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PALEOMAGNETISM OF THE YUKON AND NORTHWEST TERRITORIES

By

J.K. Park

with contributions by
K.L. Buchan, R.H. Rainbird and D.W. Morrow

Geological Survey of Canada (Calgary), 3303 - 33 Street N.W.
Calgary, Alberta T2L 2A7

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Although every effort has been made to ensure accuracy, this Open File Report has not been edited
for conformity with Geological Survey of Canada standards.

SUMMARY

This report deals with the paleomagnetic record of a region that will be compiled in an atlas entitled "Geological Atlas of the Northern Canadian Mainland Sedimentary Basin". The atlas region extends from 60°N to 70°N latitude and from 110°W to 142°W longitude. Paleolatitudes are unknown for much of the older Precambrian in this region. Where they are known, only in two instances during the Paleoproterozoic has the region been absolutely determined to be north or south of the equator. Much more detail is known of Neoproterozoic paleolatitudes which indicate that the Atlas region was within 30° of the equator until latest Neoproterozoic time when this region may have been at more than 60° south latitude.

Due to a lack of precise age determinations of most sampled units, it is still not posssible using paleomagnetic data to document relative movements between major components of the Canadian Shield with confidence. However, the paleomagnetism of dyke swarms in the Mackenzie Mountains may record the separation, or rifting, of Laurentia (i.e. North America) away from the Australian subcontinent.

Paleomagnetism in the region has recorded widespread tectonic events, such as uplifts, mountain building, Precambrian rifting and terrane movements and has substantiated an ancient origin for the northwestward curvature of the Mackenzie Arc.

INTRODUCTION

"Paleomagnetism will undoubtedly be of very great importance in determining the time order of Precambrian rocks, and in studying the nature of Precambrian orogenesis by determining any displacements that have occurred between the provinces of the Canadian Shield. Before achieving these long term objectives, variations of the Precambrian geomagnetic field must be determined by conducting detailed studies across the entire shield." So wrote Irving et al. (1972) in a study contributing towards this end. The Canadian Shield was a prime target for early paleomagnetic studies in Canada, because Pleistocene glaciations had denuded the landscape, exposing extensive areas of fresh rocks, and because the region contains many suitable rock types for study, particularly red beds and diabase dykes. In the atlas area, early studies mostly involved Proterozoic rocks overlying and adjacent to the Archean Slave Structural Province, especially the sedimentary successions and the intruding dykes (see Irving and McGlynn, 1979 and references therein). Although much data were collected, problems relating to the dating of magnetizations and to later tectonism made them difficult to interpret (Roy, 1983). Later studies in the atlas region were mainly conducted in the Cordillera, and involved paleomagnetic work on Neoproterozoic strata and magnetostratigraphic work on Cenozoic strata. A total of 157 localities of all paleomagnetic studies included here are plotted in Fig. 1 and are listed in Appendix 1.

PREVIOUS WORK

Paleomagnetic studies in the northern Canadian Shield began in the early 1960's. In 1964 work began on the Mackenzie diabase dyke swarm and the associated Coppermine lavas and Muskox intrusion in the Archean Slave Province (see Buchan and Halls, 1990). These studies were part of an overall effort to determine possible displacements among structural components of the Shield during the Proterozoic. The oldest magnetizations from the region were isolated in Paleoproterozoic dykes and other intrusive bodies of the Slave Province. Younger magnetizations were mostly obtained from the surrounding orogens, which were considered to be remnants of the Coronation Geosyncline developed on the Slave margins.

Paleomagnetic work in the early 1970's on the related Coronation, Great Slave, and Goulburn supergroups of these remnant basins began to build up a stratigraphic sequence of observations. Two groups of researchers were involved: workers from the Geological Survey and Earth Physics branches of the Canadian government (W.R.A. Baragar, W.F. Fahrig, E. Irving, J.C. McGlynn, J.K. Park, W.A. Robertson) and workers from the University of Alberta (M.E. Evans, D.K. Bingham, G.S. Hoye, E.W. McMurry, A.B. Reid). Using additional data from outside the atlas region, they recognized a major 1900-1600 Ma loop--the so-called Coronation Loop--in the existing apparent polar wander (APW) path (Irving et al., 1972; see Irving and McGlynn, 1979; Evans and Hoye, 1981)[1]. The widespread Hudsonian magnetic overprint developed in Shield rocks, and represented by poles of the Slave and Superior provinces near the cusp of the loop, suggested that the two provinces were together by ca. 1750 Ma (Irving et al., 1984). Attempts were made to determine if relative displacements of the Slave and Superior provinces had occurred in the Paleoproterozoic by comparing pre-Coronation segments of the APW path for the two provinces (see Irving et al., 1984 and references therein). Recent precise dating of paleomagnetic poles from the Superior Province (e.g., Buchan et al., 1996), however, sheds doubt on the earlier comparisons. Similar precise dating of Slave Province paleopoles is also needed before a reliable comparison of the relative location of Slave and Superior provinces in the Paleoproterozoic can be made.

While paleomagnetic studies continued on the Paleoproterozoic strata of the Slave Province and vicinity, other studies began on nearby Neoproterozoic units--the Franklin diabase dykes and related Coronation sills and Natkusiak basalts dated at about 723 Ma (see Park and Rainbird, 1995). The Franklin dykes transect much of the northern Shield from Baffin Island to the Brock Inlier north of the Slave Province.

Slightly older Neoproterozoic diabase dykes and sheets (ca. 780 Ma) were later studied around the Mackenzie Arc in the western part of the atlas region (see Park et al., 1995). These studies

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[1]Paleomagnetists publish much of their data in the form of paleopoles and apparent polar wander (APW) paths. An APW path is the curve traced out by a sequence of magnetic poles from dated rock units, assuming the land mass to remain fixed. Inversely, by allowing the paleopoles to remain fixed at geographic north, a sequence of paleolatitude maps can be produced that illustrate the movement of the land mass.

verified the Arc as a primary feature, not a product of later tectonic forces. Combining the work on 780 Ma diabases with research on other similarly dated units in the northwestern United States and in the Wopmay Orogen, Park et al. (1995) suggested that all of the dykes could have been part of a giant radiating dyke swarm that was truncated by the rifting away of Australia from Laurentia.

Many other paleomagnetic studies were conducted on the excellent stratigraphic exposure of the Arc, particularly in the Neoproterozoic sedimentary successions in the Mackenzie Mountains of the northern Cordillera. Earlier work in this region showed that the northwest curvature of the Mackenzie Mountains, or the Mackenzie Arc, is an ancient feature predating Neoproterozoic sedimentation and was not caused by Cretaceous-Tertiary Laramide-related orogenesis (Park et al., 1989). More recent studies demonstrated the existence of a new loop in the APW path for Laurentia in the period ca. 850-700 Ma (see Park, 1994), and suggested several geological conclusions. First, paleomagnetism showed that the rocks had undergone several periods of hematitization, associated with major hiatuses/rifting (Coates Lake, Rapitan rifting; see Fig. 3) and with mountain building (Laramide Orogeny) (Park and Jefferson, 1991; Park, 1994, 1997). Second, studies of the rift-related rocks revealed local block rotations that probably were caused by the rifting (Park and Jefferson, 1991; Park, 1997). Third, after the probable separation of Australia from Laurentia, perhaps as early as 750 Ma (Powell et al., 1993; Park et al., 1995), Laurentia may have passed over the south pole in earliest Cambrian time (Park, 1992).
A third set of paleomagnetic studies involved Mesozoic and Cenozoic rocks of the Yukon. These studies helped (1) to define terranes making up the western Cordillera and to describe their movement, and (2) to define magnetic paleosecular-variation sequences for world-wide correlations. The former studies (1) began with work on Triassic rocks (Jones et al., 1977) that defined Wrangellia and its northward movement, and included later work on the Upper Cretaceous Carmacks Group that suggested northward movement and rotation of the Whitehorse Trough (Marquis and Globerman, 1988). The latter studies (2) involved work on Pleistocene sediments, tephra, and basalts, mainly in the Old Crow Basin (see Pearce et al., 1982; Jackson et al., 1990; Evans and Wang, 1994).

DISCUSSION

Although significant discoveries have been made through paleomagnetic studies in the region, there is much work that remains to be done. In particular, paleolatitudes of the region are unknown for a large portion of the Precambrian. (Though paleolatitudes during the Phanerozoic Eon can be readily calculated from paleomagnetic data outside the region, they are not discussed here.) Proterozoic paleolatitudes from the best current data, including some outside the region, are shown in Figs. 2 and 3. The quality of the data is generally indicated by the uncertainties in paleolatitude, except as indicated below.

Magnetic poles from the oldest studied units of the Paleoproterozoic Era, although generally of excellent quality, are not reliably dated (reliability criteria for paleopoles and their ages are given in Buchan and Halls, 1990). The earliest paleolatitude of northwest Laurentia (CS1) that is deemed reliable represents the period 1.93-1.89 Ga and combines several results from the Sosan and Bear Creek groups of Athapuscow and Kilohigok basins, respectively. The second paleolatitude (CS2), representing the period 1.89-1.87 Ga, combines results from higher up in the volcano-sedimentary successions of the Coronation and Goulburn supergroups in basins surrounding the Slave Province. Dating errors are less than ±20 Ma. Each of these paleolatitudes represent the synchronous deposition of the Coronation, Great Slave, and Goulburn supergroups in response to rifting of the Slave margin. Later Hudsonian and Coronation magnetic overprints, documented in many rocks of the Canadian Shield, are not reliably dated; though during the events that produced the overprints, the latitude of northwest Laurentia remained equatorial. Large gaps in the Precambrian paleomagnetic record render it difficult at this time to determine the absolute polarities of paleopoles. Thus no absolute determinations of north or south paleolatitude for the Proterozoic of North America are available, except for the later Paleoproterozoic period in the Slave craton, represented by CS1 and CS2 (Fig. 2). For this period, Hildebrand (1988) determined that the Slave craton was north of the equator by combining paleomagnetic results (Irving and McGlynn, 1979) with the evidence for paleowind direction as found from stromatolite elongation and the record of volcanic ash dispersal.

Paleolatitudes for the Mesoproterozoic in Fig. 2 are obtained from units of the Shield outside the atlas area (unpublished compilation of K. Buchan, Geological Survey of Canada). All units have precise U-Pb ages, with errors less than ±4 Ma.

Paleolatitudes for the Neoproterozoic (Fig. 3) are derived mainly from units in the northern Cordillera. The quality of paleomagnetic data is high, except for that from the Little Dal lavas (LDb), Risky Formation (Ri), and Ingta and Backbone Ranges formations (I/B), in which only four sites were sampled. Only two precise U-Pb dates, with errors less than ±5 Ma, are available: one from the Franklin diabase (723 Ma) and the other from diabase of the Mackenzie Arc (780 Ma) (see Park and Rainbird, 1995). The uppermost units combined, the Ingta and Backbone Ranges formations (I/B), are latest Precambrian to early Cambrian in age. The remaining paleolatitudes are dated from interpolation along an APW path, using information relating to superposition, to tectonic events, and to older dated poles from the Grenville Province. Dating errors are estimated at less than ±20 Ma for all these remaining paleolatitudes, except for the Tsezotene/Katherine (T/K) and Risky (Ri) units, for which errors are estimated at ±50 Ma. Paleolatitudes from ca. 850-700 Ma are mainly equatorial (Park, 1997), even during the first (G1, Sturtian) of two Neoproterozoic glaciations recorded in the Mackenzie Mountains (Aitken, 1991) (Fig. 3). Although absolute polarity of magnetizations is unknown, paleolatitudes of Laurentia have been interpreted from considering a relatively simple APW path that places Laurentia over the south pole during the latest Precambrian (between Ri and I/B, Fig. 3) (Park, 1992).

CONCLUSIONS

1. Paleolatitudes are unknown for much of the older Precambrian in the Atlas region. Where they are known, only in two instances during the Paleoproterozoic has the region been absolutely determined to be north or south of the equator. Much more detail is known of Neoproterozoic

paleolatitudes which indicate that the Atlas region was within 30° of the equator until latest Neoproterozoic time when this region may have been at more than 60° south latitude.

2. Due to a lack of precise age determinations of most sampled units, it is still not posssible using paleomagnetic data to document relative movements between major components of the Canadian Shield with confidence.

3. Paleomagnetism in the region has recorded widespread tectonic events, such as uplifts, mountain building, Precambrian rifting and terrane movements and has substantiated an ancient origin for the northwestward curvature of the Mackenzie Arc.

REFERENCES

Aitken, J.D. 1991. Two late Proterozoic glaciations, Mackenzie Mountains, northwestern Canada. Geology, v. 19, p. 445-448.

Baragar, W.R.A., and Robertson, W.A. 1973. Fault rotation of paleomagnetic directions in Coppermine River lavas and their revised pole. Canadian Journal of Earth Sciences, v. 10, p. 1519-1532.

Buchan, K.L., and Halls, H.C. 1990. Paleomagnetism of Proterozoic mafic dyke swarms of the Canadian Shield. *In*: Mafic dykes and emplacement mechanisms. A.J. Parker, P.C. Rickwood, and D.H. Tucker (eds.). A.H. Balkema, Rotterdam, The Netherlands. Proceedings of the second International Dyke Conference, Adelaide, South Australia, p. 209-230.

Buchan, K.L., Halls, H.C., and Mortensen, J.K. 1996. Paleomagnetism, U-Pb geochronology, and geochemistry of Mārathon dykes, Superior Province, and comparison with the Fort Frances swarm. Canadian Journal of Earth Sciences, v. 33, p. 1583-1595.

Diehl, J.F., and Haig, T.D. 1994. A paleomagnetic study of the lava flows within the Copper Harbor Conglomerate, Michigan: new results and implications. Canadian Journal of Earth Sciences, v. 31, p. 369-380.

Emslie, R.F., Irving, E., and Park, J.K. 1976. Further paleomagnetic results from the Michikamau Intrusion, Labrador. Canadian Journal of Earth Sciences, v. 13, p. 1052-1057.

Ernst, R.E., and Buchan, K.L. 1993. Paleomagnetism of the Abitibi dyke swarm, southern Superior Province, and implications for the Logan Loop. Canadian Journal of Earth Sciences, v. 30, p. 1886-1897.

Evans, M.E., and Hoye, G.S. 1981. Paleomagnetic results from the lower Proterozoic rocks of Great Slave Lake and Bathurst Inlet areas, Norhwest Territories. *In*: Proterozoic basins of Canada. F.H.A. Campbell (ed.). Geological Survey of Canada, Paper 81-10, p. 191-202.

Evans, M.E., and Wang, Y. 1994. Paleomagnetic results from Ch'ijee's Bluff, Porcupine River, Yukon Territory. Quaternary International, v. 22/23, p. 215-219.

Hoffman, P.F. 1988. United plates of America, the birth of a craton: Early Proterozoic assembly and growth of Laurentia. Annual Reviews of Earth and Planetary Sciences, v. 16, p. 543-603.

Hildebrand, R.S. 1988. Implications of ash dispersal for tectonic models with an example from

Wopmay orogen. Geology, v. 16, p. 1089-1091.

Irving, E., Davidson, A., and McGlynn, J.C. 1984. Paleomagnetism of gabbros of the Early Proterozoic Blachford Lake Intrusive Suite and the Easter Island dyke, Great Slave Lake, N.W.T.: possible evidence for the earliest continental drift. Geophysical Surveys, v. 7, p. 1-25.

Irving, E., and McGlynn, J.C. 1979. Palaeomagnetism in the Coronation Geosyncline and arrangement of continents in the middle Proterozoic. Geophysical Journal of the Royal Astronomical Society, v. 58, p. 309-336.

Irving, E., Park, J.K., and McGlynn, J.C. 1972. Paleomagnetism of the Et-Then Group and Mackenzie diabase in the Great Slave Lake area. Canadian Journal of Earth Sciences, v. 9, p. 744-755.

Jackson, Jr., L.E., Barendregt, R., Irving, E., and Ward, B. 1990. Magnetostratigraphy of early to middle Pleistocene basalts and sediments, Fort Selkirk area, Yukon Territory. *In*: Current Research, Part E. Geological Survey of Canada, Paper 90-1E, p. 277-286.

Jones, D.L., Silberling, N.J., and Hillhouse, J. 1977. Wrangellia--A displaced terrane in northwestern North America. Canadian Journal of Earth Sciences, v. 14, p. 2565-2577.

Marquis, G., and Globerman, B.R. 1988. Northward motion of the Whitehorse Trough: paleomagnetic evidence from the Upper Cretaceous Carmacks Group. Canadian Journal of Earth Sciences, v. 25, p. 2005-2016.

McGlynn, J.C., and Irving, E. 1975. Paleomagnetism of Early Aphebian diabase dykes from the Slave Structural Province, Canada. Tectonophysics, v. 26, p. 23-38.

Paces, J.B., and Miller, Jr., J.D. 1993. Precise U-Pb ages of Duluth Complex and related mafic intrusions, northeastern Minnesota: geochronological insights to physical, petrogenic, paleomagnetic, and tectonomagmatic processes associated with the 1.1 Ga Midcontinent rift system. Journal of Geophysical Research, v. 98, p. 13,997-14,013.

Park, J.K. 1974. Paleomagnetism of miscellaneous Franklin and Mackenzie diabases of the Canadian Shield, and their adjacent country rocks. Canadian Journal of Earth Sciences, v. 11, p. 1012-1017.

Park, J.K. 1990. Paleomagnetism of the Old Crow Batholith, northern Yukon Territory. *In*: Current Research, Part E. Geological Survey of Canada, Paper 90-1E, p. 287-290.

Park, J.K. 1992. Did Laurentia pass over the south pole during earliest Cambrian time? *In*: Current Research, Part E. Geological Survey of Canada, Paper 92-1E, p. 11-22.

Park, J.K. 1994. Palaeomagnetic constraints on the position of Laurentia from middle Neoproterozoic to Early Cambrian times. Precambrian Research, v. 69, p. 95-112.

Park, J.K. 1995. Paleomagnetism of the late Neoproterozoic Blueflower and Risky formations of the northern Cordillera, Canada. Canadian Journal of Earth Sciences, v. 32, p. 718-729.

Park, J.K. 1997. Paleomagnetic evidence for low-latitude glaciation during deposition of the Neoproterozoic Rapitan Group, Mackenzie Mountains, N.W.T., Canada. Canadian Journal of Earth Sciences, v. 34, p. 34-49.

Park, J.K., Buchan, K.L., and Harlan, S.S. 1995. A proposed giant radiating dyke swarm fragmented by the separation of Laurentia and Australia based on paleomagnetism of ca. 780 Ma mafic intrusions in western North America. Earth and Planetary Science Letters, v. 132, p. 129-139.

Park, J.K., and Jefferson, C.W. 1991. Magnetic and tectonic history of the Late Proterozoic Upper Little Dal and Coates Lake groups of northwestern Canada. Precambrian Research, v. 52, p. 1-35.

Park, J.K., and Rainbird, R.H. 1995. Magnetic overprinting of the Neoproterozoic Shaler Supergroup, Amundsen Basin, Northwest Territories, Canada during the Franklin magmatic episode. *In*: Current Research, Part E. Geological Survey of Canada, p. 113-123.

Park, J.K., Norris, D.K., and Larochelle, A. 1989. Paleomagnetism and the origin of the Mackenzie Arc. Canadian Journal of Earth Sciences, v. 26, p. 2194-2203.

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

Pearce, G.W., Westgate, J.A., and Robertson, S. 1982. Magnetic reversal history of Pleistocene sediments at Old Crow, northwestern Yukon Territory. Canadian Journal of Earth Sciences, v. 19, p. 919-929.

Powell, C. McA., Li, Z.X., McElhinny, M.W., Meert, J.G., and Park, J.K. 1993. Paleomagnetic constraints on timing of the Neoproterozoic breakup of Rodinia and the Cambrian formation of Gondwana. Geology, v. 21, p. 889-892.

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

Reid, A.B., McMurry, E.W., and Evans, M.E. 1981. Paleomagnetism of the Great Slave Supergroup, Northwest Territories, Canada: Multicomponent magnetization of the Kahochella Group. Canadian Journal of Earth Sciences, v. 18, p. 574-583.

Roy, J.L. 1983. Paleomagnetism of the North American Precambrian: a look at the database. Precambrian Research, v. 19, p. 319-348.

Veevers, J.J., Walter, M.R., and Scheibner, E. 1997. Neoproterozoic tectonics of Australia-Antarctica and Laurentia and the 560 Ma birth of the Pacific Ocean reflect the 400 m.y. Pangean supercycle. The Journal of Geology, v. 105, p. 225-242.

Figure Captions

Fig. 1. Location of paleomagnetic studies. References to all studies are found in cited references. Letters denote geological units; numbers, separate or closely spaced dykes or volcanic/sedimentary localities. Phanerozoic Eon: *Cenozoic* - Pleistocene sediments/tephra (**A**; Pearce et al., 1982), (**B**, **C**, **D**, **E**, **G**; see Evans and Wang, 1994), (**F1-F3**; Jackson et al., 1990); *Mesozoic* - Upper Cretaceous lavas (**A1-A4**; Marquis and Globerman, 1988); *Paleozoic* - Old Crow batholith/ miscellaneous plutons (**A1/A2-A5**; Park, 1990), Sekwi/Backbone Ranges/Ingta fms. (**B/C/D**; Park, 1992). Proterozoic Eon: *Neoproterozoic* - Mount Harper volcanic complex (**A1-A3**; Park et al., 1992), Risky/Blueflower fms. (**B/C**; Park, 1995), Rapitan Gp. (**D1-D4**; see Park, 1997), Coppercap/Redstone River/Thundercloud fms./Little Dal basalt (**E/F/G/H**; see Park and Jefferson, 1991; Park, 1997), diabase in the Mackenzie Arc (**I1-I21**; see Park et al., 1995), Hottah sheets (**I22-I24**; see *Ibid.*), Little Dal Gp./Katherine Gp./Tsezotene Fm. (**J**, **K1-K2**, **L1-L2/M1-M2/N1-N3**; see Park and Jefferson, 1991), Franklin diabase (**O1-O8, O10-O20**), Coronation sills (**O9**), Aok/Nelson Head/Mikkelsen Islands/Escape Rapids fms., Rae Gp. (**P/Q1-Q4/R/S**; see Park and Rainbird, 1995); *Mesoproterozoic* - Muskox Intrusion/Coppermine Gp. (**A/B1-B5**, **C**; see Baragar and Robertson, 1973), Mackenzie dykes (**D1-D3**, **D6-D11**, see Buchan and Halls, 1990; **D4-D5**, Park, 1974); *Paleoproterozoic* - Et-Then Gp./Peninsula sill/Kahochella Gp. (**A1-A2/B/C**; see Irving and McGlynn, 1979), Kahochella/Pethei gps. (**D/E**; Reid et al., 1981), Takiyuak Fm. (**F**; Irving and McGlynn, 1979), Easter Island dyke/Carabou Lake gabbro (**G/J**; Irving et al., 1984), Dogrib dykes/'X' dykes/Indin dykes/Big Spruce complex/Duck Lake sill (**H1-H7/I1-I2/K1-K11/L/M**; McGlynn and Irving, 1975; see Irving and McGlynn, 1979). Archean Eon: Yellowknife sediments (**A**; McGlynn and Irving, 1975). Unknown age: Western Channel diabase (**A1-A2**; see Irving and McGlynn, 1979), Thistlethwaite dyke/Pensive Lake sheet (**B/C**; McGlynn and Irving, 1975), diabase (**D**; Park, 1974).

Fig. 2. Paleolatitude of atlas region (outline shown) from Paleoproterozoic to early Neoproterozoic time as determined from the following rock units: **CS1**, mean from lower units of Athapuscow Aulacogen (Akaitcho River Fm.) and Kilohigok Basin (Western River and Mara fms.) (see Evans and Hoye, 1981); **CS2**, mean from upper units of Athapuscow Aulacogen (Douglas Peninsula, Pearson, Tochatwi, and Stark fms.: Kahochella Gp.), Kilohigok Basin (Peacock Hills Fm.), and Epworth Basin (Takiyuak Fm.) (see Irving and McGlynn, 1979; Evans and Hoye, 1981; Reid et al., 1981); **M**, Michikamau anorthosite, Labrador (Emslie et al., 1976); **Mk**, Mackenzie dykes (see Buchan and Halls, 1990); **S**, Sudbury dykes, Ontario (see *Ibid.*); **A**, Abitibi dykes, Ontario (Ernst and Buchan, 1993); **D**, Duluth gabbro complex, Minnesota (Paces and Miller, Jr., 1993); **LS**, Lake Shore Traps, Michigan (Diehl and Haig, 1994); **H**, overprint on Haliburton intrusions, Ontario (see Park, 1994). Slave Province, Mackenzie Arc, and present northwest North America outlines are shown for reference. Tectonic and geologic events are after Hoffman (1988).

Fig. 3. Paleolatitude of atlas region (outline shown) during the middle and late Neoproterozoic as determined from the following rock units: **T/K**, mean from Tsezotene Fm. and Katherine Gp. (see Park and Rainbird, 1995); **GB**, Grassy Bay Fm. (*Ibid.*); **LDB**, Little Dal Gp., Basinal sequence (*Ibid.*); **Db**, diabase in Mackenzie Arc (see Park, 1997); **LDb**, Little Dal basalt (see Park and Jefferson, 1991); **P2(T)**, overprint in Tsezotene Fm. (see Park, 1997); **Fm**, Franklin diabase, mixed polarity, outside Amundsen Basin (see Park and Rainbird, 1995); **Fn**, Franklin diabase, normal polarity, Amundsen Basin (see Ibid.); **Rx**, Rapitan 'X' direction (see Park, 1997); **Ri**, Risky Fm. (Park, 1995); **I/B**, Ingta and Backbone Ranges fms. (Park, 1992). Slave Province, Mackenzie Arc, and present North America outlines are shown for reference. P1-P3 represent hematitization events; G1 and G2, glaciations. Geological correlations are after Rainbird et al. (1996). The age of G2 and age correlations in the latest Neoproterozoic are after Veevers et al. (1997). There is a change in the time scale at 700 Ma.

APPENDIX 1 -
LOCATION OF PALEOMAGNETIC LOCALITIES

Appendix 1 - Location of paleomagnetic localities

Age of unit	Identification	Latitude (°N)	Longitude (°W)
Cenozoic	A	67.467	139.900
Cenozoic	B1	67.858	139.827
Cenozoic	B	67.467	139.900
Cenozoic	B3	65.633	138.133
Cenozoic	B4	62.525	140.950
Cenozoic	B5	62.008	140.567
Cenozoic	C	67.850	139.800
Cenozoic	D	67.850	139.800
Cenozoic	E	67.817	139.867
Cenozoic	F1	62.858	136.819
Cenozoic	F2	62.786	137.391
Cenozoic	F3	62.749	137.252
Cenozoic	G	67.497	139.96
Mesozoic	A1	62.17	136.67
Mesozoic	A2	62.16	136.26
Mesozoic	A3	62.06	135.95
Mesozoic	A4	61.03	135.50
Paleozoic	A1	67.683	140.963
Paleozoic	A2	67.596	139.237
Paleozoic	A3	68.864	139.06
Paleozoic	A4	68.454	138.00
Paleozoic	A5	68.31	141.00
Paleozoic	B	64.483	129.567
Paleozoic	C	64.650	132.917
Paleozoic	D	63.353	128.633

Neoproterozoic	A1	64.680	139.882
Neoproterozoic	A3	64.680	139.137
Neoproterozoic	B	64.650	132.917
Neoproterozoic	C	63.433	128.500
Neoproterozoic	D1	63.500	127.000
Neoproterozoic	E	62.702	126.614
Neoproterozoic	F	62.702	126.614
Neoproterozoic	G1	63.497	126.975
Neoproterozoic	H	63.80	128.50
Neoproterozoic	I1	65.120	141.00
Neoproterozoic	I2	65.285	140.883
Neoproterozoic	I3	65.140	135.873
Neoproterozoic	I4	65.331	132.068
Neoproterozoic	I5	65.286	131.460
Neoproterozoic	I6	65.270	131.347
Neoproterozoic	I7	65.235	131.348
Neoproterozoic	I8	65.176	131.078
Neoproterozoic	I9	65.245	131.039
Neoproterozoic	I10	65.204	131.010
Neoproterozoic	I11	65.207	130.804
Neoproterozoic	I12	65.168	130.735
Neoproterozoic	I13	65.137	130.510
Neoproterozoic	I14	65.132	130.352
Neoproterozoic	I15	65.206	129.952
Neoproterozoic	I16	65.173	129.433
Neoproterozoic	I17	65.103	128.717
Neoproterozoic	I18	65.056	128.074

Neoproterozoic	I19	65.034	128.136
Neoproterozoic	I20	64.485	126.810
Neoproterozoic	I21	64.108	127.926
Neoproterozoic	I22	65.666	118.143
Neoproterozoic	I23	65.527	117.305
Neoproterozoic	I24	64.401	117.132
Neoproterozoic	J	63.356	126.941
Neoproterozoic	K1	64.876	127.227
Neoproterozoic	K2	64.539	126.945
Neoproterozoic	L1	64.539	126.945
Neoproterozoic	L2	64.876	127.227
Neoproterozoic	M1	64.096	127.836
Neoproterozoic	N1	64.158	127.965
Neoproterozoic	O1	67.917	117.000
Neoproterozoic	O2	67.790	114.514
Neoproterozoic	O3	67.455	118.285
Neoproterozoic	O4	67.400	118.069
Neoproterozoic	O5	67.166	112.524
Neoproterozoic	O6	67.748	111.550
Neoproterozoic	O7	67.091	112.774
Neoproterozoic	O8	67.726	115.82
Neoproterozoic	O9	70.744	117.736
Neoproterozoic	O10	70.748	117.712
Neoproterozoic	O11	70.725	117.798
Neoproterozoic	O12	70.730	117.763
Neoproterozoic	O13	70.724	117.737
Neoproterozoic	O14	70.670	117.742

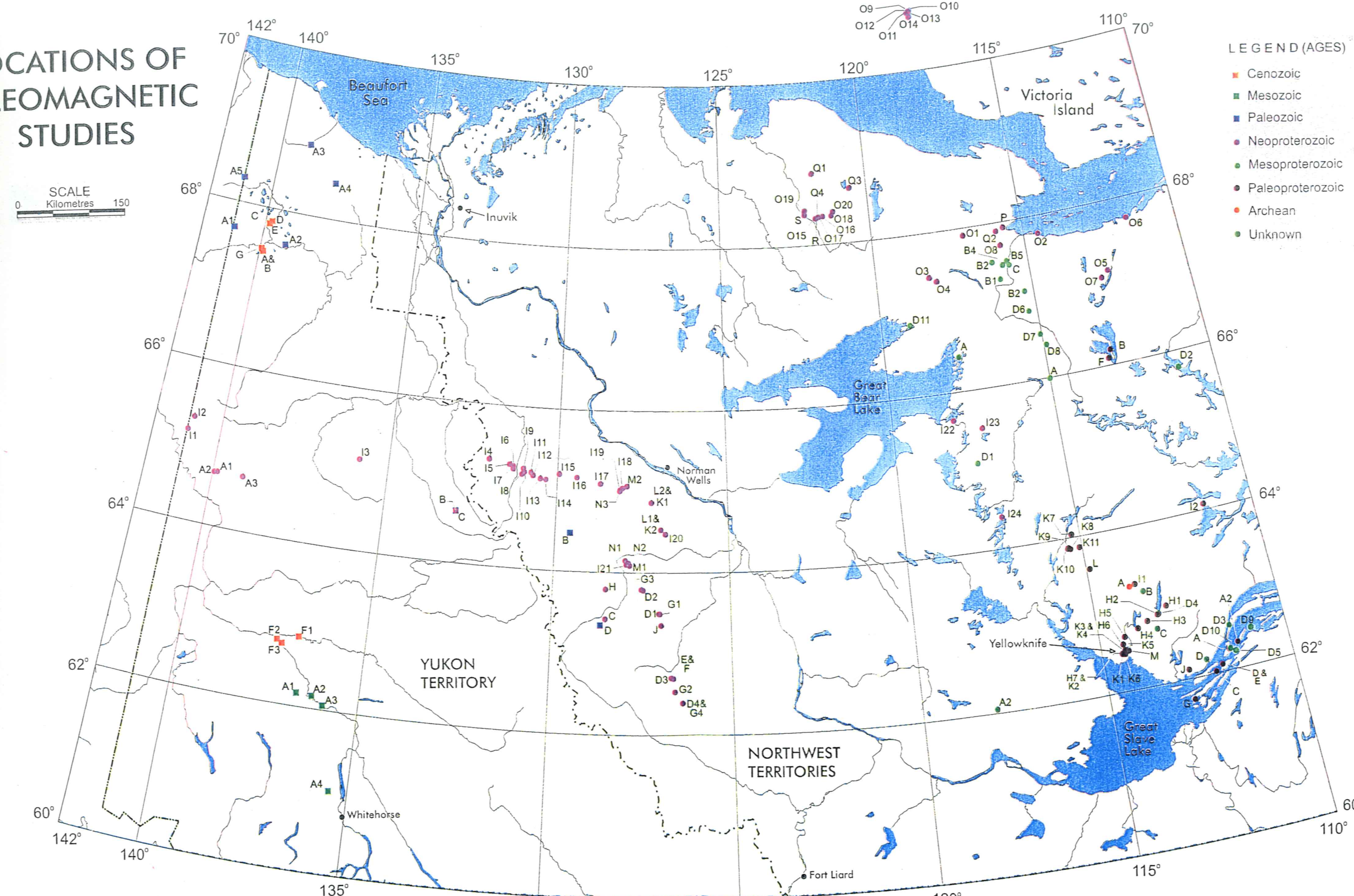
Neoproterozoic	O15	68.341	121.802
Neoproterozoic	O16	68.359	121.563
Neoproterozoic	O17	68.355	121.716
Neoproterozoic	O18	68.362	121.272
Neoproterozoic	O19	68.445	122.147
Neoproterozoic	O20	68.404	121.206
Neoproterozoic	P	67.938	115.637
Neoproterozoic	Q1	68.893	121.822
Neoproterozoic	Q2	67.906	115.883
Neoproterozoic	R	68.342	121.778
Neoproterozoic	S -	68.390	122.165
Neoproterozoic	A2	64.671	139.980
Neoproterozoic	D2	63.79	127.45
Neoproterozoic	D3	62.71	126.67
Neoproterozoic	D4	62.40	126.37
Neoproterozoic	G2	62.538	126.569
Neoproterozoic	G3	63.8	127.5
Neoproterozoic	G4	62.40	126.37
Neoproterozoic	M2	65.080	127.944
Neoproterozoic	N2	64.126	127.876
Neoproterozoic	N3	65.019	128.149
Neoproterozoic	Q3	68.681	120.574
Neoproterozoic	Q4	68.355	121.692
Mesoproterozoic	A	67.0	-115.25
Mesoproterozoic	B1	67.310	-115.968
Mesoproterozoic	B3	67.530	116.178
Mesoproterozoic	C	67.474	115.639

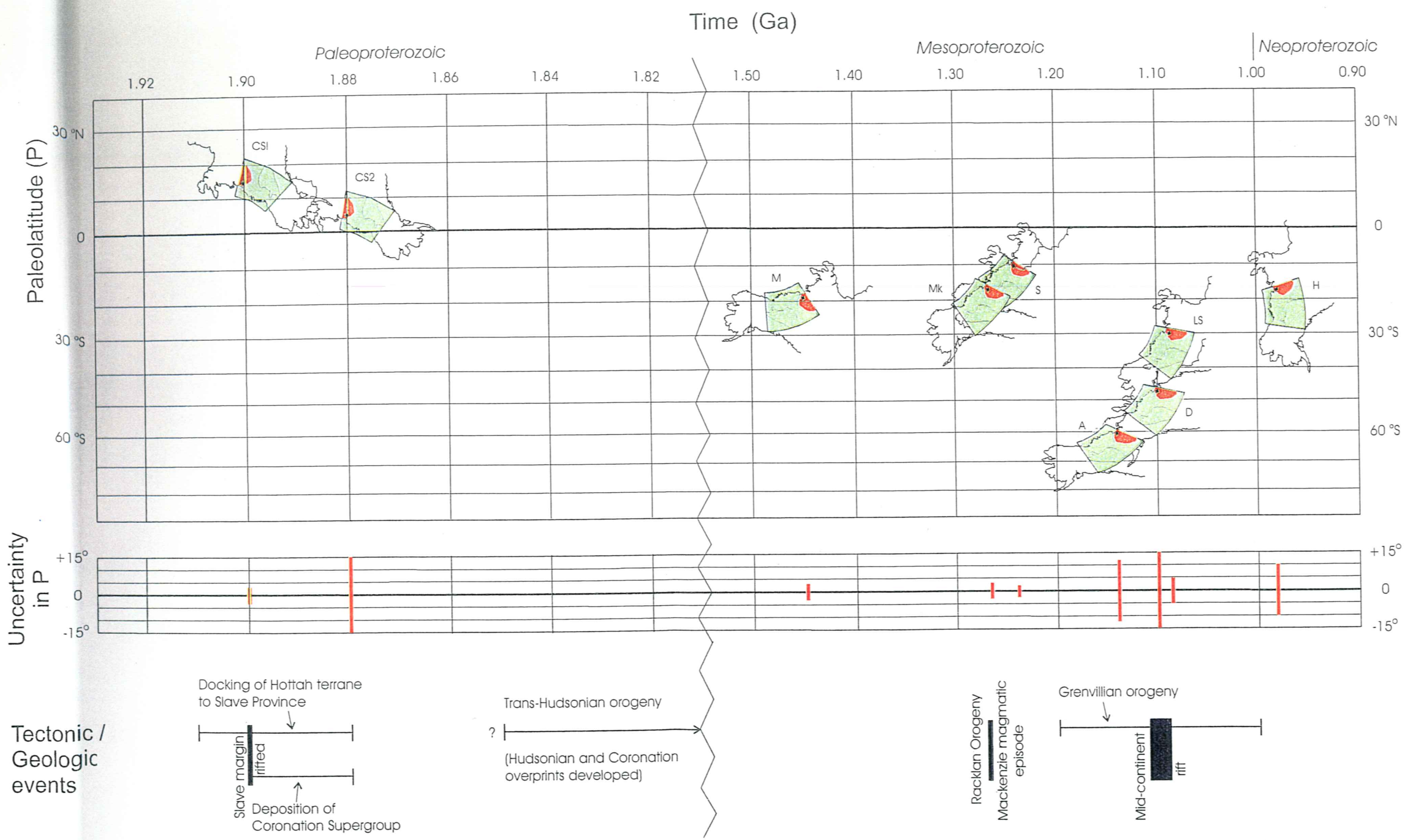
Mesoproterozoic	D1	65.10	117.60
Mesoproterozoic	D2	65.80	111.10
Mesoproterozoic	D3	62.55	111.50
Mesoproterozoic	D4	62.875	113.292
Mesoproterozoic	D5	62.225	111.475
Mesoproterozoic	B2	67.115	115.301
Mesoproterozoic	B4	67.480	115.853
Mesoproterozoic	B5	67.520	115.708
Mesoproterozoic	D6	66.862	115.276
Mesoproterozoic	D7	66.556	115.048
Mesoproterozoic	D8	66.416	114.914
Mesoproterozoic	D9	62.458	110.940
Mesoproterozoic	D10	62.265	111.610
Mesoproterozoic	D11	66.900	119.100
Paleoproterozoic	A	62.264	111.619
Paleoproterozoic	B	66.2	113.0
Paleoproterozoic	C	62.03	112.1
Paleoproterozoic	D	62.1	111.9
Paleoproterozoic	E	62.1	111.9
Paleoproterozoic	F	66.1	113.1
Paleoproterozoic	G	61.752	112.808
Paleoproterozoic	H1	62.955	113.047
Paleoproterozoic	H2	62.869	113.317
Paleoproterozoic	I1	63.293	113.758
Paleoproterozoic	I2	64.08	111.38
Paleoproterozoic	J	62.122	112.805
Paleoproterozoic	K1	62.478	114.448

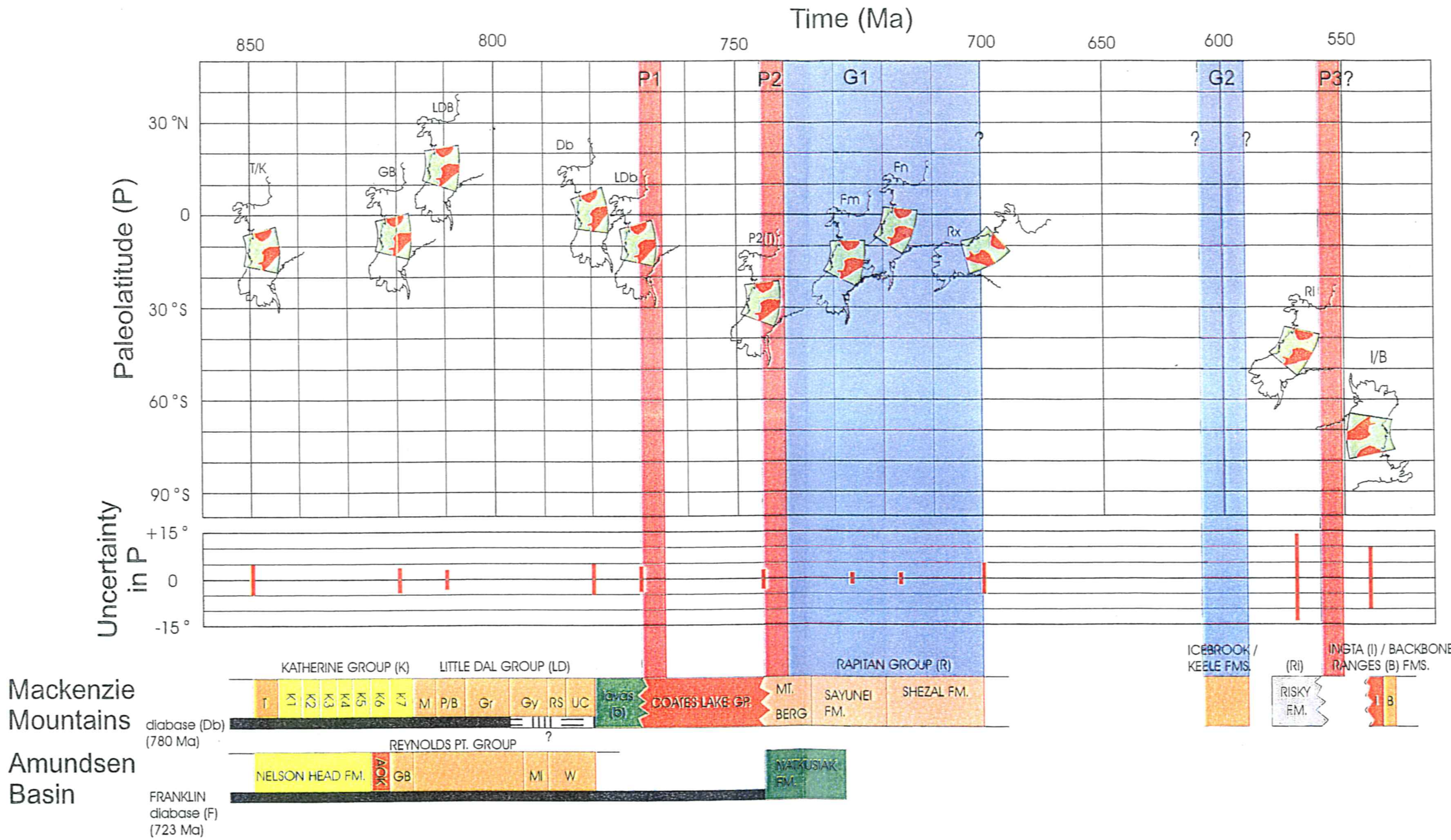
Paleoproterozoic	K2	62.478	114.453
Paleoproterozoic	K3	62.510	114.373
Paleoproterozoic	K4	62.511	114.375
Paleoproterozoic	K5	62.522	114.354
Paleoproterozoic	K6	62.469	114.381
Paleoproterozoic	K7	64.046	115.234
Paleoproterozoic	K8	63.868	115.339
Paleoproterozoic	K9	63.885	115.387
Paleoproterozoic	K10	63.878	115.403
Paleoproterozoic	K11	63.874	115.073
Paleoproterozoic	L	63.583	115.904
Paleoproterozoic	M	62.500	114.274
Paleoproterozoic	A2	62.330	111.370
Paleoproterozoic	H3	62.815	113.630
Paleoproterozoic	H4	62.750	113.917
Paleoproterozoic	H5	62.678	114.303
Paleoproterozoic	H6	62.589	114.385
Paleoproterozoic	H7	62.475	114.452
Archean	A	63.272	113.910
Unknown	A1	66.437	117.715
Unknown	B	63.185	113.582
Unknown	C	62.697	113.411
Unknown	D	62.2	112.3
Unknown	A2	66.054	118.034

Notes: Localities of published paleomagnetic data are denoted by symbols which indicate the age of the rock unit on Figure 1. Letters denote separate units; numbers denote separate dykes or, if sedimentary volcanic rocks, different localities. Some studies with numerous sites and (or) localities are represented by only one or two localities.

LOCATIONS OF PALEOMAGNETIC STUDIES




Time (Ga)
Paleoproterozoic
Mesoproterozoic
Neoproterozoic
1.92
1.90
1.88
1.86
1.84
1.82
1.50
1.40
1.30
1.20
1.10
1.00
0.90
Paleolatitude (P)
30 °N
0
30 °S
60 °S
CS1
CS2
M
Mk
S
LS
D
A
H
Uncertainty in P
+15°
0
-15°
Tectonic / Geologic events
Docking of Hottah terrane to Slave Province
Slave margin rifted
Deposition of Coronation Supergroup
Trans-Hudsonian orogeny
?
(Hudsonian and Coronation overprints developed)
Racklan Orogeny
Mackenzie magmatic episode
Grenvillian orogeny
Mid-continent rift



Time (Ma)
850
800
750
700
650
600
550
P1
P2
G1
G2
P3?
Paleolatitude (P)
30 °N
0
30 °S
60 °S
90 °S
T/K
GB
LDB
Db
LDb
P2(I)
Fm
Fn
Rx
RI
I/B
Uncertainty in P
+15 °
0
-15 °
Mackenzie Mountains
KATHERINE GROUP (K)
LITTLE DAL GROUP (LD)
T
K1
K2
K3
K4
K5
K6
K7
M
P/B
Gr
Gy
RS
UC
lavas (lb)
COATES LAKE GP.
MT. BERG
RAPITAN GROUP (R)
SAYUNEI FM.
SHEZAL FM.
ICEBROOK / KEELE FMS.
(RI)
RISKY FM.
INGTA (I) / BACKBONE RANGES (B) FMS.
I
B
diabase (Db) (780 Ma)
Amundsen Basin
REYNOLDS PT. GROUP
NELSON HEAD FM.
AOK
GB
MI
W
NATKUSIAK FM.
FRANKLIN diabase (F) (723 Ma)