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PRECAMBRIAN GEOLOGY OF THE ARSENO LAKE MAP AREA, DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES

R.A. Frith

1991

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Preface

During the course of regional mapping of the Indin Lake map area, a number of gneiss domes were discovered just west of Arseno Lake. The core rocks of the domes were dated as Archean, but they are surrounded by paragneiss belonging to the Proterozoic Snare Group. The interest in the domes generated further study by the Geological Survey of Canada, the University of Alberta and Carleton University. The gneiss domes were remapped at a 1:50, 000 scale, the structure of the domes were analysed in detail and the metamorphic assemblages present in the paragneiss of the region were studied using microprobe techniques.

This report summarizes the work to date, including older structural studies along the Slave Province boundary. The regional tectonism is reinterpreted in light of the more recent ideas brought forward by mapping the Wopmay Orogen, which showed that much of the Proterozoic rocks along the Slave Province boundary are allochthonous and were scraped along a décollement and folded against a buttress-like Slave Craton.

This bulletin is a valuable addition to the knowledge of the region and sheds some new light on some of the perplexing problems that ensue when ancient plate margins collide.

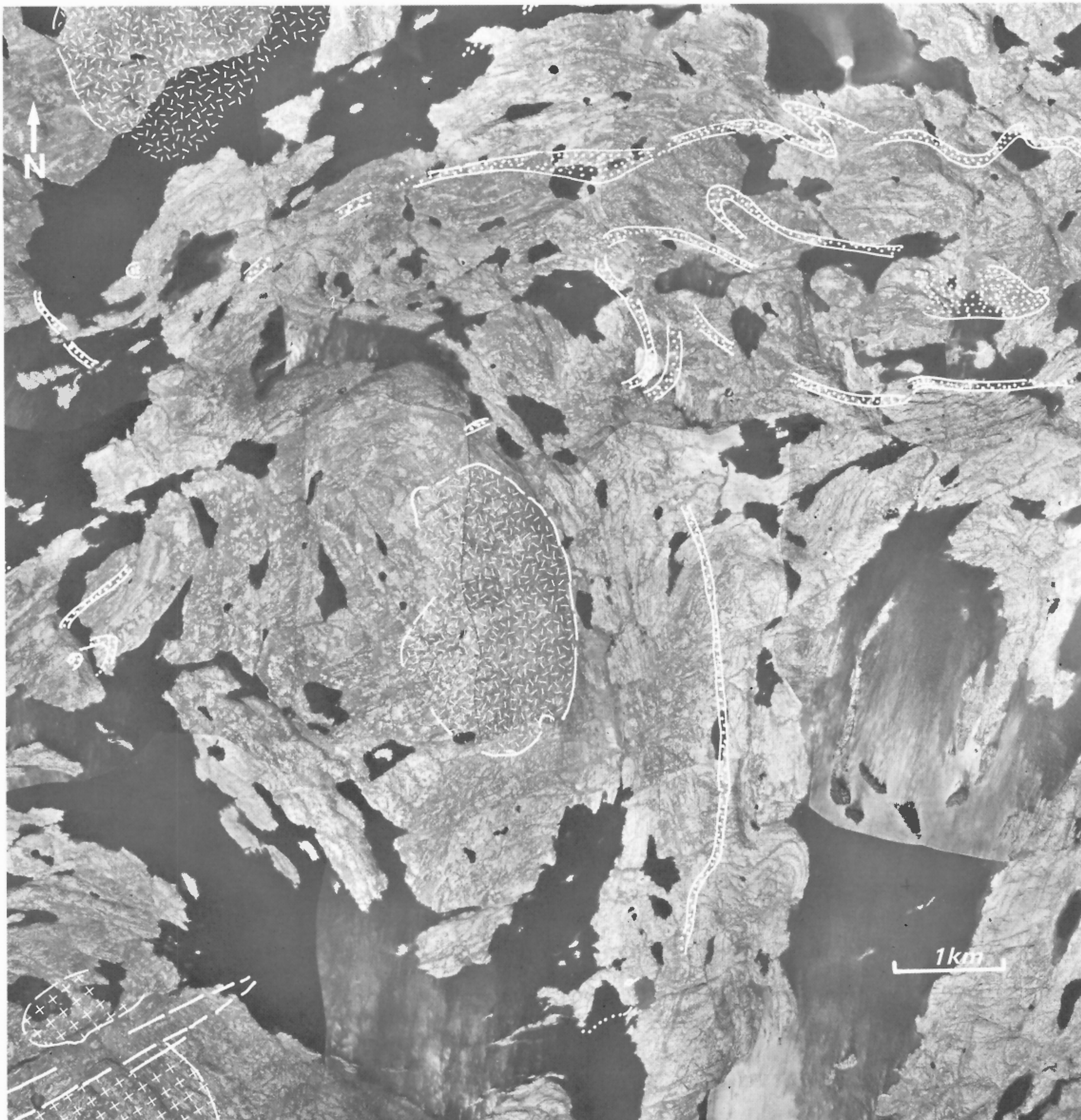
Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

Préface

Plusieurs dômes de gneiss, entourés de paragneiss protérozoïque du Groupe de Snare, ont été découverts à l'ouest du lac Arseno au cours des travaux de cartographie à l'échelle de 1/250 000 de la région cartographique du lac Indin. Ces travaux en question sont décrits dans le mémoire 424 de la CGC. L'intérêt que présentait l'origine de ces dômes de gneiss, dont l'âge isotopique remonte à l'Archéen, a mené la Commission géologique du Canada, l'Université de l'Alberta et l'Université Carleton a réaliser d'autres études. La région du lac Arseno a été cartographiée de nouveau à une échelle détaillée et on y a effectué une analyse structurale et métamorphique des dômes et du paragneiss encaissant.

Le présent bulletin qui comprend une carte géologique à l'échelle de 1/50 000 donne un résumé de ces travaux et des résultats d'études antérieures réalisées le long de la limite de la Province des Esclaves. Le diastrophisme régional est interprété à la lumière de modèles récents dérivés de la cartographie de l'orogène de Wopmay, qui montrent que la plupart des roches protérozoïques en bordure de la limite de la Province des Esclaves sont allochtones, ont été transportées le long d'un décollement et sont plissées contre le craton des Esclaves, un craton rigide en forme d'éperon. Le rapport élargit donc nos connaissances de cette zone aurifère et présente une interprétation d'une ancienne zone de collision de frontière de plaque.

Elkanah A. Babcock
Sous-ministre adjoint
Commission géologique du Canada



FRONTISPIECE

Air photomosaic of the Emile River gneiss domes with the massive core gneiss (central, stick pattern), sinusoidal quartz pebble conglomerate marker beds (dotted pattern) and intrusive granitic rocks (cross pattern) indicated.

PRECAMBRIAN GEOLOGY OF THE ARSENO LAKE MAP AREA, DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES

Abstract

The Arseno Lake map area lies mostly within the Wopmay Orogen which comes into contact with the western margin of the Slave Structural Province. The Proterozoic rocks in the area consist chiefly of Snare Group rocks of the Coronation Supergroup. These rocks were folded, metamorphosed and intruded by granites of the Hepburn Intrusive Suite during Wopmay orogenesis. Domes of Archean basement gneiss were emplaced into the Snare Group during this orogeny. Structures in the Snare Group and in the Slave Craton suggest that the bulk of the Proterozoic and Archean rocks west of the Slave Province boundary are allochthonous and were derived from the west along sole faults that coincide with the presently defined Slave Province boundary.

The basement-cored gneiss domes and supracrustal rocks in the western part of the Proterozoic allochthon have been metamorphosed to granulite facies and consist mostly of rust coloured biotite gneiss and schist derived from rocks of subgreywacke composition. Intraformational quartz pebble conglomerates serve as marker beds in this succession, outlining a complex structural history dominated by east-west compression, followed by subsequent uplift of the gneiss domes.

Toward the Slave Province margin the proportion of coarse clastic rocks decreases and siltstone, argillite, quartzite, calc-silicate rocks and dolomite are common. The Snare Group is folded in this area into tight steeply-dipping, gently north-plunging inclines that verge eastward.

Archean deformation is recognized in the Slave Province where metasedimentary rocks were folded into-northwest- to northerly-trending isoclinal structures, and the more homogeneous metavolcanic and granitoid rocks were horizontally compressed and foliated.

Proterozoic deformation further compressed Archean structures near the western margin of the Slave Craton, evidenced by south- to southwest-plunging structures similar to those in the gneiss dome areas and in the allochthonous Snare Group, and by younger structures associated with the development of the isoclinally folded Snare Group rocks near the Slave boundary.

Granulite facies metamorphism in the southernmost gneiss dome area grades down to greenschist facies near the contact with the Slave Province. This metamorphism is associated with Wopmay orogenesis, although its centre occurred farther west. Regional isograds developed during the orogeny were transported eastward with the thrusting of the sedimentary prism onto the Slave Craton. Low-grade Proterozoic retrograde metamorphism overprints Archean "Kenoran" metamorphic textures and has reset some K-Ar and Rb-Sr mineral and whole rock systems along the margin of the Slave Province.

Résumé

La région cartographique d'Arseno Lake se situe principalement dans la zone de l'orogène de Wopmay, qui se trouve en contact avec la marge ouest de la province structurale des Esclaves. Les roches protérozoïques de cette région se composent principalement de roches du groupe de Snare appartenant lui-même au supergroupe de Coronation. Ces roches ont été plissées, métamorphisées et traversées par des granites de la série intrusive de Hepburn durant l'orogenèse de Wopmay. La mise en place de dômes composés de gneiss du socle archéen s'est faite dans le groupe de Snare durant cette orogenèse. Les structures présentes dans le groupe de Snare et le craton des Esclaves semblent indiquer que l'ensemble des roches protérozoïques et archéennes situées à l'ouest de la limite de la province des Esclaves sont allochtones, et proviennent de l'ouest, le long de failles de chevauchement sub-horizontales coïncidant avec la limite présentement définie de la province des Esclaves.

Dans la partie ouest de l'allochtone protérozoïque, les dômes de gneiss composés de noyaux du socle et de roches supracrustales ont été métamorphisés au stade du faciès des granulites, et se composent principalement de gneiss à biotite et de schistes de couleur rouille, dérivés de roches dont la composition est celle d'une subgrauwacke. Des conglomérats intraformationnels, à galets quartzeux, constituent des lits repères dans cette succession, et témoignent d'une histoire structurale complexe dominée par une compression est-ouest, suivie du soulèvement ultérieur des dômes gneissiques.

En direction de la marge de la province des Esclaves, la proportion de roches clastiques grossières diminue, et les microgrès, argilites, quartzites, roches calco-silicatées et dolomies se retrouvent en abondance. Dans cette région, le groupe de Snare a été soumis à des plissements qui ont formé des structures isoclinales étroites, de fort pendage, plongeant doucement vers le nord et inclinées vers l'est.

On reconnaît des exemples de la déformation archéenne survenue dans la province des Esclaves aux endroits où les roches métasédimentaires ont subi des plissements qui les ont transformées en des structures isoclinales se dirigeant du nord-ouest vers le nord, et aux endroits où les roches métavolcaniques et granitoïdes plus homogènes ont subi une compression et un plissement à composante horizontale.

La déformation protérozoïque a davantage comprimé les structures archéennes à proximité de la marge ouest du craton des Esclaves, ainsi qu'en témoignent des structures de plongement sud à sud-ouest, comparables à celles des régions de dômes gneissiques et du groupe allochtone de Snare, et des structures plus récentes associées au développement de la zone de roches à plis isoclinaux du groupe de Snare près de la limite de la province des Esclaves.

Le degré de métamorphisme observé dans la région des dômes de gneiss les plus méridionaux, soit celui du faciès des granulites, passe progressivement au faciès des schistes verts près du contact avec la province des Esclaves. Ce métamorphisme est associé à l'orogenèse de Wopmay, bien que son centre ait pris naissance plus à l'ouest. Les isogrades régionaux apparus durant l'orogenèse ont migré vers l'est au moment du chevauchement du biseau sédimentaire sur le craton des Esclaves. Le rétrométamorphisme protérozoïque de faible intensité se surimpose aux textures métamorphiques archéennes du "Kénorien", et a remis à l'état initial certains systèmes contenant K-Ar et Rb-Sr, qu'il s'agisse des minéraux ou de la roche entière, le long de la marge de la province des Esclaves.

SUMMARY

This study is directed toward understanding the relationship between the Archean Slave Structural Province and the Proterozoic Wopmay Orogen. The Arseno Lake map area straddles the boundary between these two tectonic regions. On the Slave Province side, the rocks consist of Archean pillow basalts and turbiditic greywackes, plutonic rocks, metamorphic paragneiss and migmatite that are, on the whole, typical of the Slave Province. To the west of the boundary, bedrock is composed of Proterozoic Snare Group flysch deposits, plutonic rocks of the Hepburn Intrusive Suite and remnant areas of Archean granitoid and paragneiss basement that occur in and around a group of mantled gneiss domes.

Deformation in the Slave Province is dominantly Archean, but the rocks were overprinted during the Proterozoic by two thermal events and one deformational event. There is no equivalent of the earliest thermal event in the Wopmay Orogen. The metamorphic grade on each side of the boundary is the same, despite the time and regional spread of two distinct

SOMMAIRE

La présente étude a pour but de mieux comprendre les relations qui existent entre la province archéene des Esclaves et l'orogène protérozoïque de Wopmay. La région cartographique du lac Arseno chevauche la frontière entre ces deux entités tectoniques. Du côté de la province des Esclaves, on retrouve des basaltes en coussins d'âge archéen, des grauwackes turbiditiques, des roches plutoniques, des paragneiss et des migmatites de nature métamorphique qui sont généralement caractéristiques à la province des Esclaves. Du côté ouest, on retrouve les dépôts flyschoïdes du groupe protérozoïque de Snare, les roches plutoniques de la série intrusive de Hepburn ainsi que des lambeaux de roches granitoïdes et de paragneiss archéens de socle qui se manifestent à l'intérieur ou autour des dômes de gneiss.

Dans la province des Esclaves, la déformation est principalement d'âge archéen mais deux phases thermiques et une phase de déformation durant le Protérozoïque se sont surimposées à ces roches. Il n'y a pas d'équivalent de la première phase thermique dans l'orogène de Wopmay. Le degré de métamorphisme est le même de chaque côté de la frontière malgré l'intervalle temporel et spatial considérable qui sépare orogenies: one in the Archean, and the other in the Proterozoic.

Proterozoic deformation in the Slave Province is evident in the metasedimentary rocks as a faint penetrative cleavage, the axial planes of which dip steeply to the west. Archean linear features are regionally subparallel to the Slave Province boundary and east-west shortening associated with Proterozoic tectonic events has rotated these features toward Proterozoic foliation planes.

The major mountain-building event that gave rise to the Wopmay Orogen folded and metamorphosed Proterozoic Snare Group rocks in the map area into two distinct structural domains. Adjacent to the Slave Province boundary the rocks are folded in single phased, tight isoclinal folds that dip east, which contrast to the west-dipping Proterozoic axial planar features in the Slave Province. The western part of the map area is polydeformed and is characterized by the presence of four prominent gneiss domes.

The Slave boundary is defined as a surface separating dominantly Archean rocks of dominantly Archean deformation from dominantly Proterozoic rocks of dominantly Proterozoic deformation. The two tectonic regions have similar Proterozoic foliation trends, but these foliations dip in opposite directions. In the southern part of the map area a dominant straight-line fault separates the two tectonic regions, and slickensides suggest that late movement on the fault involved an uplift of the rocks on the Slave side. Eastward-directed thrusting of an allochthonous sedimentary prism occurs north of the map area (the Redrock Lake map area) which supports a tectonic interpretation involving convergence and possible subduction of the underlying Bear plate with the Slave plate, accompanied by eastward thrusting of an allochthon that stabilized against the Slave Craton. The Snare Group supracrustal rocks formed the leading edge of the allochthon which became folded in accordian style against an upsloping Slave Craton. The basal thrust fault emerged as a steep reverse fault that coincides with the Slave Province boundary in the map area. The allochthon included Archean basement granitoid gneiss and paragneiss, as well as Proterozoic plutonic rocks of the Hepburn Intrusive Suite.

Gneiss domes in the western part of the study area consist of Archean granitoid cores with paragneiss mantles of uncertain age. The domes have structures that indicate they formed by two-phase fold interference, followed by uplift of the gravitationally positive granitoid core regions. The second phase of folding is correlated with the single phase of folding observed in the Snare Group near the Slave boundary, whereas the first phase is only evident where rocks were hotter and deeper, i.e. where gneiss doming took place.

ces deux orogènes distinctes, soit l'une archéene et l'autre protérozoïque.

Dans la province des Esclaves, la déformation protérozoïque provoque un faible clivage pénétratif dans les roaches métasédimentaires avec des plans axiaux à fort pendange vers l'ouest. Les linéations archéennes sont régionalement subparallèles à la frontière de la province et le raccourcissement est-ouest associé au tectonisme protérozoïque a provoqué la rotation de ces linéations en direction des plans de foliation du Protérozoïque.

Dans la région à l'étude, la phase principale de formation de l'orogène de Wopmay a plissé et métamorphisé les roches protérozoïques du groupe de Snare selon deux domaines structuraux distincts. Près de la frontière des Esclaves, les roches sont plissées selon une unique phase isoclinale serrée s'inclinant vers l'est qui contraste avec les plans axiaux inclinés vers l'ouest de la province des Esclaves. La partie ouest de la région à l'étude, est polyphasée et caractérisée par la présence de quatre dômes de gneiss de taille considérable.

La frontière de la province des Esclaves est définie par une ligne séparant des roches mises en place et déformées à l'Archéen de roches mises en place et déformées au Protérozoïque. Les deux régions tectoniques ont des foliations protérozoïques semblables qui accusent des pendages contraires. Dans la partie sud de la région à l'étude, une faille importante sépare les deux régions tectoniques et les miroirs de faille semblent attester de l'existence d'un mouvement tardif de remontée des roches du côté de la province des Esclaves. Dans le secteur nord (Redrock Lake), des prismes allochtones charriés vers l'est viennent appuyer l'interprétation tectonique de la convergence et de la subduction possible de la plaque sous-jacente de Bear sous la plaque des Esclaves, mouvement qu'aurait accompagné le charriage vers l'est d'un allochtone plissé en accordéon contre la pente relevée du craton des Esclaves. Dans la région à l'étude, le charriage de base est représenté par une faille inverse redressée coïncidant avec la frontière de la province des Esclaves. L'allochtone comporte une faible quantité de gneiss granitiques et de paragneiss archéens de socle ainsi que des roches plutoniques protérozoïques de la série intrusive de Hepburn.

Dans la partie ouest, les dômes de gneiss se composent de noyaux granitoïdes d'âge archéen entourés de paragneiss d'âge incertain. Leurs structures indiquent qu'ils doivent leur formation à une double phase de plissement suivie d'une remontée de la partie granitique centrale gravitationellement positive. La seconde phase de plissement est acorrelée avec la phase unique déjà mentionnée du groupe de Snare près de la frontière de la province des Esclaves, la première phase étant évidente aux endroits caractérisés par la présence de roches plus chaudes et plus profondes, soit là où les dômes de gneiss ont pris naissance.

Le style de plissement est variable le long de la frontière de la province des Esclaves et reflète le degré régional de métamorphisme. Ce dernier est plus faible dans le sud de la région à l'étude, là où les plis sont plus ouverts. Au nord de la région cartographique, les plis sont plus serrés et deviennent plus complexes. Des inflexions d'ordre kilométrique sont déduites

The style of folding evident near the Slave Province boundary reflects the regional metamorphic grade. This style changes along the boundary. The metamorphic grade is lower to the south of the map area where the fold style is more open. North of the map area, folds are tighter and become more complex. The presence of regional kilometre scale warps are deduced from mineral lineations in the Snare Group which show dominantly north plunges in the map area. However, to the north of the map area, lineations plunge south. These changes are the only evidence for post-regional metamorphic adjustments in the Wopmay part of the map area. East of the boundary, uplifts of areas underlain by light granitoid rocks and downwarps of areas of heavier supracrustal rocks have been outlined.

The last deformation to affect the region was one of brittle failure, which is characterized by right lateral strike-separation faults that offset intrusive contacts and the Slave boundary, and which was probably due to late-stage collision coupled with the clockwise rotation of the Wopmay Orogen (Bear plate) relative to the more rigid Slave Province (Slave plate).

Archean metamorphism in the Slave Province part of the map area attained upper amphibolite facies. Proterozoic regional metamorphism was of a lower grade and is evident as retrograde metamorphism in the mafic minerals of the plutonic rocks and epidotization of some supracrustal rocks. However, for the most part Proterozoic effects are negligible. K-Ar micas give dates that reflect system instabilities at about 2.2 Ga and 2.0 Ga. Proterozoic metamorphism of the region west of the Slave Province boundary is at greenschist grade adjacent to the boundary and prograde to upper amphibolite grade toward the western boundary of the map area. Metamorphic mineral assemblages indicate a single phase of mineral growth in the lower grade rocks, but polymetamorphism occurs in some of the higher grade rocks, particularly the metasedimentary rocks in and around the gneiss domes. The same polyphase metamorphism is observed in the Archean granitoid gneiss dome cores, implying that some of the metasedimentary rocks around the gneiss domes may also be Archean, possibly related to equivalents of the Yellowknife Supergroup. Prograde metamorphism of the Snare Group occurs from a low near the Slave boundary to a "hot-spot" near the western margin of the map area, effecting both Proterozoic and Archean rocks. This common thermal metamorphism provides the key to the tectonic interpretation of the region.

Regional metamorphism in the Wopmay Orogen of the map area grades from greenschist, facies where the sedimentary wedge is thinnest, to granulite facies near the western margin of the map area. Prograding isograds include biotite, cordierite, sillimanite, sillimanite-potassium feldspar and cordierite-garnet. A unique index was used (ghanite content in spinel, after Nielsen, 1977) to qualitatively contour increasing pres-

des linéations minérales du groupe de la Snare plongeant vers le nord dans la région cartographique mais ces dernières s'inversent vers le sud au nord de cette même région. Ces changements sont les seules marques d'un réajustement post-métamorphique dans la partie Wopmay de la carte. À l'est de la frontière, des remontées de surface reposant sur des roches granitoïdes légères et des affaissements de régions de roches supracrustales plus lourdes ont été remarqués.

La plus récente déformation ayant affecté la région en est une de rupture de la roche caractérisée par des failles à rejet dextre ayant déplacé des contacts intrusifs et la frontière de la province des Esclaves l'un par rapport à l'autre, et sans doute due à une collision tardive et une rotation dextre de l'orogène de Wopmay (plaque de Bear) relativement à la province des Esclaves plus rigide (plaque des Esclaves).

Le métamorphisme archéen de la partie de la carte gisant dans la province des Esclaves a atteint le faciès supérieur des amphibolites. Le métamorphisme régional de nature protérozoïque est plus faible, comme le démontre la rétrogression dans les minéraux mafiques des roches plutoniques et l'épidotisation de certaines roches supracrustales. Généralement, les effets dus à la phase protérozoïque sont négligeables. Des âges déterminés à l'aide de la méthode K/Ar appliquée aux micas réflètent des instabilités autour de 2,2 et 2,0 Ga. À l'ouest de la province des Esclaves, le métamorphisme protérozoïque atteint le degré du faciès des schistes verts prés de la frontière et se transforme progressivement en faciès supérieur des amphibolite vers la frontière ouest de la région cartographique. Les associations minérales indiquent qu'il ne s'est produit qu'une phase métamorphique unique dans les roches de faible degré métamorphique mais qu'il s'agit d'un métamorphisme polyphasé dans les dômes de gneiss et dans les roches métasédimentaires à degré de métamorphisme plus élevé les entourant; on en déduit la possibilité que ces métasédiments datenht de l'Archéen et sont peut-être reliés ou équivalents au supergroupe de Yellowknife. Le degré de métamorphisme du groupe de Snare évolue progressivement de son niveau le plus faible à la frontière de la province des Esclaves vers un "hot spot" (point chaud) près de la marge ouest et touche ainsi aussi bien les roches archéennes que protérozoïques. Ce métamorphisme thermique commune aux deux est la clé de l'interprétation tectonique de la région.

Dans la région à l'étude, le métamorphisme régional de l'orogène de Wopmay varie du faciès des schistes verts, où le biseau sédimentaire est mince, à celui des granulites près de la marge ouest de la carte. Les isogrades qui vont en s'augmentant s'observent dans la biotite, la cordiérite, la sillimanite, la sillimanite et feldspath potassique et la sillimanite et grenat. Un index unique (contenu en ghanite du spinelle, selon Nielsen, 1977) a permis de dresser qualitativement les contours des conditions de pression et température (PT) correspondant au faciès supérieur des amphibolites et des granulites afin de localiser le "hot spot" (maximum thermique) dans la partie sud-ouest de la région cartographique. Les associations minéralogiques dans le groupe de Snare semblent indiquer que la surface d'érosion actuelle affiche des conditions de pression relativement constante et des températures qui arient entre 490 et 690°C. Les porphyroblastes font habituellement preuve sure-temperature (PT) conditions in upper amphibolite and granulite facies regions to localize a "hot-spot" (thermal peak) present in the southwestern part of the map area. Mineral assemblages in the Snare Group suggest that the present erosion surface represents conditions of relatively constant pressure, and temperatures that ranged from about 490-690°C. Porphyroblasts are commonly overgrown by the same metamorphic mineral phase, indicating that some kind of break occurred, but with PT conditions remaining similar. The break is tentatively linked to the time of eastward-directed thrusting of the basement and sedimentary wedge.

Plutonic rocks of the Hepburn Intrusive Suite intruded during the peak of regional metamorphism. The main intrusion, the Rodrigues granite, is elongated in the direction of D_2, as are its foliation planes, suggesting it intruded syntectonically. Studies outside of the map area indicate the suite formed from melted Archean granitoid basement which was transported allochthonously with the Snare Group host rocks and the Archean basement rocks.

d'une surcroissance due à la même phase métamorphique, phénomène qui révèle l'existence d'une rupture quelconque bien que les conditions de P et T demeurent les mêmes. Cette rupture est considérée synchrone au charriage du socle et du biseau sédimentaire vers l'est.

La mise en place des roches plutoniques de la série intrusive de Hepburn s'est fait durant la phase maximum de métamorphisme régional. L'intrusion principale, le granite de Rodrigues, s'étend dans la direction de D_2 comme ses plans de foliations, indiquant que l'on a peut-être à faire à une mise en place syntectonique. Des études à l'extérieur de la région cartographique indiquent que la série provient de la fusion du socle granitique archéen qui a été charrié avec les roches encaissantes du groupe de Snare et les roches de socle archéennes.

INTRODUCTION

Location

The Arseno Lake map area (NTS 86B/12) covers about 67 200 hectares between latitudes 64°30' and 64°45' north and longitudes 115°30' and 116°00' west within the District of Mackenzie, Northwest Territories. Its centre is about 235 km north-northwest of Yellowknife.

Previous work

The first geological work in the region was carried out by C.S. Lord and J.Tuzo Wilson while mapping the four mile to the inch Ingray Lake map area (Lord, 1942). Lord (1942) recognized a major unconformity near Basler Lake and concluded that the Yellowknife Group (now Supergroup, Henderson, 1970) and the granites that intrude it were Archean. The unconformably overlying Snare Group was considered to be Proterozoic. Lord (1942) assigned no ages to granitoid rocks west of the Slave Province boundary, except where intrusive relationships were observed with the Snare Group.

The eastern half of the map area was mapped at one mile to the inch by McGlynn and Ross (1963). These authors studied the deformation of the supracrustal rocks both within the map area and in other areas along the Bear Slave Province boundary (McGlynn and Ross, 1963; Ross and McGlynn, 1965). Other work from the area included a metamorphic study by Nielsen (1977), and a regional geochronological study of the Indin Lake area which included dating of the core and mantle rocks of the gneiss domes of this region (Frith, 1974). Archean basement-cored gneiss domes mapped during the regional mapping of the Indin Lake area in the Emile River area were described briefly (Frith, 1973, 1986a) and a structural study was undertaken by Leatherbarrow (1975).

Present work

The present work combines mapping carried out in the eastern part of the area by McGlynn and Ross (1963) and by Frith and others between 1972 and 1974 (Frith et al., 1974) with new mapping by the author in the western part of the map area. This work has incorporated unpublished data from Leatherbarrow (1975), and the metamorphic studies of Nielsen (1977) have been reinterpreted in light of the current theories of metamorphism of the Wopmay Orogen. Plutonic rock nomenclature in the report follows that of Streckeisen (1976).

Physiography

The underlying bedrock is reflected in the physiography of the map area. In the northwestern corner of the map area a large granite pluton, cut by steep fault-controlled valleys. The southeastern part of the map area consists of a pleateau of volcanic and granitoid rocks. Between the batholith and the plateau is a topographically lower, more rugged northerly trending belt of folded sedimentary rocks with a dome and basin area to the west of it. The average surface elevation is 365 m with total relief up to 60 m. The Emile River drains the area toward Great Slave Lake.

Bedrock is well exposed, except in the northern part of the Emile River area, where glacial drift is thick. Frost heaving of bedrock is common, particularly in poorly drained areas underlain by fissile rocks. Glacial ice moved from the northeast, but local movement was modified by the north-northeast-trending topography.

The area is near the northern limit of trees, and plateau areas are barren. However, in wind protected regions, thick stands of evergreen and deciduous trees are present.

Economic geology

Mineral deposits in the map area are restricted to free gold in quartz veins found in the Archean pillowed basalts. The known occurrences are shown on the map in the back pocket. The TINGO claims 19-22 were registered September 12, 1980 and the CASS 7 claims on December 12, 1984. Although no economically viable deposits have been described in the map area, the Indin Lake region as a whole has been the locus of considerable staking and development work up to 1987. The prospect of more gold of possible economic significance is likely greatest along the length of the Archean volcanic greenstone belt of the map area, particularly along the southwestern margin between the volcanic rocks and the overlying metasediments near Grizzly Lake.

Acknowledgments

The author gratefully acknowledges the superb help of R.W. Leatherbarrow and N. Rey who, with the author, carried out the bulk of the detailed mapping of the western part of the area. Peter Nielsen provided stimulating discussion on the metamorphic history of the region. Janet King kindly reviewed the structural geology section, and provided a link with the recent innovative work of a team, led by Paul Hoffman, which was invaluable in working out much of the geology of the Wopmay Orogen. Elizabeth Hurdle was responsible for drafting many of the figures and André Ciesielski edited the French translation of the Summary. F.C. Taylor reviewed the final draft and suggested many improvements.

GENERAL GEOLOGY

The Arseno Lake map area lies mainly within the Wopmay Orogen (Hoffman, 1980), mainly west of the Slave Structural Province boundary (Fig. 1). The boundary runs through the southeastern corner of the map area. The Slave Province is made up mostly of Archean plutonic and migmatitic granitoid rocks and supracrustal rocks of the Yellowknife Supergroup. Reworked Archean rocks correlative to those of the Slave Province occur within the Wopmay Orogen in the core of the gneiss domes emplaced into the Proterozoic cover. These domes are referred to collectively as the Emile River gneiss domes. In the map area, the Wopmay Orogen consists mostly of flysch-type metasedimentary rocks of the Snare Group (defined by Lord, 1942 and considered here as a reconnaissance geology map unit of the Coronation Supergroup), which were intruded by plutonic rocks of the Hepburn Intrusive Suite (Hoffman, 1981).

Figure 2 is a geological map of the Arseno Lake map area. Table 1 lists the sketch names and lithologies of the various rock units in the Arseno Lake map area.

Archean rocks

Yellowknife Supergroup volcanic rocks (unit AYb)

The volcanic rocks east of the Slave Province boundary are metamorphosed basalts and andesites of the Yellowknife Supergroup. They form a 200 m to 7 km wide belt of rocks (referred to in this report as the Grizzly Lake volcanic belt) that face away from the western margin of the Origin plutonic complex (unit Ap), a suite of post-Yellowknife granitoid gneiss intrusive rocks (Frith, 1986). The volcanic rocks of the Yellowknife Supergroup are typically dark grey to dark green, are fine grained and generally exhibit a subvertical foliation defined by dark and light coloured banding possibly derived from stretched pillow structures. In thin section, amphibole and plagioclase make up the bulk of the rock-forming minerals, with lesser amounts of actinolite, quartz, sphene, sulphide minerals and secondary epidote, biotite and chlorite. Deformation has flattened and elongated plagioclase grains into vertical to steep foliation planes. Similarly, pillows are flattened and stretched so that they roughly parallel the margins of the belt.

The chemical composition of the pillowed basalts that make up the bulk of the Grizzly Lake volcanic belt is unknown, but the rocks are similar in appearance and lithology to the thick succession of pillowed basalts from the Yellowknife area, which have a tholeiitic chemistry (Baragar, 1966; Condie and Baragar, 1974).

Pillow lava and pillow breccia are found throughout the sequence but are most common in the wide central part of the belt. The thickness of the belt is not known, but approximately 6 km of section is present with no apparent repetition.

Yellowknife Supergroup metasediments (units AYg, AYgh, AYp)

The Yellowknife metasedimentary rocks conformably overlie the volcanic rocks of unit AYb. The bulk of the unit consists of uniform turbidites made up of graded greywacke and mudstone beds. The rocks have a typical Bouma cycle microstratigraphy and depositional features that include graded bedding, dewatering textures, soft-sediment slump structures and rare cross-bedding. The unit has the same mineral composition as rocks in the type area near Yellowknife (Henderson, 1975). Regional metamorphism in this part of the Slave Province is above the cordierite-staurolite isograd, as well metasedimentary rocks are porphyroblastic. Porphyroblastic gneiss and schist (AYgp) and migmatitic gneiss (AYgm) with less than 50 percent leucosome make up the bulk of the unit. Although the composition of the Yellowknife metasediments in the map area is typical of the Slave Province as a whole (Frith, in press), there are some unusual

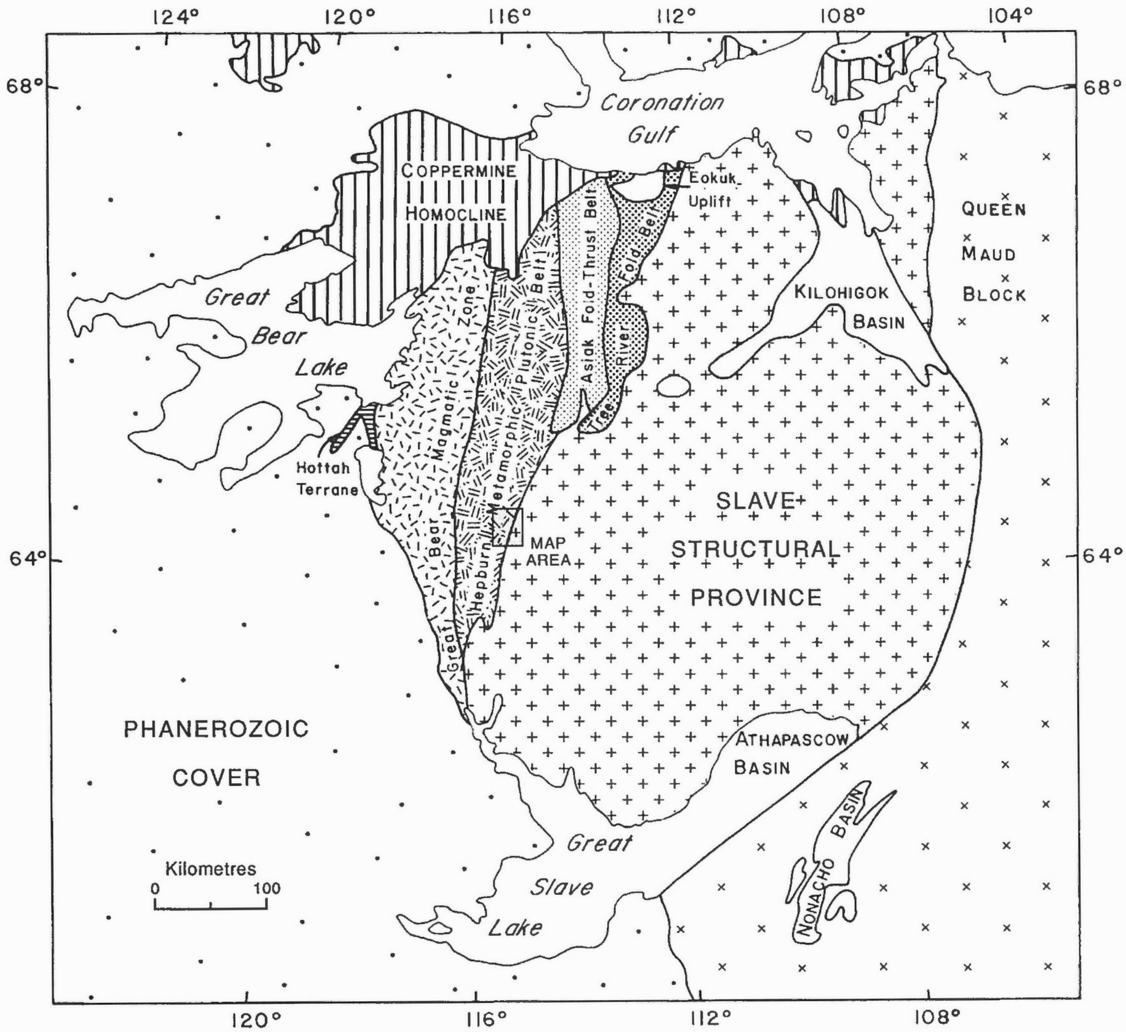


Figure 1. Regional tectonic map showing the principal tectonic elements and the location of the Arseno Lake map area.

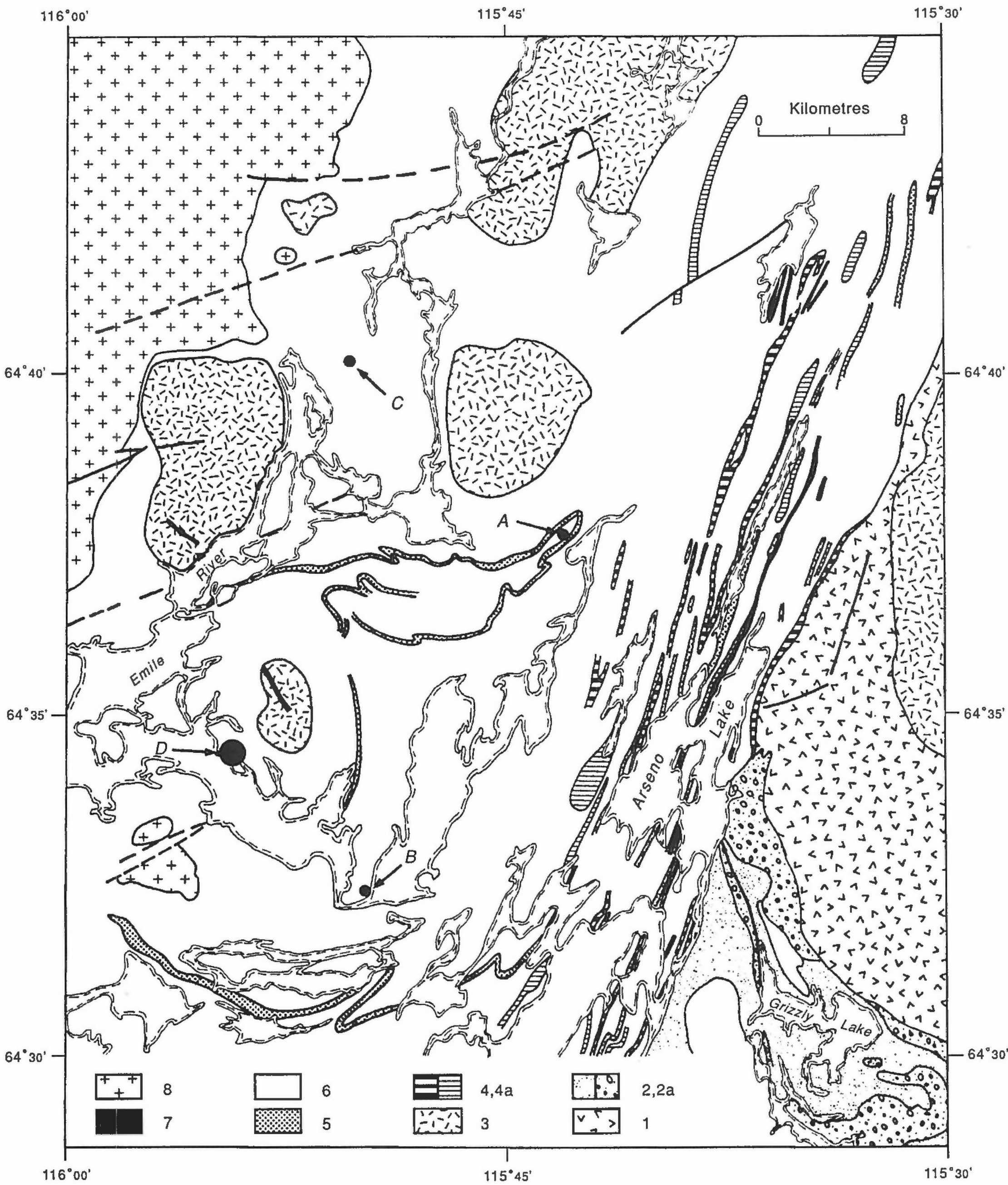
rock types including hornblendic paragneiss (AYgh) and paraconglomerate (AYp). These overlie the volcanic rocks (AYb) and are interstratified with typical greywacke-mudstone. The paraconglomerate contains large discoid clasts of granitoid and volcanic detritus, with a hornblendic matrix similar to AYgh. The presence of these clasts implies a synvolcanic or prevolcanic granitoid as well as a volcanic provenance. The age of the Yellowknife Supergroup in the map area is approximately 2.67 Ga (Frith and Loveridge, 1982).

Granitoid rocks

Archean granitoid rocks occur on both sides of the Slave Province boundary and include: migmatites that formed from rocks equivalent to the Yellowknife Supergroup metasediments, found mostly to the southwest of Grizzly Lake; plutonic orthogneiss of granodiorite or tonalite composition; migmatitic orthogneiss along the western margin of the Origin plutonic complex; gneiss dome cores in the Brownwater Lake and Emile River areas; and migmatites formed along the southern and eastern margins of the northern and central gneiss domes.

Migmatites (unit Amy*)*

The migmatites (unit Amy) in the region in the southeastern corner of the map area are part of the Meyer Lake migmatite complex described in detail by Frith (1986). The complex extends from the map area south for about 20 km, covering an area of about 160 km^2. Typically, the migmatites are layered and/or foliated, both in hand specimen and in outcrop. They are composed mostly of quartz, plagioclase, potassium feldspar and biotite, with rare muscovite and tourmaline. Contacts with metasediments are mostly gradational and are parallel to the foliation of both units. Several masses of



LEGEND

1 Yellowknife pillow basalts
2/2a Yellowknife greywackes/paraconglomerates
3 Granodiorite/tonalite

Snare Group:
4/4a Dolomite/calc-silicate rocks
5 Quartz pebble conglomerate
6 Subgreywacke, siltstone, argillite
7 Amphibolite sills, dykes
8 Hepburn Intrusive Suite - Rodrigues granite

Figure 2. Sketch map of the Arseno Lake map-area (NTS 86B/12). Geology of the east half was initially mapped by McGlynn and Ross (1963). Whole rock sample locations are shown for Samples A to D of Table 2.

Table 1. Table of formations relating the name and lithology of the various rock units in the Arseno Lake map area.

Age		Formation/Group	Relationships	Unit	Lithology (*)
PRECAMBRIAN	PROTEROZOIC	Hepburn Intrusive Suite	intrudes Snare Gp.	**PH**	granite, diorite, granodiorite
		Amphibolite sills, dykes	intrudes Snare Gp.	**Pa**	hornblende plagioclase amphibolite
		Snare Group	allochthonous (?) internally conformable	**PS**	subgreywacke, arkose & other flysch
		- conglomerate	possibly locally unconformable with other subunits	**PSc**	quartz pebble conglomerate, grit
		- orthoquarzite		**PSq**	orthoquartzite, clean grit
		- dolomite		**PSd**	dolomite
		- calc-silicate rock		**PScs**	calc-silicate rock, dolomitic argillite
	?	Migmatite	from unit Pp	**Pm**	granite migmatite, with MS & TR
		Rusty gneiss	derived from unit **PS** or **AYg**	**Pp**	BI, PG, QZ, PF gneiss and schist
	ARCHEAN	Granitoid rocks	unconformable with Snare Group outside map area	**Amy** **Ag**	migmatite orthogneiss
			intrusive into **AYb**	**Ap**	plutonic rocks
		Yellowknife Supergroup - metasediments	**AYg**/**AYb** conformable	**AYp** **AYgh** **AYg**	paraconglomerate HB paragneiss greywacke-mudstone
		- metavolcanics		**AYb**	pillow basalt, minor pyroclastic rocks

MS = muscovite; TR = tourmaline; BI = biotite; PG = plagioclase; QZ = quartz; PF = potassium feldspar; HB = hornblende

muscovite granite are present within the complex, but none are known in the map area. The migmatites range in composition from granodiorite to tonalite. The bulk composition is close to that of the Yellowknife Supergroup metasediments from which the migmatites were mostly derived. However, local variations from the bulk composition suggest that basement makes up a minor component of the rocks. The local presence of excess potassium (abundant muscovite) suggests that this element (K), plus possibly other large cations, were introduced during the peak of metamorphism (Frith, 1986).

A small irregular area of migmatite and pegmatite near the northeastern margin of the map area is overlain, possibly unconformably, by basal conglomerate of the Snare Group. The contacts of the migmatite and pegmatite are poorly exposed and where present are deformed, but the degree of variation of the migmatite and the conglomerate suggests that the migmatite is Archean.

The rocks have been dated by Rb-Sr whole rock methods at 2473 ± 101 Ma (Frith et al., 1977) which is considerably younger than the accepted age of 2596 Ma (Frith et al., 1986) for the peak of regional metamorphism determined by U-Pb methods on monazite from pre-Yellowknife Supergroup tonalite basement rocks (Frith, 1986).

Origin plutonic complex (unit **Ap***)*

The western margin of the Origin plutonic complex is mostly a gneissic tonalite (unit **Aptn**), mafic granodiorite (unit **Apgd**) or a locally-prevalent diorite (unit **Apdt**) that forms the more basic part of a polyphased intrusive complex that grades eastward to a granite composition. The rocks in the western margin of the complex in the map area are cut by numerous alaskitic and aplitic dykes of at least three generations. Hornblende and biotite are the most common mafic minerals, and these are mostly epidotized. Toward the centre of the complex, 10 km east of the Grizzly Lake volcanic belt, epidote is the only evident mafic mineral.

The chemistry of the Origin plutonic complex indicates that it is a granodiorite in bulk composition. Density determinations support field observations that the body rose diapirically. The suggestion has been put forward that the complex rose during isostatic readjustment of the margin of the Slave Craton during Wopmay Orogenesis (Frith, 1986).

The Origin plutonic complex has been dated by Rb-Sr means at 2506 ± 186 Ma (Frith et al., 1977). The more precise 2596 ± 3 Ma age (Frith et al., 1986) for the peak of metamorphism in the area determined from basement monazite is likely more realistic as the pluton has textures that suggest it was synorogenic.

Archean basement granitoid rocks (unit **Ag***)*

Granitoid rocks in all of the Emile River gneiss domes are similar lithologically to the plutonic granitoid rocks of the Slave Province except for some granulite facies gneiss in the westernmost dome. The gneiss domes are mantled by paramigmatite and paragneiss derived from the metasedimentary Snare Group or rocks similar to the Yellowknife Supergroup metasediments. The granitoid and mantle rocks locally attain granulite facies grade and are commonly migmatized.

The southernmost gneiss dome is cored with medium grained equigranular, pink to grey granodiorite or granite gneiss with 5 to 15 percent biotite, which defines a planar fabric that is well developed near the contacts with mantle gneiss. Near the centre of the dome the rocks are slightly foliated to massive and are cut by pods of coarse grained alaskite and small dykes of metagabbro or metadiabase. The gneiss is cut by a 50 m wide northwest-trending amphibolite dyke, probably derived from Archean diabase or gabbro.

The westernmost gneiss dome is lithologically and structurally heterogeneous. The rock is a buff coloured equigranular granodiorite containing hornblende and biotite, and is cut by leucocratic pegmatite and veins of aplite and alaskite. Thin sections of the core gneiss show the presence of retrograded orthopyroxene. The gneissosity and the leucosome veins are contorted. Locally, the rocks are banded, with the banding contorted. Near the margins the gneissosity parallels the contacts. Along the western margin, mullion structures plunge 70 degrees to the west. The eastern margin is sheared, and deformation has obliterated any unconformable relationship that may have been present.

The central gneiss dome is oval in outline and has a well developed concentric foliation (see Fig. 10). The western margin is sheared, and the eastern margin and the adjacent mantle gneiss are migmatized by coarse grained white quartz-feldspar leucosome. Dolomite beds occur in the Snare Group metasediments along part of the northern margin of this dome. The core gneiss is a medium grained equigranular granodiorite composed of biotite, quartz and feldspar, and is cut by pegmatite and vein aplite that is locally folded, constituting 2 to 10 percent of the rock by volume. Extension lineations near the northern, western and eastern margins show consistent west to north plunges between 30 and 40 degrees. The eastern margin is bordered by interlayered gneiss and migmatite. The southern margin host rocks are locally calc-silicate in composition, and a purple quartzite occurs at one locality.

The northern gneiss dome is similar to the central dome in its lithology and contact relationships, but its north-south, more oval shape suggests that east-west compression may have been an important factor during doming. No quartzite or calc-silicate rocks were noted around this dome.

A small outlier of basement granitoid gneiss is present south of a right lateral fault between the Rodrigues granite and the southern end of the northern gneiss dome. It is irregular in shape and bordered locally by dolomite and/or calc-silicate rocks. The rocks are gneissic, and the foliation is irregular but strikes in a generally northerly direction.

Paragneiss and paraschist of uncertain origin

Parts of the Emile River gneiss domes and the intervening paragneiss are made up of rocks of uncertain origin. The first type, mapped as unit **Pp** above the sillimanite isograd, consists of porphyroblastic rusty coloured biotite gneiss and schist associated with either Archean Yellowknife Supergroup metasediments or similar looking, similarly metamorphosed Snare Group rocks. The extent and nature of the transition between these rock associations was not readily apparent. The second type of rocks of uncertain origin were mapped as unit **Pm** and consists of migmatitic rusty coloured gneiss derived from paragneiss. Where a proximity to and correct identification of typical Snare Group rocks was locally established, the rocks were mapped as unit **Pms**. Where a Yellowknife metasedimentary parentage was suspected, the rocks were mapped as unit **Pmy**.

Porphyroblastic and migmatitic rusty paragneiss (units Pp, Pm)

Rocks of these units are characterized by a rusty colouration on both the fresh and outcrop surfaces, the presence of metamorphic porphyroblasts (unit **Pp**) and/or metamorphic segregation veining (unit **Pm**) of quartz and aplite making up less than 50 percent of the rock volume. The bulk of the rocks are porphyroblastic rather than migmatitic. The rocks are relatively uniform in bulk composition, but heterogeneous in hand specimen. They have a banded appearance with 2-20 cm thick bands. The bands reflect compositional differences in original bedding and subsequent deformational thickening and thinning, followed by later metamorphic segregation. The banding is deformed around the gneiss domes by as many as three phases of folding, giving the rusty gneiss a contorted appearance in places. The uniformity of the unit is broken by the presence of local irregular quartz pods, tourmaline, quartz veins, pegmatite, resistant- weathering quartzite, conglomerate and isolated patches of calc-silicate rocks.

The metamorphic minerals and their textures are described in more detail in the chapter on Metamorphism. Whole rock compositions are difficult to determine in hand specimen due to rusty weathering that is commonly 15-25 cm deep. Chemical analyses and mesonorms of unweathered

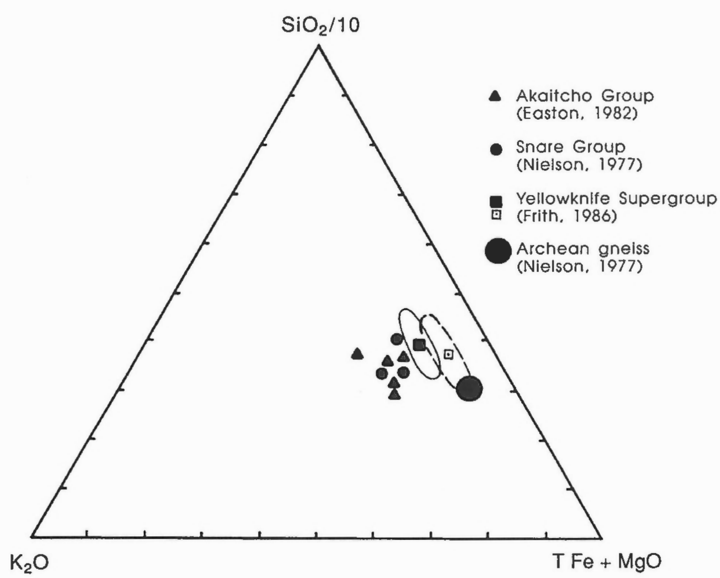


Figure 3. Major oxide distribution of the Snare Group compared with rocks of the Akaitcho Group and the Yellowknife Supergroup metasediments. The Yellowknife rocks are shown as averages with a one sigma distribution envelope around samples from the Burwash Formation (solid square) and the Indin Lake area (open square). The Snare Group samples show the closest correlation with those of the Akaitcho Group and the least with the potassium-deficient Yellowknife Supergroup, including the Archean gneiss from the map area (large dot - see Figure 2 for location).

Table 2. Whole rock analyses of the rusty paragneiss unit (unit Pp) from the Arseno Lake map area (after Nielsen, 1977). See Fig. 2 for locations and Fig. 3 for the plot of other whole rock major oxide components where it suggests that samples A-C are "Akaitcho-like" and sample D is "Yellowknife-like".

Sample No.	A	B	C	D
SiO_2	59.18	61.95	69.26	66.00
TiO_2	1.25	0.75	0.73	0.65
Al_2O_3	24.34	19.73	15.86	12.88
Fe_2O_3	0.74	1.05	0.48	1.67
FeO	5.60	4.80	4.61	9.09
MnO	0.05	0.03	0.14	0.15
MgO	1.99	2.24	2.51	2.89
CaO	0.21	0.73	1.25	1.80
Na_2O	0.80	1.82	1.10	1.44
K_2O	3.10	3.96	2.72	1.84
P_2O_5	0.14	0.07	0.21	0.12
H_2O	0.16	0.34	0.24	0.21
H_2O^+	2.32	1.84	1.04	1.43
S	nd	0.42	nd	nd
Total	99.88	99.73	100.15	100.17
Fe^{+3}/Fe^{+2}	0.05 9	0.09 8	0.04 7	0.08 3
K/Na	2.55	1.43	1.63	0.84
Fe^{+2}/Mg	1.58	1.2	1.03	1.76
Zn	nd	nd	120	nd
Cu	nd	nd	12	nd
Co	nd	nd	320	nd
Cr	nd	nd	200	nd

Notes:
Transition trace elements are in ppm.
nd = not determined.

Snare Group rocks have shown comparable major cation contents with the Akaitcho Group (Nielsen, 1977; Easton, 1982) with which they are possibly correlative. Although data is limited, chemical compositions of samples of suspected Archean age show a closer correlation with Archean age Yellowknife Supergroup metasediments from the Indin Lake region (Fig. 3, Table 2 than with either the Snare or Akaitcho Group).

Rocks around the western margin of the southern gneiss dome are characterized in thin section by the presence of spinel and more rarely by orthopyroxene. These rocks were considered to be of Archean age by Nielsen (1977) on the basis of their metamorphic mineralogy. However, they have the same appearance as rusty paragneiss derived from Snare Group rocks, hence metamorphic mineral assemblages do not categorize them. Rb-Sr whole rock isochron studies (Nielsen, 1977) are ambiguous, as the isotopic data reflect a wide margin of error in a partially open isotopic system.

Regional mapping of the rusty paragneiss extends the unit to the northern margin of the Indin Lake map area (Frith, 1986), where it has been tentatively correlated with metasedimentary rocks of the Akaitcho Group (Easton, 1981, 1982), dated at 1.9 Ga (Hoffman and Bowring, 1984).

Migmatites (unit PmM)

Migmatite derived from paragneiss (unit **P**m) makes up a small part of the mantling gneiss in the southern and eastern margins of the northern and central gneiss domes. The leucosome generally forms more than 50 percent of the rock volume. The strike of the migmatitic layering is the same as that of the migmatitic Snare Group paragneiss, implying that the migmatization and the associated deformation was Proterozoic. However, the proximity of Archean core gneiss and the original nature of the restite suggest that, like the core gneiss, some of the restite is Archean. Migmatite is common in this type of mantled gneiss dome (Ramberg, 1968a, b). The anatectic phase likely formed during Wopmay orogenesis as discussed in the section on Structural Geology.

A small elongate area of migmatite, surrounded by Snare Group rocks and overlain by Snare Group quartzite, is found west of where the Grizzly Lake volcanic belt narrows in the northeastern part of the map area. The migmatite lies on the cold side of the sillimanite isograd, suggesting that migmatization is not Proterozoic. It is further suggested that the migmatite forms part of the autochthonous Slave Craton, as discussed in the section on "Structural Geology".

Proterozoic rocks

Snare Group

The Snare Group, initially defined by Lord (1942), was believed to extend from the presently termed Slave Province boundary to the Wopmay Fault that lies 59 km to the west. More recent workers have reduced the area covered by these rocks, correlating areas previously believed to be made up of the Snare Group with the Epworth or Akaitcho groups (Fraser, 1964; Fraser and Tremblay, 1969; Hoffman, 1973; McGlynn, 1977; Hildebrand 1981), which in turn have been redefined by Hoffman et al. (1971) and Hoffman (1981).

Undifferentiated subgreywacke, arkosic sandstone, mudstone and minor rocks (unit **P***S)*

The bulk of the Snare Group in the map area consists of metamorphosed flysch-type sediments which include, in decreasing order of abundance, subgreywacke, arkosic sandstone and mudstone, some of which have a limy matrix. Minor rock types include orthoquartzite, quartz pebble conglomerate, dolomite and calc-silicate rocks, which form mappable units throughout the upright fold zone adjacent to the Slave Province boundary where metamorphic conditions are below the sillimanite isograd. The metasediments are well bedded in the undeformed areas, but west of the sillimanite isograd the rocks are highly deformed and thinned by transposition along limbs of folds. Their identification is less certain in this area, and the rocks are assigned to unit **P**ps where suspected of Snare Group affinity.

The lower Snare Group adjacent to the Slave craton is slightly metamorphosed and is composed of argillaceous sandstone mixed with minor dolomite, pure quartzite, pebble conglomerate and impure limy arkose. The stratigraphic thickness between the Slave Structural Province boundary and the sillimanite isograd is unknown, but the folded thickness may be significant, as the aeromagnetic pattern over the area is anomalously low, probably caused by a thick prism of sediments of low magnetic susceptibility (P.H. McGrath, personal comm., 1986).

Dolomite and calc-silicate rock (units **P***Sd,* **P***Scs)*

The units consist of dolomite, argillaceous dolomite and carbonate-bearing siltstone and argillite. They are most abundant in the troughs of synclines west and north of Arseno Lake where they show a relatively high stratigraphic level. Metamorphism has recrystallized and obliterated most primary structures (bedding) and textures (grain size), and deformation has obscured the true thickness. However, in the Norris Lake area located several kilometres to the south of the map area, the rocks are little deformed and dolomite beds up to 100 m thick are present with individual beds measuring 3-100 cm thick. There the rocks are dark to medium grey, fine grained and contain layers of shale, siltstone and sandstone which may account for up to 10 percent of the rock by volume. In the Arseno Lake map area, dolomite beds and limy argillaceous rocks have reacted to form calc-silicate rocks containing tremolite, chlorite and locally diopside, olivine and/or magnesite. They appear as tectonically mixed breccia-like rocks with 2-20 cm buff to rusty argillaceous or sandy "inclusions" in a white crystalline dolomitic matrix. The calc-silicate rock is distinguished from the subgreywacke and argillaceous rocks by a pitted weathered surface and a chaotic fold style.

Carbonate-bearing rocks also occur around the margins of the gneiss domes and along the Slave Province boundary (southeastern corner of the map area). Dolomite was not observed in contact with the Archean basement, but its proximity to basement rocks suggests that the carbonate rocks are stratigraphically closer to the base of the Snare Group than unit **PS**. This unit is commonly sheared out by thrusting along a basal fault where it forms part of the leading edge of an allochthonous wedge. Where the basal fault is coincident with the Slave Province boundary, the fault surface may contain slickensides of talc and rosettes of tremolite possibly derived from sheared carbonate-bearing rocks.

Calc-silicate rock occurs along the southwestern margin of the central dome and around the margins of the small basement masses that lie east of the Rodrigues granite. None of these occurrences are large enough to show on the present map. The calcareous rocks along the southern margin of the westernmost gneiss dome contain diopside and magnesite pseudomorphs after olivine as identified from X-ray diffraction.

Orthoquartzite and conglomerate (units **PSq, PSc***)*

The conglomerate in the Emile River region of the map area (Fig. 4) is made up of well rounded cobbles that range in size from 20 cm to grit-sized particles and are composed predominantly of vein and aggregate quartz with rarer clasts of quartzite, granite, tonalite, aplite, rhyolite and amphibolite. The matrix is mostly quartz with some potassium feldspar, biotite and muscovite. Sandstone and coarse grit are commonly interlayered with the conglomerate, some of it having a carbonate matrix. Cobbles are commonly stretched as much as 10:1 along the foliation plane with plunges usually to the east-southeast (see Fig. 8). Conglomerate beds are up to 100 m thick, and locally granitoid clasts make up to 20 percent of the rock. Some of the clasts are tonalitic in composition.

Bedding traces in thick conglomerate beds are faint and are not generally apparent in thin beds. Where present, bedding is commonly 1-2 m thick. The overlying and underlying beds are chiefly rusty biotite gneiss.

Conglomerate and orthoquartzite of the Snare Group serve as marker beds to outline a tight isoclinal east-verging style of folding which extends from the area west of Mesa Lake (see Fig. 8) to Norris Lake, located 5 km south of Boland Lake. The rocks are interstratified with siltstones, sandstones and limy clastic rocks, but unlike their equivalents to the west, compose relatively thin units. Many of the clasts are less compressed than those around the gneiss domes.

The orthoquartzite is massive, bluish grey and consists of fine to medium grained quartz that weathers resistantly. Locally the orthoquartzite grades from grit-sized beds to conglomerate.

Amphibolites (unit Pa)

Amphibolite derived from gabbro and diorite sills and subparallel dykes occurs within the Snare Group in the eastern part of the map area where it is folded into upright folds. The rocks are dark green to olive, medium grained, massive to gneissic and commonly contain hornblende, chlorite, epidote and altered plagioclase. Although these rocks have not been isotopically dated, they are probably about 1900 Ma, as they were deformed and metamorphosed along with the Snare Group, and are older than the Hepburn Batholith (1.85 Ga Hoffman and Bowring, 1984), which they are not known to cut. Lord (1942) suggested a genetic relationship between the basalt flows of the region and the sills.

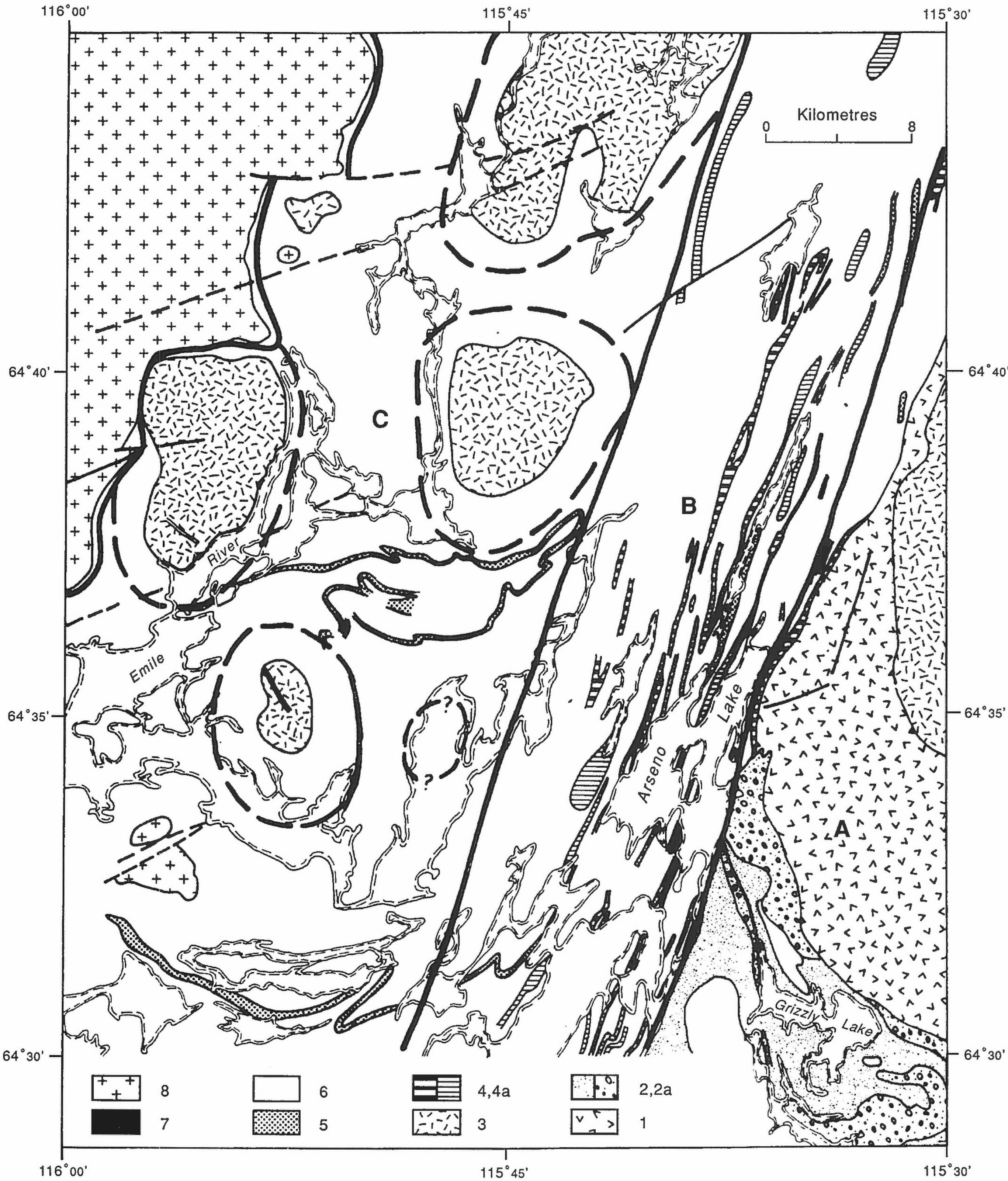
Rodrigues granite (unit PH)

The Rodrigues granite is a large elongated intrusion measuring about 10 by 30 km^2 on surface, oriented parallel to the Slave Province boundary. The southern part of the intrusion occurs within the map area. The pluton is part of a lithologically similar, more extensive suite of rocks that together form the Hepburn Intrusive Suite intruding rocks of the Coronation Supergroup, from the map area to the Coronation Gulf, some 300 km distant (Hoffman, 1984; Lalonde, 1986). Topographically, the pluton forms a plateau area bounded by steep, commonly sheared contacts with the Snare Group. The pluton is cut by several dextral strike-slip faults within and outside the map area (see Fig. 8). Several small intrusions of granite similar to most of the main body occur in the southwestern corner of the map area.

The pluton is composed predominantly of granite, with lesser amounts of granodiorite and quartz diorite. The granite is a homogeneous coarse grained rock that typically contains randomly to subparallel, 2-6 cm long megacrysts of microcline. The matrix is grey to buff brown, equigranular and made up of grey to smoky quartz, biotite and plagioclase. The megacrysts are locally rapakivi textured, suggesting that a two-stage crystal growth took place. Locally, the compositions are granodioritic and are similar to the granite in overall appearance except for a higher colour index. Dioritic rocks within the intrusion are not common, but where present they are associated with partly digested country rock. They are commonly finer grained than the bulk of the intrusion and usually contain hornblende. Large irregular areas of diorite occur near the northern margin of the intrusion outside the map area.

Evidence for an intrusive contact with the Snare Group consists of numerous aplite apophyses that extend from the Rodrigues granite into the Snare Group. The host paragneiss, the inclusions and the plutonic phases are garnet bearing in places. The contact is steep to overturned and usually sheared. Sheared apophyses were not observed.

Near the contact, elongated quartz clasts, likely derived from Snare quartz pebble conglomerate, have long axes that plunge steeply in a plane parallel to the contact. The interface with the Snare Group is commonly a zone of displacement. Megacrysts in the Rodrigues granite locally show a preferred orientation, suggesting a magmatic flow. However, at some contacts megacrysts of microcline also occur in the host paragneiss, indicating that they may also have formed metasomatically after emplacement. Host paragneiss commonly occurs as inclusions in the quartz diorite suggesting that assimilation took place near the contacts of the pluton.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1

STRUCTURAL GEOLOGY

The structure of the map area has been affected by two principal orogenies, one in the Archean, analogous to the Kenoran Orogeny and the second during the Proterozoic, referred to as the Calderian Orogeny (Hoffman and Bowring, 1984). Each orogeny has several phases of deformation associated with it. The western margin of the Slave Province was affected by both orogenies. The most conspicuous deformation in the region west of the Slave Province boundary took place during the Calderian Orogeny which obliterated most of the Archean deformation.

The map area is divided into three structural areas (Fig. 4), each characterized by a distinctive style of deformation: the Slave Structural Province, the Arseno Domain and the Brownwater Domain. Each is discussed below. The Emile River gneiss domes in the Brownwater Domain are compared with those formed elsewhere. A probable mode of origin is given.

Slave Structural Province

The part of the map area that lies within the Slave Structural Province consists of west- and southwest-facing Yellowknife Supergroup volcanic rocks and folded metasedimentary rocks in the Grizzly Lake area. These rocks were affected by at least three and possibly four phases of deformation. The first was an Archean shortening perpendicular to the northwest-trending bedding accompanied by metamorphic recrystallization and vertical stretching along planes that now strike north to northwest and dip at or near vertical. Two Archean phases of foliation (Frith, 1986a) are recognized regionally where metamorphic grades are low. Metamorphic grades are high in the Slave Province part of the map area and foliations are steep and coplanar. Subsequent Proterozoic deformation occurred during the Calderian Orogeny. The first of three compressional events (Hoffman and Bowring, 1984) is linked to compression caused by collision of the Slave Craton and its overlying west-facing continental sedimentary prism with an eastward-directed microcontinental "Bear plate" (Hoffman, 1980). Further collisions produced further crustal shortening, but the effect on the already shortened sedimentary prism was predominantly of a brittle nature (Hoffman, 1984). This shows up in the map area as dextral strike-slip faults.

The structure of the supracrustal rocks in the Grizzly Lake area is complex, particularly within the metasedimentary rocks. The volcanic rocks have been stretched in the vertical plane, and where pillows are present they show consistent tops toward the west and southwest. The orientation of the bedding foliation is arcuate around the Origin Lake plutonic complex. The overlying metasediments are folded along axes that parallel the sediment-volcanic boundary, a feature consistent with Archean deformation found elsewhere in the Slave Province (Frith, 1987). An older northeast-striking set of folds is also present in the Grizzly Lake area, which has affected both the Yellowknife metasediments and the adjacent Snare Group. This phase of folding is the principal deformation of the region, but it differs from the same phase observed in the Arseno Domain. This difference is evident in the structural analysis of this part of the map area and has important implications in working out the tectonic history of the area. Some refolded Archean folds are oriented northwest, but this folding was Proterozoic, as it also folds rocks of the Snare Group south of Arseno Lake and around Mesa Lake areas (see Fig. 8). McGlynn and Ross (1963) reported a zone of sheared, crushed and mylonitic rocks in the Grizzly Lake area which occurred during this deformation.

A Slave Structural Province

B Arseno Domain

C Brownwater Domain
- gneiss dome subdomain (ovoid areas)
- interdomal subdomain

LEGEND
Snare Group:
8 Hepburn Intrusive Suite - Rodrigues granite
7 Amphibolite sills, dykes
6 Subgreywacke, siltstone, argillite
5 Quartz pebble conglomerate
4 Dolomite/calc-silicate rocks

3 Origin Intrusive Complex
2 Yellowknife greywackes/paraconglomerates
1 Yellowknife pillow basalts

Figure 4 (opposite). Sketch map of the map area showing the structural domains. Solid lines separate domains and heavy dashed lines show subdomains. The interrogated dashed line denotes the location of a possible hidden gneiss dome. Note the multiple folding of unit 5.

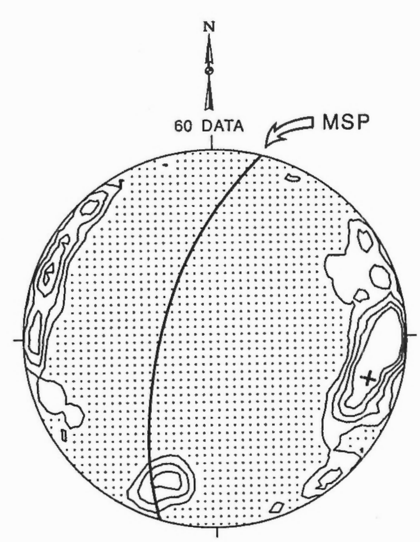
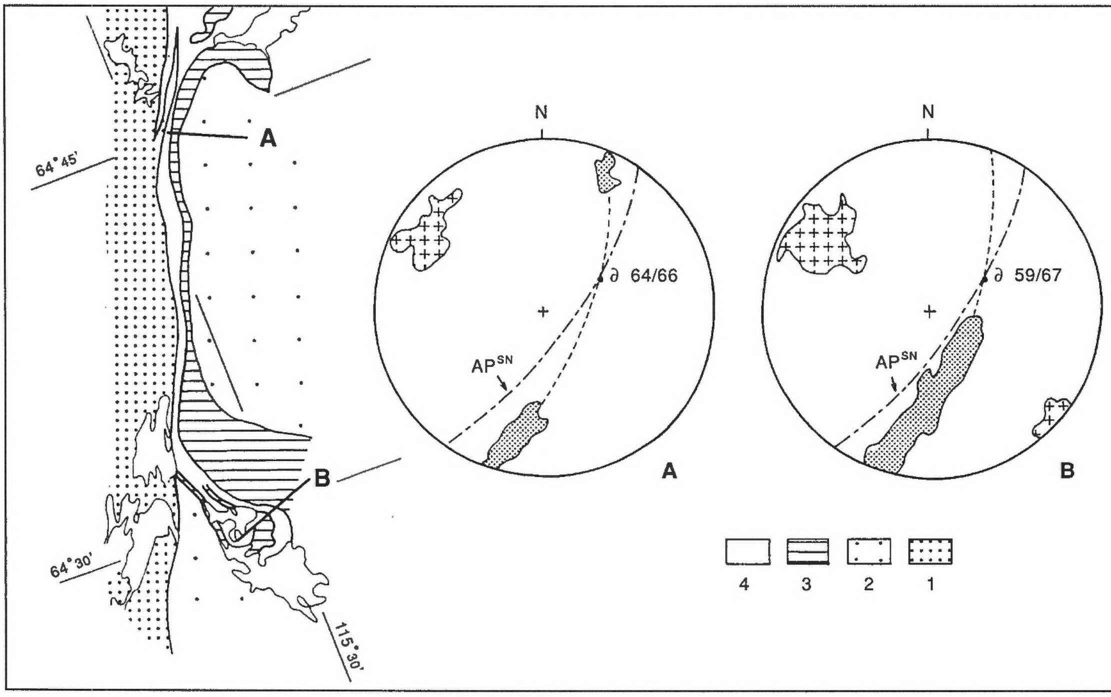


Figure 5. Poles to all foliations in the Slave Structural Province. The data show an east-west compression of Archean fabric. Poles in the southwest quadrant are from remnant west-northwest Archean foliations. MSP refers to the Mean Snare Plane (Fig. 7). Data are derived from McGlynn and Ross (1963).



Legend

4 Yellowknife Supergroup metasediments
3 Yellowknife Supergroup pillow basalts
2 Plutonic and migmatitic terrane
1 Snare Group

Figure 6. (A) Areas of poles to axial planar foliation in Archean rocks ("+" pattern) due to Proterozoic deformation. (B) Plot areas of reoriented Archean lineations (stipple pattern) in the Slave Structural Province (map and most of the data are from Ross and McGlynn, 1965). AP^{SN} = Mean axial plane, Snare Group rocks.

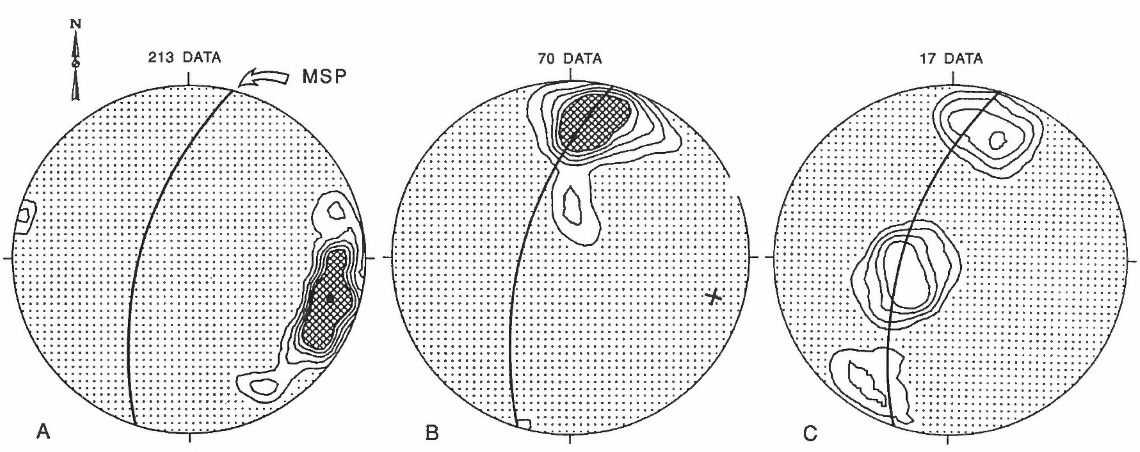


Figure 7

(A) Poles to the principal axial planar foliation of Snare Group rocks (S_2) in the Arseno Domain, and the Mean Snare Plane (MSP).

(B) Plunge direction of Snare Group principal mineral lineations (L_2) in the Arseno Domain.

(C) Pre-L_1 lineations in the Arseno Domain which have been rotated in the MSP.

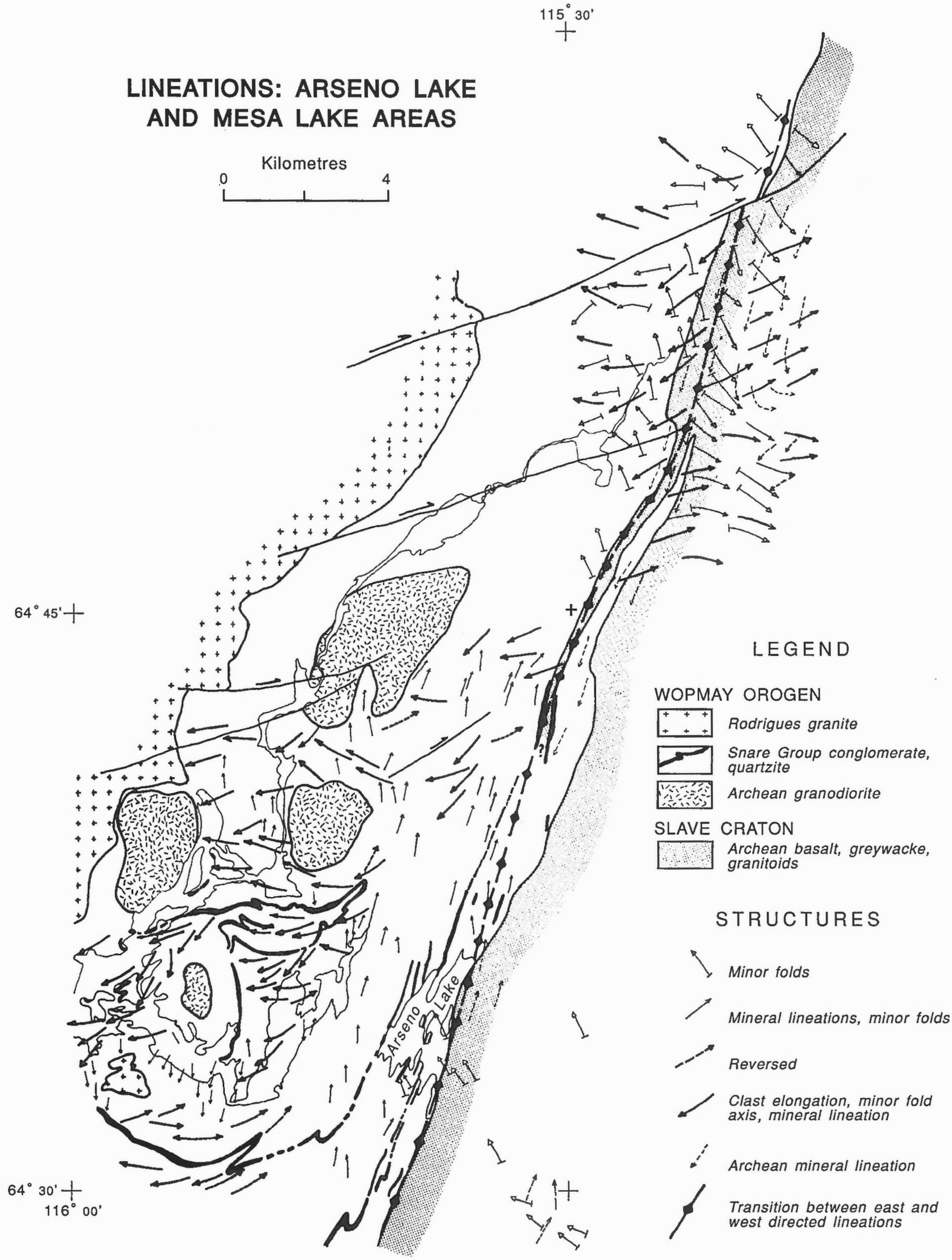


Figure 8. Map of the Mesa Lake and Arseno Lake map areas showing lineation trends in the Snare Group and Yellowknife Supergroup rocks. Data from the Mesa Lake area is from Ross (1966) and that of the southeast Arseno Lake area from Ross and McGlynn (1965).

Flattened volcanic pebbles in Yellowknife Supergroup paraconglomerate in the Grizzly Lake area indicate a 50-75 percent compression. Pebbles in the Snare Group conglomerates to the west are flattened only 20-30 percent. This difference has been attributed to Archean deformation of the Yellowknife Supergroup (Ross and McGlynn, 1965), but could be equally due to other factors such as temperature or matrix composition. In the Mesa Lake area (see Fig. 8) both Snare Group and Yellowknife Supergroup rocks were folded during the Proterozoic, and these fold axes parallel or are subparallel to Archean fold axes (Ross, 1966). Any angular discordance between the Snare Group and the Yellowknife Supergroup was thus reduced or eliminated during progressive shortening.

Structural analysis of the Slave Province

Deformation in this structural domain is considered to have occurred in three phases: during the Archean Kenoran Orogeny, during the early Proterozoic (principal phase) Calderian Orogeny and during a younger, less well understood Proterozoic phase.

Archean deformation folded the metasedimentary rocks, but not the volcanic flows, which were thinned by pure shear, imposing an axial planar foliation that is parallel or nearly parallel to bedding. These strata were increasingly thinned during east-west compression associated with the Calderian Orogeny, which generally rotated Archean planar and linear features (stretched pillows, mineral lineations, quartz veins) so that they paralleled the regional foliation. This latter foliation becomes increasingly parallel to the Slave Province boundary as the boundary is neared. These foliation planes commonly dip to the west.

Bedding planes and foliations in the southern part of the Slave Province parallel the volcanic-metasedimentary interface and trend in a northerly direction in the northern and central parts of the supracrustal belt. Pillow basalts near the volcanic-sediment margin in the south are overturned to the southwest.

Archean axial planar features have been rotated during the Calderian Orogeny about a plane, called the "Mean Snare Plane" ("MSP", which is defined as the average foliation of Snare Group rocks within the Arseno Domain, shown graphically in Fig. 7A). The MSP is oriented to the north-northeast and is inclined steeply to the west. Ross and McGlynn (1965) have shown that poles to Proterozoic cleavage, developed in the Yellowknife Supergroup metasedimentary rocks strike in the same MSP direction but dip steeply toward the **east** rather than the west (see Fig. 6). Archean lineations were probably rotated within the Archean foliation (defined by biotite) (see Fig. 6B). Archean foliations flattened toward this plane are similarly reoriented and dip +/-20 degrees from the vertical (Fig. 5). Northwest-trending foliations at high angles to the MSP were not rotated to the same degree, as they are at higher angles to the direction of compression.

The rotation of Archean foliation into the MSP is most evident in the metasedimentary rocks in the southern part of the map area within the Slave Province. However, near Grizzly Lake, Yellowknife bedding and Archean foliations were folded around axes oriented northwest. This folding is younger than folding associated with the MSP. The fold direction parallels a late penetrative fabric in the Snare Group and Yellowknife Supergroup of the Mesa Lake area (Ross, 1966). Similar oriented folds in the Yellowknife Supergroup metasedimentary rocks are present in the Indin structural basin (Frith, 1986) some 20 km southeast. Folding associated with this foliation may be coincident with late Archean folding, so the time of the last folding in the Grizzly Lake area cannot be determined from trend direction alone. The style of folding suggests that the bulk of the deformation was Archean.

McGlynn and Ross (1963) have shown that all Archean structures and their foliations were folded by the presently termed Calderian Orogeny, giving rise to the MSP. This is the last penetrative deformation in the Grizzly Lake region.

Arseno Domain

The Arseno Domain is characterized by a prominent phase of folding in the Snare Group that trends north-northeast and dips steeply to the west. Folding style changes on the regional scale, from concentric in the Mattberry Lake area 10 km to the south of the map area, to similar in the Mesa Lake area (Ross and McGlynn, 1965), reflecting the increase in the Proterozoic metamorphic grade from south to north. The Arseno Domain falls within the zone of similar folds. Axial planar foliation is characterized by the alignment of platy minerals parallel to the fold limb bedding.

The folding style is outlined by quartzite and dolomite marker beds in Figure 4 and in the pocket map. Fold axes strike north-northeast and foliations dip steeply to the west. Fold axes plunge gently to the north (with a few exceptions probably due to the presence of older structures, as discussed further on).

Structural analysis of the Arseno Domain

The most noticeable feature in the Arseno Domain is the consistent north-northeast strike of bedding (Fig. 4), F_2 fold axes and S_2 foliation (Fig. 5, 7A). Same phase lineations (e.g. minor fold axes) trend in the same direction and show shallow north-northeast plunges (Fig. 7B). These lineation directions contrast with two sets of younger structures in the Mesa Lake area (Proterozoic L_3 in Fig. 8; Ross, 1966) which trend northwesterly on the western side of the detachment zone, but change direction of plunge to the southeast on the eastern side of the detachment zone. The detachment zone is subparallel to the Slave Province boundary and coincides with it along the northeastern arm of Arseno Lake (Fig. 8). The zone is interpreted to be a demarcation between allochthonous rocks to the west, and autochthonous cover and craton rocks to the east. This zone is the eastern boundary of the Arseno Domain and traces a revised position for the boundary between the Wopmay Orogen and the Slave Province.

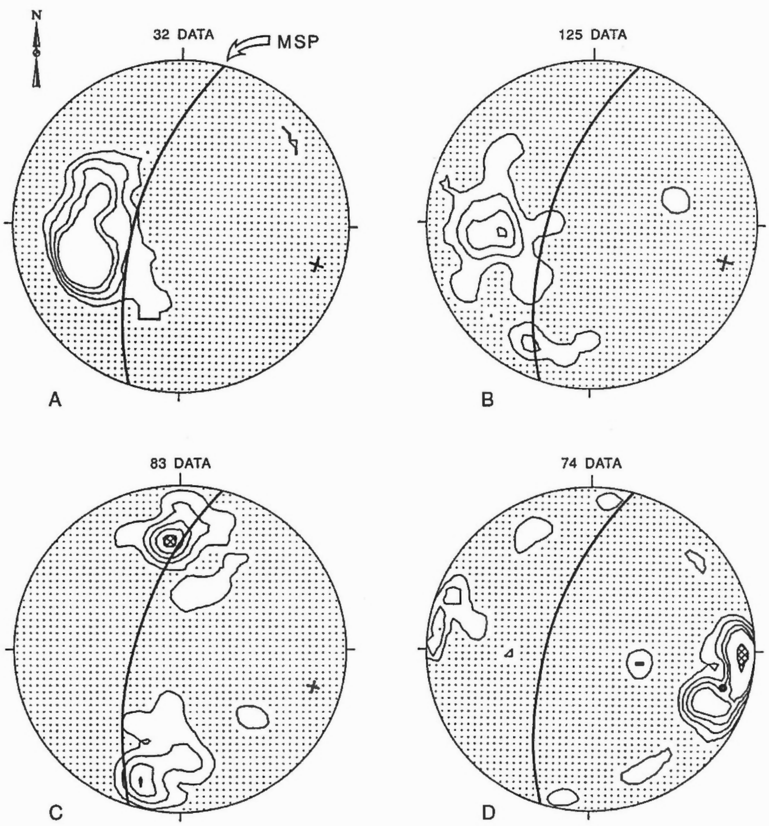


Figure 9

A - Quartz pebble elongations (L_1) from the Brownwater Domain, interdomal regions.

B - Plunge of all lineations (L_1) in the Brownwater Domain which include quartz pebble elongations, mineral lineations and minor fold axes. Some have been rotated southward by east-west compression toward the MSP in the northeast and southwest quadrants.

C - Second phase lineations (minor L_2 fold axes) in the Brownwater Domain interdomal metasedimentary rocks show north and south plunges within the MSP.

D - Poles to second phase foliations (crosscutting axial planar foliation, S_2) in the Brownwater interdomal metasedimentary rocks show similar orientation to the MSP.

The oldest recognized folds, along with their lineations (L_1) and foliations (S_1) trend southwest. Actual folds are more prevalent west of the Arseno Domain. However, lineations associated with this folding occur in the northern part of the Arseno Domain where vestiges may be traced across the Brownwater Domain, espied by their contrasting orientations. Lineations corresponding to the northwestern lineations of the Mesa Lake area (Fig. 8) are few, but where observed they appear to have been rotated to northwestward-south-eastward trending axes (Fig. 7C) parallel to the Calderian cleavage direction found in both the Wopmay Orogen and in the Slave Province (Tirrul, 1984).

Since the folds are oriented parallel to the Slave Province boundary it is likely the Slave Craton buttressed eastward-directed compression. Fold style changes from north-north-east-trending folds to southwest-trending folds in the southern part of the Arseno fold domain, as delineated by conglomerate marker beds.

Brownwater Domain

The Brownwater Domain is made up of four conspicuous gneiss domes and possibly a fifth hidden dome (Fig. 4). For structural analysis the domain has been divided into two subdomains which include: (1) the interdomal paragneiss; and (2) the Emile River gneiss domes and mantle gneiss. This domain contrasts with the Arseno Domain in the ubiquitous presence of at least two phases of deformation. The first phase folding (F_2) and associated structures are shown in Figure 8. Second phase folding with associated structures is contemporaneous the with the development of the MSP, as defined for the Arseno Domain.

Inter-domal Paragneiss

Bedding (S_0) within the paragneiss and the axial planar features due to the first phase of folding (S_1) are mostly parallel except at fold hinges, where S_1 cuts across S_0. The rocks are commonly deformed twice (D_1 and D_2. S_2 is variable but generally strikes northerly.

Second phase folding (F_2) is less well developed than for F_1. In rocks that have undergone the highest grades of regional metamorphism, both biotite and sillimanite are oriented parallel to or are coplanar with the MSP. Under these conditions of metamorphism, S_1 and S_2 are approximately coplanar. Evidence for this is found at rare fold closures where S_1 foliations wrap around F_2 folds.

Leatherbarrow (1975) carried out a structural analysis of the elongated pebbles in the conglomerate marker beds shown in Figure 4 and determined that clast elongations formed during F_1 were rotated toward planes parallel to S_2, locally modified by late uplift of the gneiss domes. The quartz pebble conglomerate beds between the southern and central gneiss domes (Fig. 4) describe a spoon-shaped basin, suggesting that a sheet of conglomerate covered much of the region in between. The first folds, which are open to isoclinal in style, were locally refolded during F_2.

Three types of linear structures are present: minor fold axes, pebble elongations (Fig. 9A) and mineral lineations. All three have a common mean orientation (Fig. 9B), except for some fold axes that have been rotated toward the horizontal by subsequent uplifts near the domes. This indicates that deformation was continuous and sufficiently penetrative that material lines like quartz pebble elongations were mostly rotated into positions approaching the orientation of non-material lines, such as minor fold axes. All lineations plunge about 40 degrees westward, but reversals due to domal uplift occur locally.

The stretched quartz pebbles at fold closures enable F_1 to be distinguished from F_2. The pebble elongation directions vary on different parts of F_2 fold limbs, due to lineations being rotated (along a horizontal axis perpendicular to the lineation) toward the horizontal and toward the strike of the MSP. F_2 has folded major F_1 axial planes, as well as their foliations. Curved kilometer-scale axial planes, as well as outcrop and thin section scale superimposed folds, describe type-3 interference patterns (Ramsay, 1967). Gentle warping of existing foliations also occurs as a third phase of folding (D_3), locally developed in the immediate vicinity of the gneiss domes and is probably related to compression during doming.

Wherever F_1 and F_2 are coplanar, further closing of fold limbs and renewed bedding compression took place. S_1 axial planar foliation wraps around the hinge zones of F_2 folds. The interdomal fold axes are vertical and their axial planes fan out toward the domal areas.

Emile River gneiss domes

The northern dome (Fig. 4) was emplaced into paragneiss derived from either the Snare Group or Archean paragneiss. Contacts, where observed, are conformable with host bedding foliations. The western dome has a more variable gneissosity than the other domes, but toward its margins the gneissosity also tends to parallel the structure of the metasedimentary host rocks. Inclusions within the gneiss, probably derived from stretched out diabase, are usually elongated parallel to the gneissosity. Along the western margin, mullion structures plunge 70 degrees to the west. The eastern margin is sheared, and deformation has obliterated any unconformable relationship that may have been present.

A detailed structural study of the southern gneiss dome showed tight to isoclinal F_2 folds with overturned axial planes that tend to become shallower and drape over the gneiss dome where they form part of the mantle gneiss.

From age data, structural relationships and density determinations, the domes have been classified as mantled gneiss domes (Leatherbarrow, 1975). Model mantled gneiss domes (Ramberg, 1968a, b) may have discordant contacts between the core and cover rocks, and the cover rocks may be overturned at or near the contact. The domes in this map area do not show any discordant contact relationships, although shearing is present locally. In places at the contact, the host rocks are marbles which were probably derived from dolomites similar to those near the lower parts of the Snare Group in the Norris Lake area (Frith, 1986), a few kilometres south of the map area. Although dolomite also occurs at other stratigraphic levels, basal dolomite may have been brought up with the rising core gneiss from the lower part of the Snare succession. The model mantled gneiss domes of Ramberg's (1968a, b) studies are commonly migmatized near the core-mantle contact, a feature that is well developed is this map area. The Rb-Sr study of the leucosome in migmatites along the southeastern contact of the southern gneiss dome (Frith et al., 1977) gave a high initial $^{87}Sr/^{86}Sr$ ratio, which suggests that the leucosome formed *in situ*. As the leucosome is folded by F_2, it is concluded that the thermal peak associated with migmatization took place prior to F_2.

Structural analysis of the Brownwater Domain

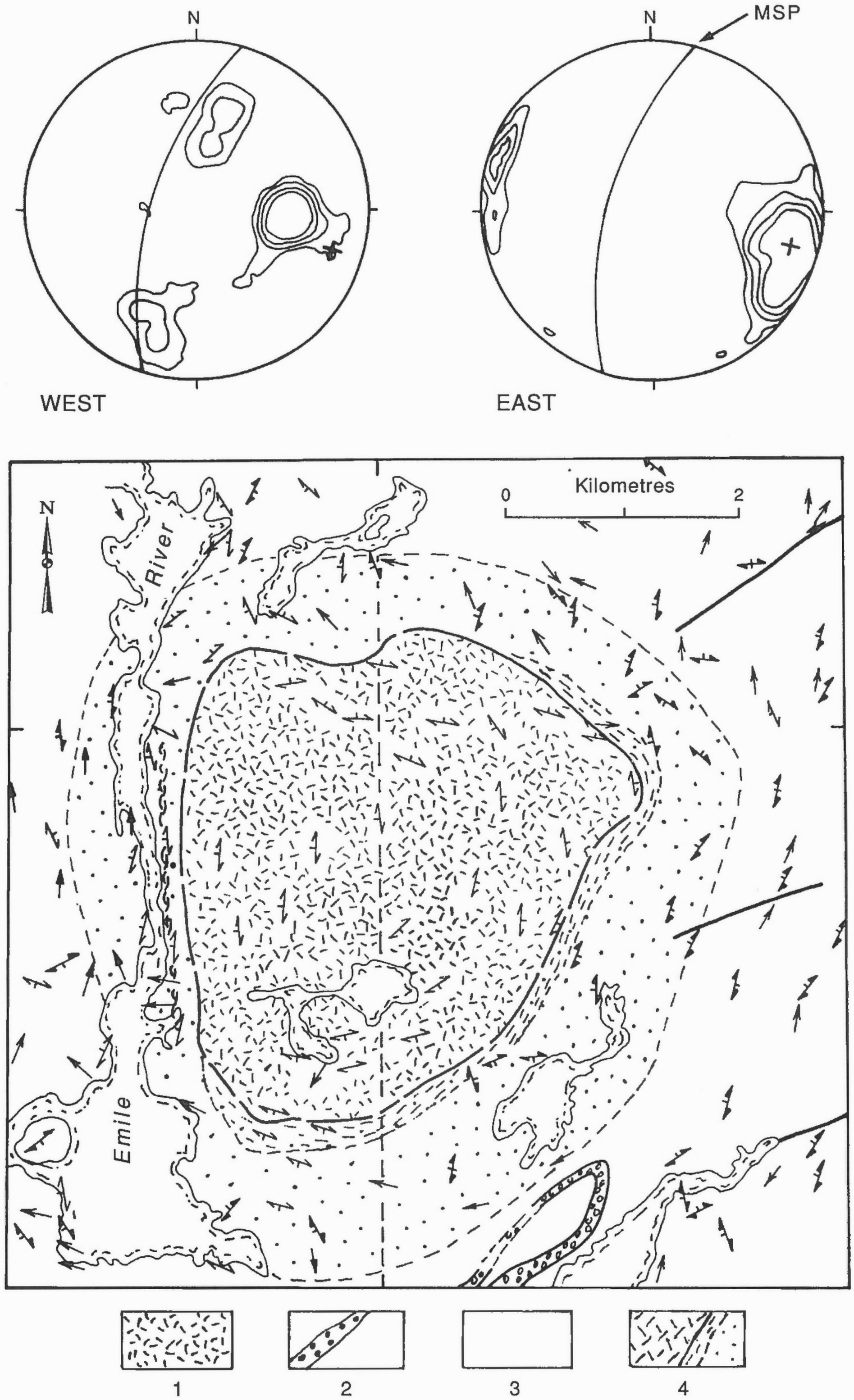
Interdomal paragneiss

The conglomerate marker beds (Fig. 4) illustrate the complexity and polyphase nature of Proterozoic folding in the paragneiss. Early folding produced an open to isoclinal fold style and a penetrative axial planar foliation (S_1) oriented west-southwest, but continued east-west compression tended to align structures into planes similar to the MSP, which is described as the second but dominant phase of folding in the Arseno Domain. Structures produced by both of these phases of deformation were reoriented again by the uplift of gneiss domes and plutons, making S_1 foliations appear randomly distributed on a stereographic projection. Comparable linear structures, including major and minor fold axes, are not so chaotic (Fig. 9C, D), and most show trends that tend to be reoriented toward the MSP direction.

Emile River gneiss domes

Structures within the gneiss domes show the effects of east-west compression, resulting in the development or reorientation of foliation similar to that of the MSP. The gneissosity of the western side of the central dome is flatter than on the east half, which has been steepened toward the MSP (Fig. 10). The flattening of foliation toward the east suggests a differential uplift of the westaern margin of the structure. The western margin is mylonitized along a steeply dipping straight zone that extends along most of its length. The elliptical shapes of several of the gneiss domes strongly suggest compression normal to the Slave Province boundary (Fig 11, north).

The southern gneiss dome is oval with its long axis oriented north (Fig. 4). The granodioritic and granitic core has a poorly developed gneissosity, which contrasts with



1 Granodiorite biotite gneiss
2 Quartz pebble conglomerate
3 Snare Group biotite gneiss
4 Granodiorite/migmatite/migmatitic mantle rocks

Figure 10. Poles to foliation in the central gneiss dome. The eastern half shows distinct MSP orientations, whereas the western half shows the effects of steepening due to uplift of the western margin of the dome which is the locus of mylonite development. Structural symbols are the same as on the pocket map.

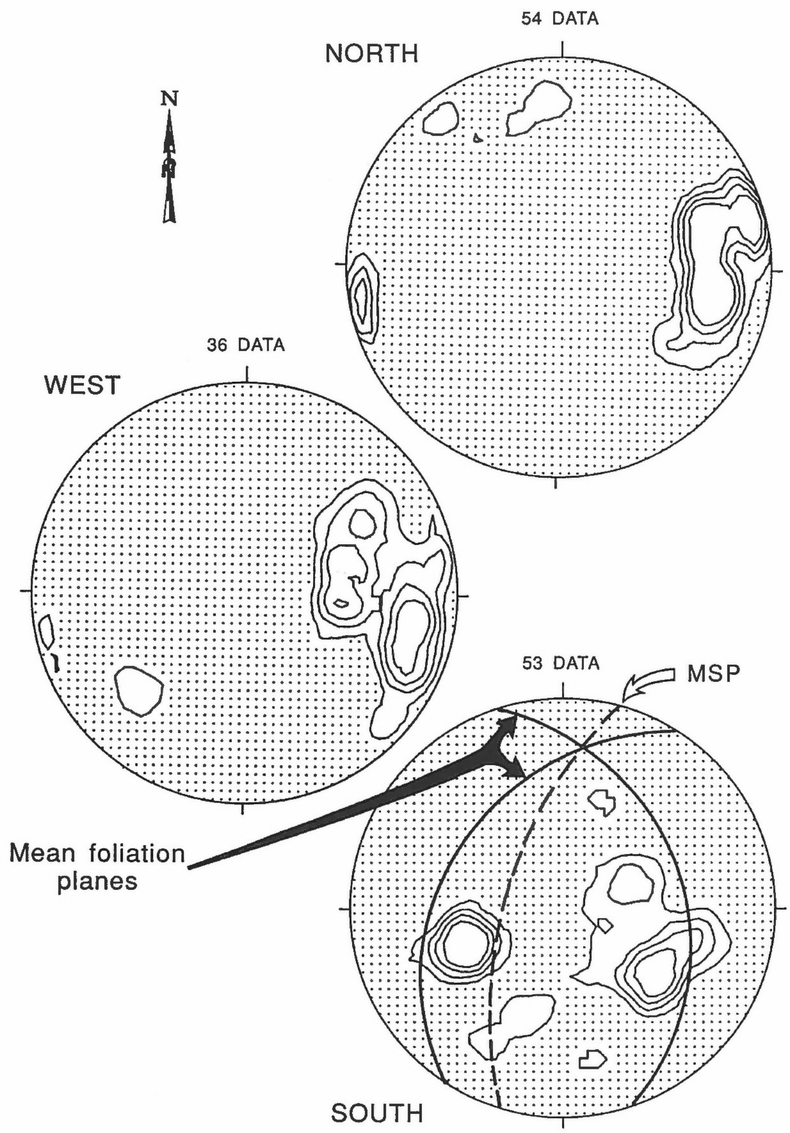


Figure 11

North

Poles to foliation in the northern gneiss dome, Brownwater Domain.

West

Poles to foliation in the westernmost dome were most likely flattened toward the MSP. The poles were steepened during uplift of the gneiss dome in some parts of the dome.

South

Poles to foliations in the southern gneiss dome suggest a steepening of foliation planes by uplift of the dome. The intersection of the two planes parallels the MSP and the plunge of the intersection coincides with lineations in the Arseno Domain (Fig. 7B).

mantle paragneiss which has a conformable foliation that wraps around the structure. The distribution of the poles to the foliations around the dome define two mean poles that suggest a north-northeast-plunging structure that strikes and plunges 010/20 degrees, which is the same as for L_2 (Fig. 11, south and 7B).

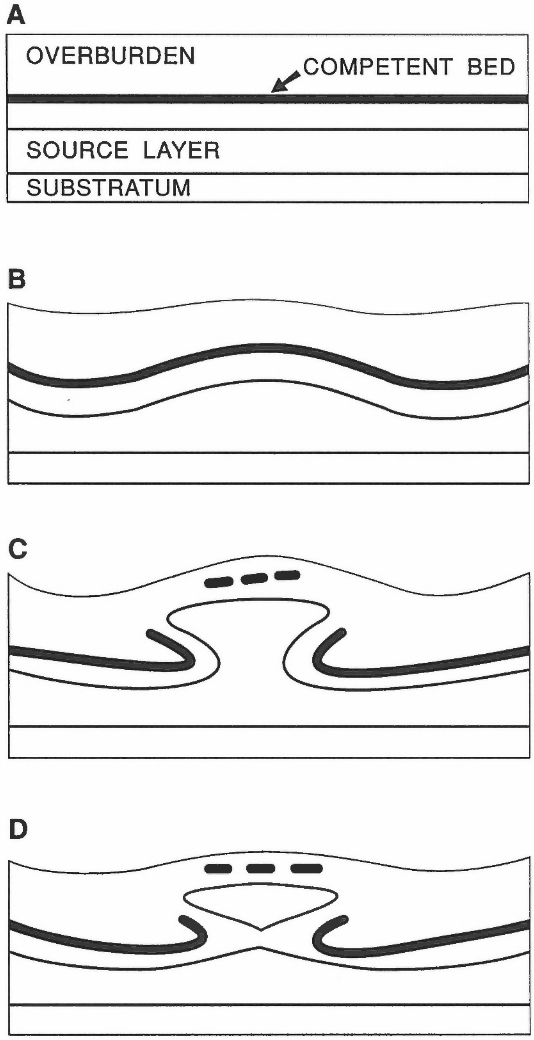
The western gneiss dome (Fig. 4 is irregular in shape and is of granulite facies metamorphic grade. The foliation is more randomly oriented than in the other gneiss domes. However, the pole to foliation corresponds to the MSP orientation (Fig. 11, west), which was likely steepened toward MSP as in the central gneiss dome. Older structures (at least pre-S_2) of possibly Archean age show curvilinear trends in outcrop pattern which show up as poles along a great circle rotated toward the MSP.

Previous studies of gneiss domes

Field observations

Structural domes, in the classical sense (Eskola, 1949) develop only by gravitationally-induced diapirism. However, it is now widely recognized that gneiss domes may also form by lateral compression which most commonly involves superimposed folding, as in the type-1 interference folding of Ramsay (1967). This mode of formation gives rise to basin and dome arrangements, particularly when the axial plane of the first direction is more than 70 degrees from that of the second. Ramsay (1967) has shown that:

1. Type-1 interference folds may be accompanied by two distinct fabrics if suitable material is available, both in the basement (core) and the mantle gneiss.



A Initial unstable system.

B Early stage of dome growth.

C Intermediate stage of growth.

D Final stage of growth.

Figure 12. Stages of gneiss dome development (Ramberg, 1967).

2. The structural trends should cut across any one dome or basin.
3. There should be no difference between structural data in the basement and the mantle gneiss, except for remnant structures or fabrics.
4. The domes and basins should be arranged in parallel rows.

Studies of Broedel (1937), Eskola (1949), Akaad (1956) and Sorgenfrei (1971) have shown that diapiric gneiss domes have many mutual field characteristics (nomenclature used is depicted in Figures 12 and 13):

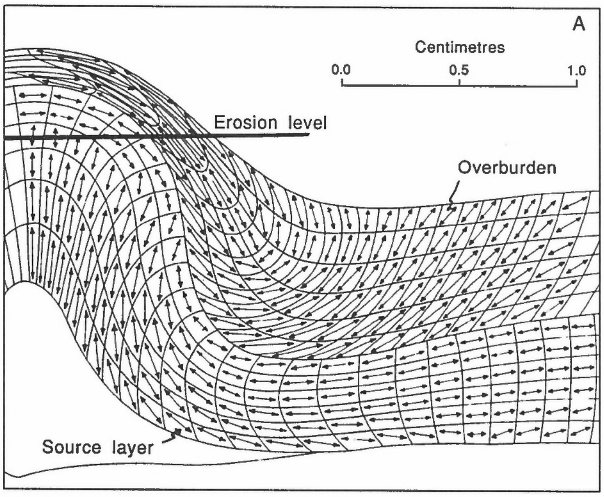
1. Gneiss domes are commonly granodioritic in composition and contain pegmatite dykes.
2. Foliation generally parallels the dome-overburden contact.
3. Overburden strata are commonly cut by the intruding dome;
4. Migmatization of the overburden near the contact is common due to latent heat of the rising dome causing partial melting, aided by the increase of fluids near the contact and possibly low heat transfer to the mantling rocks.
5. Gneiss domes commonly form during the second phase of regional deformation, the second foliation wrapping around the dome.
6. Marginal synclines, steeply plunging lineations and extensional features are intrinsic to gneiss domes.

Experimental studies of diapiric gneiss doming

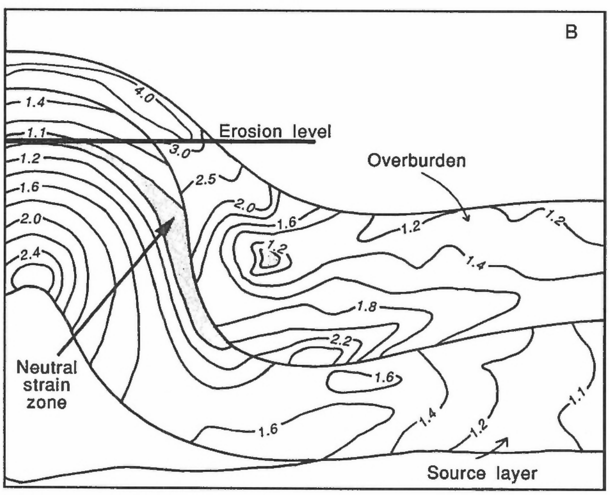
A gravitational potential exists between any strata where a less dense material is overlain by a more dense material. Rearrangement will always take place under favourable conditions. True diapirs assume a spheroidal shape when freely moving through a free flowing medium, such as oil released under water. These types of fluids tend to stratify horizontally under the influence of gravity. Rock systems also behave as fluids and follow the same rules of physics, but high viscosities and time and other factors impose limitations to the laboratory study of these effects. However, centrifuged and noncentrifuged experimental models have successfully quantified the process for some denser, more viscous materials (Ramberg, 1963, 1972a, b; Stephanson, 1972; Ramberg and Sjöstrom, 1973).

The sequence of events leading to diapirism is shown in Figure 12. The thicknesses of the various strata may vary, and the overburden may be as much as 12 km thick, as determined from metamorphic mineral pressure-temperature chemistry (Nielsen, 1977). Diapirism is initiated by lateral movements of material in the source layer forming a ridge (Fig. 12B), positioned by inhomogeneities (viscosity, composition and thickness) in the overburden. Ridges tend to form parallel to the margins (where they thin out) of the source layer, so that curved source layer boundaries will result in curved diapiric ridges.

The ridge shape becomes unstable with upward movement, developing into rows of domes familiar in gneiss dome terranes. Developed domes (Fig. 12C) spread laterally to form a "hat" and thin near the base or "root". The adjacent source layer may be depressed, as shown in Figure 12C, causing a marginal syncline to form with a width about equal to the diapir. Continued ascent may cause separation (Figure 12D), but is more commonly limited by diminution of both the gravitational potential between the source layer and overburden and by the decrease in viscosity with ascent.



A. Orientation and approximate magnitudes of normalized principal extensions.



B. Computer-generated contours of equal finite strain. The stippled area outlines regions of minimum strain.

Figure 13. The central part of the core of the southern dome, Emile River gneiss domes, is relatively undeformed, which from the experimental work of Dixon (1975) suggests it is at or near the present indicated erosion level.

Strata within the overburden (Fig. 12C, D) may record strain parallel to the outline of the source layer, and crosscutting relationships may be expected at the overburden contact. Brittle deformation may result in radial faults from the centre of the dome at high levels of emplacement.

Density and viscosity differences between the source layer and the overburden affect the rate of ascent and the level of emplacement, whereas the thicknesses of the source layer and overburden control the size and rate of formation. The thicker the overburden, the farther apart and larger are the domes. The viscosity and yield strength are also affected by temperature, and are at their lowest during the peak of thermal metamorphism.

Dixon (1974, 1975) quantified strain in centrifuged models of diapirs at the various stages of development. By varying the viscosities of the source layer and overburden he discovered that when the viscosity of the source layer was greater than that of the overburden, the latter was more deformed, which is the usual case for gneiss domes. Early stages of ascent cause vertical stretching within the core, with horizontal S-tectonite stretching at the top (Fig. 13A). Other regions of high strain occur toward the centre of the source layer, where vertical L-tectonite stretching takes place. Computerized modeling of the strain results in a neutral shadow zone which develops between the overburden and source layer (Fig. 13B).

Emile River gneiss domes and their origin

Structural studies have shown that there are three phases of folding affecting the Proterozoic Snare Group. In the Arseno Domain the dominant phase is F_2, whereas in the Brownwater Domain it is F_1. The distinction between F_1 and F_2 folding is not as clear in the Brownwater Domain, as the two are broadly coaxial. The third phase is only present locally as broad warps and is not penetrative.

Fold vergence throughout the Arseno and Brownwater domains suggest that initial folding was due to southeast-directed compression. Fold axes are generally northeasterly, but in the Arseno Domain adjacent to the Slave Craton fold axes, have assumed more northerly attitudes due to the buttressing effect of the Slave Province.

North of the map area in the Redrock Lake map area (in St-Onge et al., 1988), compression thrusted a folded hot prism of largely supracrustal rocks of the Coronation Supergroup toward the southeast over relatively cold but deformed Archean basement (St-Onge, 1984). The compression in the Arseno Lake map area was the same but the basement was also deformed. The principal compression (MSP) deforming the basement rocks suggests that slices of basement were also thrusted to the east. The basement shows the same regional grades of metamorphism as the cover rocks.

The F_2 folds and their associated structures in the Brownwater Domain were modified by diapiric uplift. A third north-south folding phase is present locally, folding both S_1 and S_2, but it did not impart a penetrative cleavage and is considered to be late-tectonic associated, with late-stage domal uplift; it is not related to the late deformation described in the Arseno and Slave Province domains. Foliation is well developed within the granitoid cores of the gneiss domes, as would be expected under conditions of high-grade regional metamorphism. Quartz pebbles were elongated during F_1 along fold lines (L_1).

Density determinations of the granitoid source layer rocks indicate they are 4 percent lighter than the supracrustal overburden rocks (Leatherbarrow, 1975). Ramberg (1963) estimated that contrasts of 7 percent are needed to initiate gneiss doming, but once initiated, a less significant contrast is required. The ascent is then controlled by temperature and relative viscosities. The small density contrast noted here may reflect vertical equilibrium (if only diapiric processes are considered) which imply that temperatures were high and that the gneiss domes were at or close to their ultimate level of ascent.

The aeromagnetic patterns in the area (Geological Survey of Canada, 1963) suggest that the depth of the metasedimentary cover in the Brownwater Domain decreased toward the south. If the domes were entirely of diapiric origin, they rose to levels of equilibration during the peak of metamorphism which accompanied the early stages of deformation. Since the size of the gneiss domes increases toward the north as does the metamorphic grade, it is concluded that the source layer was either hotter or thicker in this direction.

A detailed study of the southern gneiss dome shows that foliations show preferred northerly orientations with dips that average 50 degrees (Fig. 11, south). The intersection of the average plane for the two pole populations to a 010 azimuth plunging 20 degrees to the north, is the same as the plunge direction of lineations within the MSP, which implies that the foliations within the gneiss dome were formed by the same easterly-directed compression as the MSP in the Arseno Domain. Deviations of these foliations are best explained by shallowing due to domal uplift. The foliation was thus reoriented but not caused by the doming.

Planar fabrics in the southern dome parallel compositional layering. From theoretical studies (Fig. 13A, after Dixon, 1974) foliation would develop normal to compositional layering. This is not the case in the southern dome. Rather, the foliation is concentric, as typified by the central dome (Fig. 10). In the southern dome much of the core gneiss is massive to poorly foliated, which may indicate that this dome is at the level of erosion where neutral finite strain occurs (Fig. 13B), as suggested by Leatherbarrow (1975).

Post-Calderian tectonism

Faults

East-northeast faulting has displaced the margins of the Rodrigues granite (pocket map). Outside of the map area, the boundary of the Slave Province is displaced in a right lateral sense (Frith, 1986) and a similar sense of strike-slip motion is deduced. The faulting is due to a second collision of the Bear plate (Hoffman, 1984; Tirrul, 1984). The faulting cuts most of the rock types of the Wopmay Orogen and has caused east-west shortening and north-south extension in the eastern zones of the orogen (Hoffman et al., 1983, 1984). The same faults cut plutonic rocks of the Bear magmatic arc which have been dated at 1.84 Ga (Hoffman and Bowring, 1984) establishing the close of tectonic activity in the Arseno Lake area.

METAMORPHISM

Metamorphism of the region is associated with two principal orogenies, the Kenoran and the Calderian. Regional metamorphism is typical of the Slave Province as a whole with low-pressure mineral assemblages present in pelitic rocks (Thompson, 1978) characteristic of the Abukuma type (Miyashiro, 1958). Some Proterozoic thermal overprinting occurs along the western margin of the Slave Province, but this metamorphism was not intense enough to destroy Archean age metamorphic minerals and textures, except for some of the more reactive mafic minerals (Frith, 1978, 1986). Metamorphism in the Wopmay Orogen part of the map area occurred 500 Ma later under similar pressure and temperature conditions to those in the Slave Province. However, the regional metamorphism took place farther west and the rocks were subsequently thrust eastward over the Slave Craton margin. The thrust fault surface approximates the presently defined boundary between the Wopmay Orogen and the Slave Province. The Proterozoic metamorphism of the Snare Group was studied in detail by Nielsen (1977, 1978, 1986) who did not consider plate tectonics in interpreting the regional metamorphism. His empirical work on the metamorphism of the Arseno Lake Brownwater Lake region is nevertheless current and it forms the basis of the following account, supplemented by the work of McGlynn and Ross (1963), Frith and Leatherbarrow (1975) and Leatherbarrow (1975). These studies have been reinterpreted in light of modern metamorphic concepts and plate tectonic theory.

Metamorphism of the Yellowknife Supergroup

The Yellowknife Supergroup in the Slave Province was metamorphosed to the upper amphibolite facies. Elsewhere, metamorphism of the Yellowknife Supergroup rocks in the Slave Province grades from greenschist facies to upper amphibolite facies. Higher grades of metamorphism are not common, but some orthopyroxene-bearing granulite facies rocks are known in the Ghost Lake area, 90 km southeast of the map area (Folinsbee, 1940; Robertson and Folinsbee, 1974). None are known in the map area, but Archean rocks west of the Slave Province boundary are locally of granulite facies grade, suggesting to Nielsen (1977) that this metamorphism was also Archean. This has not yet been verified.

The upper amphibolite facies metasedimentary rocks contain cordierite and staurolite and are similar to those reported elsewhere in the Slave Province (Tremblay, 1948; Wright, 1954; Heywood and Davidson, 1969; Thompson, 1978; Frith, 1986; 1978). Rocks in the Grizzly Lake area show signs of retrograde metamorphism. Pillowed metabasalts are epidotized and chloritized. The Origin plutonic complex east of the Grizzly Lake volcanic belt (Fig. 2) is commonly epidotized and the potassium-feldspar has been discoloured to a salmon pink. Cordierite in the metasedimentary gneiss and schist has been retrograded to pinite. This retrograde metamorphism was likely of Proterozoic age. Mica ages along the eastern side of the Slave Province boundary have been isotopically rejuvenated (McGlynn, 1972) and reflect thermal events occurring at 2.2 Ma and 1.9 Ma (Frith, 1978). In the Mesa Lake area Proterozoic

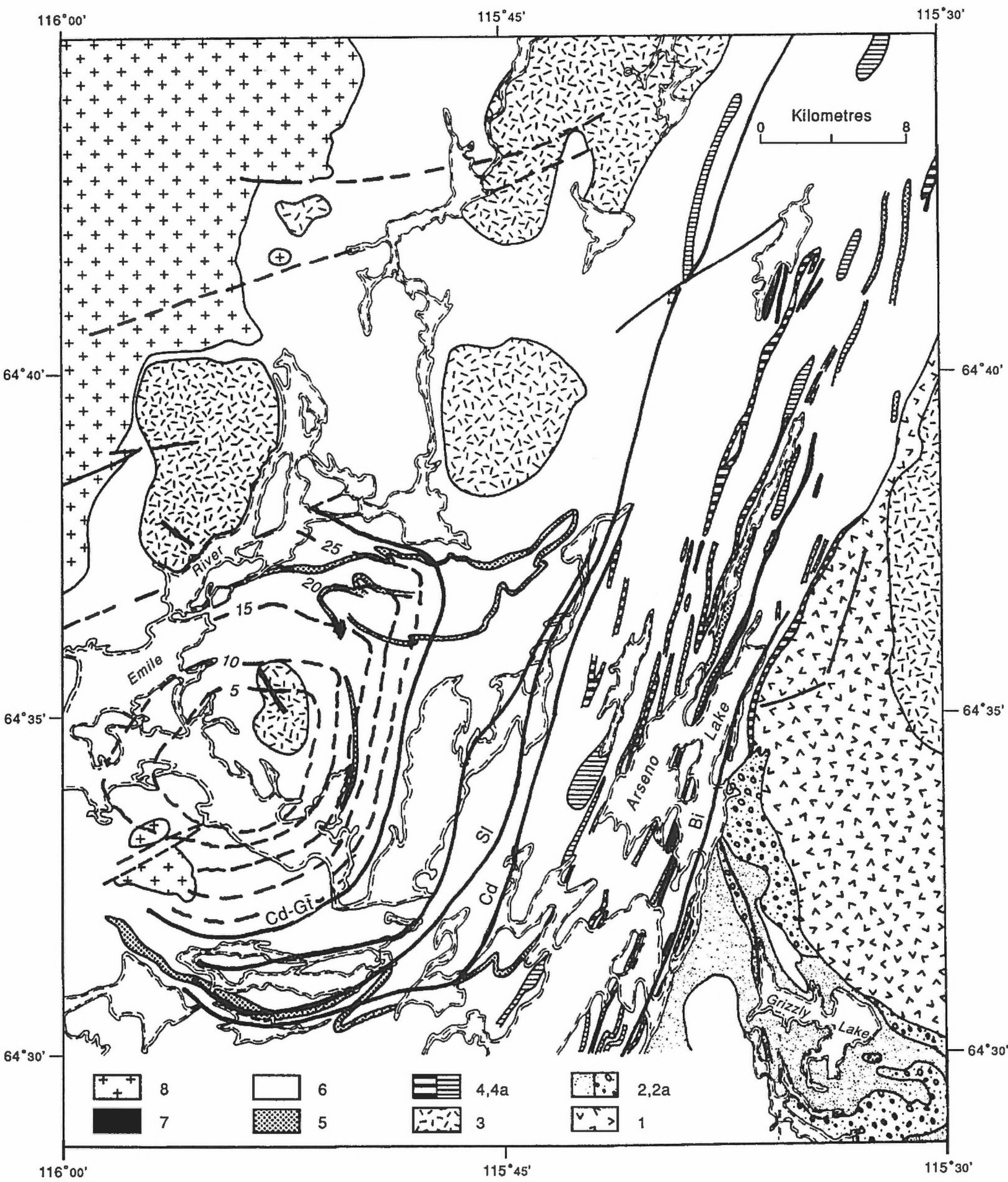


Figure 14. Geological sketch map showing isograds in the Brownwater Lake area. Metamorphism progrades westward toward a "thermal peak" indicated by the ghanite content of spinel (mole percent isopleths, proposed by Nielsen, 1977). The isograds are defined in Table 3 and as follows: Bi = biotite; Cd = cordierite; Sl = sillimanite; Sl-PF = sillimanite-potassium feldspar; Cd-Gt = cordierite-garnet. Legend follows Figure 4.

isograds have been mapped across the Slave Province boundary (Ross, 1966), suggesting that conditions were similar on both sides of the boundary.

Metamorphism in the Wopmay Orogen

The rocks on both sides of the Slave Province Wopmay Orogen boundary are similar, consisting of arkose, subgreywacke and argillite with minor calc-silicate rocks on the Wopmay side and greywacke-siltstone on the Slave side. Where calc-silicate rocks are absent on the Wopmay side the distinction of Archean and Proterozoic rocks is difficult. In addition, both regions are characterized by Abukuma-type metamorphism; to the last metamorphosism took place during the Archean (2.59 Ga) and to the west, during the Proterozoic (1.89 Ga). One tool used to separate the two age groups and their metamorphism, apart from the small changes observed in chemistry (K/Na, Table 2), is the presence or absence of potassium-feldspar. Archean Yellowknife Supergroup metasediments generally do not contain potassium feldspar although it does occur rarely. Therefore the presence of potassium feldspar does not unequivocally signify Snare Group rocks, although much of the map area west of the Slave boundary is on the high temperature side of the metamorphic muscovite breakdown to potassium-feldspar. However, the generally higher K_2O contents of Snare Group rocks and the resultant higher potassium-feldspar content may be used as a

Table 3. Mineral assemblages from the Arseno Lake map area (data mostly from Nielsen, 1986).

Chlorite Zone

Chlorite-sericite-quartz-plagioclase-ilmenite +/- detrital potassium-feldspar and pyrite
Biotite-dolomite-quartz-tremolite

Biotite isograd:
A reaction involving chlorite, muscovite and ilmenite

Biotite Zone

Biotite-sericite-chlorite-quartz-plagioclase +/- ilmenite +/- rutile +/- detrital potassium-feldspar and pyrite
Biotite-muscovite-spessartine-quartz-plagioclase +/- rutile +/- ilmenite
Biotite-muscovite-quartz-plagioclase +/- ilmenite +/- rutile
Biotite-muscovite-andalusite-quartz-plagioclase +/- ilmenite +/- rutile
Biotite-chlorite-andalusite-quartz-plagioclase +/- ilmenite +/- rutile

Cordieriteisograd:
chlorite + muscovite + quartz = biotite + andalusite + cordierite + vapour

Cordierite-andalusite zone:

Biotite-muscovite-cordierite-andalusite-quartz-plagioclase +/- ilmenite +/- rutile
Biotite-cordierite-andalusite-quartz-plagioclase +/- ilmenite +/- rutile
Biotite-cordierite-fibrolite-andalusite-plagioclase +/- ilmenite +/- rutile

Sillimanite isograd:
andalusite = sillimanite

Cordierite-sillimanite zone

Biotite-cordierite-sillimanite-fibrolite-plagioclase-quartz +/- ilmenite +/- rutile
Biotite-cordierite-muscovite-orthoclase-plagioclase-quartz +/- ilmenite +/- rutile

Sillimanite - Potassium-feldspar isograd:
muscovite + quartz = sillimanite + potassium-feldspar + vapour

Sillimanite - Potassium-feldspar zone:

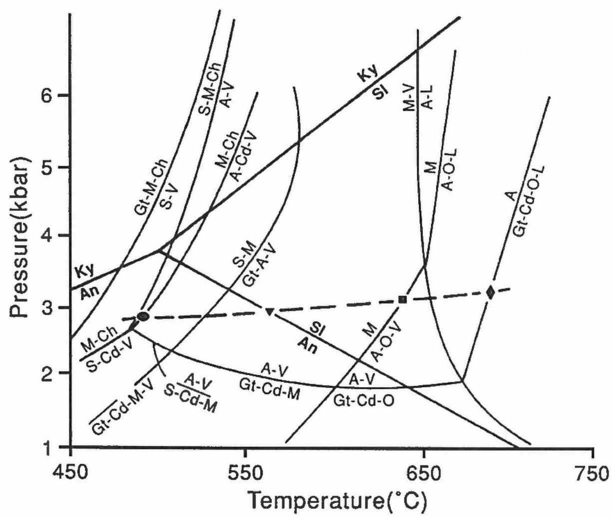
Biotite-cordierite-sillimanite-microcline-quartz-plagioclase +/- ilmenite +/- rutile

Cordierite - garnet isograd:
biotite + sillimanite + plagioclase = cordierite + almandine + potassium-feldspar + melt

Cordierite - almandine zone:

Biotite-cordierite (sillimanite)-microcline-quartz-plagioclase-garnet +/- ilmenite +/- rutile
Biotite-cordierite-garnet-microline-quartz-plagioclase +/- ilmenite +/- rutile
Biotite-garnet-microline-quartz-plagioclase +/- ilmenite +/- rutile
Biotite-cordierite (spinel-sillimanite)-potassium-feldspar-plagioclase-quartz +/- ilmenite +/- rutile
Biotite-cordierite (spinel)-potassium-feldspar-plagioclase-quartz +/- ilmenite +/- rutile
Biotite (spinel)-garnet-potassium-feldspar-plagioclase-quartz +/- ilmenite +/- rutile
Biotite-cordierite (spinel-sillimanite)-garnet-potassium-feldspar-plagioclase-quartz +/- ilmenite +/- rutile
Biotite-orthopyroxene-plagioclase-quartz-potassium-feldspar +/- ilmenite +/- rutile
Calcite-serpentine (forsterite)-ilmenite

Note: Minerals in parentheses are found only as inclusions in the preceding mineral.



Legend

A - andalusite, sillimanite, or - kyanite

C - cordierite

Ch -chlorite

G - garnet

L - granitic liquid

M - muscovite

O - orthoclase

S - staurolite

Figure 15. Pressure-temperature (PT) grid for part of the ideal pelitic system adapted from D.M. Carmichael (pers. comm., 1986). For vapour-present reactions the activity of water is approximately one, and for vapour-absent reactions it is less than one. The reactions involve quartz, biotite and sodium-feldspar. The PT path or the present erosion surface (dashed line) intersects the cordierite isograd (dot), the sillimanite isograd (triangle), the sillimanite-potassium feldspar isograd (square), and the cordierite-almandine-potassium feldspar isograd (diamond).

general indicator. This becomes less reliable toward the west, as the Snare Group becomes less potassic and more flysch-like, consisting predominantly of subgreywackes. In the mantle rocks surrounding the gneiss domes the age of the rocks (and possibly their metamorphism) is uncertain. The more potassic whole rock chemistry (Frith, 1986) and the presence local of dolomitic interlayers suggest the lithology is Snare Group.

Archean metamorphism

Rocks equivalent to the Yellowknife Supergroup greywackes and mudstones occur in the Wopmay Orogen. These rocks resulting in were overprinted during the Proterozoic metamorphic mineral assemblages that are, for the most part, the same as those in Snare Group rocks which were metamorphosed during the Proterozoic. The granitoid core rocks of the gneiss domes have preserved whole rock Rb-Sr whole rock isochron systems. However, granulite facies orthopyroxene and spinel are present in both the gneiss dome cores (western gneiss dome) and in the Snare Group paragneiss. This does not mean that Archean metamorphic minerals were not formed, nor that they were not preserved. However, for the following account all metamorphic mineral assemblages may be considered to have grown or to have approached equilibrium during thermal metamorphism associated with the Calderian Orogeny.

Proterozoic metamorphism

Metamorphic mineral assemblages are used to delineate metamorphic zones separated by isograds (Fig. 14, Table 3). The lowest grade is represented by the chlorite zone. The appearance of biotite, produced by a reaction involving chlorite, muscovite and ilmenite, marks the beginning of the biotite zone. The reactions leading to the development of other isograds are shown in Table 3. The highest grade in the area is reached in the cordierite-garnet zone. A thermal peak appears to be present at this grade, indicated by isopleths of ghanite content in spinel (Fig. 14). A high temperature favours the formation of spinel and quartz at the expense of cordierite (Nielsen, 1977). Because zinc is highly partitioned into spinel, it is concentrated into (presumably) smaller modal amounts of spinel at lower grades.

The sequence of isograds, except for the biotite isograd, can be plotted as an erosion surface pressure-temperature (PT) curve (Fig. 15). A temperature range of 450-700°C occurs at about 3 kb. The biotite isograd might correspond to about 350°C. These PT estimates are supported by various geobarometers and geothermometers (Nielsen, 1986).

Conclusions

The Slave Craton, which includes the Archean age rocks presently beneath the Snare Group in the Wopmay Orogen, was metamorphosed during the Archean and the Proterozoic. The effect of the orogeny on the Slave Province rocks east of the structural province boundary is more apparent in the deformation of the rocks than in their metamorphism, which is mostly restricted to mafic mineral epidotization (Frith, 1986). Metamorphism near the boundary in the Snare Group is of greenschist facies (Nielsen, 1977). The grade of regional metamorphism along the western margin of the Slave Province can only be estimated from the resetting of K-Ar biotite systems which commonly equilibrates at 250-300°C, or under lower greenschist facies conditions.

In the Wopmay Orogen, there is little evidence of Archean metamorphism in the map area. Rb-Sr whole rock dating of the gneiss dome core and anatectic pegmatite (essentially a mineral isochron) in the mantle gneiss yielded isochrons of Archean age for the core and Proterozoic age for the pegmatite (Frith et al., 1977). These age data indicate that local temperatures were not high enough or conditions were not wet enough to re-equilibrate whole rock rubidium and strontium systems, but were high enough to form or reconstite some rock-forming minerals. It follows that metamorphic minerals were re-equilibrated in regions of high-grade metamorphism.

SYNTHESIS AND DISCUSSION

Proterozoic tectonism

The following synthesis incorporates information obtained during this study and unpublished data from geological studies carried out between 1960 and 1985, from both within the map area and in nearby regions. It also includes recent tectonic interpretations of the Wopmay Orogen. The discussion is restricted to recent ideas pertaining to that part of the Wopmay Orogen investigated in this bulletin and its effect on the western margin of the Slave Province.

Previous work

Since Lord's (1942) mapping of the western Slave Province area there have been four important studies carried out in the map area and surroundings that have a bearing on the interpretation of the geological history of the region. These are: (1) a study of the Slave Structural Province boundary (Ross and McGlynn, 1965); (2) mapping of the Indin Lake area at a 1:125 000 scale and the Arseno Lake area at a 1:50 000 scale (Leatherbarrow, 1975; Frith, 1987); (3) a study of the metamorphism in the Arseno Lake Norris Lake area (Nielsen, 1977); and (4) the work of many Geological Survey of Canada workers between 1980 and 1985 in the northern Wopmay Orogen (summarized by Hoffman, 1984).

1. Ross and McGlynn (1965) and Ross (1966) found some basic differences between Proterozoic and Archean deformation where both are present along the western margin of the Slave Province (Fig. 6). Axial planar features to the west of the Slave Province boundary dip steeply to the west, whereas those to the east dip steeply to the east. Furthermore, the degree of shortening in the Arseno Domain contrasts with the degree of shortening observed east of the boundary, where only minor reorientation of Archean structures has taken place and deformation is restricted to weak penetrative cleavage within the more argillaceous Archean paragneiss.

Proterozoic deformation prior to the development of the dominant structural trend observed in the Snare Group adjacent to the Slave Province boundary (MSP) was recognized in the Mesa Lake area (Ross, 1966), where folding is cylindrical, the angles between limbs are moderate and the axial planes are almost vertical. These folds have northeasterly oriented axes that cut the Slave Province boundary at about 30 degrees.

2. Frith's (1974) mapping and geochronological work (Frith et al., 1977) of domal structures in the Arseno Lake map area showed the presence of Archean basement cores in gneiss domes emplaced into Proterozoic metasediments. Regional metamorphic conditions in the Brownwater Domain attained granulite facies prior to dome emplacement, as the uplift of the domes caused hotter rocks to be exposed in and around the dome region. Metamorphic isograds prograde toward this area with the grade decreasing to greenschist toward the Slave Province boundary at Arseno Lake. The lowest grade rocks in the region are found here.

Archean basement to the south of the map area was uplifted like the Archean cores of the Emile River gneiss domes, but it occurs as the central part of a large anticlinorium with infolded remnants of Snare Group cover rocks. The Archean basement and the Snare Group are separated by an erosional angular unconformity. One of the most significant findings of the study of the boundary area was the realization that the Archean granitoid areas were uplifted into domal shapes during the Proterozoic, affecting **both** the Slave and Wopmay sides of the Slave Province boundary (Frith, 1986, 1987).

Leatherbarrow (1975) suggested that the Emile River gneiss domes formed by contemporaneous gravitational doming and large-scale interference folding (Ramsay, 1967). The fabric within the gneiss domes was interpreted to be syndomal. Three phases of folding were recognized within the adjoining gneiss: an upright folding similar to folding near the Slave Province boundary; a second phase with east-trending axes with vertical and overturned axial planes; and a third phase of gentle north-oriented warps. The first two phases of folding were recognized as contemporaneous and the different orientations were thought to result from subsequent dome uplift, causing second phase foliations to wrap around the gneiss domes.

The present interpretation also favours an approximately contemporaneous development of F_1 and F_2, but the structures parallel to the Slave Province boundary are considered to be F_2, as they postdate structures found in the Brownwater Domain. Older phase folding did not occur in the lower grade rocks and it is deduced that stratiform rocks of the Snare Group were transported intact until no longer mobile and were then deformed.

Leatherbarrow (1975) considered the first two phases of folding to be contemporaneous with the peak of regional metamorphism. However, there were two phases of regional metamorphism, which is apparent as overgrowths of the same mineral phase, suggesting similar pressure and temperature conditions. Locally, regional metamorphism is lower grade and retrograde effects occur.

The third phase of folding did not impart a penetrative foliation to the rocks and took place when gravitational isostatic adjustments uplifted the gneiss domes to their final level of emplacement. This took place when the rocks had cooled below the amphibolite facies.

3. Nielsen's (1977) metamorphic mineral studies showed that regional metamorphism was constrained to a relatively constant pressure of 3 Kb (Fig. 15) and to temperatures of 600-700°C. He also showed that the granitoid basement, as well as the surrounding paragneiss, was metamorphosed to the granulite facies. Subsequent metamorphism occurred during an event dated by Rb-Sr methods at approximately 1.9 Ga (initial ratio of 0.710 recalculated using 1.42 x 10^{-1}x $y^{-1}\lambda$). Nielsen (1986) showed that the granulite facies

paragneiss surrounding the southern gneiss dome was mostly retrograded to upper amphibolite facies.

4. The most innovative and far-reaching conclusion to result from the study of the Wopmay Orogen (summarized by Hoffman and Pelletier, 1982; Hoffman, 1984) was the realization that two eastern zones are allochthonous, driven east by a collision of the Bear plate with the Slave plate. Sedimentation resulting from the early stages of tectonism included turbidites and volcanic rocks of the Akaitcho Group deposited into rift-related basins. The continuity of the Akaitcho Group into the northwestern corner of the Indin Lake map area (Acasta River and Exmouth Lake) and south to the Arseno Lake map area suggests that the Snare Group and the Akaitcho Group are the same (Frith, 1987).

Calderian Orogeny

D_1

Deformation associated with east-west shortening, vertical thickening and eastward translation onto the Slave Craton are considered to be part of the same overall deformational event (D_1), which in this study area includes F_1, F_2 and F_3 folding.

F_1 folds parallel the elongate direction of a diapir, just north of Mesa Lake (Fig. 8), which was uplifted during the Proterozoic (Frith et al., 1977). A noteworthy feature of this deformation is the change in direction of fold plunges and related mineral lineations from the southwest to the northeast. Three more phases of deformation are recognized:

D_2

Ross and McGlynn (1965) recognized broad east-west arching and different fold styles with the change in metamorphic grade along the length of the Slave Province boundary. The change of lineation plunges caused most earlier lineations to plunge to the north in the Arseno Lake area.

King's (1986) structural mapping in the Redrock Lake area, north of the Indin Lake map area, identified large scale undulations possibly related to a second continental collision (Tree River folding; Tirrul, 1984) which exposed different structural levels along the length of the Slave Province boundary (St-Onge, 1984). The change in Proterozoic metamorphic grade from greenschist in the Basler Lake Arseno Lake area to amphibolite grade in the Mesa Lake area, probably represents such an undulation.

D_3

A dextral transpressive faulting event is recognized in the northwestern part of the Wopmay Orogen where the Great Bear Magmatic Arc is dominant (Hildebrand, 1981).

D_4

Transcurrent faulting (related to terminal collision) formed a conjugate set of faults to the north of the Indin Lake map area. In the Arseno Lake map area, the faults are mostly east-northeast trending where they cut the Rodrigues granite. In the Mesa Lake area the same faults cut the Slave Province and extend 30-40 km into it. These occurred as a result of the clockwise rotation of the region (Hoffman, 1984), as the dextral set is more evident than the sinistral set, possibly due to the buttressing effect of the Slave Craton against eastward-directed compression.

Plutons

Major Proterozoic intrusions are represented in the map area by the Rodrigues granite which is part of the regionally extensive Hepburn Intrusive Suite. It has many of the properties of the Archean granitoid core areas of the Emile River gneiss domes. The rocks were likely melted from Archean basement gneiss by anatectic processes and intruded during orogenesis in zones where the host rocks were wetter and hotter (Frith et al., 1974, 1977; Lalonde, 1986). Hoffman (1984) leaves little doubt that the Hepburn Intrusive Suite and the rocks of the Coronation Supergroup are allochthonous suites of rocks. There is no evidence in the Arseno Lake map area to suggest the contrary. However, there is one significant difference. The relatively hot allochthonous sedimentary rocks of the Coronation Supergroup (Hoffman, 1984) were thrust over relatively colder granitoid basement rocks in the Redrock Lake map area, whereas in the map area the Archean granitoid windows were metamorphosed by the same Proterozoic metamorphism as the Snare Group, implying that the basement, like the Hepburn Intrusive Suite, was detached from an area to the west; thus both are allochthonous.

Age relationships

The table of formations (Table 1) summarizes the age relationships among map units. The Archean and Proterozoic rocks are separated stratigraphically by an unconformity.

The Yellowknife Supergroup has been dated at 2.67 Ga (Frith and Loveridge, 982). The plutonic rocks north-east of Grizzly Lake were correlated with syntectonic plutonic rocks found elsewhere in the Indin Lake map area which were intruded at or slightly after the peak of regional metamorphism dated by U-Pb monazite methods at 2.59 Ga (Frith et al., 1986).

Archean rocks in the cores of domal structures (Fig. 4) were dated at 2.6 Ga using Rb-Sr whole rock dating techniques (Frith et al., 1977). Nielsen (1977) considered granulite facies metamorphism in the polymetamorphosed paragneiss in the mantle rocks of the southern gneiss dome to be Archean, due to its metamorphic and structural complexity. However, regional metamorphism progrades uniformly from Proterozoic rocks through to the polymetamorphosed terrane and the structures within these rocks were formed or reoriented during the Proterozoic. Radiometric dates from the mantle gneiss of the southern gneiss dome gives an ambiguous age (Nielsen, 1977). The chemistry of its mantling gneiss is consistent with derivation from rocks similar to the Slave Province Yellowknife Supergroup metasediments (Table 1; Fig. 2). The presence of Archean age granulite facies rocks in the Ghost Lake area of the Slave Province (Robertson and Folinsbee, 1974) suggests that the western margin of the Slave Province attained granulite facies grade during the Archean. This leaves the probability that granulite facies rocks extended westward as the footwall of the sole fault of the allochthon. However, there is little doubt that Proterozoic metamorphism also reached granulite facies conditions, as isograds show a uniform prograding from the Slave Province margin toward the western margin of the map area. Furthermore, the rocks and their metamorphism were located farther to the west.

Several important age relationships outside of the map area have a bearing on relationships within the map area. South of the map area, an unconformity between Archean basement rocks and the base of the Snare Group is well known (Lord, 1942; Frith, 1973; Frith et al., 1977). Locally, the unconformity has been tilted westward by at least 45 degrees since the deposition of the lowermost Snare Group, indicating that the Slave Province was not wholly passive during Wopmay orogenesis. Large-scale anticlinorial structures were outlined within the Wopmay Orogen in the Mattberry Lake Norris Lake areas, (Frith, 1987). Metasediments similar in appearance to those of the Slave Province gave Rb-Sr whole rocks ages of 2.2 Ga (Frith et al., 1977), indicating an early Proterozoic thermal overprint of the Archean rocks of the region.

Within the Snare Group, orthoquartzites, quartz pebble conglomerates and the overlying turbiditic arkoses, greywackes and argillites are conformable, except for local scouring. Metagabbro intrudes near the base of the group as conformable sills and is similar to the intraformational sills observed in the Arseno Lake area.

The depositional age of the Snare Group in the map area has not been determined. Pegmatites around the Brownwater gneiss dome provide a minimum age of 1.77 Ga (Frith et al., 1977). The age of Proterozoic deposition in the region to the north of the map area, in the central parts of the Wopmay Orogen, is based on the age of the base of the Akaitcho Group which is dated using U-Pb zircon techniques at 1.99 Ga (Hoffman and Bowring, 1984). Despite the lack of a time-stratigraphic relationship between basal Snare and basal Akaitcho groups, they are compositionally similar (Fig. 3) and the rapid rate of sedimentation inferred from age determinations throughout the Coronation Supergroup (Hoffman and Bowring, 1984) suggests that their absolute age value is also similar.

The Rodrigues granite, part of the Hepburn Intrusive Suite, was likely derived by anatexis of Archean granitoids, as suggested from Rb-Sr studies of whole rocks of the Hepburn Suite west of Mattberry Lake (Frith et al., 1977). Oxygen isotope studies of whole rocks and minerals from the suite, found north of the map area, support this view (Lalonde, 1986). Zircon U-Pb studies from other plutons of this suite give ages of 1.89 to 1.88 Ga (Hoffman and Bowring, 1984).

Wopmay Orogen — Slave Structural Province boundary

The Slave Province boundary in the map area north to the Mesa Lake map area (Ross, 1966) and is defined by the regional change in plunge of Proterozoic fold axes and associated mineral lineations which in the Slave Province overprint Archean rocks and structures and trend to the east whereas in the Wopmay Orogen they trend toward the west. Furthermore, the boundary is interpreted as the surface expression of a décollement where Proterozoic allochthonous rocks derived from the west have been thrust over Archean rocks of the Slave Craton.

Tectonic interpretation

Archean deformation took place during the Kenoran Orogeny. Deformation in the western margin of the Slave Province occurred during two major phases of deformation, leaving structures that are presently oriented northeast to north-northeast. These phases are commonly coplanar, where regional metamorphism is high, as in the map area; however, in the centre of the Indin Lake structural basin where greenschist facies prevails, the two can be readily distinguished (Tremblay et al., 1953). A third, minor phase of folding is apparent in these low-grade areas which affects all rock types and is parallel to open folding of the Yellowknife Supergroup with an upright axial planar cleavage that trends to the northwest. Folding associated with this cleavage is observed in areas to the north and northeast of Indin Lake. The northwest cleavage and fold traces are parallel to the earliest folds observed in the Mesa Lake area with which they have been tentatively correlated. These folds and their cleavage traces are parallel to structures in the Grizzly Lake part of the map area, where phase 3 or phase 2 cannot be distinguished, as phase 2 structures are commonly parallel to the volcanic-sedimentary boundary. In any case, the structures are Archean and were rotated during the Proterozoic parallel to the Slave Province boundary.

Possible allochthonous terrane

The tight folding of the Snare Group in the Arseno Domain relative to the degree of compression observed in the basement, strongly suggests that the Coronation Supergroup in the region is allochthonous, similar to the Redrock Lake area (Hoffman et al., 1983; St-Onge et al., 1984) where an allochthonous wedge of Coronation Supergroup rocks and intrusive rocks of the Hepburn Intrusive Suite were thrust along sole faults toward the east during the Calderian Orogeny. The driving force for eastward directed thrusting was the collision of the Bear plate with the Slave plate (Hoffman, 1984). These relationships contrast with the autochthonous relationship of the Snare Group with the Archean Slave Craton in the Mattberry Lake Norris Lake area where basal conglomerates unconformably overlie the basement (Frith, 1986). The Arseno Lake area lies in the transition zone between allochthonous and autochthonous terranes.

A tentative line delineating eastward thrusting has been drawn in the map area which separates allochthonous and autochthonous terrane (Fig. 8). The line is based on a structural transition where Proterozoic axial plane and bedding attitudes on one side show consistent east vergence (Arseno Domain), whereas on the other side they show west vergence (Slave Province). The line extends from the map area into the Mesa Lake map area, where it is delineated by mineral lineations instead of axial planar vergence.

The Redrock Lake area allochthonous terrane includes intrusive plutonic rocks of the Hepburn Intrusive Suite (St-Onge et al., 1984). The same cannot be unequivocally applied to the Arseno Lake map area, as no thrust plane with a Hepburn pluton hanging wall was observed. However, southwest of Brownwater Lake, a small pluton of the suite forms an integral part of an antiformal structure that plunges to the south. Along the southeastern margin of this structure early foliations are flat lying and bedding and foliation trends diverge from a curved east-west trend toward the principal axial planar orientation (or the MSP associated with F_2).

Studies of the southern gneiss dome showed pre-MSP foliations. Reorientation (large-scale folding) of these foliations during Calderian deformation gives an interference pattern that may be treated empirically. The foliations plot in two great circles on stereographic projection (Fig.11) that intersect giving a bisecting plane of MSP orientation and an intersection line corresponding roughly to mineral lineation plunges, as observed in the Arseno Domain. The deformation in the core gneiss correlates with the deformation of the cover rocks, including the Snare Group. The deformation likely occurred after eastward thrusting of the gneiss as a basal slice.

Regional metamorphic isograds show no break from their prograde path of greenschist facies near the Slave Province boundary to granulite facies within the gneiss domes. This is consistent with an allochthonous wedge that has been uplifted more toward the west than the east. A cross section would show isograds prograding toward Archean basement. This contrasts with relationships in the Redrock Lake area where the basement has been shown to be cooler and below the thrust faulting which resulted, in places, with reverse isograds (St-Onge et al., 1984).

To the south of the map area, autochthonous Archean basement terrane in the Mattberry Lake (Frith et al., 1977) and Norris Lake area (Frith, 1986) was deformed during D_1, but like the Redrock Lake area, the basement shows only low-grade regional Proterozoic metamorphism. The overlying sediments are mostly in place, with only locally developed thrusting, and are made up mostly of conglomerates, quartzites and dolomites that have been described stratigraphically as lower Snare Group (Frith, 1986). Deformation has folded the rocks in a more open style in contrast to the tight isoclinal style evident in the allochthonous Snare Group of the Arseno Lake map area.

Extensive right-lateral transcurrent faulting occurred throughout the Wopmay Orogen when the Bear plate, which underlies both the Coronation Supergroup and the rocks of the Great Bear magmatic zone, collided obliquely with a plate to the east causing a counterclockwise rotation and consequential north-south extension (Hoffman, 1984). These right-lateral faults are most evident to the north of the map area, some of which may be seen in Figure 8. The right-lateral faulting was the last tectonic event to affect the area, apart from 1200 Ma volcanism near Coronation Gulf and associated regionally extensive diabase dyking.

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