossils and stratigraphy of the Precambrian–Cambrian boundary sequence, upper Harper Group, Ogilvie Mountains, Yukon. In Current Research, Part E; Cordillera and Pacific Margin, Geological Survey of Canada, Paper 88-1E, p. 197-203.

Mustard, P. S., Roots, C. F., and Donaldson, J. A, 1990. Stratigraphy of the Middle Proterozoic Gillespie Lake Group, in the southern Wernecke Mountains, Yukon. In Current Research, Part E; Geological Survey of Canada, Paper 90-1E, p. 43-54.

Norris, A. W., 1968. Reconnaissance Devonian stratigraphy of northern Yukon Territory and northwestern District of Mackenzie. Geological Survey of Canada, Paper 67-53, 287 p.

Norris, D. K., 1984. Geology of the Northern Yukon and Northwestern District of Mackenzie. Geological Survey of Canada, Map 1581A, scale 1:500 000.

Norris, D. K., 1985. The Neruokpuk Formation, Yukon Territory and Alaska. In Current Research, Part B. Geological Survey of Canada, Paper 85-1B, p. 223-229.

Norris, D. K. and Hopkins, W. S. Jr., 1977. The Geology of the Bonnet Plume Basin, Yukon Territories, Geological Survey of Canada, Paper 76-8, 20 p.

Okulitch, A. V., 1995. Geological time scale, 1995. Geological Survey of Canada, Open File 3040.

Olsson, W. J., 1973. The geology and petrology of the MARK claims, Hart River Mines Limited, Yukon Territory. Unpublished B.Sc. thesis, Queen's University, 33 p.

Orchard, M. J., 1991. Conodonts, time and terranes: an overview of the biostratigraphic record in the western Canadian Cordillera. In M. J. Orchard and A. D. McCracken (eds.), Ordovician to Triassic conodont paleontology of the Canadian Cordillera, Geological Survey of Canada, Bulletin 417, p. 1-25.

Park, J. K., Roots, C. F., and Brunet, N., 1992. Paleomagnetic evidence for rotation in the Neoproterozoic Mount Harper Volcanic Complex, Ogilvie Mountains, Yukon Territory. In Current Research, Part E; Geological Survey of Canada, Paper 92-1E, p. 1-10.

Parrish, R. R. and Bell, R. T., 1987. Age of the NOR breccia pipe, Wernecke Supergroup, Yukon Territory. In Radiogenic and Isotopic Studies: Report 1, Geological Survey of Canada, Paper 87-2, p. 39-42.

Parrish, R., Roddick, J. C., Loveridge, W. D., and Sullivan, R. W., 1987, Uranium-lead analytical techniques at the geochronology laboratory, Geological Survey of Canada. In Radiogenic Age and Isotopic Studies, Report 1, Geological Survey of Canada, Paper 87-2, p. 3-7.

Pigage, L. C., 1990. Anvil Pb-Zn-Ag District, Yukon Territory, Canada. In J. G. Abbott and R. J. W. Turner (eds.), 8th IAGOD Symposium, Field Trip Guidebook 14, Mineral Deposits of the Northern Canadian Cordillera, Yukon-Northeastern British Columbia, p. 283-308.

Poulton, T. P. and Tempelman-Kluit, D. J., 1982. Recent discoveries of Jurassic fossils in the Lower Schist Division of central Yukon. In Current Research, Part C; Geological Survey of Canada, Paper 82-1C, p. 91-94.

Rainbird, R. H., Darch, W., Jefferson, C. W., Lustwerk, R., Rees, M. Telmer, K., and Jones, T. A., 1992a. Preliminary stratigraphy and sedimentology of the Glenelg Formation, lower Shaler Group and correlatives in the Amundsen Basin, Northwest Territories: relevance to sediment-hosted copper. In Current Research, Part C; Geological Survey of Canada, Paper 92-1C, p. 111-119.

Rainbird, R. H., Heaman, L. M., and Young, G. M., 1992b. Sampling Laurentia: Detrital zircon geochronology offers evidence for an extensive Neoproterozoic river system originating from Grenville Orogen. Geology, v. 20, p. 351-354.

Rainbird, R. H., Jefferson, C. W., Hildebrand, R. S., and Worth, J. K., 1994. The Shaler Supergroup, and revision of Neoproterozoic stratigraphy in the Amundsen Basin, Northwest Territories. In Current Research, Part A, Geological Survey of Canada, Paper 94-1A, p. 61-70.

Rainbird, R. H., Jefferson, C. W., and Young, G. M., 1996a. The early Neoproterozoic Succession B of northwestern Laurentia: Correlations and paleogeographic significance. Geological Society of America Bulletin, v.108, p. 454-470.

Rainbird, R. H., Villeneuve, M. E., Cook, D. G., and MacLean, B. C., 1996b. Detrital zircon ages from two wells in the northwest Territories: implications for the correlation and provenance of Proterozoic subsurface strata. In Current Research, Part B; Geological Survey of Canada, Paper 96-1B, p. 29-38.

Rainbird, R. H., McNicoll V. J., Theriault, R. J, Heaman, L. M., Abbott, J. G., Long, D. G. F., and Thorkelson, D. J., 1997. Pan-continental river system draining Grenville orogen recorded by U-Pb and Sm-Nd geochronology of Neoproterozoic quartzites and mudrocks, northwestern Canada. Journal of Geology, v. 105, p. 1-17.

Robinson, M. and Godwin, C. I., 1995. Genesis of the Blende carbonate-hosted Zn-Pb-Ag Deposit, north-central Yukon Territory: Geologic, fluid inclusion and isotopic constraints. Economic Geology, v. 90, p. 369-384.

Roots, C. F., 1987. Regional tectonic setting of the Late Proterozoic Mount Harper volcanic complex, Ogilvie Mountains, Yukon. Unpublished Ph.D. thesis, Carleton University, Ottawa, 227 p.

Roots, C. F., 1988. Cambro-Ordovician volcanic rocks in eastern Dawson map area, Ogilvie Mountains, Yukon. In Yukon Geology, v. 2, Exploration and Geological Services Division, Yukon, I.N.A.C., p. 81-87.

Roots, C. F., 1990a. New geological maps for the southern Wernecke Mountains, Yukon. In Current Research, Geological Survey of Canada, Paper 1990-1E, p. 5-13.

Roots, C. F., 1990b. Geology of 106D/8 and 106D/7 (east half) map areas. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1990-3.

Roots, C. F. and Parrish, R. R., 1989. Age of the Mount Harper volcanic complex, southern Ogilvie Mountains, Yukon. In Radiogenic Age and Isotopic Studies: Report 2, Geological Survey of Canada, Paper 88-2, p. 29-35.

Roots, C. F. and Thompson, R. I., 1992. Long-lived basement weak zones and their role in extensional magmatism in the Ogilvie Mountains, Yukon Territory. In D. W. Hyndman, D. W. Mogk and R. Mason (eds.), Basement Tectonics 8: Characterization and comparison of Ancient and Mesozoic Continental Margins — Proceedings of the 8th International Conference on Basement Tectonics (Butte, Montana), p. 359-372.

Roots, C. F., Abbott, J. G., Cecile, M. P., and Gordey, S. P., 1995. Bedrock geology of Lansing Range map area (105), east half, Hess Mountains, Yukon. Geological Survey of Canada, Open File 3171.

Ross, G. M., 1991. Tectonic setting of the Windermere Supergroup revisited. Geology, v. 19, p. 1125-1128.

Ross, G. M. and Villeneuve, M., 1996 Geochronology of stranger stones in Neoproterozoic diamictites, (northern and central Canadian Cordillera). In Lithoprobe Report no. 50, p. 18-19.

Stewart, J. H., 1972. Initial deposits in the Cordilleran geosyncline: Evidence of late Precambrian (<850 m.y.) continental separation. Geological Society of America, Bulletin, v. 83, p. 1345-1360.

Tempelman-Kluit, D. J., 1970. Stratigraphy and structure of the "Keno Hill quartzite" in Tombstone River-Upper Klondike River map areas, Yukon Territory (116B/7, B/8). Geological Survey of Canada, Bulletin 180, 102 p.

Thompson, R. I., 1995. Geological Compilation (1:250 000) of Dawson map area (northeast of Tintina Trench). Geological Survey of Canada, Open File 3223.

Thompson, R. I. and Roots, C. F., 1982. Ogilvie Mountains Project, Yukon; Part A: a new regional mapping program. In Current Research, Part A, Geological Survey of Canada, Paper 82-1A, p. 403-411.

Thompson, R. I., Mercier, E., and Roots, C., 1987. Extension and its influence on Canadian Cordilleran passive margin evolution. In M. P. Coward, J. F. Dewey and P. L. Hancock (eds.); Continental Extension Tectonics. Geological Society Special Publication no. 28, p. 409-418.

Thompson, R. I., Roots, C. F., and Mustard, P. S., 1992. Geology of Dawson Map area (116B,C) northeast of Tintina Trench. Geological Survey of Canada, Open File 2849 (13 sheets, scale 1:50 000)

Thorkelson, D. J. and Wallace, C. A., 1993a. Development of Wernecke breccias in Slats Creek(106D/16) map area, Wernecke Mountains, Yukon. In Yukon Exploration and Geology, 1992. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 19-30.

Thorkelson, D. J. and Wallace, C. A., 1993b. Geological map of Slats Creek (106D/16) map area, Wernecke Mountains, Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1993-2-G.

Thorkelson, D. J. and Wallace, C. A., 1994a. Geological setting of mineral occurrences in Fairchild Lake map area (106C/13), Wernecke Mountains, Yukon. In Yukon Exploration and Geology, 1993. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 79-92.

Thorkelson, D. J. and Wallace, C. A., 1994b. Geological map of Fairchild Lake map area (106C/13), Wernecke Mountains, Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1994-6.

Thorkelson, D. J. and Wallace, C. A., 1995a. Geology and mineral occurrences of the "Dolores Creek" map area (106C/14), Wernecke Mountains, northeastern Yukon. In Yukon Exploration and Geology, 1994. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 19-30.

Thorkelson, D. J. and Wallace, C. A., 1995b. Geological map of the "Dolores Creek" Map Area (106C/14), Wernecke Mountains, northeastern Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1995-6.

Turner, R. J. W. and Abbott, J. G., 1990. Regional setting, structure, and zonation of the Marg volcanogenic massive sulphide deposit, Yukon. In Current Research, Part E, Geological Survey of Canada, Paper 90-1E, p. 31-41.

Usher, J. L. and MacDonald, A. S., 1968. The geology of Hart River Mines, Yukon Territory. Unpublished report for Hart River Mines Limited, 34 p.

Vernon, P. and Hughes, O. L., 1966. Surficial geology, Dawson, Larsen Creek, and Nash Creek map areas (116B and 116C E 1/2, 116A, and 106D) Yukon Territory. Geological Survey of Canada, Bulletin 136, 25 p.

Walker, R. G., 1984. Turbidites and associated coarse clastic deposits. In Facies Models, second edition, Geological Association of Canada, Geoscience Canada, Reprint Series 1, p. 171-188.

Weber, F. R., Smith, T. E., Hall, M. H., and Forbes, R. B., 1985. Geological Guide to the Fairbanks-Livengood Area, East-Central Alaska. Alaska Geological Society, 44 p.

Weber, F. R., Wheeler, K. L., Rinehart, C. D., Chapman, R. M., and Blodgett, R. B. 1992. Geologic map of the Livengood quadrangle, Alaska. United States Geological Survey, Open File Report 92-562.

Weber, F. R., Blodgett, R. B., Harris, A. G., and Dutro Jr., J. T., 1994. Paleontology of the Livengood quadrangle, Alaska. United States Geological Survey, Open File Report 94-215.

Wheeler, J. O. and McFeely, P., 1991. Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, scale 1:2 000 000.

Yeo, G. M., 1984. The Rapitan Group: relevance to the global association of Late Proterozoic glaciation and iron formation. Unpublished Ph.D. thesis, University of Western Ontario, 600 p.

Young, G. M., 1982. The late Proterozoic Tindir Group, east-central Alaska: evolution of a continental margin. Geological Society of America Bulletin, v. 93, p. 759-783.

Young, G. M., Jefferson, C. W., Long, D. G. F., Delaney, G. D., and Yeo, G. M., 1979. Middle and Late Proterozoic evolution of the northern Canadian Cordillera and shield. Geology, v. 7, p. 125-128.

Appendix 1. Paleontology by H.J. Hoffman, W.H. Fritz, M.J., Orchard, B. S. Norford, and A. W. Norris

FIELD NO. AND STRATIGRAPHY	LOCATION, FAUNA, AND AGE	GSC LOC. NO. IDENTIFIED BY
Narchilla Formation		
TOA93-12-1 Stratigraphic position unknown	394399E, 7160875N Zone 8W 64° 33' 30"N 137° 12' 24" NTS 116A/11 8.5 km from junction of Rae and Lake creeks at 193° *Helminthopsis abeli* Ksiazkiewicz *Oldhamia radiata*? *Planolites* sp. Small hemispherical projections on base of bed 1-2 mm across Age: Lower Cambrian	202432 H.J. Hofmann
TOA93-15-4 Top of unit	393599E, 7161900N Zone 8W 64° 34' 01"N 137° 13' 24" NTS 116A/11 7.7 km from junction of Rae and Lake creeks at 200° *Oldhamia flabellata* Acenolaza & Durand *Planolites* sp. Age: Lower Cambrian	202443 H.J. Hofmann
TOA93-11-2 Stratigraphic position unknown	400300E, 7158950N Zone 8 64° 32' 33"N 137° 04' 50"W NTS 116A/11 11 km from junction of Rae and Lake creeks at 157° *Helminthoidichnites*? sp. *Oldhamia flabellata* Acenolaza & Durand *Planolites* spp. *Chondrites*-like burrow pattern, but probably not *Chondrites* Hemispherical protrusions on base of bed 1-2 mm across. Possible impression of compacted sausage-like body 35x3 mm in shale with plumose parting. Delicate reticulate pattern on upper bedding surface with 0.5 mm wide round sandy objects surrounded by darker more shaly material (lichen alteration pattern?). Shrinkage cracks. Age: Lower Cambrian	202443 H.J. Hofmann

Remarks: The trace fossils in all three collections are poorly preserved and of low diversity. All three have *Oldhamia*. I would interpret all three collections as coming from Lower Cambrian units.

FIELD NO. AND STRATIGRAPHY	LOCATION, FAUNA, AND AGE	GSC LOC. NO. IDENTIFIED BY
Gull Lake Formation		
TOA92-13-4 Unit €Gp Stratigraphic position unknown	391020E, 7165300N Zone 8 6.4 km upstream of mouth of Lake Creek *Proliostracus*? sp Age: Lower Cambrian	108191 W.H. Fritz
TOA92-13-15 Unit €Gp Stratigraphic position unknown	7165250N, 391020E Zone 8W 6.45 km upstream of mouth of Lake Creek, SE bank *Proliostracus*? sp Age: Lower Cambrian	108192 W.H. Fritz

Remarks: Both collections (TOA92-13-4,15) contain similar, disarticulated trilobite skeletons, which broke into very small pieces before deposition. *Proliostracus*? sp. is present in both collections, suggesting that they belong to the medial part of the lower Cambrian *Bonnia-Olenellus* Zone. Associated fragments bearing a *Wanneria*-like pattern serve to strengthen the mentioned age assignment. In the Yukon, *Proliostracus* is present in the lower part of the Illtyd Formation (Fritz, 1991) and near the middle of the Sekwi Formation (Fritz, 1976, 1978a, 1979). In British Columbia, the genus is present in Unit 5 of the Rosella Formation (Fritz, 1978b) and in Alberta it is present in the lower part of the Manito Formation (Fritz et al., 1992). *Proliostracus* has not been reported so far from the Gull Lake Formation (basinal equivalent of the Sekwi Formation, see Gordey and Anderson, 1993).

TOA93-23-40.5 m Top of unit ꞒGl	64° 29' 48"N 136° 35' 36"W 3.3 km AZ 50° from peak 6208 *Bonnia* sp. (pygidium, 2 pairs of spines) *Olenellus* ? sp. *Serrodiscus* sp. inarticulate brachiopod Age: Lower Cambrian	C-202433 W.H. Fritz

Remarks: The above collection is from the middle part of the Lower Cambrian *Bonnia-Olenellus* Zone. In Laurentia, *Serrodiscus* indicates cooler (deeper) waters and is not found in platform deposits. It is possible that the abrupt boundary between the siliciclastic unit containing this collection and the underlying limestone conglomerate unit represents the lateral extension of a regional regression. In the Sekwi Formation, this regression is represented by a thin quartzite unit. There, expected lowermost *Bonnia-Olenellus* Zone fossils have not been found in or above the quartzite, suggesting that the quartzite overlies a disconformity of moderate magnitude (Fritz, 1992, p. 12).

TOA92-11-2 Unit ꞒGp Stratigraphic position unknown	Zone 8; 7165000N, 394670E 4.3 km from the mouth of Lake Creek at 201° Fossils: sphaeromorphs, tubes, shell fragments, inarticulate brachiopods Age: Phanerozoic	C-108175 M.J. Orchard
TOA92-18-2 **Unit ꞒOu** Stratigraphic position unknown	Zone 8; 7158720N, 395260E 10.2 km from the mouth of Lake Creek at 184° Fossils: conodonts Conodont taxa: ramiform elements (2) Age: Ordovician–Triassic	C-108181 M.J. Orchard

Rabbitkettle Formation

TOA91-21-7 Top of unit	Zone 8; 414931E, 7155769N 6 km from Callison Lake at 233° Fossils: sphaeromorphs, shell fragments, sponge spicules Age: Paleozoic	C-108168 M.J. Orchard
TOA91-25-3 Top of unit	Zone 8; 406741E, 7158456N 12.9 km from Callison Lake at 265° Fossils: brachiopods Age: Paleozoic	C-108167 M.J. Orchard
TOA92-17-2 Unit OSl, Base of unit	Zone 8; 7158950N, 400560E 10.8 km from the mouth of Lake Creek at 155° Fossils: conodonts, sphaeromorphs Conodont taxa: coniform elements (2) ramiform elements (4) Age: Ordovician–?Devonian	C-108180 M.J. Orchard
TOA92-19-1 Stratigraphic position unknown	Zone 8; 7156625N, 397500E 12.7 km from mouth of Lake Creek at 172° Fossils: conodonts Conodont taxa: ramiform elements (1)	C-108182 M.J. Orchard

Belodella sp. (1)
Age: Ordovician–Devonian

TOA93-17-3 Unit €Sc Top of unit?	64° 43' 06", 136° 50' 52" Zone 8; 7178150N, 412000E 12.7 km from large lake (near centre of map) at 342° Az. Fossils: conodonts, ichthyoliths, sphaeromorphs, microgastropods, echinoderms, inarticulate brachiopods, *Milaculum* sp. Conodont taxa: oistodiform elements (13) *Belodella*? sp. (1) *Belodina* spp. (5) *Coelocerodontus trigonius* Ethington 1959 (2) *Cornuodus*? sp. (2) *Dapsilodus*? sp. (2) *Drepanoistodus suberectus* (Branson & Mehl) (10) *Panderodus* spp. (43) *Plectodina*? sp. (1) *Protopanderodus* sp. (2) *Pseudooneotodus mitratus* (Moskalenko 1973) *Walliserodus*? sp. (3) Age: Late Ordovician	C-202437 M.J. Orchard

Road River Group (Unit ODRp)

TOA93-19-6 About 5 m above base of unit	64° 29' 37" N, 136° 35' 33" W 7152775N, 423500E At 3.1 km at 54° from 6208 ft. (1892 m) peak ?*Clonograptus* sp. *Tetragraptus* sp ?*Tetragraptus* sp. *T.* cf. *T. approximatus* Nicholson Age: Early Ordovician, probably early Arenig, probably *approximatus* Zone or *fruticosus* Zone	C-202423 B.S. Norford
TOA93-20-1 Less than 30 m above unit €Sc	64° 32' 03" N, 136° 44' 00" W 7157525N, 416875E 3.3 km at 237° from Callison Lake *Climacograptus* sp. *Dicellograptus* sp *Glyptograptus* sp. *Reteograptus* sp. Age: Late or late Middle Ordovician, possibly Ashgill	C-202426 B.S. Norford

Remarks: This sample appears to be late Ashgill, but the mode of preservation (in chert) prevents identification that might allow a zonal determination.

TOA93-24-3 Immediately below unit SDl	64° 38' 18"N, 137° 05' 12"W 7169600N, 400300E inarticulate brachiopod ?*Climacograptus* sp. *Dicellograptus* sp. *Glyptograptus* sp. ?*Orthograptus* sp. indeterminate arthropod Age: Middle or Late Ordovician	C-202444 B.S. Norford
TOA93-24-5 Immediately below	64° 38' 09" N, 137° 05' 28" W 7169300N, 400100E 4 km at 78° from junction of Rae and Lake creeks	C-202431 B.S. Norford

unit SDl	climacograptid *Dicellograptus* sp. ?*Orthograptus* sp. Age: Middle or Late Ordovician	
TOA93-19-7 About 5 m below unit Pd	64° 29' 30" N, 136° 35' 40"W 7152570N, 423400E 2.8 km at 56° from 6208 ft. (1892 m) peak diplograptid ?*Orthograptus* sp. *Monograptus* cf. *M. gregarius* Lapworth Age: Early Silurian, probably late Rhuddanian *M. cyphus* Zone or early Aeronian *M. gregarius* Zone	C-202424 B.S. Norford
TOA93-23-2 About 2 m above unit €Sc	64° 30' 36" N, 136° 30' 24" W 7153600N, 427650E 9.7 km at 124° from Callison Lake *Monograptus* sp. *Rastrites* sp. or *M. triangulatus* (Harkness) *sensu lato* Age: Early Silurian, Aeronian (Middle Llandovery)	C-202429 B.S. Norford
TOA93-18-1 Immediately above unit Pd	64° 29' 47"N, 136° 38' 22" W 7153150N, 421250E 2.1 km at 7° from 6208 ft. (1892 m) peak *Monograptus* sp. *M.* ex gr. *M. spiralis* (Geinitz) Age: Early Silurian, late Telychian	C-202422 B.S. Norford
TOA93-19-8 2 m above unit Pd	64° 39' 26" N, 136° 35' 44" W 7152440N, 423340E 2.7 km at 58° from 6208 ft. (1892 m) peak *Dictyonema* sp. *Monograptus* spp. *M.* ex gr. *M. priodon* Bronn *M.* ex gr. *M. spiralis* (Geinitz) Age: Early Silurian, Late Telychian	C-202425 B.S. Norford
TOA93-20-3 Talus from a 20-30 m interval below volcanic rocks (unit Sv)	64° 31' 45" N, 136° 46' 18" W 7156925N, 415000E 5.2 km at 244° from Callison Lake sponge ?*Monograptus* spp. *M.* ex gr. *M. spiralis* (Geinitz) Age: Early Silurian, Late Telychian	C-202427 B.S. Norford
TOA93-23-1 5 m above Unit €Sc	64° 30' 32" N, 136° 29' 41" W 7154400N, 428300E 9.8 km at 119° from Callison Lake ?*Monograptus* spp. *M.* ex. gr. *M. spiralis* (Geinitz) *Retiolites* or *Stromatograptus* sp. Age: Early Silurian, Late Telychian, *M. spiralis* Zone	C-202428 (=47117 recollected) B.S. Norford
TOA93-26-3 Top of unit	64° 38' 52", 137° 27' 30" Zone 8; 7171200N, 382600E 13.9 km from junction of Lake and Rae creeks at 279° Fossils: conodonts Conodont taxa: ramiform elements (10)	C-202420 M.J. Orchard

	Polygnathus? sp. (1) Age: ?Devonian–Early Carboniferous	
TOA93-26-4 Isolated outcrop of recessive dark grey calcareous shale	64° 38' 52" N, 137° 27' 30" W 7171200N, 382600E 13.9 km from junction of Lake and Rae creeks at 279° *Nowakia* sp. cf. *N. acuaria* (Richter) s.l. *Styliolina* sp. *Monograptus* sp. Age: *Nowakia acuaria* Zone of Lütke (1979), ranging from late Lochkovian and throughout most of the Pragnian of the early Devonian	C-202434 A.W. Norris

Remarks: The numerous tentaculitids in this sample are associated with a few poorly preserved specimens of monograptids. The most abundant tentaculitid is a form suggestive of *Nowakia acuaria* s.l. as described by Boucek (1964) and Lardeux (1969) which is the name bearer of the *N. acuaria* Zone This zone in western Europe ranges throughout the upper Lochkovian and most of the Pragian stages of the Lower Devonian (Lütke, 1985). In the Road River Formation of the Royal Creek area of northern Yukon Territory, *Monograptus yukonensis* and *M. telleri* occur abundantly within the *N. acuaria* Zone (Norris, 1985, section 38, fig. 6).

Unit Sv

TOA93-20-2 Grey silty limestone, interbedded with mafic volcanic rocks	64° 31' 44", 136° 46' 16" Zone 8; 7156950N, 415000E 5.3 km from Callison Lake at 244° Fossils: conodonts, sphaeromorphs Conodont taxa: coniform elements (2) ramiform elements (2) Age: Ordovician–Silurian	C-202416 M.J. Orchard

Unit SDl

TOA93-17-4 10 m above base	64° 42' 6", 136° 56' 30" Zone 8; 7176400N, 407450E 13.3 km from large lake (near centre of map) at 320° Fossils: conodonts, shell fragments, ?bryozoans Conodont taxa: ramiform elements (30) *Belodella* sp. (6) *Carniodus*? sp. (5) *Dapsilodus* sp. (20) *Distomodus*? sp. (1) *Panderodus* sp. (20) *Pterospathodus pennatus* (Wallister 1964) (1) *Walliserodus*? sp. (2) Age: Early-Middle Silurian, Llandovery–Wenlock	C-202438 M.J. Orchard
TOA93-17-6 At contact with underlying volcanic rocks, unit Sv	64° 42' 6", 136° 56' 30" Zone 8; 7176400N, 407450E 13.3 km from lake at 320° Fossils: conodonts Conodont taxa: ramiform elements (8) *Panderodus* sp. (3) *Pterospathodus*? sp. (1) *Walliserodus*? sp. (2)	C-202439 M.J. Orchard

Age: Early–Middle Silurian, Llandovery–Wenlock

Ogilvie Formation

TOA92-15-8b Top of unit	Zone 8W; 7181070N, 410570E *Spinatrypa* sp.- fragment *Thliborhynchia* sp. *Gasterocomma*? *bicaula* Johnson & Lane, 1969 Circular echinoderm ossicle with five-pointed star-shaped axial canal Echinoderm ossicle with single axial canal Age: range of *Gasterocomma*? *bicaula* is throughout most of the Emsian stage of late Early Devonian age	C-108193 A.W. Norris

Remarks: Unfortunately, the brachiopods in the sample are too poorly preserved for positive identification. The most abundant and diagnostic fossil in the "two-hole" echinoderm ossicle referred to as *Gasterocomma*? *bicaula* Johnson and Lane (1969). The range of this form in the District of Mackenzie, Yukon Territory and Arctic Islands is from the upper part of the conodont *dehiscens* Zone to the lower part of the conodont *costatus* Zone (see Figure 3 of Norris, 1985). This range coincides approximately with the Emsian Stage of late Early Devonian age.

TOA92-15-7 Base of unit	Zone 8; 7177850N, 410400E 20.5 km from Callison Lake at 332° Fossils: conodonts Conodont taxa: ramiform elements (550) *Belodella* sp. (1) *Panderodus* sp. (42) *Pandorinellina* spp. (297) *Polygnathus* ex gr. *P. dehiscens* Phillip & Jackson 1967 (3) *Polygnathus pireneae* Boersma 1974 (16) Age: Early Devonian, early Emsian	C-108178 M.J. Orchard
TOA92-15-8 Top of unit	Zone 8; 7181070N, 410570E 23.5 km from Callison Lake at 336° Fossils: conodonts Conodont taxa: drepanodiform elements (10) ramiform elements (44) *Belodella* sp. (120) *Pandorinellina exigua* (Phillip 1966) (10) *Polygnathus* sp. cf. *P. laticostatus* Klapper & Johnston 1975 (1) *Polygnathus* sp. cf. *P. costatus* Klapper 1971 (1) *Polygnathus inversus* Klapper & Johnson 1975 (65) *Polygnathus serotinus* Telford 1975 (65) *Sannemannia* sp. (102) Age: Early Devonian, middle–late Emsian	C-108179 M.J. Orchard
TOA92-22-8 Top of unit	Zone 8; 7178440N, 395450E Fossils: conodonts Conodont taxa: *Pandorinellina exigua* (Phillip 1966) (16) drepanodiform elements (30) ramiform elements (140) *Belodella* sp. (110) *Dvorakia* sp. (2) *Panderodus* sp. (12) *Polygnathus inversus* Klapper & Johnson 1975 (52) *Polygnathus* sp. cf. *P. laticostatus* Klapper & Johnston 1975 (3) Age: Early Devonian, middle–late Emsian	C-108188 M.J. Orchard

TOA93-26-5 Stratigraphic position unknown	64° 39' 5", 137° 27' 54" Zone 8; 7171685N, 382290E 14.3 km from junction of Lake and Rae creeks at 280° Fossils: conodonts, radiolarians Conodont taxa: *Pandorinellina* sp. cf. *P. steinhornensis* (Ziegler 1956) (1) *Polygnathus* sp. cf. *P. gronbergi* Klapper & Johnson 1975 (1) Age: Early Devonian, Emsian	C-202421 M.J. Orchard
TOA92-15-6 Top? of unit	Zone 8: 7177900N, 411950E 20 km from Callison Lake at 336° Fossils: conodonts, ostracodes, microgastropods, crioconarids Conodont taxa: drepanodiform elements (10) ramiform elements (108) *Belodella* sp. (160) *Panderodus* sp. (12) *Pandorinellina* sp. (2) *Polygnathus* spp. (3) *Polygnathus serotinus* Telford 1975 (19) Age: Early–Middle Devonian, late Emsian–early Eifelian	C-108177 M.J. Orchard
TOA92-21-1 Stratigraphic position unknown	Zone 8; 7171400N, 382350E 10.6 km from Two Beaver Lake at 190° Fossils: radiolarians, sponge spicules Age: Paleozoic?	C-108183 M.J. Orchard

Remarks: Pyritized radiolarians. Referred to F. Cordey.

Earn Group

TOA92-21-3 Stratigraphic position unknown; 2m thick interval of black chert and thin-bedded, grey limestone in black, siliceous shale	Zone 8; 7171550N, 383560E 10.25 km from Two Beaver Lake at 184° Fossils: conodont, sponge spicules, sphaeromorphs Conodont taxa: ramiform elements (25) *Belodella* sp. (1) *Polygnathus* ex gr. *varcus* Stauffer 1940 (7) *Polygnathus* sp. cf. *P. angustipennatus* Bischoff & Ziegler 1957 (1) *Polygnathus linguiformis* Hinde 1879 (3) Age: Middle Devonian, Givetian	C-108184 M.J. Orchard
TOA93-24-2 Thin bed of calcarenite in black siliceous shale, about 3 m above unit Sv	64° 38' 33", 137° 05' Zone 8; 7170000N, 400500E 4.3 km from junction of Rae and Lake creeks at 74° Fossils: conodonts Conodont taxa: ramiform elements (16) *Polygnathus* sp. cf. *P. linguiformis* Hinde 1879 (1) *Polygnathus* sp. indet. (1) Age: Middle Devonian	C-202419 M.J. Orchard
TOA92-21-5 Stratigraphic position unknown. Limestone concretion about 30 cm across in platy, buff, calcareous siltstone interbedded	Zone 8; 7174600N, 382320E 7.5 km from Two Beaver Lake at 195° Fossils: radiolarians, sponge spicules Age: Paleozoic?	C-108185 M.J. Orchard

with black siliceous shale

Remarks: Pyritized radiolarians. Referred to F. Cordey.

TOA93-17-7 Isolated outcrop	64° 43' 37", 137° 16' Zone 8; 7179750N, 392100E 11 km from junction of Rae and Lake creeks at 336° Fossils: conodonts Conodont taxa: '*Hindeodella*' *segaformis* Bischoff 1957 (20) ramiform elements (10) *Bispathodus* ex. gr. *stabilis* (Branson & Mehl 1934) (1) *Geniculatus*? n. sp. A. (4) Age: Early Carboniferous, Late Tournaisian	C-202441 M.J. Orchard
TOA92-22-6 Carbonate, interbedded with black shale and silty limestone, 1-m-thick bed of tan-weathering, silty limestone. Unit 13 of Green (1972). Should be assigned to Unit 14?	Zone 8; 7183320N, 393320E 8.8 km from Two Beaver Lake at 78° Fossils: conodonts Conodont taxa: ramiform elements (30) *Adetognathodus* sp. (4) *Diplognathodus* sp. (2) *Idiognathodus* sp (15) *Idiognathoides* sp. (4) *Idioprioniodus* sp. (4) Age: Late Carboniferous, Bashkirian–Moscovian	C-108187 M.J. Orchard
TOA92-22-5 Carbonate, poorly bedded, recessive, grey-brown-weathering crinoidal limestone. Unit 13 of Green (1972). Should be assigned to Unit 14?	Zone 8; 7188320N, 393280E 8.5 km from Two Beaver Lake at 76° Fossils: conodonts, radiolarians Conodont taxa: ramiform elements (10) *Declinognathodus* sp. (1) *Diplognathodus*? sp. (1) *Rhachistognathus* sp. (2) Age: Late Carboniferous, late Bashkirian	C-108186 M.J. Orchard

Appendix 2. Whole rock and trace element geochemical analyses of mafic sills and volcanic rocks

Unit	Pd (Hart River sills)				Pv	Cd (Cambrian sills)			
	TON93-4-2	TON93-4-3	TOA95-6-3	TOA95-6-5	TOA95-6-1	TOA92-17-1a	TOA92-17-1b	TON93-5-1	TON93-5-2
Na_2O	1.81	1.51	2.93	1.71	2.7	6.71	6.59	0.24	2.05
MgO	9.14	9.14	5.98	6.90	6.74	4.03	4.05	27.5	7.42
Al_2O_3	15.1	14.7	14.6	13.80	13.99	15.2	15.2	3.49	9.41
SiO_2	48.4	48.9	50.48	48.96	50.59	51.9	51.4	38.4	44
P_2O_5	0.05	0.04	0.09	0.07	0.08	0.53	0.52	0.18	0.34
K_2O	2.05	2.07	1.46	1.56	1.25	0	0	0.18	0.06
CaO	10.6	12.8	8.34	9.57	8.05	3.99	3.96	3.22	11.5
TiO_2	0.541	0.432	1.01	0.93	1.01	3.27	3.23	0.835	2.25
MnO	0.17	0.15	0.22	0.19	0.19	0.19	0.19	0.19	0.22
Fe_2O_3	8.49	7.67	13.56	12.65	10.9	11.8	11.7	14.3	11.3
LOI	3.25	2.8	2.13	1.90	3.06	2.4	2.35	8.95	11.7
Sum	99.8	100.3	100.77	98.63	98.56	100	99.2	97.6	100.2
H_2O_t	3.1	2.6	-999	-999	-999	-999	-999	9.1	4.4
CO_2	0.02	0.05	-999	-999	-999	-999	-999	0.05	7.36
Trace elements (ppm)									
Ag	0.55	0.27	0	0.70	0	1.95	1.88	0.69	-999
Ba	483.09	280.47	253.73	135.17	262.54	181.4	183.08	38.56	245.79
Be	-0.57	-0.21	1.7	1.40	2.3	1.76	1.95	0.59	-999
Bi	0.02	0.02	0.24	0.00	0	0.05	0.03	0.03	-999
Co	41.53	40.23	49	48.60	46.3	27.74	26.27	122.73	-999
Cr	1411.89	1131.09	20	200.00	157	45.88	42.88	774.06	-999
Cs	3.67	1.29	2.44	2.61	2.21	0.7	0.74	8.29	-999
Cu	79.15	55.38	157	124.00	181	32.49	30.65	30.33	-999
Hf	0.67	0.61	1.48	1.66	1.45	5.99	6.1	1.41	-999
Hg	0	0	-999	-999	-999	0	0	0	4.49
Li	51.68	37.74	-999	-999	-999	27.38	26.28	61.45	0
Mo	0.03	0.07	3.41	1.02	3.23	-999	-999	0.62	-999
Nb	1.42	1.38	2.97	3.22	2.49	57.81	56.88	12.5	-999
Ni	151.6	141.66	59	97.00	85	8.93	7.7	1446.05	31.3
Pb	0.66	3.83	0	0.00	0	8.15	9.18	2.72	-999
Rb	68.08	53.05	41.38	45.77	28.09	0.35	0.36	8.15	-999
Sb	0.2	0.56	2.51	0.25	0.52	0.12	0.13	0.17	-999
Sc	45.25	44.83	42.9	-999	47	14.28	13.36	10.94	-999
Sn	0.25	0.62	1.5	1.90	1.8	3.15	2.77	1.39	-999
Sr	152.98	142.95	138.34	127.17	131.7	197.93	197.34	57.2	-999
Ta	0.14	0.15	0.192	0.18	0.168	3.28	3.31	0.7	447.67
Th	0.24	0.29	2.143	0.50	0.551	4.52	4.62	1.14	1.64
Ti	3320	2706	6055	5575	6055	19603	19364	4677	2.95
Tl	0.67	0.52	0.38	0.38	0.34	0.03	0	-0.01	-999
U	0.07	1.16	0.147	0.14	0.147	1.14	1.2	0.33	-999
V	228.64	201.1	368	284.00	350	159.83	157.06	83.15	-999
W	0	0	-999	0.27	-999	0	0	1.52	-999
Y	10.17	8.58	21.3	19.40	22.3	32.27	32.09	8.05	31.17
Zn	60.72	51.32	78	95.00	86	125.96	120.96	106.15	-999
Zr	20.92	20.69	55.92	58.80	53.54	228.88	226.14	51.54	144.52
La	1.59	1.59	3.79	3.49	3.25	34.77	34.27	8.56	28.91
Ce	4.37	4.02	9.92	9.14	8.68	71.49	70.67	18.2	60.86
Pr	0.7	0.6	1.358	1.19	1.202	8.77	8.74	2.31	7.88
Nd	3.67	3.02	6.98	6.81	6.37	36.86	36.87	9.91	35.52
Sm	1.24	1.05	2.34	2.10	2.28	8.86	9.37	2.47	9.53
Eu	0.4	0.45	0.893	0.75	0.845	3.16	3.12	0.85	3.3
Gd	1.66	1.54	3.33	3.19	3.48	9.62	9.62	2.52	10.59
Tb	0.28	0.22	0.62	0.57	0.65	1.33	1.33	0.34	1.45
Dy	1.98	1.73	3.39	3.46	3.73	7.76	7.69	1.97	8.39
Ho	0.42	0.35	0.76	0.75	0.87	1.3	1.3	0.35	1.41
Er	1.2	1.03	2.33	2.28	2.78	3.31	3.33	0.79	3.45
Tm	0.18	0.14	0.373	0.34	0.393	0.44	0.43	0.1	0.44
Yb	1.16	0.99	2.25	2.29	2.47	2.47	2.42	0.58	2.45
Lu	0.18	0.14	0.339	0.31	0.396	0.35	0.33	0.08	0.3

NOTE: -999 = not analyzed.

Appendix 2 (Cont'd)

Unit	Cd (Cambrian sills)								COv
	TON93-5-3	TON93-5-5	TON93-5-6	TON93-5-7	TOA93-8-4	TOA93-10-2	TOA93-11-7	TOA93-22-4	TOA93-13-1
Na_2O	5.56	4.63	5.05	2.29	2.85	1.07	0.63	3.02	3.52
MgO	4.35	7.09	5	11.5	8.98	13.3	23.2	10.2	6.19
Al_2O_3	14.1	14	13.2	7.23	12.5	9.37	6.54	12.7	13.1
SiO_2	50	48.9	48.5	49.9	41.1	40.6	37.8	44.9	45.9
P_2O_5	0.66	0.42	0.69	0.21	0.96	0.7	0.46	0.54	0.56
K_2O	0.15	0.01	0.13	0.03	0.3	0.34	0.7	0	0.02
CaO	5.29	7.53	5.5	14.7	8.79	11.3	6.44	6.55	10.7
TiO_2	2.55	1.66	3.36	1.74	3.68	3.11	2.12	2.53	3.4
MnO	0.19	0.19	0.23	0.17	0.25	0.25	0.2	0.41	0.19
Fe_2O_3	11.2	10.6	14.3	10	13	12.6	13.6	13.2	13.2
LOI	4.9	3.1	2.7	1.5	4.55	5.1	6.6	4.45	2.2
Sum	99	98.2	98.7	99.3	97	97.8	98.7	98.5	99
H_2O_t	3.5	3.4	3.3	1.7	3.8	4.2	7.5	4.7	3
CO_2	2.17	0.34	0.17	0.1	1.67	1.8	0.08	0.25	0.12
Trace elements (ppm)									
Ag	2.33	1.07	2.25	0.87	3.94	3.35	1.92	2.24	2.99
Ba	570.59	156.27	534.27	272.11	856.13	1750.3	299.98	124.47	247.01
Be	1.47	1.62	1.24	1	4.46	0.2	3.21	0.83	2.4
Bi	0.06	0.03	0.04	0.04	0.09	0.05	0.05	0.08	0.04
Co	31.83	43.9	42.24	46.96	57.01	67.98	95.29	49.87	49.43
Cr	22.44	122.54	28.3	385.77	296.99	800.04	2860.68	166.03	70.58
Cs	5.62	0.87	5.27	0.32	0.73	0.18	11.4	0.24	0.64
Cu	61.91	68.11	68.74	246.95	141.84	93.38	60.87	138.01	125.84
Hf	5.62	2.18	5.01	2.44	7.8	7.05	4.15	4.6	6.35
Hg	0	0	0	0	0	0	0	0	0
Li	31.17	51.21	35.04	34.6	35.51	34.7	29.58	54.18	41.74
Mo	1.59	0.29	1.35	0.59	1.59	2.74	1.28	1.75	1.04
Nb	57.75	26.22	61.12	19.91	97.24	79.98	56.47	52.4	59.67
Ni	16.32	112.36	10.88	240.94	189.17	365.26	769.24	86.59	69.6
Pb	10.23	2.64	2.75	2.42	6.78	9.88	1.93	254.99	1.75
Rb	5.68	0.36	4.06	0.58	3.8	1.94	23.76	0.23	0.63
Sb	0.15	0.28	0.14	0.13	0.38	0.21	0.74	0.29	0.14
Sc	11.95	22.78	14.67	48.88	20.63	33.51	15.75	27.08	28.53
Sn	2.61	1.08	2.82	0.96	2.3	1.8	1.17	2.1	1.99
Sr	342.64	959.65	238.36	138.53	935.57	773.94	381.72	107.36	973.46
Ta	2.76	1.21	2.68	1.03	5.16	4.26	3.06	2.57	3.22
Th	5.45	3.36	4.21	1.57	10.88	7.44	4.63	4.43	4.06
Ti	15143	10228	21593	10348	23077	18626	11609	15276	19930
Tl	0.09	0	0.06	-0.01	0.03	0.04	0.15	0	0.02
U	1.44	0.83	1.19	0.38	3.02	1.85	1.36	1.45	1.5
V	174.37	207.08	228.21	229.11	340.41	291.18	228.26	292.08	324.52
W	0.23	0.35	0.78	0.89	0.8	0.41	1.03	0.29	0.09
Y	32.17	18.28	35.04	19.15	30.82	26.42	15.69	24.42	25.62
Zn	119.26	97.42	171.43	73.64	128	118.93	98.16	250.5	129.53
Zr	226.41	80.03	210.22	70.83	351.38	296.69	180.19	176.63	265.55
La	42.78	25	43.18	14.29	84.43	67.16	40.2	36.35	40.75
Ce	86.48	52.46	87.77	32.16	168.89	138.28	82.32	77.11	88.3
Pr	10.36	6.45	10.86	4.33	20.04	16.56	9.63	9.6	11.11
Nd	42.84	26.71	44.78	19.9	78.2	64.05	37.43	39.65	45.28
Sm	9.99	5.87	10.91	5.58	13.65	11.64	7.08	8.61	9.26
Eu	3.11	1.93	3.71	1.96	4.11	3.49	2.05	2.63	2.94
Gd	10.08	5.59	10.76	6.09	11.38	10	5.92	8.1	8.22
Tb	1.4	0.79	1.46	0.86	1.37	1.23	0.7	1.05	1.08
Dy	7.89	4.46	8.39	4.78	7.46	6.42	3.99	5.91	6.1
Ho	1.32	0.78	1.4	0.8	1.21	1.09	0.66	1	1.02
Er	3.35	1.91	3.38	1.89	2.92	2.69	1.62	2.48	2.54
Tm	0.43	0.24	0.45	0.24	0.38	0.33	0.21	0.32	0.34
Yb	2.52	1.37	2.5	1.37	2.2	1.88	1.14	1.84	1.85
Lu	0.33	0.18	0.33	0.19	0.3	0.26	0.16	0.23	0.26

NOTE: -999 = not analyzed.

Appendix 2 (Cont'd)

Unit	COv (Dempster volcanics)						PHv	Pd	
	TOA92-25-3	TOA92-27-2	TOA92-27-3	TOA95-7-5	TOA95-7-8	TOA95-7-9	TOA95-6-12	TOA92-25-1	TOA92-25-2
Na_2O	7.33	0.14	1.62	4.05	0.03	3.96	0.05	3.17	4.88
MgO	2.07	26.4	12.5	6.72	12.34	9.61	7.23	8.13	6.62
Al_2O_3	15.8	5.61	10.7	15.01	8.97	10.86	8.25	14.1	15.3
SiO_2	53.8	39.1	43.3	44.13	43.77	48.78	37.29	49.2	51.4
P_2O_5	0.51	0.15	0.87	0.58	0.46	0.47	1.05	0.22	0.32
K_2O	0.06	0.17	0.04	0.13	0	0.05	2.19	0.89	0.7
CaO	4.82	1.73	12.8	6.61	6.61	11.03	13.65	7.76	6.19
TiO_2	1.87	0.77	1.7	1.83	2.09	1.56	4.17	1.13	1.39
MnO	0.18	0.23	0.27	0.17	0.46	0.14	0.07	0.14	0.13
Fe_2O_3	10.7	14.5	12.6	11.73	12.15	8.86	10.61	10.3	10.1
LOI	1.9	9.6	3.65	7.98	11.52	4.12	14.09	3.25	2.9
Sum	99	98.7	100.1	98.94	98.38	99.46	98.66	98.3	99.9
H_2O_t	-999	-999	-999	-999	-999	-999	-999	-999	-999
CO_2	-999	-999	-999	-999	-999	-999	-999	-999	-999
Trace elements (ppm)									
Ag	1.85	0.53	5.99	0	0	0	0	0.91	1.16
Ba	208.41	51.24	139.64	167.81	21.09	67.37	616.54	1148.76	1078.59
Be	1.84	0.55	1.93	3.9	3.2	2.3	7	0.71	0.81
Bi	0.04	0.29	0.08	0.11	0.09	0.06	0.24	0.03	0.08
Co	18.1	113.84	66.12	45.3	76.1	84	28.9	35.47	38.69
Cr	66.2	2085.33	676.61	27	595	711	219	333.42	59.74
Cs	2.33	5.56	0.1	1.04	4.84	1.63	15.63	0.8	0.52
Cu	29.76	40.61	80.87	153	83	114	48	86.8	84.58
Hf	4.73	1.71	3.79	3.52	3.7	2.56	9.44	2.09	2.47
Hg	0	0	0	-999	-999	-999	-999	0	0
Li	20.86	83.57	48.59	-999	-999	-999	-999	14.83	13.13
Mo	-999	-999	-999	3.14	3.55	3.3	2.91	-999	-999
Nb	87.09	16.15	57.53	48.12	33.92	30.02	100.94	17.3	20.53
Ni	1.79	1103.51	456.19	95	382	456	43	89.25	42.99
Pb	18.98	4.83	5.24	3	3	2	7	6.55	27.19
Rb	2.46	6.94	0.36	4.21	3.35	3.1	45.09	14.26	14.05
Sb	0.3	2.18	0.34	1.09	0.94	4.47	0.59	0.13	0.7
Sc	9.46	19.52	24.84	22	23.3	24.4	17.7	34.11	29.92
Sn	3.39	1.03	1.95	2.3	2.4	2.2	3.5	1.14	2.52
Sr	804.65	64.43	499.16	513.59	582.33	186.52	337.35	309.51	432.18
Ta	4.11	1	2.53	2.536	1.858	1.409	6.176	0.99	1.08
Th	6.61	1.44	8.34	3.899	3.494	3.797	5.992	1.68	2.25
Ti	11211	4616	10192	10971	12530	9352	25000	6774	8333
Tl	0.08	0.03	0.27	0.03	0.03	0.04	0.2	0.09	0.07
U	1.69	0.36	2.04	1.145	0.943	1.007	0.928	0.54	0.61
V	49.97	115.18	191.34	270	200	186	215	201.53	229.62
W	0	0	0	-999	-999	-999	-999	0	0
Y	37.19	9.2	25.4	28.8	23.5	25.1	30.3	17.21	19.75
Zn	116.46	85.69	107.14	107	150	157	147	82.87	105.05
Zr	202.66	63.74	159.54	166.02	158.59	112.82	403.99	77.67	99.08
La	53.28	10.27	74	39.13	30.89	29.46	68.26	17.51	19.05
Ce	109.35	22.27	139.27	84.97	65.36	65.45	154.35	36.61	41.99
Pr	13.17	2.77	16.29	9.633	7.558	7.416	18.318	4.48	5.31
Nd	51.74	11.22	63.39	39.91	32.49	31.05	77.14	18.16	21.7
Sm	10.93	2.45	11.58	8.69	7.91	7.23	15.29	4	4.76
Eu	3.36	0.87	3.81	2.632	2.341	2.224	4.257	1.4	1.7
Gd	10.38	2.4	10.14	7.95	7.71	7.06	10.92	4.14	5.01
Tb	1.45	0.34	1.18	1.19	1.12	1.05	1.48	0.6	0.68
Dy	8.56	1.99	6.37	5.3	4.81	4.74	6.35	3.59	4.25
Ho	1.5	0.37	1.02	1.02	0.87	0.9	1.13	0.69	0.77
Er	3.88	1.04	2.45	2.72	2.09	2.32	2.59	1.85	2.1
Tm	0.53	0.14	0.33	0.34	0.251	0.282	0.286	0.27	0.3
Yb	3.1	0.84	1.82	1.92	1.36	1.55	1.41	1.53	1.87
Lu	0.41	0.12	0.26	0.279	0.202	0.235	0.197	0.23	0.27

NOTE: -999 = not analyzed.

Appendix 2 (Cont'd)

Unit	Pd					Sv
	TOA93-19-11	TOA93-19-12	TOA95-7-1	TOA95-7-10	TOA95-7-13	TOA95-6-13
Na_2O	3.34	3.45	2.83	4.6	2.27	5.39
MgO	7.95	8.38	6.75	5.46	8.44	3.17
Al_2O_3	13.7	12.5	15.82	14.89	14.67	14.66
SiO_2	47.8	48	48.9	51.16	46.51	54.59
P_2O_5	0.27	0.38	0.24	0.43	0.26	0.35
K_2O	0.65	0.41	0.51	0.92	2.26	0.07
CaO	8.41	8.19	9.39	8.94	6.82	4.16
TiO_2	1.42	1.84	1.35	1.59	1.08	1.64
MnO	0.17	0.2	0.16	0.14	0.12	0.04
Fe_2O_3	10.7	12.2	10.83	9.36	10.15	10.02
LOI	3.3	2.95	2.66	3.4	3.68	5.75
Sum	97.7	98.5	99.43	100.88	96.27	99.83
H_2O_t	3.7	3.5	-999	-999	-999	-999
CO_2	0.08	0.06	-999	-999	-999	-999
Trace elements (ppm)						
Ag	1.15	1.28	0	0	0	0
Ba	5918.95	1760.15	419.23	577.75	13721.55	1005.46
Be	-0.34	-0.21	1.9	2.6	2.2	1
Bi	0.04	0	0.09	0.05	0	0.08
Co	46.41	41.66	56.3	33.6	34.1	80
Cr	36.75	97.24	280	137	410	438
Cs	0.21	1.43	0.37	2.62	1.21	0.29
Cu	143.52	106.15	105	90	79	96
Hf	2.43	2.79	2.22	3.43	1.81	2.4
Hg	0	0	-999	-999	-999	-999
Li	15.25	20.17	-999	-999	-999	-999
Mo	0.7	0.61	3.6	3.93	3.17	3.18
Nb	30.06	34.62	17.73	35.6	14.44	29.93
Ni	73.15	65.97	104	52	97	403
Pb	0.91	1.73	3	4	0	0
Rb	5.13	10.04	8.44	16.43	26.41	2.06
Sb	0.04	0.73	1.05	8.17	0.51	0.27
Sc	37.75	32.53	28.2	26.2	28.8	20.5
Sn	1.1	0.8	1.7	2.1	1.7	1.8
Sr	373.97	356.63	491.02	539.9	369.83	201.61
Ta	1.35	2.65	0.926	1.881	0.963	1.548
Th	2.52	2.7	2.596	4.933	1.367	2.435
Ti	8609	11118	8093	9532	6475	9832
Tl	0.06	0.06	0.05	0.14	0.08	0.03
U	0.79	1.99	0.685	1.347	0.431	0.506
V	233.27	298.96	220	194	183	198
W	0	1.11	-999	-999	-999	-999
Y	18.16	24.09	22.3	29	16.7	16.5
Zn	81.11	123.13	95	90	84	82
Zr	99.21	103.73	91.15	140.93	72.49	108.76
La	22.57	27.87	22.5	38.72	13.78	18.04
Ce	46.75	57.99	45.68	76.43	32.25	39.02
Pr	5.67	6.99	4.99	8.121	3.813	4.372
Nd	22.24	27.26	20.22	31.94	16.41	18.05
Sm	4.87	5.95	4.53	6.86	4.18	3.96
Eu	1.69	2.05	1.481	2.087	2.895	1.231
Gd	5.74	6.43	4.76	6.83	4.15	3.77
Tb	0.68	0.88	0.75	1.03	0.71	0.61
Dy	4.21	5.32	3.96	5.06	3.12	3
Ho	0.76	0.98	0.8	1.07	0.66	0.62
Er	1.92	2.63	2.27	2.92	1.7	1.65
Tm	0.27	0.38	0.315	0.419	0.182	0.218
Yb	1.61	2.3	2.01	2.45	1.45	1.33
Lu	0.22	0.32	0.275	0.364	0.195	0.218

NOTE: -999 = not analyzed.

HART RIVER SILLS

Analytical techniques

Zircon and baddeleyite were separated from samples weighing between 5 and 20 kg, using conventional crushing, grinding, wet-shaking-table, heavy-liquid, and magnetic-separation methods. Analytical techniques employed at the Geological Survey of Canada and the UBC Geochronology Laboratory are described in Parrish et al. (1987) and Mortensen et al. (1995). Most zircon fractions were abraded before analysis, to minimize the effects of post-crystallization Pb-loss. Error ellipses on concordia plots and errors on calculated ages are given at the two sigma level.

Sample Descriptions

Sample: TOA91-9-4a-e
- Location:
  - NTS: 106D/10
  - Latitude: 64° 29' 28" Longitude: 135° 16' 55"
  - UTM Zone: 8 Easting: 486440 Northing: 7151600
  - Talus slope on east flank of Carpenter Ridge, at the head of valley south of Silver Hill.
- Geological Locale:
  - Mafic sills intrude the Gillsespie Lake Group.
- Rock Description:
  - Five talus boulders. Grey-green weathering, medium grained, equigranular, diorite? (plagioclase is ~An30). Pyroxene and plagioclase variably altered to clinozoisite, carbonate, tremolite, chlorite, minor hornblende, and biotite. One large composite quartz aggregate (fragment?) in sample 4a.

Sample: TOA91-14-4
- Location:
  - NTS: 106D/6
  - Latitude: 64° 28' 30" Longitude: 135° 11' 53"
  - UTM Zone: 8 Easting: 490800 Northing: 715050
  - Southwest end of Settlemier Ridge
- Geological Locale:
  - Sample taken from the top of a mafic sill intruding the Gillespie Lake Group.
- Rock Description:
  - Grey-green-weathering, medium grained, equigranular, diorite(?)(plagioclase composition ~An30). Pyroxene and plagioclase variably altered to clinozoisite, carbonate, chlorite, and tremolite.

Sample: TOA91-26-1
- Location:
  - NTS: 116A/10
  - Latitude: 64° 38' 20" Longitude: 136° 41' 36"
  - UTM Zone: 8 Easting: 419100 Northing: 7169150
  - Isolated knob at south end of ridge, 7.2 km from Hart River airstrip, at 106°.
- Geological Locale:
  - Inlier of middle Proterozoic Wernecke Supergroup, beneath Mackenzie Platform.
- Rock Description:
  - Massive, dark-brown-weathering, equigranular, medium grained diorite(?) (plagioclase composition could not be determined). Pyroxene and plagioclase variably altered to clinozoisite, carbonate, chlorite, and tremolite. Minor quartz.

Sample: BLENDE SAMPLE
- Location:
  - NTS: 106D/7
  - Latitude: 64° 23' 48" Longitude: 134° 44' 00"
  - UTM Zone: 8 Easting: 515450 Northing: 7140950
  - Talus slope on east flank of Carpenter Ridge, at the head of valley south of Silver Hill.
- Geological Locale:

Talus boulder derived from a mafic sill intruding the Gillespie Lake Group.

Rock Description:

Very coarse grained leucogabbro? No thin section cut.

Results

Sample TOA-91-9-4

A total of nine fractions of zircon were analyzed from the three separate samples submitted. There is certainly no problem in combining the data from the different pieces, because they were very probably from the same, relatively small, more felsic zone within the intrusion. One fraction (H) gives a $^{207}Pb/^{206}Pb$ age that is considerably older than those for the other eight fractions (1636 Ma vs. <1385 Ma), indicating that it contained an inherited component. A regression through all of the data excluding H gives upper and lower intercept ages of 1385.8 +/- 1.9 Ma and 198 Ma. The upper intercept gives the emplacement age for the body.

Samples TOA-91-14-4 and TOA-91-26-1

Four fractions were analyzed from each of these samples. Three fractions from sample 26-1 (F, G, and H) define a linear array with calculated upper and lower intercepts of 1383.0 +5.9/-5.2 Ma and 239 Ma. The fourth fraction (E) falls well to the right of this line ($^{207}Pb/^{206}Pb$ age = 1497 Ma), indicating the presence of an inherited component. Three of the fractions from sample 14-4 also contain older inherited zircon ($^{207}Pb/^{206}Pb$ ages up to 1882 Ma); however one fraction (C) falls essentially on the regression line from sample 26-1. The 1385 Ma zircons in these samples all had quite a distinctive morphology and color range, and the ones that were clearly igneous were quite strongly magnetic. The grains that gave much older ages were mainly rounded, many were frosted, and most were paler pink in colour than the 1385 Ma ones, or were colourless. In sample TOA91-14-4, fractions A and B were nonmagnetic, and B contained many rounded grains (A didn't). These fractions both gave older ages. Fraction C, which is the only fraction that falls on the regression line given by the other samples, was more typical of the igneous 1385 Ma zircons; it was magnetic, and strongly pinkish in colour. Fraction D was similar to C but was unabraded, and although most grains were strongly pinkish, some clear, colourless, rounded grains that were probably xenocrysts were included.

Sample BLENDE

Four zircon fractions were analyzed; they define a linear Pb-loss array with calculated upper and lower intercepts of 1380.2 +4.0/-3.8 Ma and 121 Ma, respectively. The upper intercept gives the age of intrusion.

PALEOZOIC SILLS (UNITS ₵d & Pd)

Analytical techniques

Zircon and baddeleyite were separated from samples weighing between 5 and 20 kg, using conventional crushing, grinding, wet-shaking-table, heavy-liquid, and magnetic-separation methods. Analytical techniques employed at the Geological Survey of Canada and the UBC Geochronology Laboratory are described in Parrish et al. (1987) and Mortensen et al. (1995). Most zircon fractions were abraded before analysis, to minimize the effects of post-crystallization Pb-loss. Error ellipses on concordia plots and errors on calculated ages are given at the two sigma level.

Sample Descriptions

Sample: TOA92-25-2

Location:

NTS 116A/12

Latitude: 64° 38' 20" Longitude: 137° 31' 45"

UTM Zone: 8 Easting: 379200 Northing: 7170450

9.25 km from the junction of West Hart River and Lomond Creek at 180°.

Geological Locale:

The sample is from the top of a sill which intrudes graptolitic black shale of the Road River Group.

Sample Description:

Coarse-grained, massive, dark-green-weathering gabbro? Weakly saussuritized, aligned feldspar laths (50%), and weakly altered clinopyroxene (20%) form subhedral crystals. Very fine-grained chlorite (20%), intergrown with opaques (10%), forms anhedral, interstitial clots.

Sample: TOA92-25-3

Location:

NTS 116A/11

Latitude: 64° 32' 48"   Longitude: 137° 10' 30"

UTM Zone: 8   Easting: 395730   Northing: 7159540

9.4 km from the junction of Rae and Lake creeks at 182°.

Geological Locale:

The sample is from the top of a sill about 60 m thick, which intrudes maroon and green shale of the Narchilla Formation.

Sample Description:

Coarse- to very coarse-grained (pegmatitic), dark-green-weathering leucogabbro? Plagioclase (65%) forms coarse intimately intergrown grains. Fine-grained chlorite (25%), opaques (10%), and quartz (<1%) form anhedral interstitial intergrowths.

Results

Sample TOA92-25-2

Only a very small amount of zircon (<100 micrograms) was recovered from this sample. The best quality and coarsest grains were strongly abraded (fraction A) and two other fractions of finer, poorer quality zircon were not abraded before analysis. The three analyses define an apparent Pb-loss line anchored by fraction A, which gives a concordant, although very imprecise, analysis. A weighted average Pb/Pb age for the three analyses is 275 +/- 34 Ma, which suggests a Late Paleozoic age for the gabbro body.

Sample TOA92-25-3

No zircon was recovered from this sample; however it did yield a small amount of baddeleyite, as fine flakes and needles. Four unabraded fractions of baddeleyite were analyzed. All are moderately discordant and the error ellipses overlap one another. A weighted average Pb/Pb age for the three analyses is 518.2 +/- 2.9 Ma, which is taken as the best estimate for the age of the unit.

Bulletin 1	The Whitehorse Copper Belt: Mining Exploration and Geology 1967 - 1980 (105D)	D.Tenney
Bulletin 2	Geology and Genesis of the Mount Skukum Epithermal Gold-Silver Deposits, Southwestern Yukon Territory (105D)	B.W.D. McDonald
Bulletin 3	Shape and Composition of Lode and Placer Gold from the Klondike District, Yukon, Canada (115O, parts of 116B)	J.B.Knight, J.K. Mortensen and S.R.Morison
Bulletin 4	Sedimentology of Placer Gravels near Mt. Nansen, Central Yukon Territory (115I)	W.P. LeBarge
Bulletin 5	Natural Land Reclamation for Mineral Exploration Properties and Placer Mines in Yukon	C. Mougeot
Bulletin 6	Geology of the McQuesten River region, Northern McQuesten and Mayo Map Areas, Yukon Territory (115P/14-16, 105M/13-14)	Donald C. Murphy
Bulletin 7	Geology of the Mayo Map Area, Yukon Territory (105M)	Charlie Roots
Bulletin 8	A Transect Across Northern Stikinia: Geology of the Northern Whitehorse Map Area, Southern Yukon Territory (105D/13-16)	Craig J.R. Hart
Bulletin 9	Geology of the Upper Hart River Area, Eastern Ogilvie Mountains, Yukon Territory (116A/10,11)	Grant Abbott

Copies available from: Geoscience Information and Sales, Exploration and Geological Services Division, Indian and Northern Affairs Canada, 102-300 Main St., Whitehorse, Yukon, Y1A 2B5.
Phone 867 667-3264, Fax 867 667-3267.
Visit our Web Site: http://www.yukonweb.com/government/geoscience/