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ASSESSMENT OF MINERAL AND ENERGY RESOURCE POTENTIAL IN THE BROCK INLIER - BLUENOSE LAKE AREA, N.W.T.

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TABLE OF CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

In 1989 the Canadian Parks Service proposed establishment of a national park in the vicinity of Bluenose Lake, southeast of Beaufort Sea, N.W.T. The proposed park would embrace approximately 25,000 km^2 of Crown lands, located south of Amundsen Gulf and stretching from the watersheds of the Hornaday River to Bluenose Lake inclusive. In order to place the proposed park in a regional context this mineral and energy resource assessment (MERA) considers all land areas from 67°30' to 70°00 latitude, and 118°30' to 124°30' longitude. This MERA is based on the application of mineral deposit models and models of hydrocarbon plays to geological data compiled from literature research and eight weeks of field examinations and prospecting, supplemented by descriptions and chemical analyses of 112 rock, 67 silt and 48 heavy mineral concentrate samples covering most of the study area at sparse reconnaissance scale, and selected areas we considered to have the highest mineral potential, at about 1:50,000 scale.

Three main geologic domains underlie the study area (figures 1, 3, 4):

Domain I	Late Proterozoic platformal strata and gabbros of the Amundsen Embayment;
Domain II	Cambrian to Late Devonian platformal strata of the Mackenzie Platform; and
Domain III	Mesozoic-Cenozoic clastic deposits of the Anderson Basin.

Figures 1, 2, and tables 1, 2 and 3 summarize our resource potential ratings by geographic area. Except for the aggregates used by Paulatuk, none of the mineral or hydrocarbon resources in the study area are currently economic. Potential for construction aggregate is rated high (2) in all domains. In Domain I potential is rated high (2) for gypsum in unit Hce (central area), high (2) for copper in the southeast corner (outside the current park proposal), moderate (4) for carving stone, low to moderate (5) for nickel, copper, platinum-group elements and gold in Hadrynian gabbros, and (5) for phosphate.

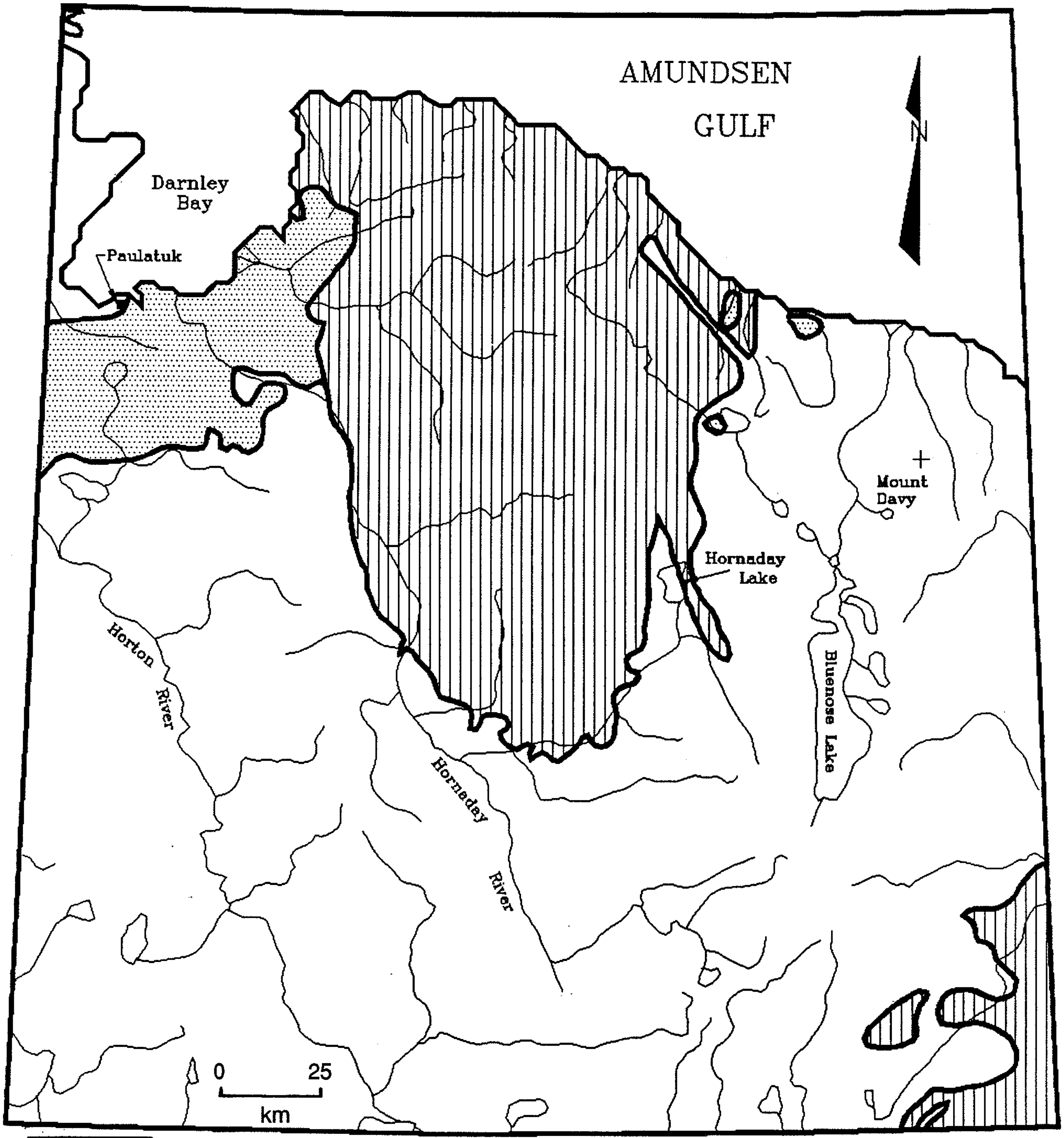
The potential of Domain II to host significant accumulations of fluid hydrocarbons decreases across the study area from moderate (4) in the southwest corner to low (6) adjacent to Domain I and in the remainder of the study area. The potential for deposits of heavy oil in Domain II is rated as moderate (4). Potential for salt in the Saline River Formation is rated as high (2).

In Domain III potential for coal of relatively good (sub-bituminous) grade is high (2). Other combinations of commodities and domains are rated as low-to-moderate (5) to low (6) in potential. As of December 1991, no active mineral permits or valid mineral claims were held in the study area.

The above ratings are strictly geological and limited by the reconnaissance nature of the data base. Application of the ratings to mineral exploration and land-use decisions would be influenced by a number of economic considerations as follows. Remoteness of the area would affect operating costs and demand, more for high-volume commodities such as gypsum and construction aggregate, than for precious or specialty commodities. All carving-stone samples submitted for assessment by local carvers were judged to be substandard. The Hadrynian intrusions with which gold, nickel, copper and platinum-group-elements might be associated are thin at surface. A large intrusion located beneath Paulatuk is judged from seismic data to be at about 3 km depth, and becomes deeper toward the proposed park area. The quality of the gypsum is unknown. Accumulations of conventional oil, heavy oil or gas, if present, would be in competition with the large reserves in Alberta and Saskatchewan. The coal is of unknown ash content, would be thin-bedded, mainly located under Inuvialuit land, and best suited for local use.

Table 1. Summary of resource potential ratings of assessment domains. Figure 5 shows outcrop pattern for each unit. Numerical codes give resource potential rating; categories explained in Table 2. Deposit model codes are explained in Table 3.

Area Concerned	**Rating**	**Deposit Model**	**Potential Host Rock Units**
Domain I			
Proterozoic Rocks			
Ia: Brock Inlier	5	Ag	Sills intruding Shaler Group sediments (Hb)
	5	Au	Thrust-faulted Shaler Group carbonates (Hct, Hc, Hce)
	5	Cu1	Shaler Group sandstone (Hq)
	5	Cu2	Shaler Group shales overlying sandstone (Hc)
	6	Fe	Shaler Group iron-rich strata (Hc)
	2	Na	Upper Shaler Group (Hce)
	5	Ni	Proterozoic diabase & gabbro (Hb + equivalents)
	6	P	Stromatolitic carbonates in Shaler Group (Hct, Hc)
	5	Pb1	Shaler Group carbonates (Hct, Hc, Hce)
	6	Pb2	Shaler Group shale (Hp)
	5	U1	Shaler Group sandstone (Hq)
	6	U2	Sandstone above an unconformity (Hq)
	4	IM1	Marble, serpentinite at diabase contact, shale (Hb, Hp)
Ib: Coppermine Homocline	6	Ag	Sills intruding Rae Group Sediments (Hb)
	6	Au	Faulted Rae Group carbonates (HR)
	5	Cu1	Rae Group sandstone (HR)
	2	Cu2	Rae Group shales above basalt and above sandstone (HR)
	6	Cu3	Coppermine River Group basalts (NV)
	6	Fe	Rae Group iron-rich strata (HR)
	5	Ni	Proterozoic diabase & gabbro (Hb)
	6	P	Stromatolitic carbonates in Rae Group (HR)
	5	Pb1	Rae Group carbonates (HR)
	5	U1	Rae Group sandstone (HR)
	6	U2	Sandstone above an unconformity (HR)
	4	IM1	Marble, serpentinite at diabase contact, shale (Hb, HR)
Domain II			
Mackenzie Platform	6	Au	Faulted Paleozoic carbonates (C FM, CO FMm, OFM, DBR, DH)
	6	Cu1	Mount Clark sandstone (lC MC)
	5	Cu2	Mount Cap shale unconformably overlying Proterozoic sediments (mC MC)
	2	Na	Saline River evaporites (C SR)
	5	Pb1	Cambrian, Ordovician, Devonian carbonates (C FM, CO FMm, OFM, DBR, DH)
	5	U1	Mount Clark sandstone (lC MC)
	6	U2	Mount Clark sandstone (lC MC)
	5	C2	Resevoir-quality Paleozoic formations (lC MC, mC MC, CO FM, DBR)
DOMAIN III			
ANDERSON BASIN	6	Cu1	Sandstone of the Langton Bay Fm. (KLB)
(+ UNCONSOLIDATED	5	U1	Sandstone of the Langton Bay Fm. (KLB)
COVER SEDIMENTS)	2	CM1	Quaternary alluvium, glaciofluvial deposits, raised beaches (TQs)
	2	C1	Basal Langton Bay Fm. (KLB)
	5	C2	Cretaceous sandstones (KLB)
	5	Ni	Inferred mafic lopolith at 3km depth (Hb equivalent)



▒	Domain III	High for coal, aggregate; low-to-moderate for nickel, copper, platinum-group-elements, gold
☐	Domain II	High for salt
▥	Domain I	High for gypsum, moderate for carving stone.

Figure 1. Summary mineral resource potential, Bluenose Lake study area. Assessments for each Domain are summarized in Table 1 and detailed in text. The rating categories are explained in Table 2, and the deposit models in Table 3. Deposit models for which exploration interest has been high, or whose potential is assessed to be greater than low to moderate for a given Domain, are specified in the Executive Summary.

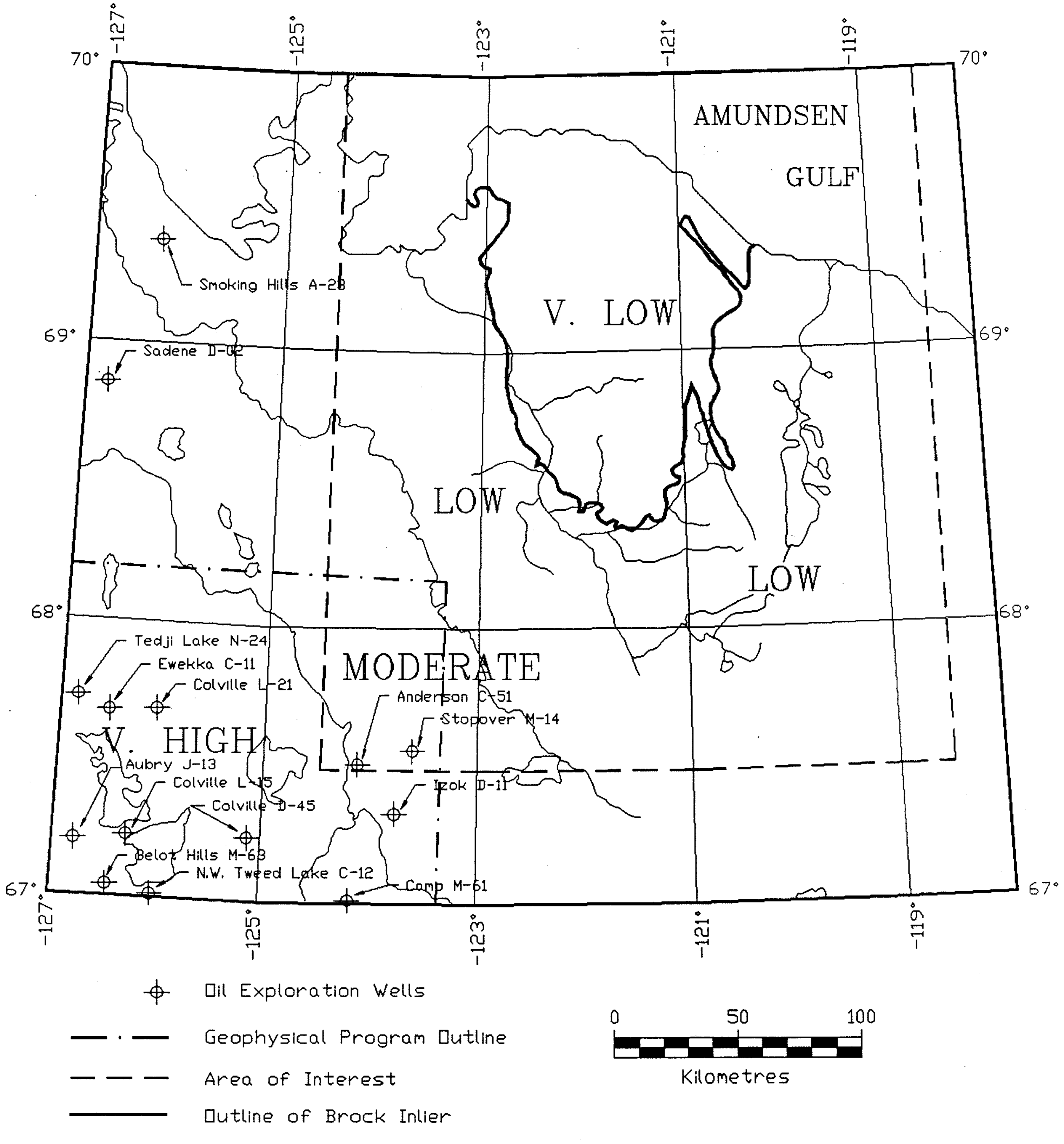


Figure 2. Summary oil and gas potential, Bluenose Lake study area. Ratings, rating categories and deposit types are summarized in tables 1, 2, and 3 respectively, and detailed in text.

Table 2. Explanation of rating categories for mineral, hydrocarbon potential (after Scoates et al., 1986). For mineral potential, the rating is based on the application of mineral deposit types (models, analogues; e.g. Eckstrand, 1984) to the geological setting.

Symbol	Potential	Criteria
1	Very High	- Geological environment is very favourable. - Significant deposits/accumulations[a] are known. - Presence of undiscovered deposits/accumulations is very likely.
2	High	- Geological environment is very favourable. Occurrences[b] are commonly present but significant deposits/accumulations may not be known. - Presence of undiscovered deposits/accumulations is likely.
3	Moderate to high	- Intermediate between moderate and high potential - Reflects greater uncertainty[c].
4	Moderate	- Geological environment is favourable, occurrences may or may not be known. - Presence of undiscovered deposits/accumulations is possible.
5	Low to moderate	- Intermediate between low and moderate potential. - Reflects greater uncertainty[c]
6	Low	- Some aspects of the geological environment may be favourable but are limited in extent. - Few, if any, occurrences are known. - Low probability that undiscovered deposits/accumulations are present.
7	Very low	- Geological environment is unfavourable. - No occurrences are known. - Very low probability that undiscovered deposits/accumulations are present.

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[a] "Deposit/accumulation" is a mineral or energy resource of a size that is conceivably developable.

[b] "Occurrence" refers to a mineral or energy resource of a size that is noticeable; may or may not include part of a hidden deposit/accumulation (e.g. sulphide showings, trace hydrocarbon seeps or stains in wells).

[c] "Uncertainty" results from insufficient data.

Table 3. Deposit models used in evaluation of mineral resource potential of the Bluenose Lake study area, N.W.T. CODE is key to deposit model codes in Table 1. Numbers in brackets refer to identification numbers used in Eckstrand (1984).

CODE	METALLIC MINERALS
Ag	Arsenide Vein Silver, Uranium (22)
Au	Carlin Type Carbonate Hosted Gold (8.1)
Cu1	Continental Red Bed Copper (6.3b)
Cu2	Kupferschiefer Type Copper (6.3a)
Cu3	Volcanic Redbed Native Copper (10)
Fe	Iron-Rich Sedimentary Strata (2)
Na	Evaporites (Salt and Gypsum) (1)
Ni	Gabbroid-Associated Nickel, Copper, Platinum-Group Elements, Gold (12.2)
P	Stratiform Phosphate (4)
Pb1	Mississippi Valley Type Lead, Zinc (6.1)
Pb2	Shale-Hosted Lead, Zinc (9.2)
U1	Sandstone Type Uranium (6.4)
U2	Unconformity-Associated Uranium (21)
	INDUSTRIAL MINERALS
IM1	Carving Stone
	CONSTRUCTION MATERIALS
CM1	Aggregate
	HYDROCARBONS
C1	Coal
C2	Oil, Gas

INTRODUCTION

Purpose of Assessment

It is the policy of Indian and Northern Affairs Canada that the mineral and energy resource potential of areas in the Yukon and Northwest Territories be assessed prior to their formal establishment as new national parks. The Geological Survey of Canada has been charged with conducting the required mineral and energy resource assessments (MERAs), here directed by a senior MERA committee comprising Assistant Deputy Ministers of Indian and Northern Affairs Canada, Environment Canada, Energy Mines and Resources Canada and the Government of the Northwest Territories.

MERA information may be used to modify the boundaries of the proposed park, or, in areas of particularly high resource potential, would indicate that establishment of a park is inappropriate if development of the resources is desired. Exploitation of mineral and energy resources is prohibited within the boundaries of Canada's national parks. If the resource potential is judged to be low, this knowledge may reduce the conflicts or impediments to park establishment.

Study Area

The Canadian Parks Service has proposed a national park in the Bluenose Lake area in order to represent Natural Region 15, the Tundra Hills. Proposed provisional boundaries embrace Crown Lands only (Figure 3). To aid the research for this MERA and to accommodate potential variations in the park boundaries, a larger area was outlined, termed the *study area* (the outer frame of figures 1 to 3; context in Figure 4).

The Bluenose Lake area is south of the Arctic coast, some 250 km east of the Mackenzie (Dehcho) River delta, and east of the community of Paulatuk. The study area for this MERA covers all land areas between 67°30' and 70°00' latitude, and 118°30' and 124°30' longitude, and is approximately 62,000 km^2 in size (figures 1 - 4).

Physiography

The study area was one of the last in Canada to be explored and mapped by Europeans. The mouth of the Hornaday River, large by any standards, was not mapped until 1898 (Mackay, 1958). Mackay wrote that the region between Horton River, Darnley Bay and the Amundsen Gulf coast had remained virtually unexplored up to his time. The following physiographic description is summarized after Mackay.

The central portion of the study area is occupied by the Brock Upland, a broad plateau rising to 800 metres above sea level, between Hornaday River, the Amundsen Gulf, and Bluenose Lake (Figure 4). This plateau, parts of which may not have been glaciated during the last episode of Wisconsin glaciation (Klassen, 1971; St-Onge and McMartin, 1987; S. Zoltai, personal communication), is underlain by Proterozoic strata intruded by diabase, and covered by a discontinuous veneer of glacial drift and alluvium. To the west of this upland the Anderson Plain/Horton Plateau is underlain by flat-lying Paleozoic and Mesozoic strata.

The area immediately surrounding Bluenose Lake, east of the upland, is dominated by glacial end-moraine deposits; eastward, toward Coronation Gulf, a thin veneer of glacial drift overlies flat-lying Paleozoic carbonates. The extreme southeastern portion of the study area is underlain by Proterozoic volcanic and sedimentary rocks of the Coppermine Homocline.

Access and Infrastructure

Paulatuk (population approximately 280) is the only permanent settlement within the study area. The hamlet is serviced twice weekly from Inuvik by air flights which land at a well maintained dirt strip.

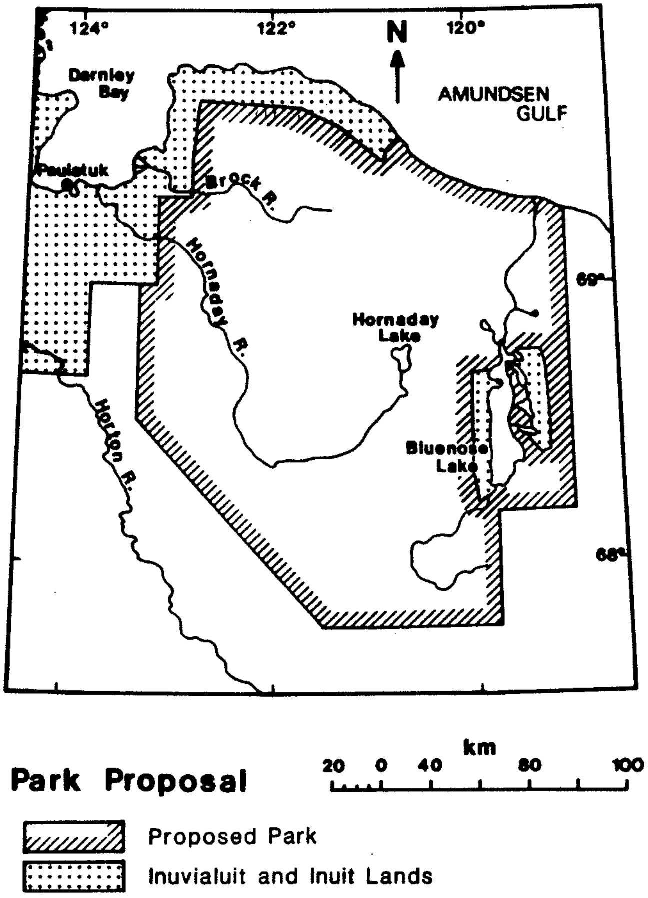


Figure 3. Bluenose Lake study area, showing proposed park boundaries which do not include Inuvialuit lands. Proposed park boundaries may be modified, subject to the results of this MERA and various governmental and public consultations.

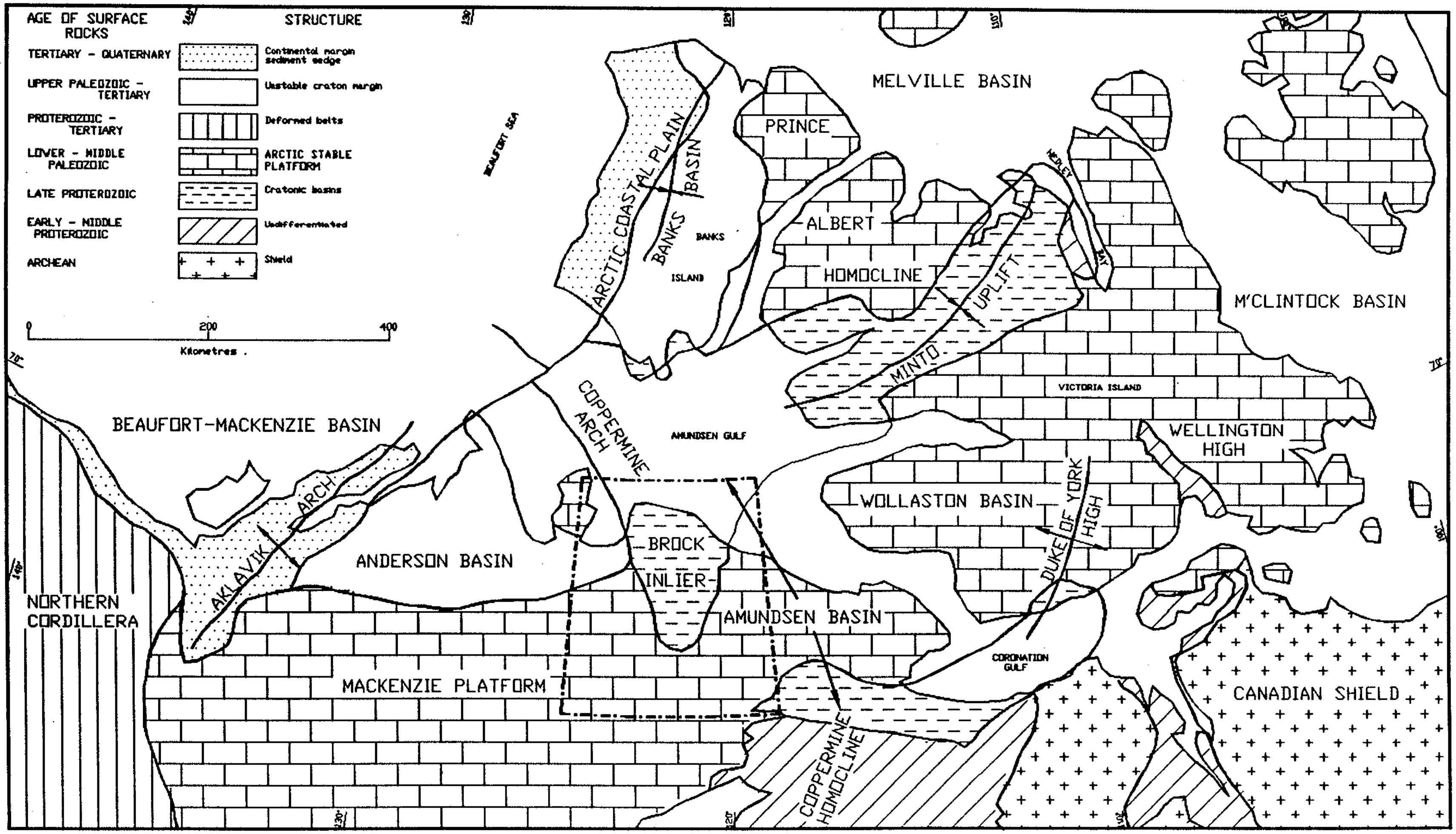


Figure 4. Regional lithostratigraphic elements of western Arctic Canada, with location of study area. (after Miall, 1976; Campbell, 1981; and Douglas, 1968 in Jefferson et al., 1988).

A shallow harbour is located on the east side of the peninsula. Barge delivery is once yearly from Inuvik and the Mackenzie (Dehcho) River.

Access to the coast by water is often good during July and August. Offshore ice dampens waves, however when the pack is blown onshore, sea travel is curtailed. Fixed wing aircraft on floats can land on large lakes from about mid-July to September, and on skis from mid to late winter. Access to the remainder of the study area for geological purposes in the summer months is essentially by helicopter only. The distance from any convenient staging area means that moving fuel and the helicopter itself into the area are very expensive.

Previous Work

Only reconnaissance bedrock and surficial geological maps have been published for this area.

The coastal geology was first mapped by John Richardson in 1826 (Franklin, 1828), except for the southern portion of Darnley Bay, mapped by the Canadian Arctic Expedition in 1915 (O'Neill, 1924).

In the early 1950's, geographer J. Ross Mackay completed a series of trips along the coast and into the interior from Paulatuk for the Geographic Branch of the then Department of Mines and Technical Surveys. His report (Mackay, 1958) summarizes what was known of the geology of the area prior to his work, and documents exploitation of mineral and coal resources in the area by the Inuvialuit. Aside from Mackay's limited traversing, the inland portion of the study area was not mapped until the staging of helicopter-supported Operations Coppermine and Norman in the late 1950's and 1960's by the G.S.C. All of the study area east of longitude 124° was mapped in 1958 at a scale of 1:500,000 (Fraser et al., 1960). That portion of the area lying west of longitude 120° and north of latitude 68° was remapped in 1968 at 1:250,000 (Balkwill and Yorath, 1970, 1971; Cook and Aitken, 1969; Yorath et al., 1969). The region south of latitude 68° and west of longitude 119° was remapped at 1:500,000 (Cook and Aitken, 1971), also in 1968.

The surficial geology of the region was mapped by Craig (1960), and that of most of the study area by Klassen (1971). St-Onge and McMartin (1987) and McMartin and St-Onge (1990) mapped and sampled the Quaternary geology of the area east of longitude 120°.

A recent compilation map of the Horton River Map sheet (NR 9,10,11,12) at scale of 1:1,000,000 (Okulitch, 1991) includes all of the study area north of latitude 68°.

Previous bedrock mapping relied heavily on interpretation of air photographs with helicopter transport restricted to stops at regular 4- to 8-kilometre intervals supplemented by investigation of structurally complex sites. During the course of our fieldwork, we in turn relied heavily on these reconnaissance maps and regional stratigraphic studies (e.g., Aitken et al., 1978b; Jefferson and Young, 1979; Young et al., 1989) to orient our field work.

The reconnaissance geological maps were ground-checked, and limited new outcrop data were collected. The area was not completely remapped and we continued to rely heavily on air photographs to extend ground information. The additional data we acquired were used to produce the modified 1:500,000-scale geological map included in this report (Figure 5); to revise regional lithostratigraphic correlations (Figure 6); and to illustrate 1:50,000-scale study of the fold and thrust belt east of Bluenose Lake (figures 7 and 8).

Confidence in this Assessment

This assessment is considered to be intermediate between Phase 1 and Phase 2 in confidence level (Scoates et al., 1986). Phase 1 assessment involves primarily literature research, whereas Phase 2 assessment involves collection of substantial amounts of new data by field work and subsequent laboratory analysis.

Many of the conclusions here were reached by literature study and review, although new geological fieldwork enhanced our understanding of the geological history of the area. The geochemical sampling and prospecting done for this assessment, although widespread, were of very low density because of the large size of the study area, and cannot be considered definitive or comprehensive.

These assessments are based on current knowledge of geology and mineral deposit models (e.g., Eckstrand, 1984). As noted in Jefferson et al. (1988) once-and-for-all assessments of resource potential cannot be made. Areas should be reassessed periodically as new data become available, as new concepts are developed, as new uses and extractive technologies are devised, and as the local and world economies change. Some of the areas that have little identifiable resource potential may contain new types of mineral deposits, recognizable and exploitable only in the future.

Users of this study must keep in mind such elements of temporal change and the scale of this study. The study area is approximately 66,000 km^2; in comparison Nova Scotia covers 55,490 km^2 and New Brunswick, 73,440 km^2. Our geoscience knowledge base of the Bluenose Lake area is modern and much less complex than that of the maritime provinces but the density of observations is similar to that of these provinces about 90 years ago. Establishment of a national park may maintain this dichotomy of modern concepts but limited data.

Local Factors Affecting Economic Potential

This report analyzes the mineral and hydrocarbon potential of a relatively remote area in Canada's Arctic. The resource potential is, in most cases, evaluated according to a set of geological criteria (Table 2) which do not take into account numerous economic factors, including the location of the resource. Economic criteria do influence our ratings somewhat in the case of large tonnage, low-cost commodities such as phosphate and aggregates. Private companies are unlikely to invest in projects which do not provide an adequate return on investments. Factors such as politics, proximity to market, operating costs versus technology in the arctic, and higher average northern salaries all affect the potential for profitability of northern operations. Although the future effects of factors such as these are difficult to evaluate, they are important in assessing the potential for profit of any identified resource. These factors are known to change dramatically over time; the element of local change must therefore also be considered in long-term decisions on land use.

Responsibilities of the Authors

Research and compilation of relevant geological literature were completed mainly by the first author.

Eight weeks were spent by the first and second authors and A. Insinna, prospecting, describing and sampling outcrops, sampling stream sediments, and mapping in areas where existing maps showed insufficient detail or were demonstrably incorrect. Fieldwork included time spent remapping in greater detail the areas east and north of Hornaday Lake, as well as investigating copper prospects on Victoria Island and in the Coppermine Homocline.

Mineral potential ratings were assigned by the first author, after Jefferson et al. (1988), to specific portions of the stratigraphy by comparing current mineral deposit models with the above-compiled data. The ratings were revised after discussion with the second author, and further revised after critical comments by W.A. Padgham, G. Patterson, R.F.J. Scoates and W. Wagner.

This report involved more than one full year of work on the part of the first author under the terms of DSS Contract No. 34 SZ 23226-0-0004/01 from the G.S.C. The first author is continuing to study field data and samples, and expects to derive further geological and structural interpretations for graduate study at Laurentian University under the direction of D.G.F. Long. The second author was scientific authority on the contract; contributed to the fieldwork and writing; and technically edited, word-processed and produced the final version. The third author was responsible for assessing fluid hydrocarbon potential, based on literature research and analysis.

Acknowledgments

Helicopter support was organized by Polar Continental Shelf Project, who also supplied 15 hours of flight time. Usage between parties was coordinated by F. Hunt. Air photographs were loaned by D. St-Onge and J.D. Aitken. In the summer of 1990, A. Insinna was field assistant, and Tony Green did camp duties. Discussions regarding land use (past and present) with M. Stevenson, G. Hamre, D. Harvey, and the Paulatuk Parks Committee were most enlightening.

Noranda Inc. generously shared confidential data at an early stage in their exploration program, which allowed us to properly assess the copper deposit models which might apply to the region. Noranda also provided logistic support, cordial hospitality in the field and made their charter helicopters available for our use at cost-recovery. Cominco Ltd. also took us into their confidence with internal company data and reports, one of which is cited here (Hole and Bradley-Isbell, 1990).

A. Pedder and P. Copper provided input regarding putative Devonian outcrops in the east-central portion of the area. Thanks go to D.A. St-Onge, R.W. Klassen, and S.C. Zoltai for discussions regarding the surficial deposits and glacial history of the area. F. Goodarzi provided reflectance and maturity data, and advice regarding coal potential.

Various other aspects of the bedrock geology of the Bluenose area were discussed with W. Darch, W.A. Gibbins, A.N. LeCheminant, R.L. Lustwerk, P. McGrath, F.M. Nixon, D. Paré, K. Pride, M. Rees, and G.M. Young; this study has benefitted from their input.

A.V. Okulitch generously provided topographic and geological information from an in-progress compilation in AutoCAD file format, which simplified map production immensely. A. Gallie provided useful direction in selection and interpretation of satellite imagery. The larger maps were produced by J. Paraino of A.J. Robinson and Associates. Figures 3, 6, 7 and 8 were drafted by N. Kim; figures 1, 2, 4 and 15 were prepared by A. Insinna; L. O'Neill did the final corrections and printing of tables; K. Powis expedited sample preparation and helped compile the manuscript.

The manuscript was much improved by critical comments from D.G.F. Long and W.A. Padgham. G. Hamre, D. Harvey, P.J. Lee, A. Okulitch, G. Patterson, R.F.J. Scoates, and W. Wagner are thanked for their comments on selected parts of the report. Any errors or omissions remain the responsibility of the authors.

Finally, many thanks to P. Green and the other residents of Paulatuk, for making us feel welcome on our visits to that community, and for their considered responses to our wide-ranging questions.

GEOLOGY

The bedrock geology of the study area has been studied within the framework proposed by Okulitch (1991, sheet 2), and is reviewed as follows, referring to the geology map of the study area (Figure 5), and stratigraphic summaries (tables 4 and 5).

The proposed Bluenose Lake National Park encompasses the entire area of the Brock Inlier (Figure 4), an uplifted geological window exposing platformal Proterozoic sedimentary rocks of the Shaler Group which are intruded by Late Proterozoic diabase dykes and sills. The Brock Inlier is framed on the west, south and east by onlapped Cambrian to Devonian strata. A relatively thin, discontinuous veneer of Cretaceous strata unconformably overlies the older rocks, mostly near the present day coast, both west and east of the Brock Inlier.

Quaternary glacial deposits include: 1) spectacular terminal moraines and relict glacial ice around Bluenose Lake (McMartin and St-Onge, 1990); 2) drumlin fields and 3) glacio-fluvial outwash deposits in the northern part of the area. Surficial deposits in the central part of Brock Inlier do not to appear to have been modified by Late Wisconsin glacial processes.

Hadrynian Amundsen Embayment

The Amundsen Embayment (Young and Jefferson, 1975), includes Late Proterozoic strata of the Shaler Group on the Arctic Coast (Brock Inlier) and on Banks and Victoria islands (Minto Uplift), as well as the closely correlative Rae Group (Coppermine Homocline) (figures 4, 6). In the Hadley Bay and Wellington High areas on Victoria Island, Helikian siliciclastic rocks unconformably overlie basement gneisses which are intruded by granite for which an age of 1673 ± 42 million years has been determined by the K-Ar method (W.A. Gibbins *in* Campbell and Cecile, 1979).

The southern and eastern boundaries of the Amundsen Embayment may have extended much farther than the preserved limits of exposure of the Shaler and Rae groups, although paleokarst in cherty dolostones of the Glenlg Formation and equivalent in Coppermine Homocline (Rainbird et al., 1992) suggests that the shoreline was near the present edge of exposure for the lower formations. The northern and western extent of the Amundsen Embayment are covered by Paleozoic and Mesozoic strata (Young and Jefferson, 1975). The Amundsen Embayment has been interpreted to represent a broad, reentrant of a shallow Late Proterozoic sea that was connected to the Mackenzie Mountains area (Aitken et al., 1978b; Young 1979, 1981; Young et al., 1979; Jefferson, 1983, 1985; Jefferson and Young, 1989, Rainbird et al., 1992).

Brock Inlier

The Brock Inlier was recognized by Cook and Aitken (1969) as underlain by an extension of the same Late Proterozoic strata which were mapped on Victoria and southern Banks islands as the Shaler Group by Thorsteinsson and Tozer, (1962). The Shaler Group (Young, 1981) is a laterally uniform, intercalated sequence of fluviodeltaic sandstones, stromatolitic and oolitic marine carbonates, and two major units with sulphate evaporites and minor red mudstones. The capping Natkusiak Formation basalts on Victoria Island (Jefferson et al., 1985) and related Franklin gabbro-diabase dykes and sills which have been dated at 723 ± 3 million years by the uranium-lead method on badellyite (Heaman et al., 1990) have been included in the Shaler Group by Rainbird et al. (1992). The upper evaporites, carbonates, quartzarenites and basalts of the Shaler Group are not preserved in Brock Inlier, but the lower evaporites, carbonates, clastics and Franklin gabbros are present (Table 6, Figure 6).

The age of the Shaler Group is bracketted between the 1200-1270 million year-old Coppermine lavas (Wanless and Loveridge, 1972; LeCheminant and Heaman, 1989) and the 723 million year-old Natkusiak lavas (Palmer et al., 1983; Heaman et al., 1990). Rainbird (1991) has demonstrated that upper Shaler Group strata on Victoria Island (Kuujjua Formation) were not indurated when the Natkusiak basalts were erupted, and inferred that the Shaler Group is younger than 900 million years old.

The Shaler Group was deposited in a large, shallow water embayment of a Late Proterozoic sea. Throughout its depositional history shallow marine seas alternated with coastal river and delta braid plains which prograded generally to the northwest. Several periods of restricted circulation caused accumulation of sulphate evaporites.

Pelitic Unit (Hp; P1; Lower Clastic Member, Glenelg Formation)

Young (1981) described the lower clastic member as comprising shale, siltstone, and sandstone; the dominant rock type is grey and green shale, commonly with spherical calcareous concretions. Balkwill and Yorath (1971) estimated P1 (Hp) to be at least 900 metres thick on the coast near Cape Lyon.

Outcrops visited during this study consisted of thin-laminated grey-green to brown shale and siltstone, containing coarsely crystalline dolomite concretions. Ripple marks are common in siltstone at some locations. Some siltstone beds preserve hummocky cross-stratification in concretions. Many outcrops expose pervasive, sub-vertical faults, with minor offset on individual faults. Pyrite and secondary carbonates are common on fault surfaces, and in adjacent gash fractures. Chemical

Table 4. Table of Formations, with Domains indicated (all data from Okulitch, 1991; and Baragar and Donaldson, 1973).

DOMAIN	ERA	PERIOD	FORMATION		SYMBOL	BRIEF DESCRIPTION
III	CENOZOIC	QUATERNARY	[Quaternary alluvium]		TQs	sand, gravel
			[Quaternary moraine]			
		NEOGENE (TERTIARY)	BEAUFORT FM.		mTNB	sand, gravel
	MESOZOIC	CRETACEOUS	HORTON RIVER FM.		KHR	shale, iron formation
			LANGTON BAY FM.		KLB	sandstone, limestone, shale
II	PALEOZOIC	DEVONIAN	HUME FM.		DH	argillaceous limestone, calcareous shale
			BEAR ROCK FM.		DBR	dolomite, carbonate breccia
		GILURIAN	MOUNT KINDLE FM.		OSc	argillaceous dolomite, chert
		ORDOVICIAN	FRANKLIN MOUNTAIN FM. (upper member)		OFM	stromolitic dolomite, chert
			FRANKLIN MOUNTAIN FM. (middle member)		COFMm	laminated dolomite
		CAMBRIAN	FRANKLIN MOUNTAIN FM. (lower member)		CFM	cyclic laminated dolomite
			SALINE RIVER FM.		Csr	shale, evaporite, siltstone, dolomite
			MOUNT CAP FM.		mCMC	shale, glauconitic sandstone, siltstone
			MOUNT CLARK FM. OLD FORT ISLAND FM.		lCMC, COFI	conglomerate, quartzite
I PROTEROZOIC	HADRYNIAN	NEO-HADRYNIAN	SHALER GROUP	gabbro dykes, sills	Hb	gabbro dykes, sills
		PALEO-HADRYNIAN		carbonate, evaporite	Hce	dolomite, limestone, shale, quartzite, chert, gypsum
				carbonate	Hc	dolomite, shale, stromolitic limestone
				quartzite	Hq	quartzite, sandstone
				carbonate, chert	Hct	dolomite, cherty dolomite
				pelite	Hp	shale, siltstone, mudstone
	HELIKIAN	NEO-HELIKIAN	COPPER-MINE RIVER GROUP	COPPER CREEK FM.	Nv	plateau basalts, associated dykes and sills

the types of contacts are indicated as follows:

────────	conformable contact	- - - - - - - -	angular unconformity
··············	disconformity	▬▬▬▬▬	igneous intrusive contact

Table 5. Correlation of stratigraphic map units used for fieldwork, Bluenose Lake area. All formations listed under reports other than Okulitch are the most commonly mapped equivalent of the designated Okulitch unit, but a single formation may correspond to more than one of Okulitch's formations. Detailed subdivision of Hc (P4) is given in Figures 9 and 10 and described in text.

HORTON RIVER 1:1,000,000 Okulitch, 1992			NORTH CENTRAL DISTRICT OF MACKENZIE 1:506,880 Fraser, 1960	ERLY LAKE 1:250,000 Cook & Aitken, 1969	SIMPSON LAKE 1:250,000 Balkwill & Yorath, 1970	BROCK RIVER 1:250,000 Balkwill & Yorath, 1971	COLVILLE LAKE 1:500,000 Cook & Aitken, 1971	FRANKLIN BAY / MALLOCH HILL 1:250,000 Yorath et al, 1975	COPPERMINE / DISMAL LAKES 1:250,000 Barager & Donaldson, 1973
[Quaternary alluvium]		TQs	nm	Q	Qal	Q	nm	Qal	nm
[Quaternary moraine]		TQs	nm	Qm	Qm	Qm	nm	Qm	nm
BEAUFORT FM.		mTNB	--	Tb	--	--	--	Tb	--
HORTON RIVER FM.		KHR	25	--	Kb	Kb	K	Klh	--
LANGTON BAY FM.		KLB	24, 25	Ks	Ks	Ks	K	Kll	--
HUME FM.		DH	22	Dh	Dh	--	Dh	ss	27
BEAR ROCK FM.		DBR		Db	Db	Db	Db	ss	
unassigned Ordovician/Silurian carbonate		OSc		nm	nm	nm	nm	nm	
MOUNT KINDLE FM.		OSc		--	--	--	OSk	ss	
FRANKLIN MOUNTAIN FM. (undivided)		COFM		--	--	--	--	COfc (per Okulitch)	
FRANKLIN MOUNTAIN FM. (upper member)		OFM		Or2b	Or2b	COr2b	COr2b	COfc (per Jones)	
FRANKLIN MOUNTAIN FM. (middle member)		COFM m		Or2a	COr2a	COr2a	COr2a	ss	
FRANKLIN MOUNTAIN FM. (lower member)		CFM		Or1	--	COr1	Cr1	--	
SALINE RIVER FM.		CSR	21	Cs	--	Cs	Cs	--	?
MOUNT CAP FM.		mCMC	20	Ccp	--	Ccp	CCp	--	?
MOUNT CLARK FM. OLD FORT ISLAND FM.		lCMC, COFI		Cck	--	Co	Cof	--	26
Hadrynian gabbro dykes, sills		Hb	18	P6	--	P6	Pcd	--	F
SHALER GROUP (= RAE GROUP HR)	carbonate, evaporite	Hce	15,17	P5	--	P5	--	--	? 25 ?
	carbonate	Hc	15,17	P4	--	P4	--	--	24
	quartzite	Hq	16,17	P3	--	P3	--	--	23
	carbonate, chert	Hct	15,17	P2	--	P2	--	--	22
	pelite	Hp	14,17	P1	--	P1	--	--	19-21
[COPPERMINE RIVER GP] (basalt flows)		Nv	12	--	--	--	Pcb	--	17-18

?	correlation uncertain
--	no equivalent mapped
nm	unit not mapped
ss	subsurface only
[ ]	unit name or description not derived from Okulitch (1991)

n.b. highlighted block indicates description in original source pertinant to mapping Bluenose Lake area

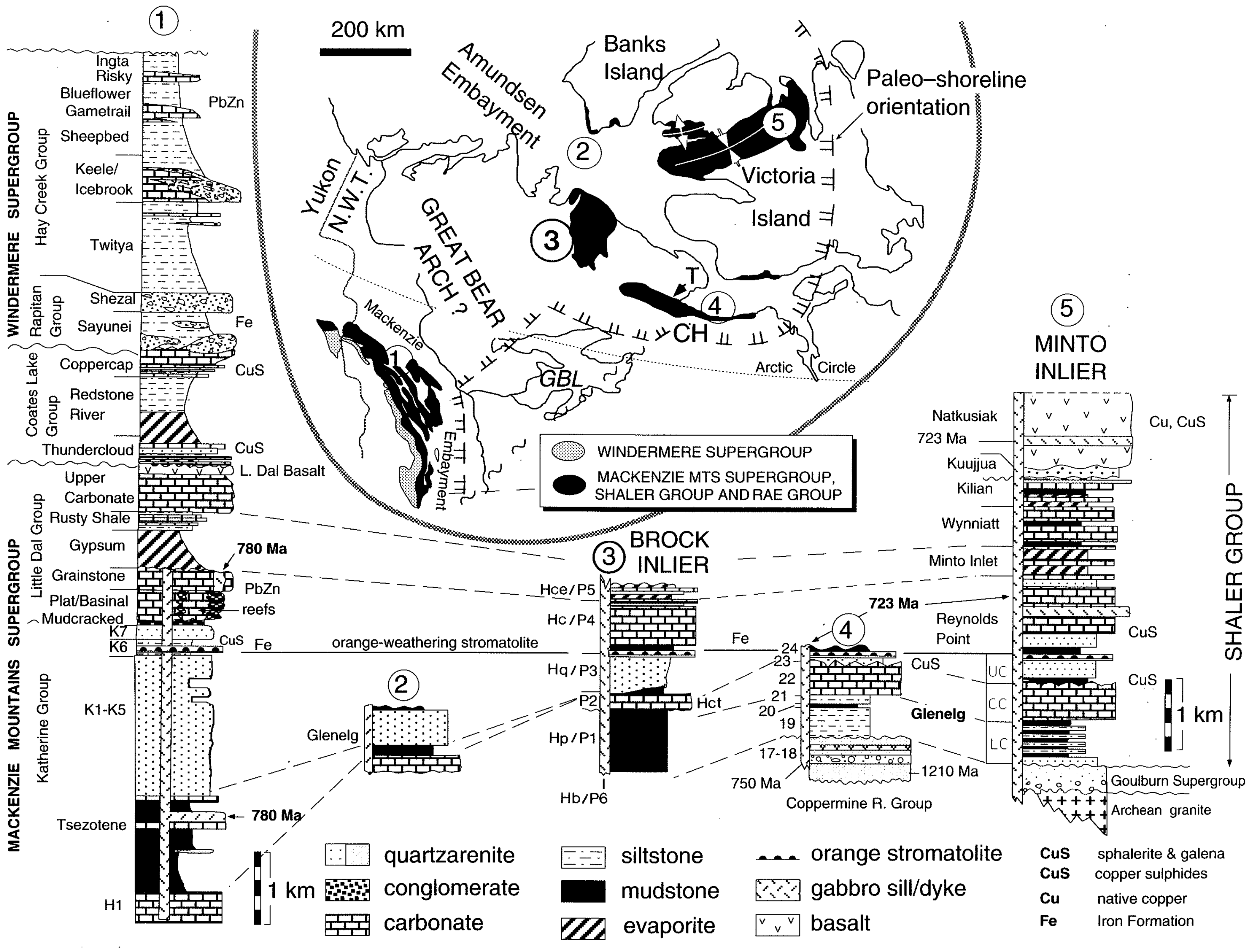
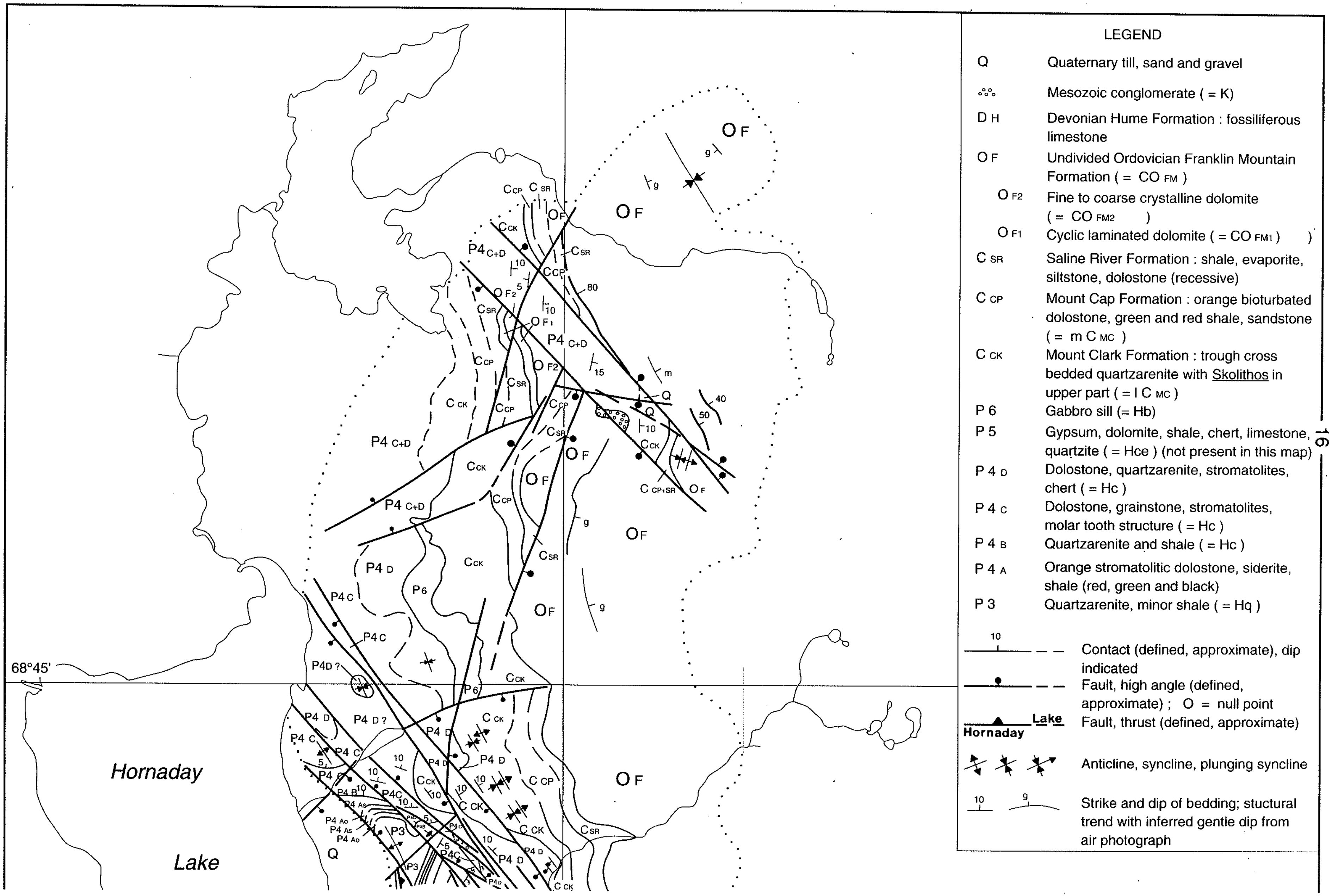


Figure 6. Late Proterozoic strata in NW-Canada (after Jefferson and Young, 1989). 3 = study area. GBL = Great Bear Lake. CH = Coppermine Homocline.

Table 6. Proterozoic stratigraphy, Brock Inlier/Coppermine Homocline, Amundsen embayment.

FORMATION		MEMBER	THICK-NESS	LITHOLOGY	COLOUR	SPECIFIC FEATURES	ENVIRON-MENT
	H b (P6) gabbro dykes, sills	- -	- -	diabasic gabbro, tholeitic	dark green, dark grey	olivine to quartz gabbro, very fine to med. grained, as dykes and sills	
SHALER GROUP (=RAE GROUP HR)	**H ce (P5) carbonate, evaporite**	- -	150+ m	dolostone, siltstone, gypsum, quartz arenite, calcarenite	maroon, light green, grey, red	gypsum thin-bedded,carbonates often have chert nodules, dolostone laminated	shallow marine, restricted circulation
	H c (P4) carbonate	P4d	100+ m	chert, dolostone, quartzarenite	light buff, grey	laminated, with silicified oolite, marine quartz arenite	shallow marine
		P4c	est. 500 m	dolostone, limestone	buff, grey	columnar stromatolites in large domal/lensoid bioherms, oolitic grainstone	shallow marine, tidal
		P4b	50-100 m	shale, siltstone, quattz arenite	dark green, maroon, grey	glauconitic	marine-deltaic
		P4a orange cherty dolostone	5-50+ m	dolostone, cherty dolostone, siderite	light pink-buff, deep orange weathering	variably 1-2 columnar branching stromatolite biostromes, associated sideritic zones	shallow marine, tidal
	H q (P3) quartzite	- -	460 m	quartz arenite	light pink, light grey, locally maroon to dark red	fine to coarse grained, resistant, thick-bedded to poorly bedded, local karst on Hct	fluvio-deltaic complex
	H ct (P2) carbonate, chert	cherty dolostone	240 m	dolostone, chert	light buff, light pink, light grey	laminated, massive, and reticulate chert; fenestrae, ripple marks, flaggy, columnar and large domal stromatolites, teepee structures	tidal, supratidal
		thin-bedded dolostone		dolostone	maroon, buff	finely crystalline, non-porous, columnar stromatolites	shallow marine
	H p (P1) pelite	shale, siltstone	910+ m	shale, siltstone	dark grey green	calcareous, micro-micaceous on partings	shallow marine
COPPER-MINE RIVER GROUP	**Husky Creek Formation**	- -	1200+ m	sandstone, siltstone, basalt	sediments are red, volcanics black, grey	cross-bedded, friable sandstone, siltstone; basalt as Copper Creek Fm.	subaerial
	Copper Creek Formation	- -	3000+ m	continental tholeitic basalts	black, grey	tholeitic, amygdaloidal flows, microporphyritic, native Cu	subaerial

Information in table derived from Balkwill & Yorath (1971), Barager & Donaldson (1973), Cook & Aitken (1969), Jefferson & Young (1989), Young (1981), Jefferson & Jones (1991) and unpublished personal observations.


LEGEND
Q Quaternary till, sand and gravel
Mesozoic conglomerate (= K)
D H Devonian Hume Formation : fossiliferous limestone
O F Undivided Ordovician Franklin Mountain Formation (= CO FM)
O F2 Fine to coarse crystalline dolomite (= CO FM2)
O F1 Cyclic laminated dolomite (= CO FM1)
C SR Saline River Formation : shale, evaporite, siltstone, dolostone (recessive)
C CP Mount Cap Formation : orange bioturbated dolostone, green and red shale, sandstone (= m C MC)
C CK Mount Clark Formation : trough cross bedded quartzarenite with Skolithos in upper part (= l C MC)
P 6 Gabbro sill (= Hb)
P 5 Gypsum, dolomite, shale, chert, limestone, quartzite (= Hce) (not present in this map)
P 4 D Dolostone, quartzarenite, stromatolites, chert (= Hc)
P 4 C Dolostone, grainstone, stromatolites, molar tooth structure (= Hc)
P 4 B Quartzarenite and shale (= Hc)
P 4 A Orange stromatolitic dolostone, siderite, shale (red, green and black)
P 3 Quartzarenite, minor shale (= Hq)
10 Contact (defined, approximate), dip indicated
Fault, high angle (defined, approximate) ; O = null point
Hornaday Lake Fault, thrust (defined, approximate)
Anticline, syncline, plunging syncline
10 9 Strike and dip of bedding; stuctural trend with inferred gentle dip from air photograph
Hornaday
Lake
68°45'
OF
OF2
OF1
CSR
CCP
CCK
CCP+SR
P4C+D
P4D
P4D?
P4C
P4B
P4As
P4Ao
P6
P3
Q
g
m
80
50
40
15
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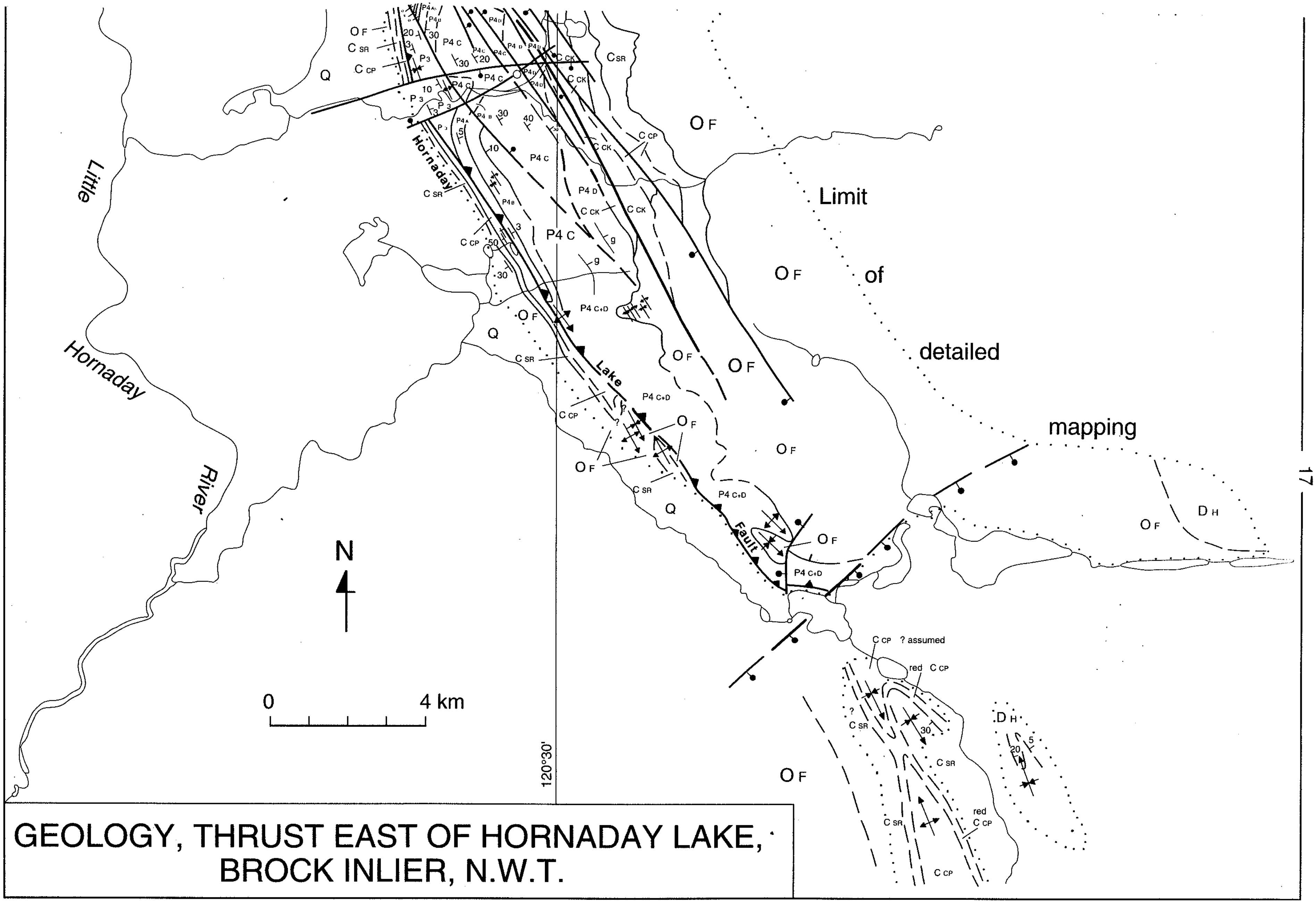

GEOLOGY, THRUST EAST OF HORNADAY LAKE, BROCK INLIER, N.W.T.

Figure 7. Geology, 1:50,000 scale, of faulted and folded structural panel east of Hornaday Lake. Geology by C.W. Jefferson and T.A. Jones, based on 4 foot-traverses, helicopter reconnaissance, air photograph interpretation, and data from Cook and Aitken (1969).

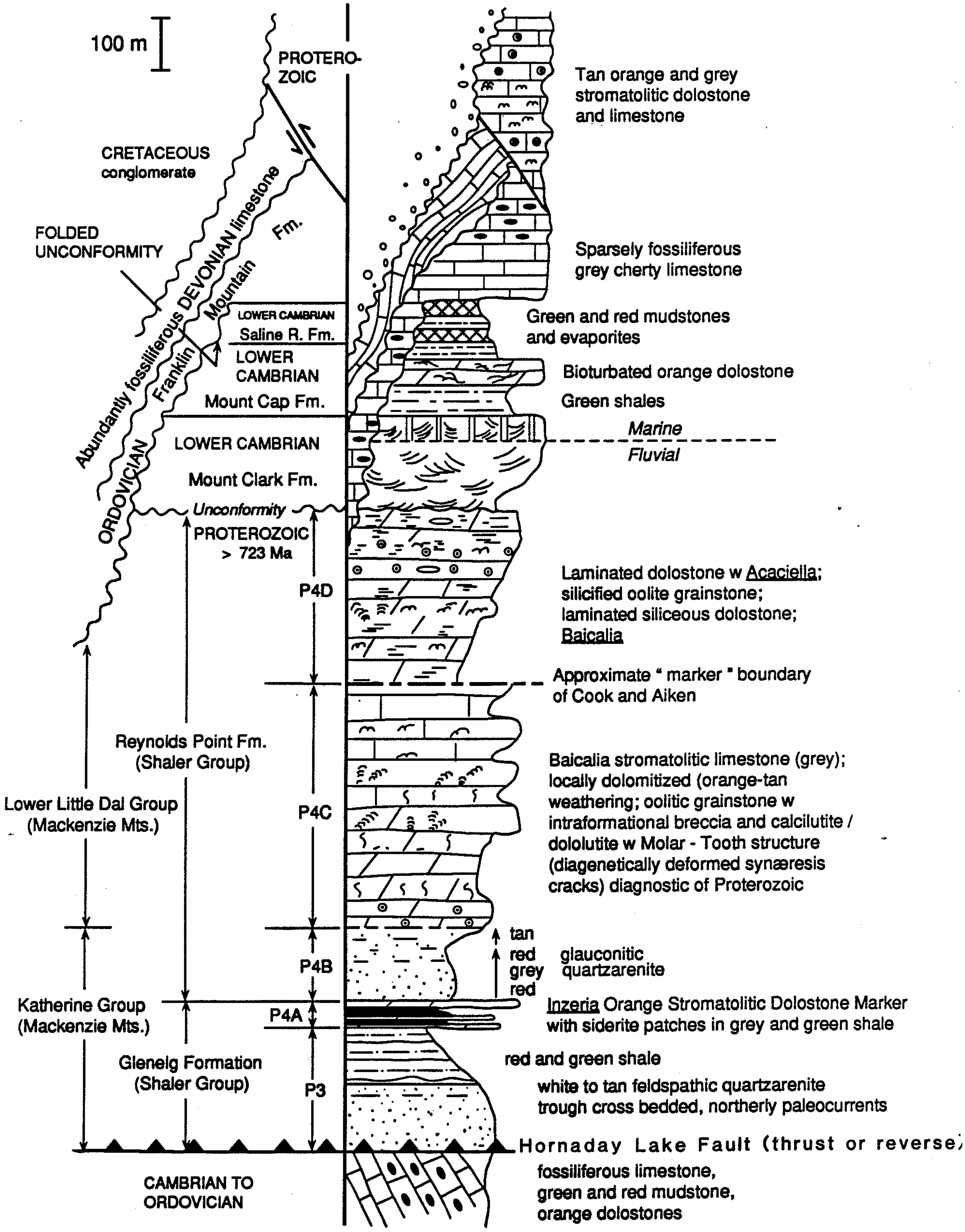

Figure 8. Composite stratigraphic/structural columnn, faulted and folded structural panel east of Hornaday Lake. Based on reconnaissance measured sections in the central part of Figure 7.

analyses of samples from these veins are discussed in Bedrock Lithogeochemistry.

Rainbird et al. (1992) have interpreted the lower clastic member of the Glenelg Formation on Victoria Island as recording marine deposition below wave base; they have suggested that mudstones with intercalated arenite layers indicate distal suspended sediment deposition (muds) punctuated by density current deposition (sandstone) triggered by failure on continental slopes. No sandy interlayers were noted in the Brock Inlier, suggesting that deposition here took place further from shore.

Carbonate, Chert Unit (Hct; P2; Cherty Carbonate Unit, Glenelg Formation)

Balkwill and Yorath (1971) separated this unit into an upper and lower section, and estimated the total thickness at 240 metres. They described the lower section as thin-bedded finely crystalline non-porous dolomite. The upper section is described as similar, but containing abundant reticulate chert masses and with disconnected vuggy porosity.

Unit Hct is characterized in outcrop in the Brock Inlier by tan dolostone with variable amounts of chert. We observed stratiform, bulbous, digitate and columnar non-branching stromatolites, intraformational flat-chip conglomerate, finely laminated light grey limestone beds, and one outcrop of a partly silicified oncolitic calcarenite.

The upper cherty portion of the unit forms the walls of a spectacular canyon in the lower reaches of the Brock River; by contrast the lower portion of the overlying Hq unit weathers recessively. Finely laminated strata and low-relief stromatolite biostromes suggest a flat sabkha-like shoreline (Rainbird et al., 1992).

Quartzite Unit (Hq; P3; Upper Clastic Member, Glenelg Formation)

Balkwill and Yorath (1971) described this unit as consisting of well cemented thick-bedded orthoquartzites. Cook and Aitken (1969) describe it as generally poorly bedded, locally cemented with iron oxides or clay minerals, and containing "abundant grains altered to white clay" (feldspar). D.G.F. Long (personal communication, 1992) found minor patchy phosphatic cement in some units.

In the field we noted significant variability in the composition and bedding of this unit. Although logistics prevented us from determining the stratigraphic level of many outcrops, at several locations the unit comprised variable proportions of: 1) flaggy, thin-bedded hematitic sandstone with abundant crossbeds and ripples, 2) friable light pink quartzarenite, and 3) very fine grained finely laminated quartzarenite with shale chips. We examined in detail that portion of the unit directly above its contact with the underlying carbonate unit. In the Brock River canyon the basal beds consist of 8 - 10 metres of deep red flaggy fine grained siltstone, and finely laminated sandstone with shaly partings. Some beds are glauconitic, some contain shale chips. Unit Hq grades upward at this locality to a blocky arkose. Large scale composite bedforms, exposed in the walls of the canyon, have been interpreted in terms of deposition by intermediate to high sinuosity streams (Long, 1978). Northwest of the canyon, carbonates of unit Hct (P2) are immediately overlain by several metres of black, green and red shales, followed by sandstone. In the southern part of the Brock Inlier, The basal portion of Hq is poorly exposed; deep red chips of silty sandstone characterize the till just above exposures of cherty dolostone of Unit Hct.

We suggest that Unit Hq represents a northwest prograding fluvio-deltaic complex. We consider that the basal portion of this unit in the Brock Inlier represents relatively deep platformal marine sedimentation. In contrast, in the Hadley Bay area on Victoria Island the lowest portion of the same unit contains carbonate breccia, conglomerate "composed of rounded pebbles of chert and carbonate in a matrix of quartzarenite" (Rainbird et al., 1992), plus secondary vuggy porosity and iron and copper sulphide minerals. Rainbird et al. (ibid) interpret these features as evidence of "karst topography or exposure surfaces developed on emergent carbonate platforms". No evidence of paleo-karst development at the Hct-Hq contact was seen in outcrop in the Brock Inlier.

Carbonate Unit (Hc; P4 a-d; upper Glenelg Formation, lower Reynolds Point Formation)

This unit was first recognized as a subdivision of the Shaler Group during mapping conducted as part of Operation Norman (Yorath et al., 1969;Cook and Aitken, 1969; Balkwill and Yorath, 1971). It was originally estimated as 60 to 150 metres thick (200 - 500'; Cook and Aitken, 1969); they described it as consisting "mainly of massive and resistant dolomites, characterized by the predominance of orange-weathering colours and an abundance of stromatolites". They also noted cross-bedded dolomitic calcarenite, and grey limestone with columnar stromatolites. A 30 metre (100') zone of "dark grey, microcrystalline, thin bedded limestone" was also noted by Yorath et al. (1969).

This unit outcrops extensively in the southeastern portion of the Brock Inlier, on the coast in the vicinity of Deas Thompson and Clinton Points, and in a faulted and open folded structural panel east of Hornaday Lake.

Unit Hc was previously undivided and of uncertain correlation. Mapping in 1991 (figures 7, 8) has resolved some of these uncertainties (Jefferson and Jones, 1991) as follows.

Unit Hc (P4) comprises four members (for convenience labelled here as P4a-d) which correlate with members of the Shaler Group on Victoria Island, and with subdivisions of the Mackenzie Mountains Supergroup.

The basal P4a dolostone member (5 to >50 metres) comprises a double layer of bright orange-weathering, branching stromatolitic (cf. *Inzeria*) dolostone biostromes which are separated and overlain by black and green glauconitic shale.

The P4a member is but one occurrence of the "orange stromatolite" whose sideritic character and stromatolite morphologies have been correlated over a wide area (Jefferson and Young, 1989): on northern Victoria Island a single biostrome marks the top of the Glenelg Formation; in Mackenzie Mountains, a double biostrome is contained in shales of unit K6 of the Katherine Group. In Brock Inlier the P4a stromatolite has a relatively basinal appearance, particularly toward the north where it is greyish-tan weathering, draped by black shale and exhibits abrupt lateral facies changes to nodular laminated dololutite (Figure 9). Component bioherm edges trend north-northwesterly.

The overlying 50 - 100 metre clastic member, P4b, coarsens upward from glauconitic mudstone to quartzarenite and grades into arenaceous calcarenite. This marine-deltaic sandstone is a key marker, separating P4a from the overlying Proterozoic carbonate strata.

The gradationally overlying tan dolostone and grey limestone member, P4c (estimated 500 metres) which is characterized by oolitic grainstones and cf. *Baicalia* stromatolites.

The top carbonate-siliciclastic member, P4d, comprises at least 100 metres of laminated grey dolomite, with subunits of marine quartzarenite, silicified oolite, and a finely laminated stromatolite, cf. *Acaciella*.

The newly recognized P4b,c,d members correlate lithostratigraphically with members of the Reynolds Point Formation on Victoria Island and with the upper Katherine Group (K7) to the lower Little Dal Group in Mackenzie Mountains (Aitken et al., 1978a).

These P4 members are considered to be relatively more basinal yet still epicontinental counterparts of their equivalents recognized in the Reynolds Point Formation of Victoria Island, and in the Rae Group (Jefferson and Young, 1989).

Carbonate, Evaporite Unit (Hce; P5; Minto Inlet Formation)

This unit is the youngest Precambrian sedimentary unit found in the Brock inlier. Balkwill and Yorath (1971) and Cook and Aitken (1969) indicate that it is characterized by finely laminated microcrystalline red or green dolostone, and white, grey, pale green or grey gypsum beds. Also noted are particulate limestones, quartzarenite, mudcracked green shale with intercalated green siltstone, and chert nodules and masses in some carbonate members. Balkwill and Yorath (1971) estimated that this unit attains a maximim thickness of 500' (150 metres) near the Buchanan River (Figure 10).

In the field it is difficult to distinguish this unit from the underlying carbonates of Hc/P4. The intercalated gypsum, dolostone, and red to green shales of Hce are superficially similar to the overlying Paleozoic Mount Cap and Saline River formations (shales and dolomites). This similarity is especially difficult to discriminate in locations where the intervening Mount Clark quartzarenites are thin or absent. Some outcrops previously mapped as P5 (Hce) by Balkwill and Yorath (1971) showed evidence of burrowing, and consequently have been remapped as Mount Cap Formation on Figure 5 (see Jefferson and Jones, 1991, for a discussion of this and other changes to existing maps).

According to Young (1981) the Minto Inlet Formation (unit Hce) represents a shallow water tidal current dominated depositional environment, with periodic and cyclic salinity changes, and occasional subaerial exposure.

Coppermine Homocline

Coppermine River Group (Nv) - Copper Creek Formation

This Group and Formation were first proposed by Baragar and Donaldson (1973); their descriptions are summarized as follows.

The Copper Creek Formation comprises approximately 10,000' (3,000 metres) of tholeiitic plateau basalt flows, with very minor amounts of intercalated red sandstone in the upper third. Native copper is a very minor constituent of many flows, and in general sulphide minerals are essentially absent.

Most of flows were erupted under subaerial conditions; the flows are dated at approximately 1,200 million years, corresponding to the 1270 ±4 million year age for the comagmatic Muskox intrusion and the Mackenzie dyke swarm (LeCheminant and Heaman, 1989).

These basalt flows outcrop in the extreme southeastern portion of the study area as a westward extension of the Coppermine Homocline: due to time and logistics constraints they were not visited during the course of this study. These Proterozoic rocks are spatially separated from the Brock Inlier by cover of Hadrynian Rae Group and Paleozoic strata; detailed structural-stratigraphic relationships between these poorly exposed Proterozoic rocks and the Brock Inlier are not well understood. For further information on the Coppermine Homocline and its types of copper showings, the reader is referred to Baragar and Donaldson (1973), Jefferson et al. (1985), Kindle (1970), and Thorpe (1970).

Figure 9. Facies change from stromatolite bioherm (left) to laminated dolostones (right) at the base of Proterozoic map unit Hc (member P4a). View is toward the southeast, on the Arctic coast west of Tysoe Point. About 14 m of section are shown.

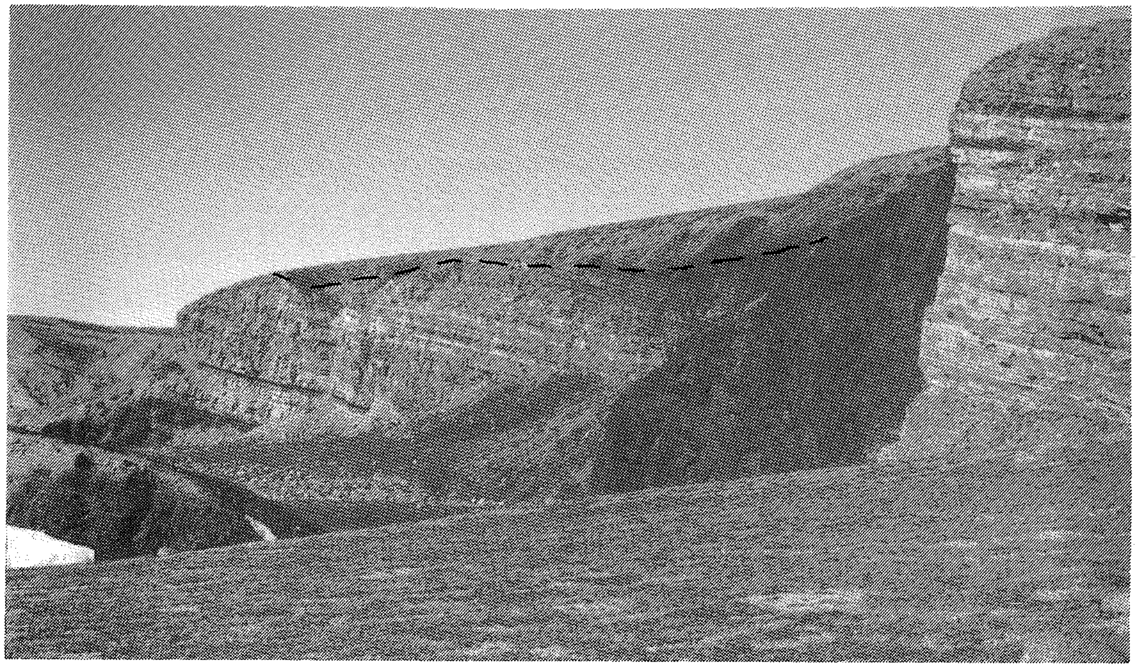

Figure 10. Rare vertical section of Proterozoic shales and dolomites (mapped in Figure 5 as Hce, could be Hc overlain by Hq). Underlain in distance by diabase sill (est. 30-35 m thick) and unconformably overlain (dashed line) by friable hematitic sandstone. Diabase dyke (dark) cuts the same shales and dolostones in foreground. View looking north, about 13 km up the Wob River from the coast. Section in distance 40-45 m high. Several hundred metres to the south and west, similar but intensely bioturbated strata are assigned to the Mount Cap Formation.

Rae Group (HR)

The Rae Group was first proposed by Baragar and Donaldson (1973) to include all sedimentary rock units above the Coppermine River Group and below the Paleozoic for NTS 86-N and 86-O (east of 118° and south of 68°, including the Coppermine area). They suggested an aggregate thickness of 4000' (1200 metres) minimum.

The Rae Group strata exposed in the Coppermine Homocline are considered to be the correlatives of the Shaler Group strata in the Brock and Minto Inliers (Rainbird et al., 1992; Jefferson and Young, 1989) (Figure 6, see also Figure 11). They unconformably overlie the Neohelikian Coppermine River Group.

Baragar and Donaldson subdivided the Rae Group into 7 unnamed formations, and described them in terms of their map units 19 - 25. Young (1977) correlated the Rae Group in detail with the Shaler Group, and Young et al. (1979) extended the detailed correlation to the Mackenzie Mountains Supergroup (Figure 6), enhancing the general correlation by Aitken et al. (1973) between Brock Inlier and Mackenzie Mountains (Figure 11). Jefferson (1977) and Jefferson and Young (1989) described the stromatolites in units 22 and 24.

Dixon (1979) noted that some areas mapped as units 24 and/or 25 contain trace fossils and therefore must be Paleozoic. We believe that Dixon's interpretation of some mapping errors is correct; we too noted a number of localities in Brock Inlier where bioturbated orange dolostones and green shales were mapped as Proterozoic. Nevertheless, outcrops north of Rae River that the second author was able to inspect in 1991 had been mapped correctly as Proterozoic, because they are intruded by gabbro sills, and they are lithostratigraphically identical to the Shaler Group units as mapped on Victoria Island, in the Brock Inlier and elsewhere, as proposed by Young (1977). The lithostratigraphic correlation is as follows:

RAE GROUP	SHALER GROUP
Unit 25	Paleozoic (e.g., mCMC); P5 (Hce); Upper P4 (Hc/P4d)
Unit 24	Lower P4 (Hc/P4abc)
Unit 23	Unit P3 (Hq)
Unit 22	Unit P2 (Hct)
Units 19-21	Unit P1 (Hp)

Rae Group outcrops only in the extreme southeast of the study area, and has not been subdivided on existing maps of that area (Fraser et al., 1960). Based on maps by Baragar and Donaldson (1973) to the east, it is likely that the equivalents to each of units P1 - P4 occur as narrow bands of exposures within the area mapped as Rae Group in Figure 5. Rae Group units 22 and 23 were observed in outcrop immediately to the east of the study area, and are confirmed as Proterozoic by the diabase sills that intrude them.

Rainbird et al. (1991) discussed the correlation between the Rae and Shaler Groups and noted the mismapping of some Paleozoic strata as Proterozoic in the Brock Inlier. Jefferson *in* Rainbird et al. (1992) interpreted the depositional environment of the Rae Group as being similar to that of the basal Gelenelg Formation (Shaler Group) on Victoria Island, but more shoreward than the same Shaler Group equivalents in the Brock Inlier.

Hadrynian Diabase-Gabbro Sills and Dykes (Hb; P6; Coronation Sills; Franklin Magmatic Suite)

All Shaler Group equivalents in the Brock Inlier are intruded by a series of prominent gabbroic dykes and sills. Their texture ranges from very fine to medium grained diabasic, and composition from olivine gabbro to quartz gabbro (Cook and Aitken, 1969). Related sills on Victoria Island have been dated at 723 ±3 million years (Heaman et al., 1990). Thick sills in the Rae Group (Coronation Sills of Baragar and Donaldson, (1973) in the southeastern portion of the study area belong to the same magmatic suite.

In the Brock Inlier, sills belonging to this unit are an important component of the stratigraphy. They are concentrated within mudrocks (Hp) and near contacts between map-units of differing competency: Hp\Hct, Hq\Hc, Hc\Hce (Figure 5). Between Deas Thompson Point and Wob River (informal name: **w**est **o**f **B**uchanan; parallel to and approximately 5 km west of Buchanan River) they form many cuestas and cliffs which preserve exposures of softer Shaler Group strata.

Dates obtained by Heaman et al. (1990) from various Franklin intrusions span only a few million years (723 ±3). LeCheminant and Heaman (1989) suggested that the Darnley Bay anomaly, a circular 130 mGal gravity anomaly centered immediately south of Paulatuk (Hornal et al., 1973), represents a large mafic intrusion of the Franklin suite at shallow depth. Magnetic and gravimetric modelling has suggested a steep-sided, basic to ultrabasic intrusion, at a depth of 1.5-3.3 km, that could be as thick as 15-20 km (Chavez et al., 1987). Seismic evidence supports the compositional interpretation but indicates that the intrusion is a lopolithic mass at least 3 km below surface and less than 1 kilometre thick (Vye, 1972; corroborated by Hole and Bradley-Isbell, 1990). P. McGrath (personal communication, 1992) has stated that the seismic evidence is much stronger than the magnetic and gravimetric modelling.

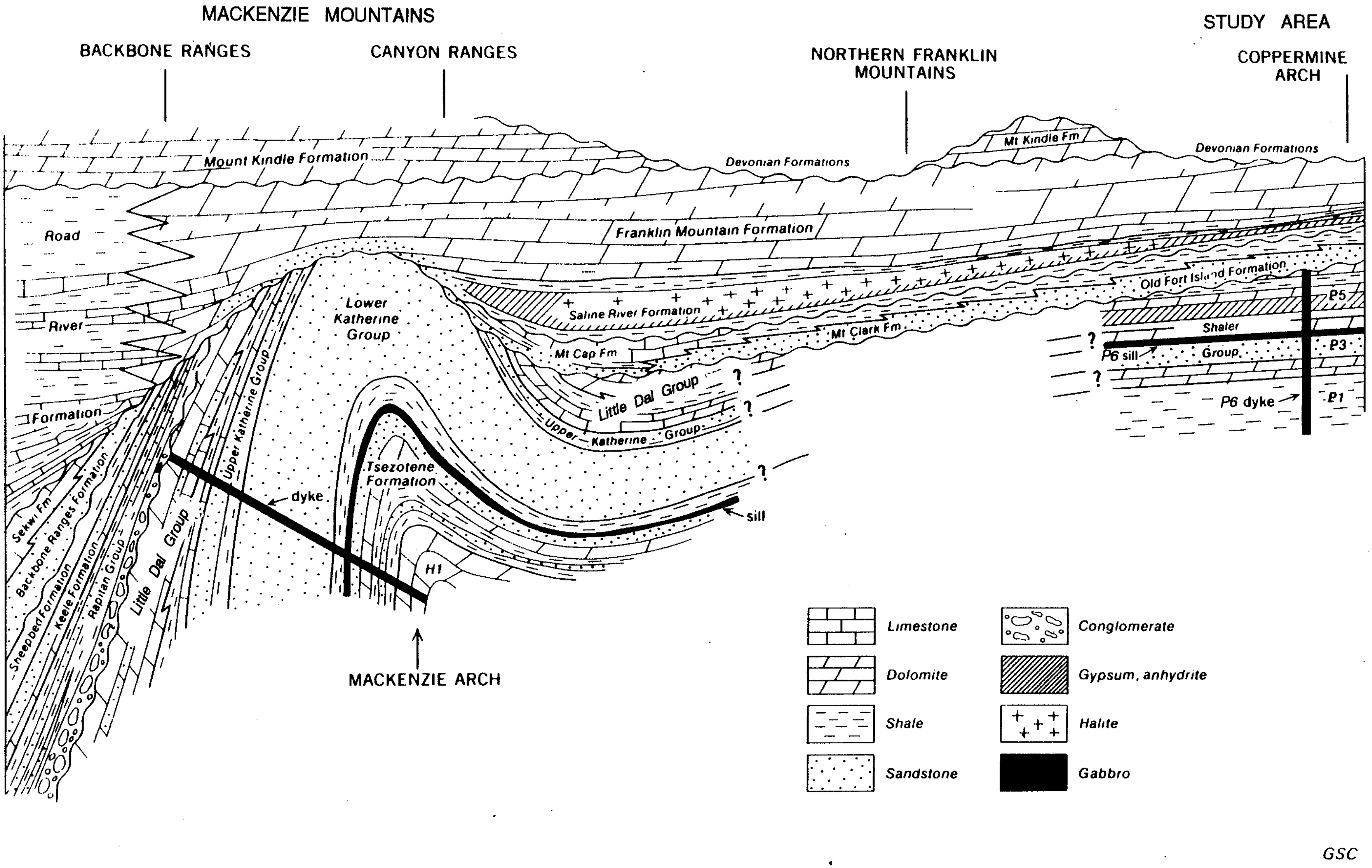

Figure 11. Diagrammatic restored stratigraphic cross-section, interior Mackenzie Mountains to Coppermine Arch (Brock Inlier) (modified from Figure 3 of Aitken et al., 1973). For location of Mackenzie Mountains and more detail on Proterozoic correlations, see Figure 6.

Early Paleozoic Mackenzie Platform Strata

The Paleozoic rocks of the Bluenose Lake area are grouped into a single structural-stratigraphic unit, the Mackenzie Platform succession (Table 7). Figure 11 is a cross-section from Mackenzie Mountains to the Brock Inlier, correlating Proterozoic and Lower Paleozoic strata.

The Cambrian to Devonian interval appears to have been characterized by a gradual but persistent marine transgression southward and eastward onto the Canadian Shield. Cambrian to Early Silurian strata include mixed carbonate and terrigenous clastic rocks deposited in a shallow marine environment which overlie fluvial deposits of the basal Mount Clark Formation. The appearance of *Skolithos* at the top of the Mount Clark Formation records the onset of marine conditions. Little record is preserved of major local tectonism altering the extent and configuration of the craton. A significant exception may be the local pinch-out of the Mount Clark Formation quartzarenite and subsequent onlap of the Mount Cap Formation and younger carbonate units in the eastern part of the Brock Inlier (e.g., the faulted area east of Hornaday Lake (figures 5, 7, 8). A disconformity is mapped at the base of the Mount Kindle Formation (Ordovician-Early Silurian), and another just below Middle Devonian carbonates of the Bear Rock Formation. The latter has local relief of 45 metres (150'; Balkwill and Yorath, 1971).

Paleozoic strata are eroded from most of the Brock Inlier; Cretaceous sandstones and conglomerates directly overlie the Precambrian at Wob River. The absence of Paleozoic units likely results from pre-Cretaceous erosion and subsequent overlap by basal Cretaceous clastic rocks.

Mount Clark (lCMC) and Old Fort Island (COFI) formations

The type Mount Clark Formation (Williams, 1923) is a series of quartzarenite units at the base of the Paleozoic in the Franklin Mountains. It is contiguous with the Old Fort Island Formation of Norris (1965) which was defined on the west and north shores of Great Bear Lake. The Old Fort Island Formation consists of friable, cross-bedded quartzarenite above an unconformity with up to 60 metres of paleo-relief (200', Cook and Aitken, 1969).

The Mount Clark Formation is exposed in a discontinuous band around the Brock Inlier; it is locally absent, for example, in the section between Clinton Point and Wob River. Isolated outliers unconformably overlying Shaler Group strata in the central portion of the Brock Inlier include previously unmapped outcrops immediately inland from House Point (91-JP-48-R). In the Hornaday River area the thickness is a relatively uniform 60 metres (200'), but it thins toward the northeast, and appears to be missing entirely near the coast west of Buchanan River.

In the study area the Mount Clark Formation is composed of friable, unidirectionally trough-cross-bedded quartzarenite and quartz siltstone, with common limonite. It includes conglomeratic beds; at one location a gossanous basal conglomerate consists of rounded vein quartz and shale chip clasts in a friable sandy matrix (samples 91-JP-104 to 106-R).

This unit is readily identifiable from aircraft as a soft textured cream/grey band, and has been used extensively as a photo-geologic marker. It is preserved in many places as isolated caps on Shaler Group sections.

The Mount Clark / Old Fort Island Formation is a blanket-like deposit, interpreted by Aitken et al.(1973) as part of a transgressing shallow water marine quartzarenite sheet laid down on Proterozoic basement during Lower and Middle Cambrian time. Our observations suggest that the initial deposits of this sand sheet were from a broad braided river plain; later deposits containing *Skolithos* were reworked in a gradually transgressing shallow marine environment.

Mount Cap Formation (mCMC)

The Mount Cap Formation was proposed by Williams (1923) to describe a sequence of green, limonitic thin-bedded sandstones and green, limonitic, fissile mudrocks outcropping on Cap Mountain southwest of Fort Norman on the Mackenzie (Dehcho) River.

In the Bluenose Lake area, the Formation consists of grey, green and red shales interbedded with glauconitic sandstone and siltstone that is extremely burrowed (Cook and Aitken, 1969), with orange-weathering dolomite at some locales (e.g., Wob River section). We found some outcrops which consist largely of interbedded light green dolomite and red and green fissile shale, as did Balkwill and Yorath (1971). The Formation is recessive; its best exposures are in or adjacent to downcutting streams.

The Mount Cap Formation is conformable with the underlying Mount Clark Formation (Aitken et al., 1973). Although it superficially resembles mudstones and dolomites of the Proterozoic Shaler Group (e.g. parts of units Hc,Hce), bioturbation and worm burrows indicate assignment to the Paleozoic (Figure 12). This information is particularly useful for mapping in areas where the Mount Clark Formation is absent; here the Mount Cap lies directly on Proterozoic strata with which it might be confused.

Aitken et al. (1973) measured a maximum thickness of 70 metres (230') in the Erly Lake area. Cook and Aitken (1969) suggested the Formation is relatively uniform in thickness.

Table 7. Paleozoic stratigraphy, Mackenzie Platform.

FORMATION		MEMBER	THICKNESS	LITHOLOGY	COLOUR	SPECIFIC FEATURES	ENVIRONMENT
Hume Formation	**D H**	- -	80-135 m	argillaceous limestone, shale	brown to medium to dark grey	fossiliferous (calcarenite, biosparite), thin bedded, nodular, rubbly outcrop	marine shelf
Bear Rock Formation	**D BR**	- -	80-245 m	dolostone, shale, gypsiferous dolostone breccia	buff to grey dolomite; pale green, maroon shale	overlies disconformity (relief to 45 m), recent and pre-Cret. karst, bituminous, basal chert pebbles and shale, brecciation in gypsiferous lower portion, upper portion dolarenite	shallow restricted circulation marine shelf
Mount Kindle Formation	**OSc**	- -	0-?753 m	dolostone, minor limestone	brown to medium to dark grey	thick bedded, abundant chert nodules, vuggy porosity (+- bitumen), silicified fauna	marine shelf
Franklin Mountain Formation	**O FM**	upper	120-345 m	cherty dolostone, chert	light to medium grey, buff	cherty: as beds, replacing stromatolites; drusy quartz + coarse dolomite in coarse vugs	marine shelf
	CO FM m	middle	150-215 m	alternating fine/coarse dolostone	pale brown, grey, grey orange	banded appearance, fine vuggy porosity	marine shelf
	C FM	lower	19-44 m	dolostone with shaly partings	pale yellow weathering, shale green	fine laminations, intraclasts, stromatolites, oolites, fine shale partings	marine shelf
Saline River Formation	**C SR**	- -	60+ m	shale, gypsum, halite	pale red + green	mud cracks, salt casts, halite in subsurface only, recessively weathering	very shallow marine
Mount Cap Formation	**mC MC**	- -	70 m	shale, glauconitic sand/siltstone, dolomite	red, green shale; green, orange dolomite	bioturbation, worm burrows	near-shore shallow marine
Mount Clark Formation, Old Fort Island Formation	**IC MC, C OFI**	- -	0-60 m	quartzarenite, siltstone, conglomerate	white, limonitic staining	friable, coarsely crossbedded	beach, shallow marine

Information in table derived from Aitken et al. (1973), Balkwill & Yorath (1970), Balkwill & Yorath (1971), Cook & Aitken (1969), Cook & Aitken (1971), Yorath et al. (1975), and personal observation. For ages of units see Table 4.

Figure 12. Burrowed saccharoidal orange and tan dolostone interpreted to be Mount Cap Formation (mCMC). Slab (about 25 cm in diameter) from talus on the Wob River about 8.5 km upstream from sample 90-JP-009-H,S.

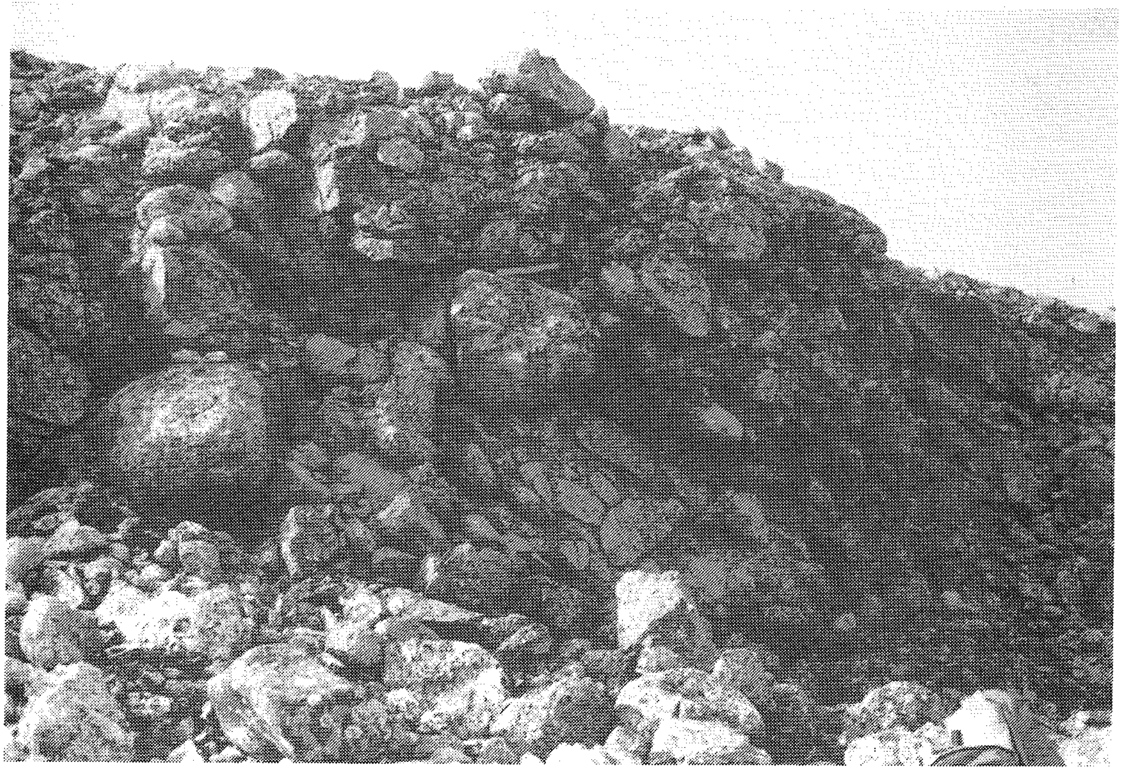

Figure 13. Poorly sorted Mesozoic boulder conglomerate found in isolated outcrop on Paleozoic basement, adjacent to a fault. Located several kilometres northeast of Hornaday Lake, on east side of Brock Inlier (Figure 7). Boulders are mostly tan-weathering Paleozoic carbonate of local derivation. Hammer handle approximately 35 cm long.

The Mount Cap Formation outcrops around the perimeter of the Brock Inlier, and in the extreme southeast of the study area. Some outcrops, in the area between Wob River and Tysoe Point, were previously considered to be Shaler Group but are here reassigned to the Mount Cap Formation on the basis of trace fossils (bioturbation) (see Figure 5, compare with Balkwill and Yorath, 1971, Map 13-1970).

The Mount Cap Formation was interpreted by Aitken et al. (1973) as a shallow water marine deposit, formed as part of a Middle Cambrian transgression over a surface of little relief. Aitken et al. suggested (1973, p. 38) that the presence of only a few carbonate beds indicates a relatively near-shore origin. A relative increase in the proportion of dolomitic material in the Wob River area suggests a decrease in the supply of terrigenous sediment at that time.

Saline River Formation (CSR)

The Saline River Formation was defined by Williams (1923) as a series of red and green shales with salt casts and subordinate gypsum, in its type section at the confluence of the Saline and Mackenzie (Dehcho) rivers.

In the study area the Saline River Formation is 30-60 metres (100'-200') thick (Aitken et al., 1973, p. 30); Cook and Aitken (1969); the unit is 60 metres (195') thick on the Little Hornaday River and appears to vary little in thickness. The Formation outcrops in a band surrounding the Brock Inlier; this band is quite broad between Brock Inlier and the next exposures of Proterozoic strata to the southeast (Rae and Coppermine River groups).

The Saline River Formation consists of recessively weathering red and green papery shale interbedded with light grey-green and greenish buff, very finely crystalline platy dolomite (Aitken et al., 1973). We observed fine mudcracks and salt casts in outcrop, however this Formation weathers recessively, and in most places the only exposure is red and green shale chips in frost boils.

Aitken et al. (1973) interpreted the Saline River Formation to record shallow partly discontinuous depressions developed on the sub-Upper Cambrian erosional surface. Salt casts and mudcracks indicate periodic desiccation.

D.G. Cook and J.D. Aitken have noted (in Yorath et al., 1975, p. 73) that the Saline River Formation elsewhere has been a décollement along which thrust faults have propagated.

Franklin Mountain Formation (CFM, COFMm, OFM)

Cambro-Ordovician carbonates overlying the Saline River Formation were first mapped as Ronning Group, in the late 1960's by geologists of Operation Norman; this Group included (from the base up) a 'cyclic', 'rhythmic', and 'cherty' unit, plus the Mount Kindle Formation. Present usage is Lower, Middle and Upper Members, Franklin Mountain Formation; plus Mount Kindle Formation.

The lower member of the Franklin Mountain Formation is 19-44 metres (63-145') thick (Balkwill and Yorath, 1971; Cook and Aitken, 1969). It comprises cyclic repetitions of dense, laminated, oolitic, conglomeratic and stromatolitic dolomite beds; the cyclic thin beds and partings of green dolomitic shale readily distinguishes this unit from the overlying middle member.

The middle member of the Franklin Mountain Formation is approximately 150 metres (500') thick in the Hornaday River canyon (Balkwill and Yorath, 1971) thickenning to 216 metres (710') in the subsurface just west of Franklin Bay (Yorath et al., 1975). It includes thick beds of pale brownish-grey coarsely crystalline dolomite, commonly with vuggy porosity; alternating with greyish-orange very finely crystalline, in part laminated dolomite (Cook and Aitken, 1969). Mudstone partings are absent.

The upper member of the Franklin Mountain Formation is approximately 400' (120 metres) thick in the Hornaday/Brock River area (Balkwill and Yorath, 1971) and 1130' (345 metres) in the subsurface west of Franklin Bay (Yorath et al., 1975). The member consists of grey to buff dolomite with abundant quantities of bedded and nodular chert, typically replacing stromatolites. Both drusy quartz and coarse dolomite are common, lining coarse vugs.

Much of the area to the southwest and southeast of the Brock Inlier is underlain by dolomite belonging to one of the above units. Previous mappers were able to assign most outcrops to specific members, but in some parts of the study area this was not possible (i.e., most of the area east of Hornaday Lake). This is partly due to lack of good outcrop, and partly because the mapping was reconnaissance. Where new outcrops were found (east of Hornaday Lake: area marked Provisional Mapping on Figure 5), we attempted to assign each outcrop to one of the sub-members of the Franklin Mountain Formation, based on comparison with the above-cited literature descriptions, but our identification in several places is tentative. Figure 5 reflects minor changes in map pattern based on these new data.

The Franklin Mountain Formation was deposited in a stable marine shelf environment.

Mount Kindle Formation Equivalent (OSc)

The Mount Kindle Formation conformably overlies the Franklin Mountain Formation; in parts of southern Mackenzie Mountains the the Formation lies directly on Precambrian basement (Christie et al., 1972). It does not outcrop in the study area, except the equivalent (OSc) was compiled by Okulitch (1991) in the southwest corner

(Figure 5); it was apparently removed to the east by pre-Devonian erosion. In the western part of the study area the Mount Kindle Formation is 753 metres (2470') thick in Elf Horton River well G-02, west of Franklin Bay (Yorath et al., 1975).

The Mount Kindle Formation consists of brownish grey to medium grey, finely crystalline, very thick-bedded, resistant dolomites characterized by beds containing abundant nodules of light grey to white chert and a silicified Late Ordovician to Early Silurian fauna (Cook and Aitken, 1969). Widspread vuggy porosity locally contains solid hydrocarbons. The dolomites are variably argillaceous and glauconite is present near the base of the Formation (Yorath et al., 1975).

The Mount Kindle Formation, which we did not observe in outcrop, is fossiliferous (see measured sections by Cook and Aitken, 1971); it records deposition on a shallow marine shelf.

Bear Rock Formation (DBR)

The Devonian Bear Rock Formation unconformably overlies the Mount Kindle and Franklin Mountain Formations; local paleo-relief ranges to 45 metres (150', Balkwill and Yorath, 1971). The unit is composed of pale brown, laminated to thick-bedded dolomite, pale grey pelletal limestone, and gypsum (Cook and Aitken, 1971). The lower portion is the most gypsifrous, and is commonly brecciated. Karst development on the unit during the Cretaceous and at present is suggested by similar breccias located below Cretaceous rocks and at surface. The Bear Rock Formation is as thick as 80 to 245 metres to the immediate southwest and west, but has been removed from most of the study area by pre-Cretaceous erosion.

In the canyon of the lower Hornaday River the Bear Rock Formation consists of fine to very fine grained crystalline limestone, with coarse fenestral porosity. Vugs contain dolomite, calcite and bitumen. Mud cracks and calcarenite are present locally.

The Bear Rock Formation represents deposition on a restricted shallow marine shelf.

Hume Formation (DH)

A large outcrop of the Devonian Hume Formation caps a fault bounded slice east of Hornaday Lake (figures 5; easternmost DH in Figure 7). It consists of coral-fragment and stromatolite conglomerate, with minor shales (Cook and Aitken, 1969). A.H. Pedder advised (personal communication, 1991) that whereas the Formation here is lithologically similar to the Hume Formation elsewhere, its age corresponds to the younger Hare Indian Formation.

Work by this study suggests that the Devonian strata extend farther south. Preliminary analysis by P. Copper (personal communication, 1992) of abundantly fossiliferous samples collected from site T115 approximately 8 km southeast of the above location (southern DH, Figure 7) suggests a Devonian age. Fossils include *Favosites*, stromatoporoids and amphiporoids. One amhiporoid is enveloped by about 1 cm of a fossil green algae, typical of the Devonian and rare in the Silurian. Copper interpreted the samples as lagoonal facies, most likely Late Early to Middle Devonian. Site T115 is in the core of a tight syncline, and the further distribution of Devonian rocks is unknown.

The Hume Formation is 79 metres (260') thick in the Elf Horton River G-02 well, west of Franklin Bay. It records deposition on a moderate-to-high-energy marine carbonate shelf.

Cretaceous Anderson Basin Strata

Cretaceous strata of the Anderson Basin rest with a marked unconformity on Proterozoic to Devonian strata (Yorath et al., 1975).

The following description of strata in the Anderson Basin, mainly derived from Yorath and Cook (1981), is summarized in Table 8 and Figure 14. At the beginning of the Cretaceous Period the study area was probably a broad, low relief landmass. Deposition of the nonmarine Gilmore Lake Member of the Langton Bay Formation began in Aptian time. On the Brock Inlier this member is represented by locally preserved coarse conglomerate. Toward the northwest the Gilmore Lake Member comprises fluvial to marine sandstones.

In the early and middle Albian, transgression led to deposition of mudstones of the upper Crossley Lakes Member of the Langton Bay Formation, and of the Horton River Formation. According to Yorath and Cook (1981) this was followed by regression, then late Coniacian marine transgression recorded by deposition of pyritic shales, the Smoking Hills Formation. Maastrichtian (late Cretaceous) marine regression caused deposition of the Mason River Formation shales.

Post-Cretaceous erosion has removed what may have been a continuous cover of Cretaceous strata over the central portion of the Brock Inlier, and as far east as Croker River and Bluenose Lake.

Langton Bay Formation (KLB)

This name was assigned by Yorath et al. (1975) to a series of sandstones which grade upward to siltstone and mudstone and lie unconformably on Paleozoic and Proterozoic rocks. (Yorath and Cook, 1981) established a composite type section along the Horton River and divided the Formation into the lower, Gilmore Lake Member and the upper, Crossley Lakes Member.

Table 8. Mesozoic (Anderson Basin), Tertiary (Arctic Coastal Plain), and Quaternary stratigraphy.

FORMATION	MEMBER	THICKNESS	LITHOLOGY	COLOUR	SPECIFIC FEATURES	ENVIRONMENT
[Quaternary alluvium]	--	variable	unconsolidated gravel, sand, silt, clay	--	discontinuous	floodplain, delta
[Quaternary moraine]	--	variable	unconsolidated till, sand, gravel	--	discontinuous, Wisconsinan-age missing in central portion area of interest	morainal, fluvio-glacial
BEAUFORT	--	3 m	unconsolidated gravel, sand	--	quartz, carbonate, chert pebbles, wood, humic material	fluvial
HORTON RIVER	--	150-235 m		black	soft, plastic, with ironstone concretions	epeiric marine
LANGTON BAY	Crossley Lakes	122-226 m	mudstone, siltstone, sandstone, coquina	medium, & dark grey	silty carbonate concretions, locally bituminous, woody material, coaly lenses	shallow marine
	Gilmore Lake	0-198 m	sandstone, coal	white, buff, black	poorly consolidated, crossbedded, marcasite nodules, locally coarsely conglomeratic, patchy distribution	local sub-aerial

Information in table derived from Yorath et al (1975), Yorath & Cook(1981), and personal observation.
For ages of units see Table 4.

The Gilmore Lake Member is extremely variable in thickness, patchy in distribution. It is 67 metres thick at the type section, but is absent in places under the Crossley Lakes Member (Yorath and Cook, 1981). In the Bluenose Lake area it is semicontinuous west of the lower Hornaday River, and forms outliers at the mouth of the Brock River, immediately south of Pearce Point, along the Wob River, and in a series from Hornaday Lake northnortheastward to the coast near Tinney Point. It consists variably of friable white sandstone, lignite, and chert or silicified limestone cobble and/or boulder conglomerate (Figure 13).

Yorath and Cook (1981) interpreted the Gilmore Lake Member as local terrestrial sediment derived from a source area (Coppermine Arch) which coincides with the present day Brock Inlier. Northeast of Hornaday Lake (figures 7, 13) a limestone boulder conglomerate is adjacent to a major southeasttrending fault, which suggests active normal faulting of the Brock inlier area during the Cretaceous.

The Crossley Lakes Member of the Langton Bay Formation is a interpreted as a shallow marine mudstone with intercalated sandstone and siltstone (Yorath and Cook, 1981). It is 122 metres thick in a well on the west side of Franklin Bay (west of the study area). We did not examine this unit in outcrop.

Horton River Formation (KHR)

This name was assigned by Yorath et al. (1975) to a bentonitic zone. The Formation consists of black shales with ironstone concretions, weathers recessively, and ranges in thickness from about 150 to greater than 235 metres (Yorath and Cook, 1981, p.15). It is exposed locally to the north and west of the mouth of the Hornaday River.

The Horton River Formation was deposited in an epeiric sea, although the extent of the marine transgression is unknown. Yorath and Cook (1981, p. 44, Figure 32) suggested that the Horton River Formation was deposited across the entire Brock Inlier and that postCretaceous erosion has led to its removal. They suggested that the lack of coarse clastic strata in the Horton River Formation indicates that the central Brock Inlier (Coppermine Arch) was not exposed during the Cretaceous. We observed finely laminated soft mudstone of Cretaceous aspect in heaved outcrop near Tinney Point on the northeast side of the Brock Inlier, supporting this inference.

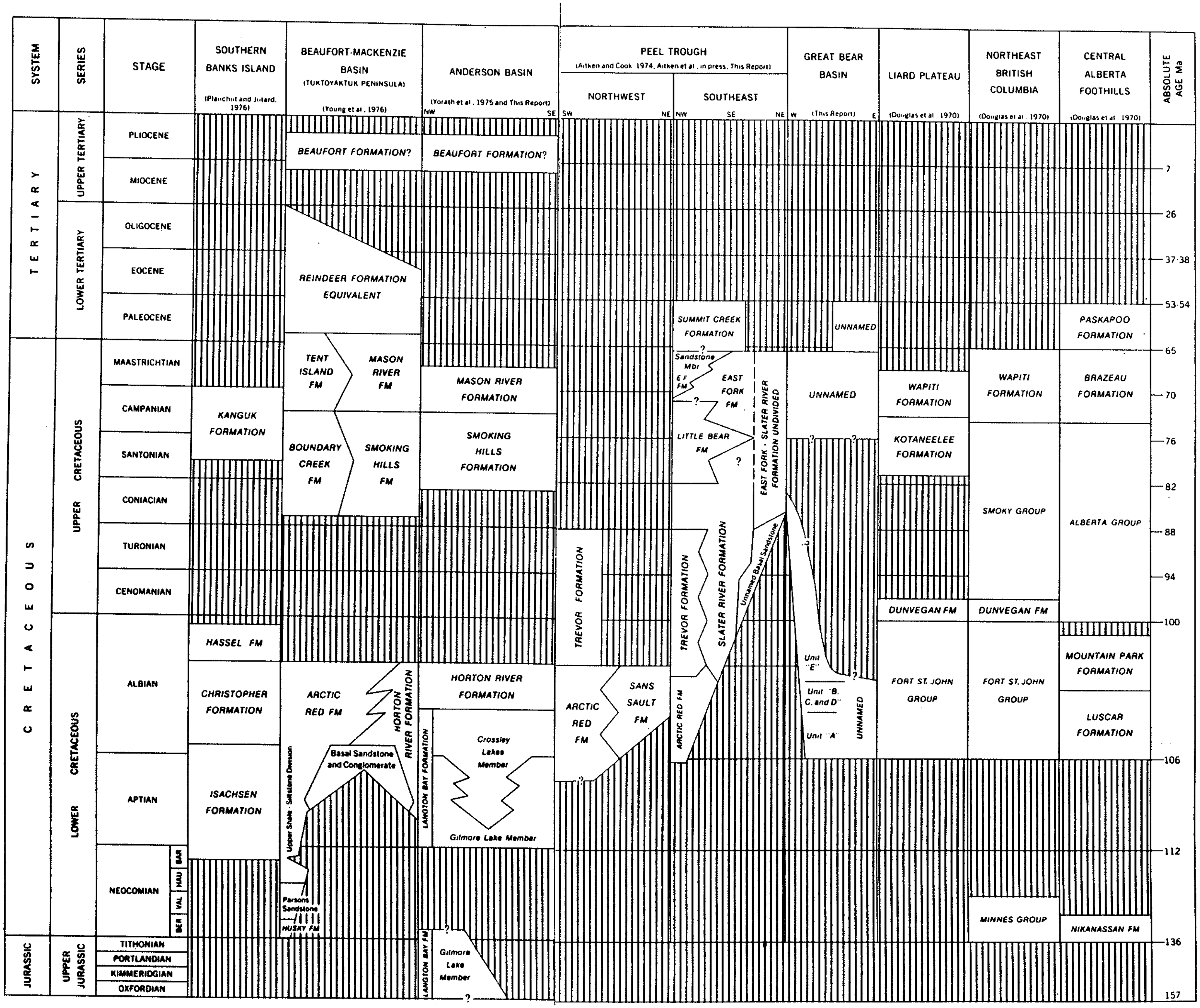

Figure 14. Regional correlation chart, Upper Jurassic to Upper Tertiary, Northern Interior Plains; from Yorath and Cook (1981).

Tertiary Strata of the Arctic Coastal Plain

Unconsolidated fluvial sediments constitute a thin (2.43 metres) discontinuous veneer which was deposited on preexisting strata during the late Miocene and early Pliocene, in the Franklin Bay / Malloch Hill map area, west of Paulatuk (NTS 97C, F), by a stream system which drained to the northwest (Yorath et al., 1975).

Beaufort Formation (mTNB)

Unconsolidated fluvial sands and gravels are exposed on each side of the lower Horton River and may extend eastward, but have not yet been found in the study area. If present, they could be masked by Quaternary alluvium and till. This unconsolidated material is thought to correlate with the Beaufort Formation on Banks Island, which records subaerial transport and deposition across the now Amundsen Gulf during the Tertiary (Yorath and Cook, 1981, p. 45).

Quaternary Deposits (TQs)

Quaternary Till, Moraine and Fluvioglacial Deposits

Quaternary sediments blanket much of the perimeter of the study area (figures 1, 5, 15). The most prominent exposures are in a 2540 kmwide belt trending parallel to the coast, located 1025 km inland between the mouth of the Hornaday River and Buchanan River. This belt is characterized by hilly topography and is termed the Melville Hills Morainic Belt. In the headwaters of Buchanan River the belt of prominent morainal deposits curves southward and extends along the west side of Bluenose Lake, where it has been mapped in detail (St-Onge and McMartin (1987; McMartin and St-Onge, 1990). The morainal belt includes glacial till in moraines and drumlins, numerous kettle lakes, as well as fluvioglacial outwash deposits which include some gravel (Klassen, 1971). Giant kames are located at the south end of Bluenose Lake. A pingo is located on the coast near Tinney Point, and several others are inland (Figure 15).

Extensive glacial deposits of more subtle topographic expression wrap completely around the Brock Inlier, and represent the limit of Wisconsin glaciation (St-Onge and McMartin, 1987; McMartin and St-Onge, 1990; Klassen, 1971). In the central Brock Inlier most of the uplands appears to have escaped glaciation during the Wisconsin glacial advance (Figure 15), although low mounds of till and scattered glacial erratics testify to complete glaciation at an earlier time. The unglaciated area is bounded approximately on the south and west by the Hornaday River. North of the Melville Hills Morainic Belt the flatter coastlands are partly covered by thinner glacial drift, dominated by drumlin land forms.

Continental ice flow in the region around the study area was from the southeast to northwest. The Brock Inlier formed a buttress against which the Laurentide ice sheet repeatedly shoved terminal moraines over each other, preserving ice between interpreted thrusts of till (McMartin and St-Onge, 1990). The recently exposed ice is melting rapidly.

Wisconsin ice flow was split into two streams which flowed around the Brock Inlier topographic high toward the northwest and southwest. The Melville Hills Morainal Belt represents the southern margin of the northern ice stream. Drumlins mapped by Klassen (1971) show that ice flowed around the Brock Inlier and curved toward the west and southwest in the area of Paulatuk. The topographic expression of subglacial and ice-marginal deposits south of Brock Inlier is much more subtle, but includes drumlins, perched fluvioglacial outwash deltas, roches moutonnées, and striated outcrop surfaces.

Glacial Refugium

As noted above, the central portion of the Brock Inlier was apparently not glaciated during the last ice age (Figure 15); it appears to have served as a refugium for various plant species (G. Scotter, personal communication, 1990). Wood lying loose on the beach on Hornaday Lake has been dated at >40,000 b.p. and includes white pine which indicates a climate similar to that of southeastern Canada (S. Zoltai, personal communication, 1991), indicating preservation from at least the interglacial period immediately preceding Wisconsinan glaciation. The first author discovered that the wood is being eroded from low banks of till along the eastern shore of Hornaday Lake.

Recent Alluvium

Post-Quaternary alluvium consisting of sand and gravel is concentrated in the narrow floodplains of major streams (Balkwill and Yorath, 1971; Klassen, 1971). Major deltas are currently being constructed at the mouths of Hornaday and Brock Rivers.

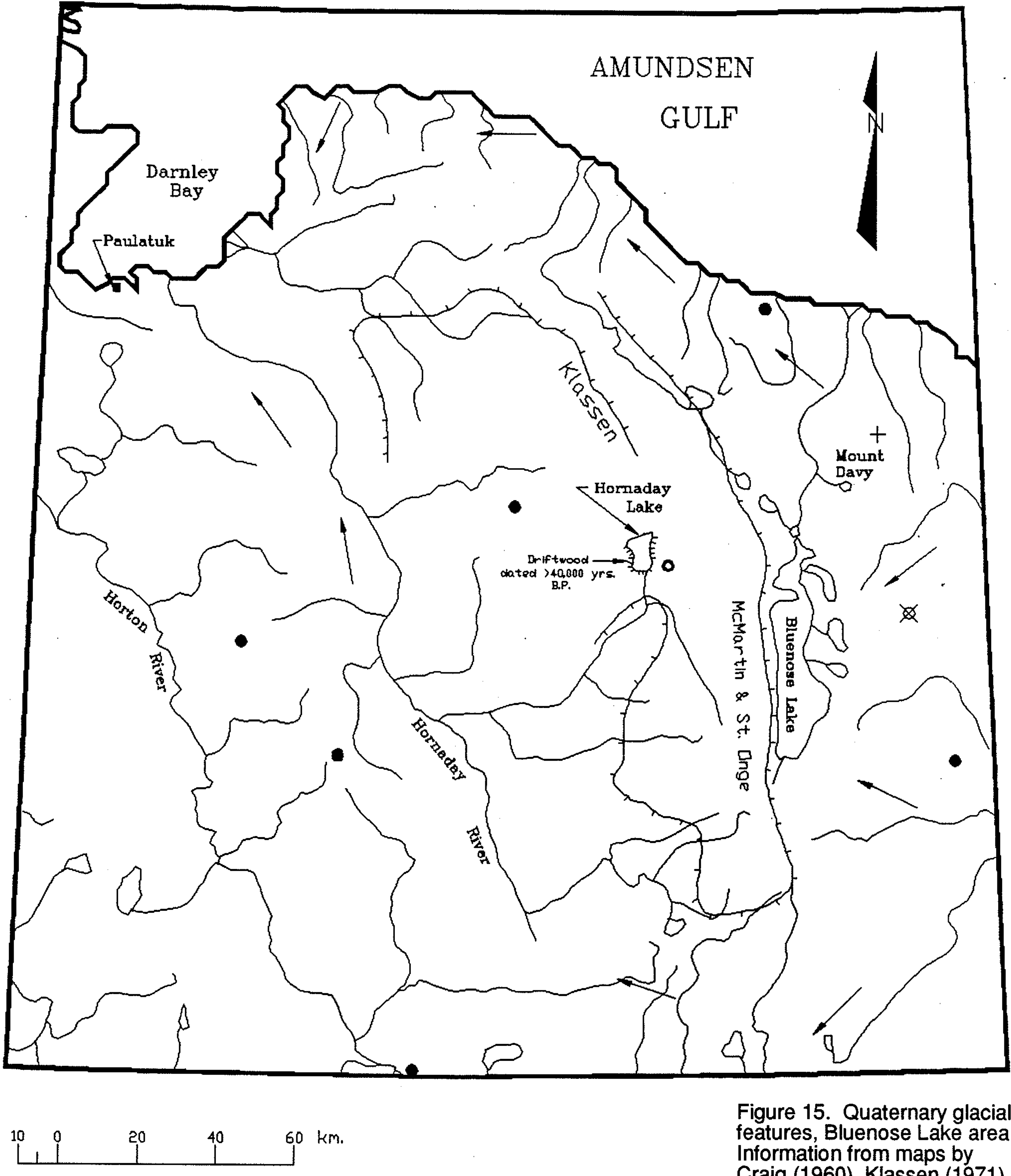

Figure 15. Quaternary glacial features, Bluenose Lake area. Information from maps by Craig (1960), Klassen (1971), McMartin & St-Onge (1990), and personal observations by the authors.

—┴—┴—┴—┴— Limit of Late Wisconsin glaciation, Hachure on ice side (after McMartin and St-Onge, 1990, and Klassen, 1971)

● Pingo

○ Coal in fluvioglacial outwash

⊗ Buried glacial ice exposed in slumped bank

← Wisconsin ice flow from landforms

⬠ Location of wood debris, several samples of which are more than 40,000 years old

Geological History and Structural Evolution of the Study Area

The following synopsis is after Cook and Aitken (1969), supplemented by personal observations by the first and second authors (see also Jefferson and Jones, 1991).

Proterozoic sedimentary strata of the Shaler Group appear to be generally conformable and continuous in the Brock Inlier. Cook and Aitken (1969) inferred that locally thinner sections of unit Hc (P4) in fault bounded blocks indicate faulting prior to the deposition of unit Hce (P5). Our observations suggest that the thinner sections may be a result of measuring different parts of Unit Hc, which we now know contains four mappable members. We consider that the transition from Hc to Hce is everywhere conformable and gradational. No sedimentary evidence (e.g., conglomerates, breccias, angular discordances) is present to support differential uplift. We reinterpret the faults referred to by Cook and Aitken (1969) as being first developed in latest Proterozoic or Paleozoic time.

The Proterozoic sequence was regionally uplifted, folded gently along a northwest-southeast axis and subjected to erosion during latest Precambrian time. Progressively older rocks were exposed to the northwest in the core of the Inlier. Remnants of the youngest Proterozoic strata, Hce, are now preserved in a gentle southerly plunging regional syncline which crosses the Little Hornaday River and is bevelled by basal Cambrian strata from east to west.

The Cambrian depositional sequence, in the study and adjoining areas, is generally continuous. Over most of the study area the basal Cambrian unit is the Mount Clark Formation, but locally the oldest Cambrian unit is the Mount Cap, Saline River or Franklin Mountain formation, as noted above. With these exceptions, the absence of facies changes suggests that the Coppermine Arch was not yet a major feature in the Cambrian. Faulting and folding of the lower Paleozoic succession is, therefore, mainly post-Cambrian.

The late Cambrian through Early Silurian sequence also tends to be laterally unbroken and generally covers older strata of the study area. One exception is the onlap unconformity below the Cambro-Ordovician Franklin Mountain Formation, which is exposed in the fold-thrust belt east of Hornaday Lake (figures 7, 8). This indicates that some uplift along that belt took place during the late Cambrian.

Another exception to uniform Paleozoic stratigraphy is the disconformity at the base of the Early Silurian Mount Kindle Formation. The general absence of the Late Ordovician and Early Silurian Mount Kindle Formation beneath Middle Devonian strata confirms the existence of a sub-Middle Devonian unconformity that is well documented in map areas to the southwest, and suggests pre-Middle Devonian (Caledonian?) tectonism causing incipient uplift of the Coppermine Arch.

The rare Devonian outliers southeast of Hornaday Lake which record shallow marine deposition suggest that the Brock Inlier was a subdued platformal area at this time.

Basal Cretaceous Formations are unconformable on older strata, and appear to be restricted to sub-Cretaceous topographic 'lows', especially near steep faults (figures 7, 13).

The sub-Cretaceous unconformity, as documented mainly in the region to the west, records gentle northwestward regional tilting followed by erosional bevelling that resulted in the subsequent deposition of Cretaceous strata lying upon successively older formations toward the core of the Brock Inlier. The youngest tectonic movements in the region as identified by Cook and Aitken (1969) are indicated by basal Cretaceous strata that are involved in compressional structures in the Colville Hills southwest of the map area. Regional uplift and erosion of the Coppermine Arch to form the Brock Inlier is mainly post-Middle Devonian. Much of the uplift probably postdated deposition of the Cretaceous strata of the area.

Present-day structures may be the result of movement during one or more of at least four tectonic episodes (Figure 16). Most folds and many faults trend parallel to the axis of the Coppermine Arch. A less prominent set of kink-style folds and few faults trends at right angles to the arch (Figure 17).

Interpretation of fault mechanisms from the shapes of folds and from stratigraphic offsets is required because the the fault planes are rarely exposed. The northwesterly trending faults of greatest displacement were interpreted by Cook and Aitken (1969) as reverse because of their close association with folds that indicate compression, and because of the well documented reverse fault near the head of Little Hornaday River.

The northeasterly faults and many of the northwesterly faults were considered by Cook and Aitken (1969) to have normal offset because of their almost vertical dips as inferred from straight surface traces.

Our detailed mapping of the area east of Hornaday Lake (Figure 7) has corroborated the above interpretations. A reverse, or thrust fault is interpreted for one major northwest trending fault which was previously mapped by Cook and Aitken (1969). On the southwest side and at the base of a line of rounded hills, a westward-directed thrust or high-angle reverse fault juxtaposes Hq-Hc on vertical, west-facing Cambrian to Ordovician strata. This is here named the Hornaday Lake Fault.

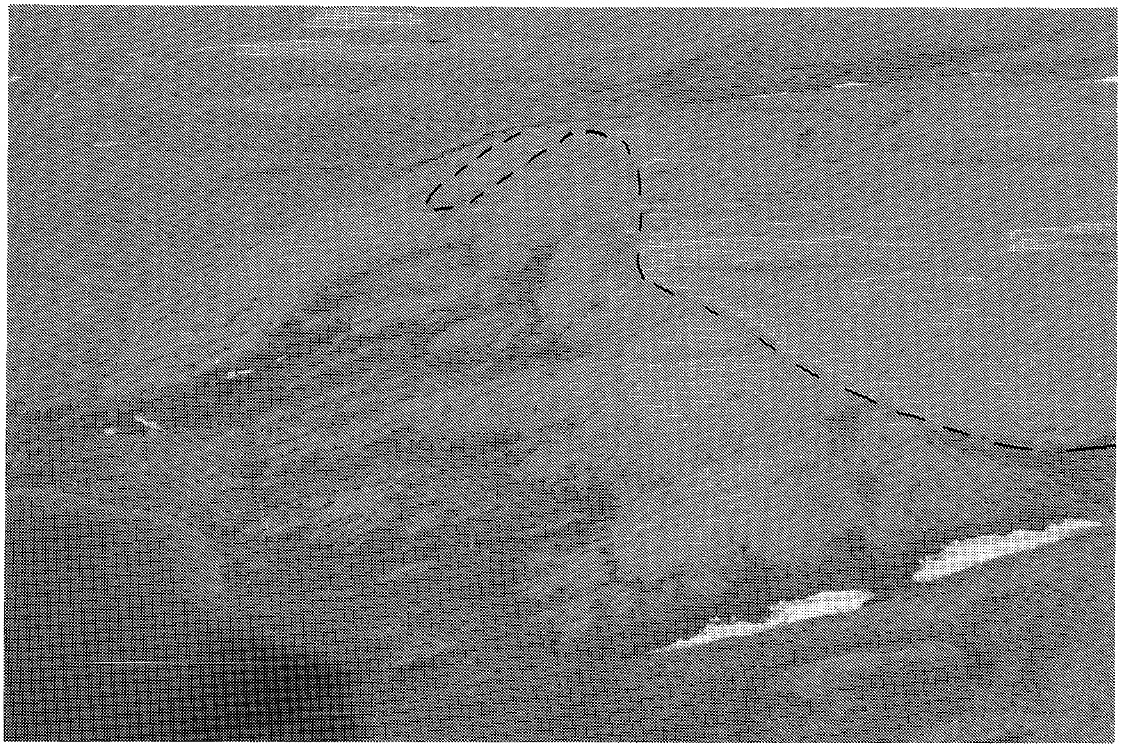

Figure 16. View looking northwest at folded unconformity between Proterozoic dolostones (P4c+d) below and Ordovician Franklin Mountain Formation above. The Proterozoic rocks are thrust westward over Paleozoic strata. Lake in foreground is shown by asterisk on Figure 7. Width of view in mid-ground is about 3 km.

Figure 17. Folded Proterozoic strata in the Brock River canyon. Beds on ridge in middle distance dip 24° westward at extreme left (south) of photo, but steepen to 45° in center of photo at base of clouds. Strata are cherty dolostones belonging to unit Hct of the Shaler Group. Photo taken 25 km from mouth of Brock River. Weathering is typical of canyon. Note glacial erratic on spur in middle distance. Canyon is 150 m deep at this location.

Above the Proterozoic strata, the fault panel carries an east-to-west onlap unconformity on which the Franklin Mountain Formation rests successively on early Cambrian to Proterozoic (Hc) strata. The sub-Franklin Mountain Formation unconformity is folded along northwesterly axes (Figures 7, 16).

The Hornaday Lake Fault trends about 320° into a till-covered area in the northern part of Brock Inlier, but is replaced to the south by a series of tight to open 130° to 150° trending folds in Paleozoic rocks. The change from fault to folds takes place across a distinct northeast-trending vertical fault which had also been mapped by Cook and Aitken (1969).

The Hornaday Lake and nearby thrust/reverse faults were therefore active during late Cambrian time. A similar reverse fault affects strata of units Hq and Hc from Brock River Canyon south to the Little Hornaday River. This fault (here termed the Brock River Fault) was also mapped by Cook and Aitken (1969) who interpreted that it was active during deposition of unit P4 (Hc) because different thickness of that unit are preserved on each side of it. We believe that the Brock River Fault was not active until the latest Proterozoic or later for the following reasons.

As noted in the earlier description of Proterozoic stratigraphy, map-unit Hc (P4) comprises four members. On the west side of the Brock River fault, only the lowest member (the orange stromatolite) is preserved. On the east side three members are preserved: the orange stromatolite, the clastic member and the carbonate member characterized by oolitic grainstones. The thickness of the lowest member is similar on both sides of the fault. These are the youngest Proterozoic strata; the carbonate-evaporite unit (Hce / P5) is not present as mapped by Cook and Aitken (1969). The Brock River Fault also offsets Paleozoic strata in a similar way to the Hornaday Lake Fault.

Some other northwest trending faults are more difficult to interpret. In the faulted section immediately east of Hornaday Lake, we observed numerous southeasterly trending normal faults which cut obliquely across the Hornaday Lake Fault. The oblique faults have throws from 100's to 1000's of metres. Northeast of Hornaday Lake a slim rectangular fault block of P4 (Hc) is juxtaposed against Cambrian to Ordovician strata on the northeast and southwest by southeast-trending normal faults. Patches of conglomerate, interpreted as the Cretaceous Gilmore Lake Formation, are dominated by coarse clasts of local origin, adjacent to some of the normal faults. These normal faults, coupled with the conglomerates, indicate that extension followed compression along the same north-northwest zones of weakness.

Asymmetric folds (west limb dipping to 45° southwest, east limb dipping 5°-10° to the northeast) were observed at a number of locations on both sides of the Inlier (e.g., Figure 17). These have similar trends to the Hornaday Lake and Brock River faults and corroborate compressional movement.

Open east-west folds which intersect the northwesterly folds have produced dome-and-basin patterns both in Proterozoic and in overlying Paleozoic strata; these patterns were observed south and east of Hornaday Lake, along the Little Hornaday River.

GEOCHEMISTRY

Three types of reconnaissance geochemistry were done for resource evaluation of the study area.

1. Rock samples were collected for analysis at most outcrops visited.

2. Bulk stream sediment samples were taken from 32 major (first order) watersheds. The samples were processed into a Heavy Mineral Concentrate (HMC) and a -80 mesh silt fraction.

3. Silt samples only were collected from second and third order streams in detailed surveys of three first order watersheds identified as targets for specific mineral deposit types.

Bedrock Lithogeochemistry

Over 130 rock samples were collected from the >150 outcrops investigated during two seasons of field work (tables 9, 10, 11; Figure 18; Appendix I). We collected representative rock type samples from most formations, and grab samples of all veins and sulphide minerals observed.

112 rock samples were crushed, milled, and dissolved by aqua regia, followed by multi-element inductively coupled plasma analysis. 20 samples considered prospective for gold, platinum group elements, or uranium were analyzed by neutron activation and/or fire assay followed by direct current plasma emission spectroscopy. All samples were analyzed for at least 23 and as many as 27 elements (Appendix I).

Analytical results of the rock samples were difficult to interpret for several reasons. There are too few samples, from too great a diversity of rock types, for statistical analysis to be a useful tool. In addition, we were looking for geochemical indications (possibly quite subtle) of many different mineral deposit models (Table 3).

For those samples which showed little or no evidence of base or precious metals, and did not include veins, we relied on a detailed table of the range of mean values for common trace elements

Table 9. Summary of elevated and anomalous geochemical results, representative rock samples.

SAMPLE #	FORMATION SYMBOL	MATERIAL SAMPLED	COLOUR ANOMALY	ELEVATED RESULTS (* = considered anomalous)		COMMENTS
90-JP-33-R	H b	diabase dyke + vein	red coating	Ag 0.4 ppm, Au 6 ppb, Cu 273 ppm, Li 17 ppm, Pd 25 ppb[b]		quartz veining with bright red stain
90-JP-34-R	H ce	green mudstone	–	Pb 181 ppm	*	loose block from above dyke 33-R
90-JP-38-R	K LB	sandstone	limonite concretion	Ag 0.5 ppm, As 4.0 ppm, Co 106 ppm, Ni 82 ppm, Zn 56 ppm	*	reduction zone in sandstone ?
90-JP-48-R	IC MC	green shale	--	Cu 831 ppm, U 6.3 ppm	*	2-3 cm shale interlayer in friable ss.
90-JP-53-R	C SR ?	brown carbonate	--	As 5.0 ppm, Be 2.3 ppm[a]		ripple marks
90-JP-54-R	und. Mes.	conglomerate	--	As 8.0 ppm[a]		chert pebble congl., carbonate matrix
90-JP-64-R	H b	olivine diabase	--	Cu 158 ppm, Li 17 ppm, Sb 5.0 ppm[b]		no sulphides; typical diabase
90-JP-65-R	H p	chert nodule	--	Ag 0.6 ppm		nodule in laminated shale, siltstone
90-JP-69-R	unconf. Dev.\Cret.	friable sandstone	large gossan	Ag 0.9 ppm, Ba 498 ppm, Be 1.4 ppm, Pb 48 ppm, Sb 13 ppm, Zn 76.5 ppm	*	altered mat'l, probably Cret. sandstone near unconformable contact, Dev. carb.
90-JP-80-R	H ct	carb. granule congl.	--	Be 2.7 ppm, Co 5.0 ppm		stratigraphically adjacent 79-R
90-JP-82-R	H q	siltstone	biological green	U 10 ppm		adjacent contact units H q and H ct
90-JP-85-R	H b	diabase sill	--	Cu 146 ppm[b]		samples from top to bottom of a single sill
90-JP-87-R	H b	"	--	Cu 176 ppm, Li 15 ppm[b]		
90-JP-88-R	H b	"	--	Au 6 ppb, Cu 175 ppm[b]		
90-JP-89-R	H b	"	--	Li 18 ppm[b]		
90-JP-91-R	H b	diabase dyke	--	Cu 184 ppm, Li 22 ppm[b]		est. 20 m wide
90-JP-93-R	H c	carbonate	--	As 3.0 ppm, Be 2.7 ppm[a]		stromatolitic
90-JP-94-R	H q	quartz arenite	--	As 7.0 ppm		found below carbonate unit
90-JP-98-R	C FM	dolomite	malachite?	As 4.0 ppm, Be 3.3 ppm[a]		finely laminated, re-crystallized
90-JP-99-R	C FM	carbonate	--	Be 2.6 ppm, Cr 12 ppm, Cu 108 ppm	*	mud-cracked, adjacent green shale
90-JP-104-R	mC MC	hematized sandstone	Fe stain	As 5.0 ppm		basal congl. immed. above unconformity
90-JP-108-R	C FM	laminated dolomite	--	As 3.0[a]		inter-layered with green shale
90-JP-112-R	D BR	carbonate	bituminous	As 6.0 ppm, Be 4.1 ppm, Mo 5.0 ppm[a]	*	re'xtallized, oily smell, paleo-Karst ?
90-JP-118-R	HR	meta-limestone	--	Be 2.3 ppm, Pb 55 ppm, Pd 3 ppb, Pt <10 ppb, Sb 6.0 ppm		immed. adjacent v. thick diabase sill
90-JP-119-R	HR	meta-limestone	--	Be 2.9 ppm, Pd 10 ppb[a]		15 m stratigraphically below 119-R
90-JP-120-R	Hb	diabase dyke	--	Cu 198 ppm[b]		coarse grained
91-JP-38-R	mC MC	bioturbated dolostone	--	Au 17 ppb, Cu 665 ppm, Pb 14 ppm, Zn 47.4 ppm	*	appears to overlie pre-Paleozoic unconformity
91-JP-48-R	IC MC	quartz arenite	gossanous	Ag .6 ppm, As 33 ppm, Co 24 ppm, Pb 72 ppm		skolithos
91-JP-128-R	Hq	siltstone	red stain	Cu 181 ppm		immediately above(?) Hct/Hq contact

[a] range of mean ppm for As, Be reported in Reedman (1979, p.99) for limestone appears to be low (As 2.5 ppm, Be <1-1 ppm)

[b] range of mean ppm for Cu (100 - 150 ppm) reported in Reedman (1979, p.100) for basic igneous rocks is low for Bluenose area diabases

Table 10. Geochemical analyses, vein and sulphidic rock samples.

ELEMENT	METHOD OF ANALYSIS	SAMPLE NUMBER (all JP)											
		90-030-R	90-031-R	90-032-R	90-035-R	90-043-R	90-046-R	90-066-R	90-071-R	90-072-R	91-031-RA	91-130-R	91-131-R
Ag (ppm)	ICP	0.20	< 0.10	0.20	< 0.10	< 0.10	< 0.10	0.70	0.40	0.10	< .10	0.70	1.20
As (ppm)	DNA	4.00	18.00	- -	2.00	2.00	< 2.00	7.00	- -	- -	25.00	42.00	120.00
As (ppm)	ICP	< 3.00	10.00	< 3.00	5.00	4.00	< 3.00	9.00	47.00	3.00	17.00	38.00	107.00
Au (ppb)	FA/DCP	- -	- -	< 1.00	- -	- -	- -	- -	< 1.00	< 1.00	- -	- -	- -
Au (ppb)	DNA	< 5.00	< 5.00	- -	< 5.00	< 5.00	< 5.00	< 5.00	- -	- -	< 5.00	< 5.00	< 5.00
B (ppm)	ICP	14.00	21.00	4.00	< 2.00	< 2.00	2.00	< 2.00	6.00	< 2.00	- -	- -	- -
Ba (ppm)	ICP	48.00	25.00	29.00	19.00	4.00	5.00	28.00	27.00	16.00	19.00	120.00	147.00
Be (ppm)	ICP	3.50	3.10	1.40	2.10	3.00	1.60	2.50	< 0.50	< 0.50	4.70	2.10	1.60
Cd (ppm)	ICP	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	2.00	< 1.00	< 1.00	< 1.00	< 1.00
Co (ppm)	ICP	5.00	19.00	14.00	6.00	< 1.00	< 1.00	17.00	2.00	3.00	36.00	38.00	68.00
Cr (ppm)	ICP	15.00	16.00	12.00	9.00	6.00	7.00	7.00	7.00	6.00	8.00	8.00	1.00
Cu (ppm)	ICP	11.00	82.80	60.10	7.00	4.60	3.20	14.60	4.70	0.70	42.3	256.00	625.00
Li (ppm)	ICP	21.00	16.00	22.00	6.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	3.00	5.00	< 1.00
Mo (ppm)	ICP	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	59.00	3.00	3.00	< 1.00	< 1.00
Ni (ppm)	ICP	13.00	16.00	25.00	5.00	< 1.00	< 1.00	6.00	11.00	6.00	38.00	15.00	26.00
Pb (ppm)	ICP	< 2.00	84.00	< 2.00	6.00	< 2.00	< 2.00	75.00	28.00	8.00	6.00	58.00	619.00
Pd (ppb)	FA/DCP	- -	- -	5.00	- -	- -	- -	- -	< 1.00	< 1.00	- -	- -	- -
Pt (ppb)	FA/DCP	- -	- -	< 10.00	- -	- -	- -	- -	10.00	< 10.00	- -	- -	- -
Sb (ppm)	DNA	< 0.50	26.00	- -	< 0.50	< 0.50	< 0.50	1.20	- -	- -	< .50	18.00	42.00
Sb (ppm)	ICP	< 5.00	13.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	7.00	< 5.00	5.00	10.00	26.00
Sc (ppm)	ICP	2.60	3.40	2.40	1.30	< 0.10	< 0.10	1.70	< 0.10	< 0.10	5.90	4.30	< 0.50
Se (ppm)	ICP	< 20.00	< 20.00	< 20.00	< 20.00	< 20.00	< 20.00	< 20.00	< 20.00	< 20.00	- -	- -	- -
Sr (ppm)	ICP	203.00	154.00	106.00	69.40	57.60	26.60	159.00	5.30	17.40	37.20	31.40	51.00
Sn (ppm)	ICP	< 10.00	10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00
V (ppm)	ICP	35.60	20.90	20.40	15.10	4.00	1.90	< 0.50	< 0.50	< 0.50	10.00	4.00	< 2.00
W (ppm)	DNA	< 2.00	< 2.00	- -	< 2.00	< 2.00	< 2.00	< 2.00	- -	- -	< 2.00	< 2.00	< 2.00
W (ppm)	ICP	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00
Y (ppm)	ICP	8.40	8.10	25.50	4.80	0.30	< 0.10	20.60	< 0.10	0.10	34.90	23.70	39.90
Zn (ppm)	ICP	22.60	27.10	21.50	17.60	2.00	1.60	27.30	19.50	13.60	123.00	32.40	934.00
Zr (ppm)	ICP	13.30	10.70	1.70	6.70	< 0.50	< 0.50	3.50	6.70	2.80	6.20	7.20	2.80

in 8 major igneous and sedimentary rock types, which was compiled from the geochemical literature by J.H. Reedman (1979, p. 99 - 101). We compared the measured value for selected elements in each sample with the range of the mean of that element in the appropriate rock type as listed by Reedman. Most samples in which the measured amount of at least one listed element exceeds the mean value or range of mean values for the appropriate rock type are listed in Table 9, along with a description of their geological environment.

The elements considered in the above simple screening are:- silver, arsenic, beryllium, barium, chromium, cobalt, cadmium, lithium, molybdenum, nickel, lead, antimony, uranium, vanadium and zinc. Reedman did not report means for gold, palladium, or platinum. Our results for these elements are generally quite low (many below detection limit); nevertheless the highest values are listed in Table 9 as examples. All diabase samples returned values of 14-25 ppb palladium, 1-10 ppb platinum and 100-200 ppm copper, which appear to be backgrond in mafic rocks (cf. Baragar, 1977 for copper).

Some of the rock analyses are listed in Table 9 because the reported values, e.g. arsenic, are slightly above Reedman's filter threshold. Those samples in Table 9 which are considered to be anomalous using the above procedure are marked by asterisk and explained as follows, in numerical order.

The moderately elevated silver-gold-copper-lithium-palladium suite in sample 90-JP-33-R is apparently of magmatic origin, possibly modified by the hydrothermal alteration recorded by pervasive quartz veins transecting the sill.

Samples 90-JP-34-R (lead 181 ppm), 90-JP-38-R (polymetallic), and 90-JP-48-R (copper 831 ppm) are thought to record transport and precipitation of metals in local reducing environments during diagenesis. Sample 90-JP-34-R is a loose block taken at the foot of a 15-20 m Proterozoic diabase cliff, overlain by about 3 m of shale. Sample 90-JP-38-R is of a limonite-cemented concretion in Cretaceous sandstone. Sample 90-JP-48-R is of a 2-3 cm shale layer in friable Cambrian sandstone which contained little metal.

Sample 90-JP-69-R was taken from a gossanous, friable, Cretaceous sandstone that is about 9-12 m thick and extends hundreds of metres along a steep river bank, close to an unconformity between the sandstone and underlying Devonian carbonates. The sample was taken within a few metres of overlying coal measures and may represent (1) a burned-out coal bed, or (2) diagenetic concentration of metals in a local reducing environment, related to the unconformity. Samples 90-JP-71-R and 90-JP-72-R, which yielded background metal values (tables 10, 11), were taken from the same site.

Table 11. Summary of anomalous vein and sulphidic rock samples.

SAMPLE #	HOST FORMATION	MATERIAL SAMPLED	VISIBLE MINERALIZATION	SELECTED ANOMALOUS RESULTS
90-JP-31-R	H ce	fault breccia	–	As 18.0 ppm, Cu 82.8 ppm, Sb 26 ppm, Sn 10 ppm, Sr 154 ppm
90-JP-32-R	H b	quartz vein in diabase	blood red coating	Sr 106.0 ppm, Pd 5.0 ppb, Y 25.5 ppm (see sample 33, Table 2)
90-JP-66-R	H p	fault with secondary carbonate	pyrite ?	Pb 75 ppm, Sr 159 ppm
90-JP-71-R	K LB	marcasite nodule	marcasite	As 47 ppm, Mo 59 ppm, Pt 10 ppb, Sb 7 ppm
91-JP-31-RA	H q	gossanous soil over outcrop	entire specimen gossan	Co 36 ppm, Cu 42.3 ppm, Ni 38 ppm, Zn 123 ppm
91-JP-130-R	H p	gash fracture with pyrite	pyrite	As 42 ppm, Co 38 ppm, Cu 256 ppm, Ni 15 ppm, Sb 18 ppm, Pb 58 ppm, Y 23.7 ppm, Zn 32.4 ppm
91-JP-131-R	H p	fault with secondary pyrite, carbonate	pyrite	As 120 ppm, Co 68 ppm, Cu 625 ppm, Ni 26 ppm, Sb 42 ppm, Pb 619 ppm, Y 39.9 ppm, Zn 934 ppm

Sample 90-JP-99-R, with 108 ppm copper, is laminated dolostone with thin green shale interlayers, of the Franklin Mountain Formation. Sample 90-JP-112-R, with 5 ppm molybdenum, is Devonian Bear Rock Formation, crystalline bituminous dolostone from a ?paleokarst breccia. The settings of these samples are not considered to contain the known mineral deposit types (e.g Kupferschiefer copper, and porphyry molybdenum) that typically are the sources of these metals.

Sample 91-JP-38-R, a bioturbated dolostone, ran 665 ppm copper and 17 ppb gold. This dolostone, previously mapped as Proterozoic unit P5 (Hce), is here assigned to the Mount Cap Formation. The anomalous metal values may represent diagenetic concentration of metal ions originating in underlying Proterozoic strata (see Kupferschiefer Type Copper).

Only rock analyses which match one of Reedman's reported lithology types have been evaluated using the above method. Complete results for the remaining samples (mostly vein material, or samples containing abnormal amounts of sulphide) are given in Table 10. Anomalous values of vein samples (Table 11) were decided by visual inspection of the data in Table 10.

Stream Sediment Geochemistry

A total of 32 bulk stream sediment samples and were collected. The number is small because of limited resources and the decision to emphasize geological investigations and prospecting.

In 1990, we sampled 25 watersheds covering the entire study area. The watersheds range in size from approximately 300 to 3000 km^2. One 5-9 kg sample of <1 cm stream sediment was collected at the down-stream confluence of each watershed (Table 12; Figure 19; Appendices II and III). All samples were taken from active or recently active bars. Bank slump material was avoided. Considerable difficulty was experienced in collecting sufficient fine (<1 cm) material in many of the streams. No panning or sieving of the samples was performed in the field, to save time and limit helicopter costs, hence the large samples. Large samples were also taken because we wished to increase our detection capabilities in the large drainage basins.

From each bulk sample one silt sample and one heavy mineral concentrate (HMC) were derived. All samples were wet-sieved and divided into >850 , 850-180 , and <180 fractions. A 1/3 split (ranging from 0.70 to 4.60 g) of the <180 fraction was submitted as silt for geochemical analysis. The remainder was analysed for heavy minerals.

Heavy Mineral Concentrates

Preliminary processing of the bulk samples from the initial 25 drainage basins indicated that heavy minerals are very sparse. The size range processed was therefore made as large as possible to increase the yield of heavy minerals. The 180 to 850 fraction was passed on a water-washed, black-deck, vibrating concentrating table by Consorminex Inc. to remove the light minerals as described by Stewart (1986). The table operator purposely included a cut of heavier light minerals to increase HMC size sufficiently for neutron activation analysis (Jones and Jefferson, 1991). Magnetic heavy minerals were then removed. A uniform 9 to 10 g split of the non-magnetic HMC was subsequently analyzed by Bondar Clegg Ltd., for gold plus 33 elements by direct neutron activation.

To bolster the sparse data set, three extra HMCs were produced as above from small samples (90-JP-49, 95, 101) which were originally collected as stream silts only, from several smaller streams. In 1991, seven additional bulk samples were collected for HMCs to resample suspect 1990 sites and to check more drainages for gold.

Final HMCs weighed between 15.3 and 63.4 g, derived from original samples of 5.6 to 9.1 kg. Splits sent for direct neutron activation analysis ranged from 7.31-11.94 grams. The results for the geochemical analysis of these splits showed no apparent pattern (see Appendix III) even though experience suggested that there should be a correlation between background geochemical levels and bedrock type. Consequently, a methylene iodide separation was done on each split to determine the percentage of true heavy minerals (>2.5 S.G.) in each original HMC; these ranged from about 1% to 75%. This extreme range of dilution by light minerals clearly affects the reliability of the original results.

To salvage the sample results, the geochemical analyses were recalculated as follows:

$$
\begin{aligned}
& [\text{original value (ppm/ppb)}] \\
\times\; & \frac{[\text{weight original HMC (grams)}]}{[\text{weight true heavy minerals (grams)}]} \\
=\; & [\text{derived value (ppm/ppb)}]
\end{aligned}
$$

The derived value estimates what the analytical result would have been if all light minerals had been separated from the HMC by heavy liquids, and if the HMC had been big enough for neutron activation (5-10 g). The derived values were used only for those elements which we believe were mainly partitioned into the >3.2 S.G. portion of the original HMC. Arsenic, gold, cobalt, chromium, uranium, tungsten, and zircon were selected as examples of such elements on the advice of geochemist R. Lustwerk (personal communication, 1991).

Table 12. Selected derived geochemical analysis results, Heavy Mineral Concentrate (HMC) samples. Shading represents values exceeding anomaly threshold established by inspection. Boxed anomalous values are considered to be significant for resource evaluation purposes. Note that a significant number of values <u>might</u> exceed the threshold but are reported as a <<u>x</u> value, as a result of the mathematical manipulation used to generate these numbers. For further discussion see geochemistry section in text, and sections dealing with evaluation of individual deposit types.

Sample #	Weight (grams)	% true HMC[1]	As (ppm)	Au (ppb)	Co (ppm)	Cr (ppm)	U (ppm)	W (ppm)	Zr (ppm)
anomaly by inspection			>200 ppm	>100 ppb	>250 ppm	>2000 ppm	>150 ppm	>100 ppm	>80,000 ppm
90-JP-001-H	10.10	31.86	69	< 16[2]	88	630	8.5	< 6	2,500
90-JP-002-H	9.63	19.32	31	< 26	120	620	5.2	< 10	< 2,600
90-JP-003-H	9.96	14.97	127	< 33	160	1,300	26.7	13	13,000
90-JP-004-H	9.02	22.12	32	< 23[2]	110	680	6.3	< 9	< 2,300
90-JP-005-H	11.94	58.59	20	< 9	79	1,300	23.9	9	17,000
90-JP-006-H	11.76	10.9	73	< 46	130	1,000	110.0	< 18	70,000
90-JP-007-H	8.99	66.82	10	210	49	1,390	156.0	9	120,000
90-JP-008-H	9.35	3.03	132	< 165	530	2,600	23.1	< 66	< 17,000
90-JP-009-H	10.78	5.30	57	< 94	280	3,000	88.7	< 38	45,000
90-JP-010-H	9.01	28.19	110	28	74	640	71.0	< 7	43,000
90-JP-011-H	9.23	16.06	31	44	130	1,900	230.0	19	170,000
90-JP-012-H	9.28	75.42	23	81	40	810	201.5	13	> 120,000
90-JP-013-H	11.83	3.15	63	< 159	480	3,200	38.1	< 63	17,000
90-JP-014-H	9.32	31.52	311	< 16	130	670	24.7	6	15,000
90-JP-015-H	9.52	9.30	43	< 54	250	2,600	41.9	< 22	20,000
90-JP-016-H	9.21	76.92	12	< 6	69	1,100	48.1	9	30,000
90-JP-017-H	9.71	64.56	20	< 8	90	980	54.2	5	39,000
90-JP-018-H	9.30	9.09	22	< 55	140	2,100	176.0	< 22	140,000
90-JP-019-H	9.69	1.44	208	< 347	< 690	< 3,500	76.4	< 140	< 35,000
90-JP-020-H	9.73	16.34	43	110	67	2,600	281.5	< 49	170,000
90-JP-021-H	10.70	1.59	252	< 314	755	3,200	113.0	190	41,000
90-JP-022-H	7.31	14.29[4]	287	< 35	180	540	6.3	< 14	< 3,500
90-JP-023-H	11.41	1.83	55	< 273	< 550	< 2,700	32.8	< 110	< 27,000
90-JP-024-H	10.30	21.83	23	< 23	170	1,400	14.2	< 27	6,000
90-JP-025-H	9.14	3.54	28	< 141	370	2,000	25.4	< 57	< 14,000
90-JP-049-H	10.12	--[3]	<1	<5	<10	<50	0.5	<2	<500
90-JP-095-H	8.80	--[3]	6	<5	<10	54	2.3	<2	<500
90-JP-101-H	8.98	--[3]	2	<5	<10	52	0.7	<2	<500
91-JP-060-H	9.58	3.86	62	259	< 260	2,150	153.00	< 52	88,000
91-JP-062-H	9.94	22.05	23	< 23	110	680	6.8	< 9	< 2,300
91-JP-066-H	9.89	17.07	29	269	70	1,200	135.	< 12	76,000
91-JP-100-H	9.84	21.16	13	< 24	71	710	170.0	9	85,000
91-JP-101-H	9.68	40.00	20.5	< 12.5	92.5	775	32.5	10	19,000
91-JP-118-H	9.93	15.73	14	< 32	70	950	76.3	< 13	46,000
91-JP-119-H	9.95	18.97	8	< 26	90	1,300	68.5	< 11	40,000
91-JP-120-H	9.87	60.56	9	< 8	83	760	9.9	3	5,000

1 % of true heavy mineral in original 'as analyzed' Heavy Mineral Concentrate, determined by methylene iodide separation, after analysis.

2 Single flakes (300x300 µ) of gold were removed on the concentrating table before neutron activation analysis.

3 % true H M C unavailable for these samples, results shown (<u>in italics</u>) are original uncorrected underived.

4 This value represents an average of two determinations: 12.82 %, 15.76 %.

Derived results for these seven elements are in Table 12. A correction factor was not available for samples 90-JP-49, 95, 101H; hence values shown for these are original laboratory results. Where original results had been expressed as <(ppm/ppb) derived results are shown as <(corrected ppm/ppb).

The low percentage of true heavy minerals present in samples 90-JP-19, 21, 23-H suggests that the derived data are unreliable for these samples. Note that sample 91-JP-101-H, which is a re-sample of sample 90-JP-21-H, shows much lower results.

Because derived results are still highly variable, anomalous results have been identified by inspection only, and are indicated by shading in Table 12. Tungsten values are uniformly low, with many <*X* ppm values. Uranium and zirconium values vary together and are likely derived from zircons. Cobalt and chromium vary together and are commonly high in samples from drainage basins containing unit Hb gabbros; this is considered background for this rock type. Arsenic values appear to vary with gold.

Gold values are probably the only truly interesting result: individual flakes (300 x 300 microns) were recovered in samples 90-JP-01, 04-H, and samples 90-JP-07 to 20-H and 91-JP-60, 66-H ran greater than 200 ppb gold (derived value).

It seems likely that samples 90-JP-01, 04, 07, 20-H are derived from glacial drift. The bedrock geology is not typical of gold districts, and significant moraines, drumlins and glacial outwash deposits mark the limits of Late Wisconsinan glaciation in the region (figures 2 and 3 in McMartin and St-Onge 1990). The gold is therefore interpreted as glacially transported. Its presence in surficial deposits of this area is probably a result of concentration by meltwater which reworked glacial deposits brought by sustained ice flow (after personal observations of the first author in the area of Sudbury Ontario, similar observations of auriferous outwash at the Wisconsin terminal moraine in Ohio by W. Shilts, personal communication 1991, and discussions with D. Paré, personal communication, 1991).

Samples 91-JP-60 and 66-H were collected in streams draining the Hornaday Lake Fault (figures 5, 7, 19); the weakly anomalous gold values here could be derived from a Carlin type gold deposit, but could also be glacio-fluvial in origin.

Stream Silt Geochemistry

In 1990, 28 silt splits were derived from the stream samples as described above. Heavy metals were leached by nitric aqua regia, then measured by multi-element inductively coupled plasma emission spectroscopy at Bondar-Clegg Ltd.

Table 13. Anomalous and selected elevated geochemical results, 1990 stream silt samples.

SAMPLE #	RESULTS
90-JP-001-S	12 ppm Pb
90-JP-002-S	33 ppm Cu, 12 ppm Pb
90-JP-004-S	22 ppm Cu
90-JP-013-S	25 ppm Cu, 34 ppm Zn
90-JP-014-S	11 ppm Pb
90-JP-021-S	22 ppm Cu, 11 ppm Pb, 37 ppm Zn
90-JP-024-S	47 ppm Zn
90-JP-025-S	22 ppm Cu
90-JP-095-S	13 ppm Pb.

Geochemical results are generally low for most elements. Although only 28 samples were analyzed in 1990, the copper, lead, and zinc values were statistically evaluated. All values greater than their respective means (15.3, 7.9, 21.5 ppm) + one standard deviation (21.1, 10.5, 30.2) are listed in Table 13; complete analytical results are in Appendix III.

None of the copper-lead-zinc results of samples collected in 1990 exceed 2 standard deviations (26.9, 13.1, 38.8 ppm respectively). Several of these samples contain greater than average amounts (>1 standard deviation) of iron and manganese, therefore some elevated copper and zinc abundances may be a result of adsorption. Lead, which is commonly transported as galena, would not be tied to iron and manganese.

The regional silt analyses do not support high mineraql potential, but neither do they negate the possibility of mineral deposits because the bulk stream-sediment sample sites are too widely separated to fulfil the requirements of even a reconnaissance silt geochemical survey. Undetected anomalies in second and third order drainages could readily be diluted to near-uniformity in the first-order drainages we sampled. Regrettably, the time and resources available for this assessment did not permit a comprehensive stream-silt survey over the entire study area.

In 1991, several second and third order drainage systems were targeted by geological models and 1990 results: streams draining the Hct (P2) \ Hq (P3) contact which might be a locus for copper (Rainbird et al., 1992); upstream from sample 90-JP-21-H,S, which showed above background copper, lead and zinc; and silt was collected at each 1991 HMC sample site.

1991 results are reported in Appendix II. Except for a single stream draining unit Hp (P1), results are low for all elements. Samples 91-JP-101-116-S and 117-T are highest in zinc (to 67 ppm). Highest copper is 30 ppm and lead, 24 ppm. Such higher background metal concentrations are not considered to be evidence of anomalous concentrations of sulphide minerals in bedrock.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Method of Assessment

In order to evaluate the mineral resource potential of the area, we first decided which mineral deposit models might be applicable to the geology of the study area. Each geological unit was then investigated in the field, keeping in mind the attributes of relevant mineral deposit models.

For the final assessment the many geological units were grouped into three major domains in order to reduce the number of times each deposit model was applied to the geology.

Fieldwork included outcrop description and sampling of each geological unit; the stream sediment surveys described above; prospecting in areas of perceived high mineral potential; and geological mapping in areas where good exposures invited further work, or where initial field observations suggested that the existing maps would benefit most from revision and more detail.

The chemical analyses of Heavy Mineral Concentrates (HMCs), stream silt samples, and rock samples were assessed for their favourability for mineral resources (see GEOCHEMISTRY above, and Appendices I - III).

Finally, all data pertaining to each major geological domain was analyzed in order to evaluate its mineral resource potential by comparison with the appropriate mineral deposit models, and a mineral potential rating was assigned for relevant models.

Definition of Domains

To facilitate coal and mineral resource evaluation, the many rock units were grouped into three geological domains (Figure 1, Table 4):

Domain I, Proterozoic Rocks comprises one large central area in which Proterozoic rocks of the Brock Inlier are at surface, and a smaller area to the southeast underlain by the Coppermine Homocline . These areas include the Shaler and Rae groups, the Hadrynian gabbros and diabases of the Franklin Suite and, in the Coppermine Homocline, the underlying Coppermine River Group basalt flows, interbedded sandstones, and minor dolomite of the Dismal Lakes Group.

Domain II, Mackenzie Platform, is the large perimeter of the study area in which outcrop is dominated by Paleozoic strata from the Lower Cambrian Mount Clark Formation to the Devonian Hume Formation.

Domain III, Anderson Basin + unconsolidated material, includes the large area around Paulatuk with surface exposures of Cretaceous sedimentary strata overlying Proterozoic and Paleozoic strata. Cretaceous rocks include the Langton Bay and Horton River Formations. Three small outliers of these strata on the northeast corner of Brock Inlier are included in Domain III. Tertiary and Quaternary sediments of the entire study area are also considered in Domain III.

The basement under most of Domains II and III is probably the extension of Domain I. South of Paulatuk, basement rocks include an interpreted large, deep, flat, mafic and/or ultramafic intrusion of the Franklin suite.

Mineral Deposit Models

The mineral deposit models which we consider might apply in the study area are listed in Table 3. The important characteristics of each deposit model are summarized in Table 14. Specific attributes of each deposit model are considered in the following sections.

Arsenide Vein Silver

The thick diabase-gabbro sills which intrude Shaler Group sedimentary rocks on Banks and Victoria Island were considered to have moderate to high potential (3) (Jefferson et al., 1988) for arsenide vein silver and uranium deposits of hydrothermal origin (Thorpe, 1984a).

In the Bluenose Lake study area metamorphism was observed at several sill contacts, but sulphides were not seen at the contact or in the country rock. Samples taken from diabase contacts were not geochemically enriched in silver, and we saw no gossans. Accordingly, we consider that Domain I has low to moderate potential (5) for arsenide vein silver deposits. In any case, such deposits rarely support more than a small mine (Economic Geology Division, 1980; Thorpe, 1984a).

Carlin-Type Carbonate-Hosted Gold

Carlin-type deposits (Thorpe, 1984b) typically comprise finely disseminated gold in platform carbonates, adjacent to thrust faults. This model was considered because carbonates are an important component of the Proterozoic and Paleozoic stratigraphy of the area, and because thrust or high angle reverse faults are present, especially along the eastern edge of the Brock Inlier.

HMC samples 91-JP-60,66-H ran 259 and 269 ppb gold respectively after correcting original assayed values to reflect true HMCs (see heavy mineral concentrates section above); both were collected from streams draining across the Hornaday Lake Fault which cuts both Proterozoic and Paleozoic carbonates (figures 7, 19).

None of several rock samples taken in carbonates adjacent to this and another reverse fault contained anomalous gold. As the HMC gold anomalies are minor, they do not indicate large exposed sources of gold in the catchment basins. Potential for this type of deposit is therefore considered to be low to moderate (5) for Proterozoic and Paleozoic rocks.

Continental Red Bed Copper

Sedimentary copper deposits of the continental red bed type (Kirkham, 1989) are similar to sandstone type uranium deposits, and are generally hosted by permeable sandstones laid down under warm arid continental conditions. Copper dissolved in circulating pore fluids is precipitated when fluids pass through a localized reducing environment.

Unit Hq of the Shaler Group, the Cambrian Mount Clark Formation and the Cretaceous Gilmore Lake Member of the Langton Bay Formation are all permeable sandstones laid down under continental conditions.

The Turner copper showing, previously reported from the Rae Group (Thorpe, 1970), is at the contact between carbonate unit 22 (Baragar and Donaldson, 1973) and the overlying sandstone unit 23; paleokarst breccia was noted at this contact (Rainbird et al., 1992). Copper sulphides are present in both the karst breccia and the basal orthoconglomerate. In the Hadley Bay area on Victoria Island (locality 5, Figure 6), Noranda Exploration is currently exploring the same unconformable contact between the Middle Cherty Carbonate and Upper Clastic Members of the Glenelg Formation. The highest concentrations to date have been found by Noranda in the lower parts of the quartzarenite, and in a locally developed basal chert pebble conglomerate. In both the Hadley Bay and the Turner prospects the unconfority investigated corresponds to the Hct\Hq (P2\P3) contact within the Shaler Group of the study area.

Because of the above discoveries, in the summer of 1991 we thoroughly investigated the Hct\Hq contact (e.g., Figure 20) in all possible locations. We first examined the Hadley Bay and Turner showings through the kindness of Noranda Exploration Limited (Wayne Darch and Matt Rees). We next examined as many localities as possible in the Brock Inlier, searching for evidence of disseminated copper sulphides. We sampled and prospected the exposed contact in three areas, and we sampled stream sediments in drainages transecting the contact in the area of the Little Hornaday River. However, we saw no copper sulphides in outcrop; stream sediment sample results range between 6 and 20 ppm copper; and only two rock samples contain elevated amounts of copper. Sample 91-JP-31-RB (a deep red gossanous siltstone just above the contact) yielded 42 ppm copper, and sample 91-JP-128-R (a siltstone within 10 m above the contact) ran 181 ppm copper.

Jefferson and Jones (1991) suggested that unit Hq of the Shaler Group in the Brock Inlier was deposited in a deeper shelf environment relative to its correlatives in the Rae Group (unit 23, Baragar and Donaldson, 1973) and eastern Victoria Island (Upper Clastic Member, Glenelg Formation, see Rainbird et al., 1992). The sandstone copper deposit type considered here, especially the Dzhezkasgan example (explained by Kirkham, 1990), and the showings examined by Rainbird et al. (1992) suggest that the shelf margins, uplifts and unconformities are key factors for this type of copper deposit. Consequently, there appears to be less evidence in the study area than in the Coppermine Homocline or on Victoria Island for sedimentary copper in this unit; we have accordingly assigned it low to moderate potential (5).

The Paleozoic Mount Clark and Cretaceous Langton Bay Formations were prospected and sampled for copper; no evidence of mineralization was seen, thus they are assigned low potential (6) for this deposit type.

Kupferschiefer Type Copper

Stratabound sediment-hosted disseminated copper sulphides (Kirkham, 1984b) are typically found within pyritic or carbonaceous shales at the base of a marine transgressive unit overlying a red bed sequence. We rated three subdivisions of the Cu deposit type (tables 2, 3, 14). Regarding the Kupferschiefer type (Cu2), marine units overlie redbeds at three stratigraphic levels in the study area: (a) the mainly unexposed contact between the basal unit 19 of the Rae Group (Hp=P1 of the Shaler Group) and the underlying Coppermine River Group, (b) the contact between units Hq and Hc (P2 and P3) of the Shaler Group, and (c) the local onlap unconformity between the Paleozoic Mount Cap Formation and underlying clastic rocks of the Shaler Group.

(a) The contact between basal unit 19 of the Rae Group (=P1, =Hp, =Basal Glenelg Formation of the Shaler Group) and underlying basalt of the Coppermine River Group is exposed immediately east of the study area (in NTS 86N; Baragar and Donaldson, 1973). From here the contact is projected westward into the sketchily mapped southeast corner of the study area (see Figure 5). Limited resources and priorities within the proposed park boundaries prevented us from sampling this basal contact. It extends in the subsurface an unknown distance northwestward toward the Brock Inlier.

Baragar and Donaldson (1973) described unit 19 as glauconitic sandstone interbedded with black shales, containing abundant sulphide crystals and nodules; some samples were noted to contain

Table 14 (left). Summary of significant characteristics for selected mineral deposit models (after Eckstrand, 1984a).

MINERAL DEPOSIT MODEL	METALLIC COMMODITY PRESENT	TYPICAL GRADE	TYPICAL TONNAGE	GEOLOGICAL SETTING
Arsenide Vein Silver, Uranium	Ag, U (As, Co, Ni, Cu, Bi)	1100-2100 g/tonne Ag, up to 34000 g/tonne Ag	360,000 tonnes	related to tensional faults and mafic magmatism: diabase intrusion into Precambrian volcanic rocks
Carlin Type Carbonate Hosted Gold	Au (As, Hg, Ag, Sb, Tl)	1.0 to 10 g Au/tonne	5 million tonnes	host rocks deposited in shelf-basin transitional environments: rocks presently allochthonous in thrust fault slices
Continental Red Bed Copper (Cu1)	Cu (Ag, Co)	1 to 2 % Cu and 1 to 30 g Ag/tonne	1 to 10 million tonnes	cont. or shallow marine sandstone, arid to semi-arid env.: anoxic fluvial & lacustrine rocks above or interlayered with redbeds
Kupferschiefer Type Copper (Cu2)	Cu (Ag, Co)	highly variable 1.0 to 5.0 % Cu, 1 to 30 g Ag/tonne	5 to 500 million tonnes	cont. or shallow marine strata rocks, arid to semi-arid env.: anoxic marine rocks overlie or are interlayered with redbeds
Volcanic Redbed Native Copper (Cu3)	Cu (Ag)	0.6 to 4.0 % Cu	1 to 10 million tonnes	cont. to very shallow marine volcanic sequences, arid to semi-arid env.: occur in cont. rift-related flood basalt sequences
Ironstone	Fe (Mn, P)	30-55% Fe	up to 1x10^{9}	shallow marine to estuarine, associated with black pyritic shale, ferruginous sandstone, carbonate
Marine Evaporites - halite (salt)	NaCl, KCl, (S, Mg)	90 to 100% NaCl 15 to 30 % K$_2$O	10's x 10^{6} > 1 x 10^{9} tonnes	large restricted marginal marine basins and extensive coastal sabkhas in arid areas
Marine Evaporites - gypsum	Ca $_2$SO$_4$	90-100 % Ca $_2$SO$_4$	10x10^{6} to 10^{9} tonnes	large restricted marginal marine basins and extensive coastal sabkhas; associated with shale, carbonates, red beds
Gabbro-Associated Nickel, Copper, platinum-group elements, gold	Ni, Cu, PGE, (Co, Au, Ag, S, Fe)	0.6 to 1.6 % Ni, 0.2 to 1.3 % Cu, PGE approx. 1 g/t	200,000 to 10's x 10^{6} tonnes	layered intrusions in cratonic setting; intracontinental rifts & flood basalts; Archean greenstones and stocks
Stratiform Phosphate	P (U, F, V, artificial gypsum)	typically 31 - 36% P$_2$O$_5$, mineable to 24%	100's x 10^{6} to 10^{9} tonnes	miogeosynclinal-flexure zone between shallow shelf and deeper basin: platformal-cratonic basins & stable shelves bordering cratons
Mississippi Valley Type Lead, Zinc	Pb, Zn (Ag, Cd)	5 to 10 % combined Pb-Zn	1 to 10 x 10^{6}; camps = $\sim$100 x 10^{6}	platform carbonate successions: commonly located between zone of tectonic instability and the tectonically stable platform
Shale-Hosted Lead, Zinc	Zn, Pb, Ag, barite (Cd, Cu, Sn)	.6 - 18% Zn (7.3), .3 - 13% Pb (4.0), 0 - 1% Cu (.1%)	4 to 550 x 10^{6} tonnes (avg. 60)	within second order, often tectonically controlled sed. basins in cont. rise, cont. shelf or intracontinental marine basin
Sandstone Type Uranium	U (V, Mo, Se)	0.1 to 0.2% U	1000 to 10,000 tonnes	mainly in closed sed. sccessor basins adjacent to cont. hinterlands containing granitic and/or felsic volcanic rocks
Unconformity-Associated Uranium	U (Ni, Co, As, Se, Ag, Au, Mo)	0.3 to 3% U though some exceed 5%	very small to 5 mil. tonnes ore	undeformed, intracratonic, Helikian sed. basins unconformably on intensely deformed Archean rock: faulting at unconformity

Table 14 (right)

MINERAL DEPOSIT MODEL	HOST ROCKS (AGE, TYPE)	METALLIC ORE MINERALS	ACCESSORY MINERALS	ORE CONTROLS / GUIDES TO EXPLORATION
Arsenide Vein Ag, U	Archean, Aphebian volcanics + sediments	native silver, pitchblende, Co-Ni arsenides	dolomite, calcite, quartz	1) Proterozoic unconformities 2) proximity to diabase 3) pre-ore sulfides in country rocks
Carlin Type Carbonate Hosted Au	Cambrian - Devonian interbedded shale/carbonate	native gold	pyrite, arsenopyrite, stibnite,	1) highly carbon. carb. or shale-carb. 2) presence of small felsic plutons 3) As & Hg geochem anomalies v. fav.
Continental Red Bed Cu (Cu1)	Early Proterozoic - Tertiary; carbon. ss., cong., clays	chalcopyrite, bornite, native Cu, chalcocite	pyrite, other sulphides, sed. minerals	1) arid cont. & shallow marine seds. 2) sources of Cu = Cu-bearing basement 3) exten. redbed or oxidized aquifer
Kupferschiefer Type Cu (Cu2)	Early Proterozoic - Tertiary; carbon. ss., cong., clayS	chalcopyrite, bornite, native Cu, chalcocite	pyrite, other sulphides, sed. minerals	1) arid cont. & shallow marine seds. 2) sources of Cu = Cu-bearing basement 3) exten. redbed or oxidized aquifer
Volcanic Redbed Native Copper (Cu3)	Early Prot. - Tert. mafic-felsic tuff, amygdaloidal flows	native Cu, bornite, chalcopyrite, chalcocite,	calcite, qtz., epidote, K-spar, albite	1) permeable zones - strat. units - faults, fractures 2) favourable host rocks
Ironstone	pC to recent, hematite-siderite-chamosite- clay beds	hematite, goethite, siderite, chamosite	calcite, ankerite, clay, phosphate fossils, pyrite	1) good stratigraphic control 2) neritic/estaurine sed. facies 3) clean beds, free from shale
Marine Evaporites - halite	Late Proterozoic to Recent: salt, potash, borate	anhydrite, halite, sylvite, carnalite, gypsum	dolomite, clay mins., quartz, calcite	1) evaporitic basins, large is better 2) mining sites generally near surface 3) geochem. & geophys useful
Marine Evaporites - gypsum	Late Prot. to Rec.: salt, potash, gypsum, anhydrite	gypsum, anhydrite, halite, sylvite, carnalite	calcite, dolomite, clay, quartz, pyrite	1) evaporitic basins, large is better 2) miing sites generally near surface 3) geochem. & geophys useful
Gabbro-Associated Ni, Cu, Pt Gp. Elements	Precambrian mafic intrusions; few younger	pentlandite, PGE, chalcopyrite, cubanite	pyrrhotite, pyrite, sphalerite	1) basal contacts common sites Ni-Cu 2) PGE layers thin high above base 3) differen., mult. phase stock-like
Stratiform Phosphate	Proterozoic to Holocene; phosphorite	apatite group minerals	quartz, clays, carbonates	1) lithologic associations of marine shelf/cratonic environments (chert) 2) paleotopographic structural assoc.
Mississippi Valley Type Pb, Zn	Cambrian to Triassic; carbonate rocks	sphalerite, galena	pyrite/marc., calcite, dolomite,	1) secondary breccia in dolomite 2) unconform. within carbonate seq. 3) reefs
Shale-Hosted Pb, Zn	1.43 to 0.34 Ga; deep marine clastic seds.	sphalerite, galena, barite	quartz,pyrite, pyrrhotite, chalcopyrite	1) many assoc. with intracontinental or continental margin basins 2) second order basins prime targets
Sandstone Type U	mainly post-Devonian; clastic cont. seds.	Reduced: coffinite, pitchblende Oxidized: autunite	pyrite, marcasite, clays	1) mineralized beds bound above and below by imperm. strata 2) "stack" type deposits - faults N.B.
Unconformity-Associated U	base: Aphebian to Archean, cover: Helikian; clays	pitchblende, coffinite, minor U oxides	Ni-Co arsenides + sulphides	1) mineralization at/near unconformity Helikean ss., Aphebian/Archean base. 2) assoc. graphitic base. rocks

Figure 20. Upper slopes, lower Brock River canyon. Photo taken looking eastward across a north-south tributary to the main river, 25 km from the mouth. The steeper walls in the lower portion of the photo are cherty dolostones of unit Hct; unit Hq weathers recessively on the upper portion of the slope. The contact between these two units was investigated for copper mineralization at several locations here and at the south end of the Brock Inlier.

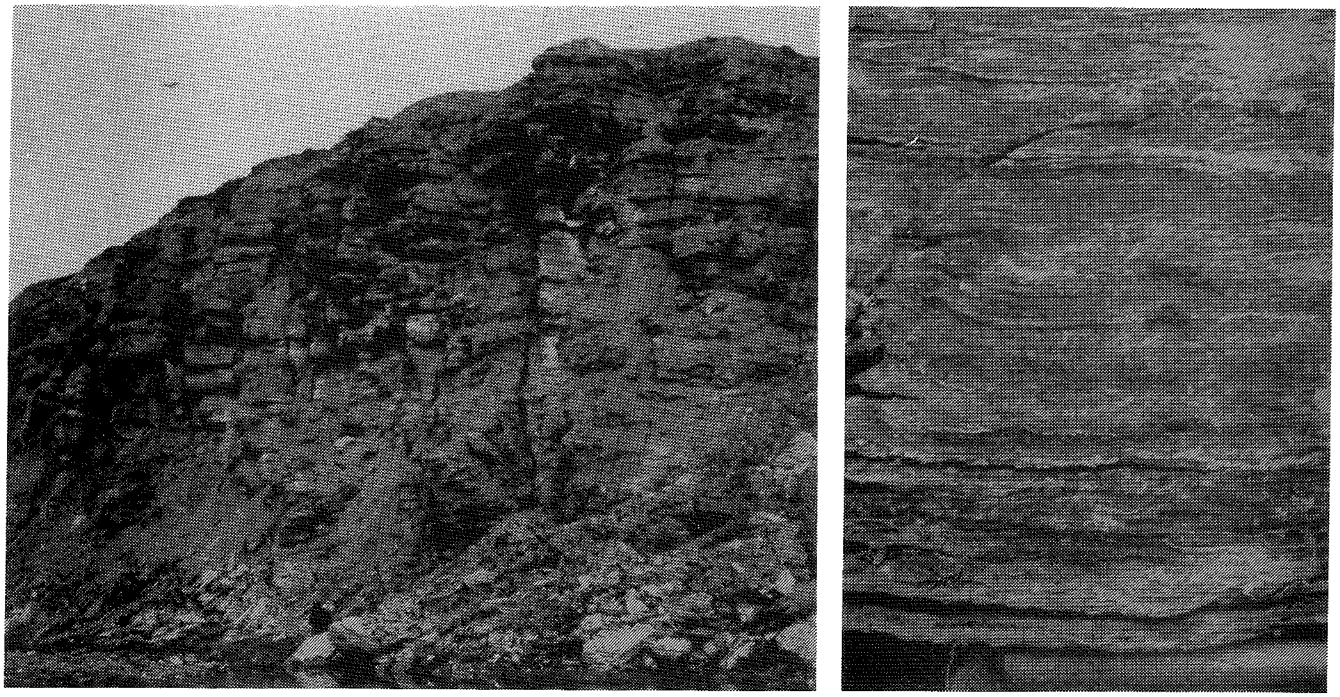

Figure 21. Laminated gypsum hand sample (right) and section of bedded gypsum (left), capped by laminated dolostone in Proterozoic map-unit Hce (P5). View is toward the northeast, section located on tributary to Little Hornaday River about 17 km east-southeast of station 90-JP- 104-R. About 10 m of section are shown on left; 30 cm on right.

small amounts of disseminated chalcocite. Kindle (1970) and Kirkham (1970) documented numerous sediment-hosted disseminated copper sulphide showings in these rocks. Cominco Ltd. currently holds large claim groups covering unit 19, and has been actively exploring them. The basement rocks of this area consist of cupriferous basalt flows of the Copper Creek Formation, Coppermine River Group.

(b) The basal member of unit Hc is defined by an orange stromatolite biostrome. In the Hornaday Lake fault panel, the orange stromatolite is underlain by 6-10 m of black shale. The shale exhibited no evidence of copper in the field and was not geochemically analyzed in the study area. The stromatolite biostrome also shows no evidence of enrichment in any metallic elements except iron (sample 90-JP-93-R, see Appendix I) in the study area. Thicker black shale was observed at other locations in unit Hc, but its stratigraphic position relative to the base of the unit is unknown.

(c) In the northeastern part of the Brock Inlier the Mount Cap Formation directly overlies Proterozoic Shaler Group rocks, with no intervening Mount Clark/Old Fort Island Formation sandstones (Figure 5). The Mount Cap Formation here consists of grey, green and red shales interbedded with burrowed glauconitic sandstone and orange dolomite. In the area immediately inland from the coast between Tysoe Point and "Wob" River, Mount Cap Formation shales and bioturbated dolomite overlie carbonates and shales of unit Hc of the Shaler Group. Sample JP-91-86-R (bioturbated dolostone) from the Mount Cap Formation ran 665 ppm copper (Table 9). Mount Cap Formation elsewhere appears to directly overlie redbeds of Shaler Group unit Hq; although this was not observed in outcrop, it is implied in our interpretation of the map area north of Hornaday Lake (Figure 5).

The potential for Kupferschiefer type copper is considered to be low to moderate (5) for (b) the base of unit Hc of the Shaler Group, and (c) the Mount Cap Formation where it appears to directly overlie Shaler Group redbeds. In both cases the rating reflects much uncertainty regarding the lateral extent of the potential host rocks.

The basal unit of the Rae Group overlying Coppermine River Group basalt and its unexposed equivalent, the base of Brock Inlier unit Hp (P1) are rated high (2) in potential for Kupferschiefer type (cu2) copper. These ratings are tempered by the location of the prospective strata: the high rating applies only to the Coppermine Homocline part of Domain I which includes unit 19 in the extreme southeast corner of the study area. In the Brock Inlier part of Domain I, the prospective Hp stratum would be located at an unknown depth in the northeast part of the study area. No indication of copper was given by stream silt sampling in the north. The rating here for Cu2 is therefore low to moderate (5).

Volcanic Redbed Copper

Proterozoic Coppermine River Group basalts outcrop in the extreme southeastern portion of the study area but are not exposed within the proposed park boundaries, although they may be present beneath Paleozoic cover. Such basalt flows contain native copper, chalcocite and bornite which are disseminated and concentrated located in fracture zones with veins (Kirkham, 1984b).

Copper in the basalts was known to the Inuit long before Europeans entered the area. Samuel Hearne made an epic trip to the Coppermine area (1769-1772) specifically to investigate reports of native copper. The basalts were extensively prospected and explored during the period 1967-1969 (Thorpe, 1970). Baragar and Donaldson (1973, p. 16) indicated that the best copper prospects are in the upper portion of the 3000 m-thick Copper Creek Formation. They quoted one deposit ('47' Zone) as containing 4.16 million tons grading 2.96 % copper. Cook and Aitken (1971, p. 5) suggested that pre-Paleozoic erosion removed much of the Coppermine volcanic sequence within the study area, and that probably no more than the lowermost few thousand feet of basal basalts remain (ibid., p. 5). More recently Sevigny et al. (1991) have identified, in oil well cores from beneath Anderson Plain, basalts which are chemically matched with the Coppermine lavas. They have presented seismic records that suggest these basalts underlie extensive areas. LeCheminant and Heaman (1989) also suggested that the basalts continue beneath the entire Brock Inlier. However, because of the great depth of the basalts under the Brock Inlier, and because the surface exposures have been extensively prospected, the potential is considered to be low (6) for accessible deposits of the volcanic-redbed type within the study area.

Iron-Rich Sedimentary Strata

Iron-rich strata (ironstone and iron-formation; Gross, 1984) are minor in the Proterozoic of the Brock Inlier. A single siderite zone, 0.5 m thick, is at the top of the basal orange stromatolite member of unit Hc (P4a). Coarsely crystalliine siderite in this member above the Hornaday Lake Fault forms the matrix between, and partially replaces, columnar stromatolites. Although this siderite was not analyzed, a similar zone about 0.6 m thick near the top of the Katherine Group in Mackenzie Mountains (member K6, Figure 6) assayed up to 50 % iron (Jefferson, 1983).

Iron formation containing up to 90% magnetite (Fe_3O_4) over a stratigraphic thickness of 15 m is in basinal shales of the Little Dal Group at two localities about 24 km apart in Mackenzie Mountains (Hewton, 1982); these strata are approximately equivalent to but a different facies from, the upper portion of the Hc (P4b, c) unit in the Brock Inlier. Black shale is draped over a lower Hc (P4a) bioherm on the coast, approximately 5 km west of Deas Thompson Point, but iron formation was not seen there.

The potential for large iron formations in Shaler Group sedimentary rocks is rated as low (6).

Evaporites

Sulphate evaporites (Kirkham, 1984c) characterize the upper portion of the Proterozoic Shaler Group (unit Hce). To date, only gypsum has been recognized here. A vertical thickness of at least 10-12 m of finely bedded gypsum is exposed in a tributary to the Little Hornaday River (Figure 21); presumably similar and greater thicknesses are in the subsurface. The remoteness of these high (2) potential gypsum suggests that commercial exploitation is unlikely at this time. Unit Hce is present near and on the Arctic Ocean coastline, between Clinton Point and the Buchanan River; any gypsum in this area would be cheaper to transport.

Exploration well Stopover K-44 (Figure 2) intersected 80 m of halite in the Saline River Formation, thus potential for pure evaporites in the study area is considered to be high (2), even though evaporites were not seen at surface in this formation. Exploitation of halite would be subject to more severe transportation constraints than Proterozoic gypsum.

Rare metals and minerals might be located where diabase sills have interacted with evaporites of the Shaler Group. For example, Jonasson and Dunsmore (1979) discovered coarsely crystalline Danburite ($CaB_2Si_2O_8$) in the Queen Elizabeth Islands where evaporite diapirs are intruded by diabase sills, dykes and ring dykes. This or other rare minerals could have been formed adjacent to the Franklin intrusions in the study area.

We were unable to find any outcrops of diabase intruding evaporites; evaporites in general are not well exposed above diabase, and diabase sills form bluffs with talus covering basal contacts.

A low-to-moderate potential (5) is assigned to contact metasomatic rare minerals, reflecting uncertainty as to what residual brines might have been preserved in the Late Proterozoic evaporites of the Shaler Group.

Gabbroid-Associated Nickel, Copper, Platinum-Group Elements and Gold

A variety of base and precious metals (nickel, copper, platinum group elements) have been traditionslly associated with diabase-gabbro sills and dikes (Eckstrand, 1984b). More recently, stratabound disseminated gold has been recognized in the Skaergaard Complex which is a classic example of such intrusions (Bird et al., 1991).

Most dikes sampled contain concentrations of copper (175-275 ppm) which are average for basalt of this type (Baragar, 1977). Sample 90-JP-33-R also shows minor enrichment in silver, gold and Palladium (Table 9), but abundant sulphide minerals were not seen in the study area. Potential for base and precious metals associated with dikes and non-layered sills is therefore considered low (6) in the Brock Inlier part of Domain I. This deposit type was not tested in the Coppermine Homocline part of the study area, because we did no field work there. The uncertainty associated with the poor exposure and lack of data in the southeast corner of Domain I results in a low to moderate rating there (5).

Regional gravity, aeromagnetic and seismic surveys indicate that a large mafic to ultramafic intrusion underlies most of Domain III in the northwestern portion of the study area (centred at approximately 69° 15' N, 124° 45' W) (LeCheminant and Heaman, 1989). As summarized in the geologic descriptions earlier in this report, we favour the model of a body less than one kilometre thick at a depth of at least several kilometres (Vye, 1972; Hole and Bradley-Isbell, 1990; P. McGrath, personal communication, 1992). If this intrusion is layered, it could host stratiform concentrations of nickel, copper, platinum group elements and gold. The uncertainty factor suggests a low-to-moderate (5) potential for deposits of this type within Domain III. Furthermore, the mineral rights to much of the anomaly are owned by the Inuvialuit, with only the eastern portion of the anomaly extending beneath the proposed park. The approximate 3-kilometre depth of the body would make exploration drilling very expensive, although future changes in infrastructure, technology and mineral market forces could change the economic parameters of exploration.

Stratiform Phosphate

The following evaluation of phosphate potential in the Proterozoic Shaler Group is after Jefferson et al. (1988). Stratiform platformal phosphate (Christie, 1984) may be present within stromatolitic carbonates of the Shaler Group. Late Proterozoic stromatolite beds in China are an important source of phosphate (Christie, personal communication, 1984). Christie (1984) noted paleotopographical domes and basins as guides to exploration for the platformal type of stratiform phosphate deposit, which would be applicable to the Amundsen Embayment as a whole. For example, the orange stromatolite marker unit at the base of unit Hc (P4=top of Glenelg Formation) contains sedimentologic and paleontologic evidence of local basin development within an overall platformal setting (Jefferson and Young, 1989; Jefferson and Jones, 1991; this report). Similarly, the siderite ironstone that is associated with this stromatolite in Mackenzie Mountains contains 0.7% P_2O_5 (Jefferson, 1983); this is somewhat more than the general 0.1 to 0.2% P_2O_5 which is characteristic of the other platformal strata, although far lower than the 30 to 40% grades being mined at foreign deposits (Christie, 1984).

Jefferson et al. (1988) rated the potential for undiscovered stratiform platformal phosphates to be moderate (4), by matching the positive geological analogies to the criteria listed in Table 2. Little new information is available, except the additional data from Rainbird et al. (1992) indicating laterally variable paleokarst and paleotopography (i.e., paleodomes and paleobasins) in unit Hct (P2). There still has not been systematic exploration or geochemical testing for, such deposits. The moderate rating is down-graded here to low (6) by considering that the deposits of this type which are being mined for fertilizer are located in India (Christie, 1984), close to intensive agriculture.

Mississippi Valley-Type Lead, Zinc

Both Proterozoic and Paleozoic carbonates (units Hct, Hc, CFM, COFMm, OFM, and possibly Hce, Hc, DBR, and DH) are considered in many places to be prospective hosts for Mississippi Valley Type lead-zinc deposits (Sangster, 1984). This type of deposit is commonly found in flat-lying dolomites or magnesian limestones, immediately below an unconformity, and adjacent to or within reef structures or other major facies changes. The deposits are best developed in rocks exhibiting paleokarst breccia or other types of increased porosity.

Paleokarst collapse breccia was not found in any Proterozoic rocks in the study area, even though it was discovered by Rees and Jefferson (in Rainbird et al., 1992) at the contact Hct\Hq (Rae Group units 22\23) east of the study area, on the lower Rae River. Possible paleokarst breccia was noted within the Franklin Mountain Formation (upper member?) at sample location 90-JP-42-R (Appendix I) immediately west of Bluenose Lake, and south and east of the Devonian (DH) mapped there. The Devonian Bear Rock Formation (DBR) lies unconformably on the upper Franklin Mountain Formation in the Simpson Lake area to the west of the study area; the local paleo-relief on this disconformity ranges up to 15 m (50'; Balkwill and Yorath, 1970). In the Simpson Lake area, the lower portion of the Bear Rock Formation contains breccias which we interpret as solution-collapse structures and paleokarst.

We observed no galena or sphalerite in the study area. The only carbonate rock which showed elevated levels of lead or zinc was sample 91-JP-38-R (Table 9), which is from a bioturbated dolostone unit in the Mount Cap Formation. The 14 ppm lead and 47 ppm zinc in this sample are not considered significant in terms of the Mississippi Valley deposit type, especially because no breccias were noted in the area.

Moderately elevated lead and zinc were noted in several stream sediment samples taken from streams draining carbonate units. Only three samples exceeded mean + 2 standard deviations for lead or zinc: 90-JP- 24-S, 91-JP-62-S, and 91-JP-120-S. Appendix II lists all stream sediment results, Figure 19 shows their locations, and the geochemistry section of this report discusses the analytical results. The stream sediment results do not indicate high potential for the Mississippi Valley lead-zinc deposit type highly anomalous, and are not considered to mineralization, though they do indicate elevated lead and zinc in some catchment basins.

Although geological and geochemical factors permit the Mississippi Valley deposit type, their weaknesses suggest the potential is low to moderate (5) for both the Proterozoic and Paleozoic carbonate units evaluated.

Shale-hosted Lead, Zinc

Stratiform sediment-hosted lead-zinc and lead-zinc-silver-barite deposits (Lydon and Sangster, 1984) are considered for the shale/siltstone units of Hp (P1), chiefly because of minor enrichment in lead and zinc in rock and stream sediment samples.

Rock samples 90-JP-66-R, 91-JP-130 and 131-R, which are samples of carbonate and pyrite-filled open fault and/or adjacent gash fractures in unit Hp, are enriched in arsenic, copper, nickel, lead (58-619 ppm), and zinc (32-934 ppm) (see Table 11). Sample 90-JP-65-R, a dolomitic nodule in the same host unit, contains 0.6 ppm silver (Table 9). The silt sample derived from a heavy mineral sample collected at the mouth of an unnamed stream draining the area south and east of Halcro Point (sample 90-JP-21-S) provided above background (> mean + 1 standard deviation) lead (11 ppm) and zinc (37 ppm) (complete results in Appendix II). In 1991, 17 stream silt samples were taken upstream of the original sample from third-order tributaries in order to confirm the original results and to determine if there were any specific sources for the lead and zinc. Results were uniform: all samples yielded <2-24 ppm lead, and 40-59 ppm zinc (Appendix II). Some samples contained slightly elevated copper (to 30 ppm). No evidence of lead or zinc minerals was noted in outcrop.

Although these results indicate minor regional enrichment in lead, zinc and some other elements in the Hp (P1) unit, there is no evidence of anomalous local stratigraphic concentrations of these elements. The unit also does not match the geological model for sediment hosted lead-zinc deposits because it lacks marked facies changes, silicious facies, graphitic facies and contains no barium, manganese or boron minerals. There is no evidence to suggest that deposition was in a fault controlled basin. The shale and siltstone are green and chloritic, not black and carbonaceous. No tuffs or volcanic flows (a positive factor for shale-hosted lead-zinc) are known in Hp or adjacent units.

The base of the unit is unexposed in the Brock Inlier. Unit Hp may overlie and is almost certainly partly derived from the Coppermine basalts; this could be a regional background source of metals in unit Hp. The elevated lead-zinc abundances appear to be typical of shales, and are only noticeable in the regional context because of their contrast with the lower background values of surrounding sandstones and limestones (units Hct and Hq). We thus assign a low (6) potential for deposits of this type.

Sandstone Type Uranium

Proterozoic (Shaler Group, unit Hq), Paleozoic (Mount Clark Formation), and Cretaceous (Langton Bay Formation, Gilmore Lake member) sandstones are possible hosts for sandstone uranium deposits. This type of deposit (Ruzicka and Bell, 1984) is formed in porous sandstone in closed successor basins developed under arid continental conditions adjacent to source areas commonly containing granitic/felsic volcanic material.

All of the above units were reconnaissance prospected and sampled for uranium; only minor geochemical anomalies were detected. A sample containing carbonaceous plant debris from the Langton Bay Formation collected along the "Wob" River (sample 90-JP-37-R) contained 1.4 ppm uranium. A Cretaceous gossanous sandstone (90-JP-69-R) from the lower Hornaday River showed minor enrichment in vanadium, lead, zinc and silver (28, 48, 76.5, and 0.9 ppm respectively), but was not analyzed for uranium. A sample of a Cretaceous coal interlayer from the same outcrop (90-JP-73- R) contained background uranium. Anomalous uranium-bearing rock samples are discussed in Unconformity-Uranium, below.

The Proterozoic, Paleozoic, and Cretaceous units are assigned a low to moderate (5) rating for sandstone type uranium because, even though many of the ore controls appear to be present (porous sandstone, bounding by less permeable horizons, arid climatic conditions in depositional period), there appears to be a lack of uranium in the system, or, possibly, there was no locus for the reduction reactions necessary to precipitate uranium. In any case, this type of deposit is now of little consequence to the world uranium supply as a result of the very high grade unconformity-type uranium deposits (see below) which have been discovered in northern Saskatchewan and Australia. Time and technology will determine the future economic viability of this deposit type.

Unconformity-Associated Uranium

In northern Saskatchewan and Baker Lake areas, deposits of this type (Tremblay and Ruzicka, 1984) occur where Helikian sandstones unconformably overlie Aphebian or Archean basement rocks, some of which contain higher than average uranium. The Helikian sandstones are generally quite porous: the basement is not porous except where cut by fault zones.

Few possible hosts for deposits of this type are in the Brock Inlier. The only sandstone units above an unconformity are unit Hq of the Shaler Group (old map-unit P3) (evidence for unconformity from Shaler Group on Victoria Island and Rae Group), the Mount Clark Formation (Cambrian), and the Langton Bay Formation (Cretaceous). None of these sandstones are known to overlie uraniferous source rocks.

Outcrops of the basal portion of these sandstones were sampled and examined for evidence of uranium or associated mineralization. Rock samples 90-JP-48 and 82-R, of green shale layers at the base of the Mount Clark and Hq units respectively, are slightly enriched in uranium (6.3 and 10 ppm), but stratigraphically adjacent sandstone samples are not uraniferous. Very limonitic and hematitic, friable basal conglomerate was examined in one outcrop of Mount Clark Formation but samples 90-JP-104, 105, 106-R yielded less than 1 ppm uranium.

The potential for unconformity-associated uranium in the study area is thus considered to be low (6).

Carving Stone

P. Green (personal communication, 1991) has advised that to be considered as a suitable carving material by local carvers, a given rock must be relatively soft (in geological terms about 2 -5 on Mohs scale of hardness), yet competent. Prospective geological units within the study area include serpentinite (formed by contact metamorphism of Shaler Group dolostones intruded by late Proterozoic dykes and sills), marble (formed in the same fashion), and soft blocky shales of the basal unit (Hp) of the Shaler Group (for a discussion of these and other potential carving stones, see Gibbins, 1983).

There is no evidence of current usage of local rock by Paulatuk carvers; they carve primarily in bone and muskox horn, and occasionally in imported stone. Paulatuk carvers have been looking for a local source of (soft) stone; consequently we visited various geologically prospective locales, collecting samples for evaluation by local carvers. We found abundant quantities of impure marble adjacent to several diabase sills (especially Pearce Point area, also see Figure 22), sampled laminated siltstones in the P1 unit of the shaler Group, and sampled one serpentinized dolomite. All samples were described as "too hard" by Paulatuk carvers (P. Green, personal communication, 1991). The serpentinite

Figure 22. Impure laminated marbles developed in carbonates of unit Hc as a result of contact metamorphism adjacent to a diabase dyke; width of view 3 m in foreground. Same location as Figure 9. Material was investigated for use as carving stone.

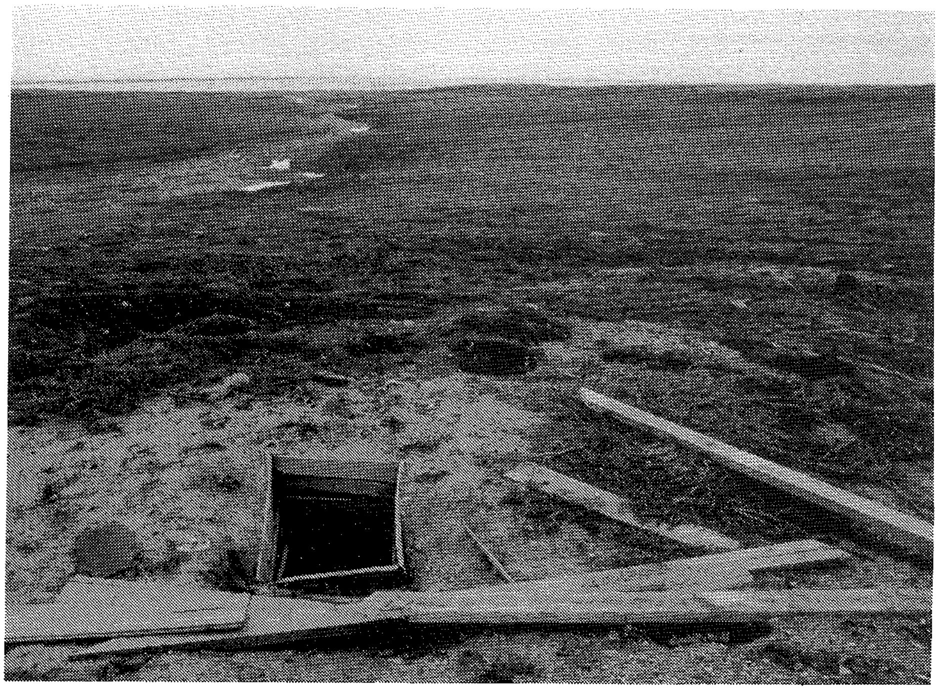

Figure 23. Collar of small abandoned coal shaft (approximately 60 x 60 cm) in Cretaceous Langton Bay Formation just north of BrockLagoon. View looking westward, with the lagoon and Darnley Bay in the background.

and siltstone we found are also relatively brittle and difficult to collect in large pieces.

It seems probable that the only carving stone likely to suit Paulatuk carvers now would be relatively uniform serpentinite formed in a thick contact metamorphic zone. The serpentinite that we sampled in one such zone was, instead, blocky, impure, and a maximum of 20 cm thick. Potential for discovery of thicker, less impure deposits of serpentinite in the Shaler Group is considered to be moderate (4).

Jefferson et al. (1991) documented Inuit usage of power tools in the eastern Arctic in order to carve harder rock, e.g., banded gneiss. Should Paulatuk carvers become interested in these methods and harder rock, competent contact metamorphic marble (found, for instance, in the Pearce Point area) might become an attractive alternative to traditional materials.

Aggregate

Abundant sources of aggregate are present in most parts of the study area. These include unconsolidated fluvial sands of the Tertiary Beaufort Formation, Quaternary raised beaches, glaciofluvial outwash and deltas, and Recent river deposits of sand and gravel.

Potential for aggregates is high (2) for all parts of the study area; many deposits are on Inuit and Crown lands outside of the proposed park area.

Aggregate is one commodity where shipping costs determine usage; local deposits are primarily useful as a source of construction material for local projects.

Building Stone

The dolostone of unit Hct (P2) and the quartzarenites of Hq (P3) are blocky to flaggy. Some would be suitable for local building stone, however even local transport would be very expensive, and stone is not an energy-saving building material. Some of the stromatolitic patterns on these rocks are attractive, but the unmetamorphosed dolostones would not be competent enough to warrant transport to urban markets for facing stone. Typical industrial building stones are very competent granites and metamorphic rocks (e.g., gneisses and marbles); these are not in the study area. Building stone potential is therefore rated as low (6).

Coal

Coal has been mined sporadically in the vicinity of Paulatuk since at least 1936, when the Roman Catholic mission was established there because of the availability of coal as a heating fuel (Mackay, 1958). The name Paulatuk derives from the Inuvialuktun phrase for soot caused by the burning of coal (T. Green, personal communication, 1990) (Figure 23 shows the top of abandoned coal mining shaft; a similar shaft is pictured in Mackay (1958; Plate XII.b).

Coal is widespread within the Cretaceous Gilmore Lake Member of the Langton Bay Formation; the coal units near Paulatuk are considered to be correlative (Yorath and Cook, 1981).

We sampled and prospected the original deposits (locally known as Coalmine) which are at the junction of Rummy Creek with Hornaday River. Two coal beds at least 1 m each in thickness are within a 6.5 m vertical section comprising 80-85 % coal. Jarositic sandstones and mudstones intervene between individual coal seams. This coal measure is in a sequence of friable sandstone. Two samples taken from these units are sub-bituminous in grade (reflectance 0.5-0.53) (F. Goodarzi, personal communication, 1992) which would be suitable for use as a home-heating fuel and as boiler feedstock, depending on the ash content. Insufficient sample was collected to determine ash content, but a number of the seams observed were relatively low in detrital material.

The Gilmore Lake Member of the Langton Bay Formation forms sub-continuous cover over Paleozoic sedimentary rocks south and west of Hornaday River, and outliers north and east of that river (Figure 5). Coal is reported from the vicinity of House and Pearce points (Mackay, 1958) and was seen by the first author on the frost heaved crest of a pingo, immediately west of Tinney Point. A small piece of coal found in glaciofluvial alluvium on the east side of Hornaday Lake is unlikely to have travelled far. Yorath and Cook (1981) stated that the Gilmore Lake Member rests unconformably on Devonian and older rocks, and tends to infill paleotopographic relief up to 100 m.

Only local use of the coal may be economically possible because the coal units are not very thick, their distribution within the Gilmore Lake Member is patchy and the Member is eroded from large portions of the study area. Lignitic coals usually contain much water and ash, and suffer spontaneous combustion, hence are difficult to ship, however the sub-bituminous grade of the two samples analysed suggests the shipping potential is good. However, within these constraints, the potential rating for small deposits suitable for local use is high (2) within Domain III. A large proportion of this area is within Inuvialuit lands which are not included in the park proposal (figures 1 and 3).

Economic potential of this coal potential is dependent on at number of considerations:
(a) the grade and reserves of the coal would have to be proven by drilling and bulk sampling.
(b) the value of coal as a local fuel is enhanced considering that the fuel presently used for home heating and electrical generation is expensive

diesel oil, brought in by barge from Norman Wells on the Mackenzie (Dehcho) River.

(c) new coal-burning technology could produce electrical energy with less pollution than in the past. Dr. Fari Goodarzi at the Institute of Sedimentary and Petroleum Geology in Calgary would be pleased to provide more information on this topic.

(d) the suitability of the coal for such local power generation would have to be tested.

(e) capital costs, time and effort spent to to install coal-powered electrical generating facilities must be determined.

(f) mining of the coal could generate small-scale, on-going local employment, if local people are inclined toward such activities.

Summary of Mineral Potential by Domain

Table 1 (Executive Summary) summarizes the mineral resource potential rating of the Bluenose Lake area by domain for each of the deposit models considered. For the purposes of this table, mainly the rock units at or near surface are considered. Discussion of the Darnley Bay gravity anomaly (Domain III) is an exception.

Little is recorded of the exploration history of the study area. As of December 1991, the Mining Recorder's Office informed us that no mineral claims or mineral exploration permits were in good standing. We are aware only of the exploration for the three types of copper deposits, and for gabbroid associated nickel, copper, platinum-group elements and gold which might be associated with the Darnley Bay gravity anomaly. The exploration history of these deposit types is included in their respective assessments above.

Potential for any deposit type not specifically noted is considered to be very low. The potential for most deposit types is rated as low (6), or low to moderate (5); some of the latter and all higher assessments are summarized by domain in the following sections.

Domain I, Proterozoic Rocks

For most mineral deposits the strata in Brock Inlier and Coppermine Homocline rank as equivalents, but some differences exist and the two areas are geographically separated, therefore they are documented separately in Table 1.

Potential is considered to be high (2) for gypsum in unit Hce of the Shaler Group, however shipping costs will likely preclude exploitation under present economic conditions. Potential for gabbro-associated gold, nickel, copper and platinum-group mineralization is considered to be low to moderate (5) for near-surface Hadrynian intrusions in Shaler/Rae Group strata.

Potential is moderate (4) for small deposits of contact metamorphic serpentinite and marble for carving.

At least two companies have been (1990-91) exploring the Coppermine Homocline which has high potential (2) for red-bed and Kupferschiefer type copper, supported by information derived from copper showings in the Glenelg Formation of the Shaler Group on Victoria Island. The potential for copper is only low to moderate (5) in the central study area because:

1) the copper minerals, the paleokarst in the middle cherty dolostone (Hct=P2), the Hct\Hq (P2\P3) unconformity, the conglomerates, and the carbonaceous sandstone facies (Hq=P3) of Victoria Island are absent or poorly developed in this southeast portion of the Amundsen Embayment (Rainbird et al., 1992), and
2) the highly prospective basal Rae/Shaler Group strata outcrop in only the extreme southeast corner of the study area, and extend at great depth under the central study area.

Domain II, Mackenzie Platform

The potential for salt is rated high (2); other mineral deposits are rated low to moderate (5) or less in Paleozoic strata. Potential in Proterozoic basement, for deposit types discussed under Domain I, is limited by the thick Paleozoic cover.

Domain III, Anderson Basin (+ Unconsolidated Material)

Potential for construction aggregate is rated high (2), but aggregate would be of local interest only, as it is of low bulk value.

Potential for small deposits of sub-bituminous coal is considered to be high (2). Due to its thin bedding and patchy distribution coal is considered to be of interest primarily for local consumption.

Considerable uncertainty is associated with our low-to-moderate (5) rating for nickel, copper, platinum and gold in basement beneath much of Domain III. The potential host mafic intrusion is approximately 3 km below surface.

ASSESSMENT OF FLUID HYDROCARBON RESOURCE POTENTIAL

No oil or gas fields have been discovered within the boundaries of the Bluenose Lake study. Exploration has been limited to seismic reconnaissance and two exploratory wells in the extreme southwestern corner of the area. These wells lie 100 km east of significant discoveries in the Colville Hills, made in the period 1974-86, and represent the northeasterly limit of associated exploration. However, the extent of exploration does not necessarily indicate the limits of hydrocarbon potential in remote areas. In recent years, hydrocarbon exploration in much of the north has stopped because of economic and political factors.

The Colville Hills gas discoveries, although of substantial size, are remote from proposed pipelines in the Mackenzie Valley and there are no current plans to develop the reserves. Ultimately, development of this area must await the construction of a pipeline connecting gas reserves in the Arctic Islands to southern markets.

The hydrocarbon potential of the study area is dependant on the age and nature of sedimentary strata preserved west and north of the Canadian Shield. The potential for oil and gas reserves in metamorphosed shield rocks is minimal. In contrast, potential in unmetamorphosed Precambrian, Paleozoic and Mesozoic strata which abut the Shield varies from Very Low to Moderate, as detailed below. Criteria for the qualification of potential are given in Table 2.

Summary Stratigraphy Relevant to Hydrocarbon Potential

Precambrian (Neo-Helikian) sedimentary rocks of the Shaler Group are exposed in the Brock Inlier in the north central part of the study area. These rocks dip gently to the south-southeast beneath Paleozoic strata along the axis of the Coppermine Arch. Precambrian rocks in the southeast corner of the study area are the northwest-dipping homoclinal sequence of the Coppermine River Group continental basalts, overlain by platformal shale, sandstone and carbonate strata of the Rae Group.

Seismic lines in the southwestern quadrant of the study area show continuous reflections indicating a very thick sedimentary section beneath an angular unconformity at the base of the Paleozoic (Sevigny et al., 1991). Major folds and faults are also evident in the Precambrian on most seismic lines. Most of the major folds predate the Paleozoic but many faults have been reactivated. The Precambrian rocks of the Brock Inlier are unmetamorphosed (Cook and Aitken, 1969) and retain some potential as reservoir and source rocks. However, these rocks are poorly known because most exploratory wells have penetrated only a few tens of metres below the basal Cambrian unconformity.

Paleozoic rocks ranging in age from Cambrian to Middle Devonian age constitute bedrock across the remainder of the study area, apart from a thin veneer of Pleistocene sediments, a thinning wedge of Mesozoic strata in the extreme west and several outliers of Mesozoic strata. Paleozoic strata increase in thickness from zero along the edge of the Proterozoic rocks to approximately 1000 m in the southwest, where they are termed the northern part of the Western Canadian Sedimentary Basin. A shallow Paleozoic basin is preserved east of the Brock Inlier, beneath the waters of Coronation Gulf and across much of southern Victoria Island. No Paleozoic rocks younger than Ordovician/Silurian occur at outcrop east of the Brock Inlier.

Cambrian strata attain thicknesses of 400-600 m in the study area; they comprise continental to shallow marine sandstones of the Mount Clark Formation, marine strata of the Mount Cap Formation and evaporites and shales of the Saline River Formation.

The Mount Clark Formation consists of coarse sandstones with minor conglomerate, fining upward into finer sandstones and siltstones. The Formation outcrops along the Brock Inlier (Cook and Aitken, 1969) and appears to be regionally extensive in the subsurface (Hamblin, 1990). The rock is friable at outcrop and has fair to good porosity in wells southwest of the study area (for example, Well History Report for Tedji Lake K-24).

The Mount Clark Formation is overlain by marine shales, siltstones, fine sandstones and dolomite stringers of the Mount Cap Formation which is in turn succeeded by evaporites and shales of the Saline River Formation.

The transition from shales of the upper Saline River Formation into carbonates of the Ordovician Franklin Mountain Formation of the Ronning Group is gradual. The Ronning Group is more than 500 m thick in the subsurface to the southwest of the study area and measures at least 150 m in outcrop (Cook and Aitken, 1969). The lithology is principally dolomite; chert is common in the upper "Cherty Unit" in which Macqueen and MacKenzie (1973) report vuggy and fracture porosity in the Colville Hills E-15 well southwest of the study area.

The Middle Devonian Bear Rock Formation overlies a major pre- Middle Devonian unconformity which truncates older Paleozoic strata across most of the area, entirely removing the Late Ordovician to Silurian Mount Kindle Formation. The Bear Rock Formation has been reported from the northwestern part of the Erly Lake map area (Cook and Aitken, 1969) but has been removed by pre-Cretaceous erosion elsewhere. Outliers may be preserved elsewhere in structural lows beneath Pleistocene cover; preservation is more widespread immediately west of the study area. Solid and liquid bitumen fill vuggy porosity in exposures of the Bear Rock Formation on the Hornaday River.

The Mesozoic of the study area comprises outliers of Early Cretaceous strata. The Cretaceous is unlikely to attain any significant thickness beneath Pleistocene cover, and was not penetrated in either of the two wells drilled in the study area. The exposures examined by the first author on the Hornaday River are of conglomeratic sandstone, carbonaceous shale and petroliferous coal. No oil seeps or odour were observed in the Cretaceous rocks near the Brock Inlier.

Structure Relevant to Hydrocarbon Potential

Upturned and truncated Paleozoic strata are exposed around the margin of the Brock Inlier. This feature, part of the north-northwesterly trending Coppermine Arch, underwent several periods of reactivation, notably pre-Middle Devonian and post Lower Cretaceous (Cook and Aitken, 1969; Yorath and Cook, 1981; see Geological History, p. 33-35).

Faults exposed in the Brock Inlier trend NNW-SSE parallel to the axis of the Coppermine Arch and several are mapped as reverse or thrust faults (Cook and Aitken, 1969; this paper, Figure 7). Faults in Precambrian strata are also indicated on seismic records of the extreme southwest of the study area between the Coppermine and Keele Arches (Petro-Canada Seismic Programme 9229-P28-1E, 1984, National Energy Board Files). These faults likely create potential hydrocarbon traps in Lower Paleozoic strata.

The Keele Arch is a regional feature of comparable scale to the Coppermine Arch southwest of the study area (Figures 2, 4). Several north-trending faults with vertical displacements of several hundred metres and possible strike-slip movement are visible on seismic lines in the Colville Hills areas (Davis and Wilcott, 1978; seismic lines in National Energy Board Files). Faults in the Colville Hills clearly break pre-Saline River strata; younger strata show comparable displacements above the salt, although fault breaks are rare. Structures are also visible on aerial photographs (Haimila, 1975). The most recent uplift and faulting of the Keele Arch may be related to Laramide tectonism. However, it is less likely that Laramide tectonism was as strongly imposed on the Coppermine Arch. This deformation in the Colville Hills has created large subsurface closures which may be hydrocarbon traps.

Exploration History

A few reflection seismic lines and two exploratory wells are located in the southwest corner of the study area. Union OIL Stopover K-44 was drilled to 943 m in 1975, and Forward et al. Anderson C-51 was drilled in 1983 to 1010 m.

Both of these wells penetrated comparable Silurian to Precambrian strata: dolomites and shales of the Precambrian Shaler Group, Cambrian sandstones of the Mount Clark Formation immediately above the basal Cambrian peneplain, a section of mixed shale, sandstone and interbedded dolomite in the Mount Cap Formation, shales and evaporites of the Saline River Formation, and Ordovician-Silurian Franklin Mountain carbonates. Total depths to the Precambrian are 867 m and 939 m for the K-44 and C-51 wells respectively. These depths are 200-400 m shallower than in wells farther west along the Keele Arch.

The Precambrian dolomites of the Shaler Group encountered near total depth in both wells are micro or cryptocrystalline with no porosity reported in cuttings samples for K44 or side-wall cores (C-51). Two sidewall cores from Anderson C-51, described as cherty dolomitic sandstone or siltstone, were reported as having dark brown oil staining in places and some intergranular porosity.

The Mount Clark Formation sandstones overlie dolomite at a major unconformity in both wells. Conventional core was cut in these sandstones in Stopover K-44. The core descriptions (Well History Report, Union stopover K-44) indicate contrasting colour (red and white), and marked variability in grain-size (very fine to coarse), roundness (subangular to well rounded) and sorting (fair to very well sorted) between sandstone beds. There is an overall fining-upward trend; the upper sandstones are mainly fine to very fine grained, silty, subangular, moderately sorted and glauconitic. Beds of coarser, better rounded and sorted sandstones are more common downward. The sandstone is hard with no porosity except for a 3m interval where bands of fair and good porosity are described in well sorted, medium to coarse grained sandstone. Of particular note are the reports of light brown oil bleeding from certain sections of the core and of some black bitumen in the core. Oil bleeding only took place after one hour of the core being at surface, indicating low permeability and\or viscosity.

The Mount Cap Formation comprises interbedded shales, dolomites and glauconitic siltstone and very fine grained sandstone. A trace of pin point or small vuggy porosity was noted in samples from one 3 m (10') interval in Stopover K-44 (2620-2630', Well History Report). A trace of light brown oil stain and scattered bright yellow fluorescence was associated with this porosity. The Mount Cap Formation is overlain by about 80 m of halite (with minor shale interbeds) and an equivalent thickness of shales, together comprising the Saline River Formation. No porosity or hydrocarbon shows were noted through this interval.

Carbonates of the Franklin Mountain Formation were drilled in the upper section of both boreholes. Although some vuggy porosity was noted, no staining or shows were described.

Hydrocarbon Geology

The petroleum geology of the study area is described here in terms of two Petroleum Systems (sensu Magoon and Dow, 1991) separated by Saline River salts which may be a regional barrier to vertical hydrocarbon migration. A Petroleum System is a group of stratigraphic units comprising: a source or source rocks, potential reservoir rocks, and potential seal (cap) rocks. It is separated by discontinuity from adjacent Petroleum Systems.

Lower Petroleum System (LPS)

The LPS comprises Cambrian and Precambrian strata below the potential seal of the Saline River salt.

Source rocks include known potential source rocks in the Cambrian, and possible source rocks within the Precambrian Shaler Group.

Reservoir rocks include the proven reservoir-quality sandstones in the Mount Clark Formation and lower Mount Cap Formation, and some possibly porous Precambrian dolomites of the Shaler Group. Oil staining is characteristic of Mount Clark sandstones where porosity is developed, oil has also bled from fractured Precambrian dolomite in core taken from Tweed Lake C-12 (Well History Report, core description 1323.67-1328.43 m).

Some deep potential also exists for liquid hydrocarbons in Precambrian strata. Seismic lines indicate a thick Precambrian section across much of the study area, but the nature of these strata beneath the base of well control is unknown. Precambrian rocks are rarely petroliferous, largely because of overmaturity and absence of reservoir. Such is likely to be the case for the bulk of the Precambrian section in the study area.

The LPS includes the Tedji Play, an established hydrocarbon play with three significant gas and gas/condensate discoveries in large structures along the Keele Arch southwest of the study area (Tedji Lake K-24 (1974), Tweed Lake M-47 (1985) and Bele O-35 (1986). This play is principally for gas although an oil leg is probable but untested in the Tweed Lake pool. A potential source rock for oil has been identified in shales of the Cambrian Mount Cap Formation (Wielens et al., 1990). The gas may have come from the Cambrian or possibly the Precambrian and migrated updip into the structures. The reservoir is sandstone of the basal Cambrian Mount Clark Formation. The immediate seal is provided by the source mudstones of the overlying Mount Cap Formation; downward migration of oil from the Mount Cap Formation rock would have been enhanced by the overlying impermeable halite seal of the Saline River Formation.

The proven Tedji Play is restricted to structural highs along the Keele Arch which trapped hydrocarbons migrating updip from deeper parts of the basin further west. The Keele Arch may therefore prevent hydrocarbons from migrating further east into the study area. For this reason, the Tedji Play is unlikely to extend to the area between the Keele Arch and the Coppermine Arch. However, a less attractive play involving smaller fault-bounded structures may exist in the study area. The necessary elements of the LPS extend across this area to outcrop of the Cambrian section but potential sources of hydrocarbons and migration paths in this area are very uncertain and less favourable.

The Cambrian source rock in the wells drilled in the Colville Hills is immature for oil generation from the predominantly alginite source rock discovered within the Cambrian section (Wielens et al., 1990). A deeper and thermally mature section should occur down-dip to the west of the Keele Arch and possibly to the southeast (Hamblin, 1990). The depth of the Paleozoic rocks to the northeast into the study area appears insufficient to achieve thermal maturity for oil generation: hence lateral migration over long distances would be necessary to emplace oil in the Cambrian section within the study area. This restriction would not necessarily apply to gas derived from Precambrian rocks.

The geographic limits of the LPS coincide with the outcrop of the Saline River Formation. Down-dip from this outcrop essential elements of the system - source, reservoir and seal - are likely to exist although the extent and maturity of source rocks are low in potential (=high risk). There is, however a gradation of increasing potential as the thickness of the Paleozoic section increases westerly toward a proven play in the Colville Hills and away from the aquifer charge zone. This gradient in potential is expressed qualitatively as an increase from low (6) in the outcrop zone to moderate (4) in the extreme southwest corner of the study area (Figure 2).

Upper Petroleum System (UPS)

The UPS comprises Cretaceous clastic and Paleozoic carbonate strata above the Saline River salt.

Potential source rocks for UPS comprise Devonian and basal Cretaceous shales (now eroded from the study area). Potential reservoir rocks include carbonates of the Franklin Mountain and Bear Rock formations, and Cretaceous sandstones. Potential seals are tight Ordovician and Devonian carbonate units.

Elements of the UPS are absent or their existence is highly uncertain across much of the study area. In particular, Cretaceous rocks, although "early mature" for oil generation on the basis of high coal rank (this study), lack an effective seal. Biodegradation and breaching of reservoirs also presents a severe limitation on prospectivity.

Oil stains have been noted within the Franklin Mountain Formation (Macqueen and MacKenzie, 1973) and in the Bear Rock Formation in the upper section of Bele O35 (Well History Report). Samples of bitumen were collected by the first author from vugs in Bear Rock Formation dolomites in the Hornaday River. These samples proved to be severely weathered and gave no clue as to derivation (P. Brooks, personal communication, 1991). However, a Cambrian source rock can be excluded for samples from surface seeps elsewhere in the region (Wielens et al., 1990). Younger Devonian or lower Cretaceous shales seem to be the preferred sources for seeps but these units outcrop to the west of the study area.

Vuggy porosity appears common in the Bear Rock Formation and, to a lesser extent, in the cherty unit of the Franklin Mountain Formation. The former unit is only patchily preserved within the study area. Charging of Paleozoic rocks with oil from stratigraphically younger source rocks and the subsequent exhumation of these units is the origin of some heavy oil deposits of Alberta, notably the Grosmont Formation. The potential for deposits of this kind within the study area is rated as moderate (4). Clearly such potential is limited to areas where Paleozoic carbonates were once covered by younger source rocks.

Summary of Hydrocarbon Potential

Two petroleum systems exist across the study area with the exception of areas of Precambrian outcrop. The Lower Petroleum System includes a proven gas play (Tedji Play) in the Colville Hills west of the study area and a demonstrated oil source rock. Potential for this and similar plays to host significant accumulations of hydrocarbons within the study area declines from moderate (4) to low (6) as the Brock Inlier is approached from the southwest.

The Upper Petroleum System is incompletely preserved across the study area and has low potential (6) for accumulations of conventional hydrocarbons. However, potential is moderate (4) for heavy oil deposits.

The study area is remote and small accumulations of conventional oil or gas will not be of commercial interest. It is improbable that gas discoveries of a size comparable to the Tedji Lake play will be made. Deposits of heavy oil, if present, have little economic significance given the large reserves in Alberta and Saskatchewan.

GEOLOGICAL ATTRIBUTES OF PARK VALUE AND POTENTIAL PARK ACTIVITY

The canyons developed in the lower reaches of the Brock, Croker and Hornaday rivers are dramatic features: slots up to 150 m deep are cut vertically into low, rolling tundra; spires and pinnacles left standing form a landscape reminiscent of the American southwest (Figure 24). The other geological features of interest to the layman are less obvious.

Much of the northern portion of the Brock Inlier is low and undulating, with sparse, stunted vegetation. In contrast sharp-sided valleys of rivers such as the Wob and Outwash are oases of lush grass and flowers, protected from harsh Arctic winds and watered by relatively deep snow accumulations.

As described earlier, the central portion of the Brock Inlier was apparently not glaciated during the last (Wisconsin) ice age (Figure 15). It appears to have served as a place where various plant species continued to grow during continental glaciation (G. Scotter, personal communication, 1990). Potential park visitors may wish to observe but not remove the wood lying on the beaches around Hornaday Lake. It is more than 40,000 years old and includes a Pinus strobus (white pine) type which suggests a climate similar to that of present-day southeastern Canada (S. Zoltai, personal communication, 1991).

A pingo is located on the coast near Tinney Point, and several others are to be found in the interior (Figure 15). Giant kames (conical piles of sand and gravel built by meltwater flowing from the surface of the ice down to the base of the ice) can be observed at the south end of Bluenose Lake. More subtle features which were formed beneath and at the edge of the continental ice sheet are widespread, including: drumlins, perched outwash deltas from meltwater streams, roche moutonées (icesculpted rock), and ice-striated bedrock surfaces.

McMartin and St Onge (1990) reported relict ice, east of Bluenose Lake, which they interpreted as being preserved from the time of Wisconsin glaciation. This ice is partly buried by till, but its exposed portions are receding annually as it melts into an adjacent kettle lake.

The coastal landscape is generally unspectacular but pretty; its generally low relief and shingle beaches invite hiking. Hiking would be more rugged near the site of the former DEW Line station at Pearce Point. Here striking sea cliffs, rock bridges and pinnacles are developed in stromatolitic carbonates of map unit Hc. The cliffs and narrow cobble beaches wrap around an inlet which forms a protected harbour.

The stromatolites exposed in these cliffs are geologically exceptional; they are silent testimony to a vast marine shoal complex which stretched from northeastern Victoria Island to Mackenzie Mountains about a billion years ago. Lateral changes in these stromatolites provide clues to where the warm waves once pounded ancient lagoons and reefs populated only by soft green algal mats.

Should a national park be established in this area, prospective visitor activities might include the following: hiking along the coast or over the uplands of the Brock Inlier, canoeing or kayaking on the upper Hornaday, bird watching, and small boat trips along the coastline from Paulatuk. Some of these potential visitor activities might generate income for local inhabitants. Although much of the landscape is delicate and could not withstand much traffic, the

Figure 24. Photo taken from the air on lower reaches of Hornaday River. Canyon is incised down to 150 m into Paleozoic carbonates. During spring runoff (in July!) the river completely fills the bottom of the canyon along several tens of kilometres, making it unsafe for boats or canoes; shortly afterward the water is so low that only shallow draft craft might be able to get through. Peregrine falcons commonly nest along the edges of the canyon.

Figure 25. Historical use of local stone as a building material. Stone circle represents base ring for a semi-permanent skin tent; possibly part of a seasonally occupied hunt camp. Note the sleep platform constructed from stone. Many broken and half- finished stone and bone implements were found nearby. This habitation may date from occupation of the region by Dorset people (Marc Stephenson, pers. comm., 1991).

high cost of reaching this area may initially provide automatic limits to the number and status of visitors.

The proposed park is a landscape of subtle contrasts, and one which rewards patience on the part of the visitor. With the exception of the features noted above, the scenery is generally not spectacular, but the visitor would be able to concentrate on the patterns of the sky and light, the subtle colour banding of hills in the distance, the incredibly abundant wild flowers, individually subtle in their display. Wildlife is plentiful, yet often not seen on the ground unless the visitor is quiet over a period of hours. We awoke one morning at our 1992 fly camp on the little Hornaday River, surrounded by hundreds of caribou, and found ourselves in the direct path of a grizzly stalking the herd....

The landscape is currently essentially devoid of obvious human activity except along the coast where Inuvialuit of the region do most of their hunting and fishing. Even here, the effects are subtle. In completing our geological fieldwork it was hard not to sense the presence of earlier inhabitants: evidence of hunting and camping activity is present throughout the interior in the form of tent rings (Figure 25), stone tools, and meat caches built from boulders. Obviously these earlier inhabitants made good use of geological materials at hand.

CONCLUSIONS

No currently economic mineral or hydrocarbon resources are known in the study area, except for aggregates being utilized by the community of Paulatuk. As of December 1991, no active mineral permits or valid mineral claims were held in the study area.

Potential for aggregate is high (2) in all domains. Much of this aggregate would be available outside of the proposed park area.

In Domain I potential is rated high (2) for gypsum in unit Hce (central area), high (2) for copper in the southeast corner (outside the current park proposal), moderate (4) for carving stone, low to moderate (5) for nickel, copper, platinum-group elements and gold in Hadrynian gabbros, and low-to-moderate (5) for phosphate in carbonate strata.

The potential of Domain II to host significant accumulations of fluid hydrocarbons decreases across the study area from moderate (4) in the southwest corner to low (6) adjacent to Domain I and in the remainder of the study area. The potential for deposits of heavy oil in Domain II is rated as moderate (4). Potential for salt in the Saline River Formation is rated as high (2).

In Domain III potential for coal of relatively good (sub-bituminous) grade is high (2). Other combinations of commodities and domains are rated as low-to-moderate (5) to low (6) in potential.

Figures 1, 2, and Table 1 summarize all resource potential ratings by geographic area.

Application of the geologically derived resource-potential ratings to exploration and park boundary decisions would be influenced by a number of economic considerations. Factors such as proximity to market, operating costs in an arctic winter environment, and higher average northern salaries all would affect the potential for profitability of any northern operation. Remoteness of the area would affect operating costs and demand, more for high-volume commodities such as gypsum and construction aggregate, than for precious or specialty commodities.

Specific constraining economic factors apply to several ratings. The relatively pure thick sections of Proterozoic gypsum (quality unknown) and Paleozoic salt are unlikely to be exploited given their remote location. All carving-stone samples submitted for assessment by local carvers were judged to be substandard. The Hadrynian intrusions with which gold, nickel, copper and platinum-group-elements might be associated are thin at surface. A large intrusion located beneath Paulatuk is judged from seismic data to be at about 3 km depth, and becomes deeper toward the proposed park area. The coal is of unknown ash content, would be thin-bedded and best suited for local use. Much of the coal potential is located under Inuvialuit land which is not being considered for the proposed park. Accumulations of conventional oil, heavy oil or gas, if present, would be in competition with the large reserves in Alberta and Saskatchewan. Potential heavy oil deposits would have little economic significance given the large reserves in Alberta and Saskatchewan.

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APPENDIX I. CHEMICAL ANALYSES OF ROCK SAMPLES

APPENDIX I. CHEMICAL ANALYSES OF ROCK SAMPLES.

SAMPLE #	(METHOD OF ANALYSIS)	90-JP-030-R	90-JP-031-R	90-JP-032-R	90-JP-033-R	90-JP-034-R	90-JP-035-R
UTM Zone		10	10	10	10	10	10
Northing		7790980	7790980	7792240	7792240	7792240	7792430
Easting		605870	605870	606240	606240	606240	606250
Au (ppb)	FA/DCP	- -	- -	< 1	6	- -	- -
Au (ppb)	DNA	< 5	< 5	- -	- -	< 5	< 5
Li (ppm)	ICP	21	16	22	17	18	6
Be (ppm)	ICP	3.5	3.1	1.4	< 0.5	3.7	2.1
Na (%)	ICP	- -	- -	- -	- -	- -	- -
Mg (%)	ICP	- -	- -	- -	- -	- -	- -
Al (%)	ICP	- -	- -	- -	- -	- -	- -
P (%)	ICP	- -	- -	- -	- -	- -	- -
K (%)	ICP	- -	- -	- -	- -	- -	- -
Ca (%)	ICP	- -	- -	- -	- -	- -	- -
B (ppm)	ICP	14	21	4	6	14	< 2
Sc (ppm)	ICP	2.6	3.4	2.4	12.2	1.8	1.3
Ti (%)	ICP	- -	- -	- -	- -	- -	- -
V (ppm)	ICP	35.6	20.9	20.4	169	22.9	15.1
Cr (ppm)	ICP	15	16	12	22	12	9
Mn (%)	ICP	- -	- -	- -	- -	- -	- -
Fe (%)	ICP	- -	- -	- -	- -	- -	- -
Co (ppm)	ICP	5	19	14	25	2	6
Ni (ppm)	ICP	13	16	25	58	2	5
Cu (ppm)	ICP	11	82.8	60.1	273	29.6	7
Zn (ppm)	ICP	22.6	27.1	21.5	66.2	180	17.6
As (ppm)	DNA	4	18	- -	- -	< 2	2
As (ppm)	ICP	< 3	10	< 3	< 3	< 3	5
Se (ppm)	ICP	< 20	< 20	< 20	< 20	< 20	< 20
Sr (ppm)	ICP	203	154	106	80.2	134	69.4
Y (ppm)	ICP	8.4	8.1	25.5	11.2	4.7	4.8
Zr (ppm)	ICP	13.3	10.7	1.7	5.8	4.1	6.7
Mo (ppm)	ICP	< 1	< 1	< 1	< 1	< 1	< 1
Pd (ppm)	FA/DCPICP	- -	- -	5	25	- -	- -
Ag (ppm)	ICP	0.2	< 0.1	0.2	0.4	< 0.1	< 0.1
Cd (ppm)	ICP	< 1	< 1	< 1	< 1	< 1	< 1
Sn (ppm)	ICP	< 10	10	< 10	< 10	< 10	< 10
Sb (ppm)	DNA	< 0.5	26	- -	- -	1.7	< 0.5
Sb (ppm)	ICP	< 5	13	< 5	< 5	< 5	< 5
Ba (ppm)	ICP	48	25	29	13	302	19
W (ppm)	DNA	< 2	< 2	- -	- -	< 2	< 2
W (ppm)	ICP	< 10	< 10	< 10	< 10	< 10	< 10
Pt (ppb)	FA/DCP	- -	- -	< 10	10	- -	- -
Pb (ppm)	ICP	< 2	84	< 2	< 2	181	6
U (ppm)	DNC	- -	- -	- -	- -	- -	- -

APPENDIX I continued.

90-JP-034-R	90-JP-035-R	90-JP-037-R	90-JP-038-R	90-JP-039-R	90-JP-040-R	90-JP-041-R	90-JP-042-R
10	10	10	10	10	10	10	11
7792240	7792430	7793490	7793490	7793490	7793490	7793490	7580500
606240	606250	606	606	606	606	606	376650
- -	- -	- -	- -	- -	- -	- -	- -
< 5	< 5	- -	- -	- -	- -	- -	< 5
18	6	< 1	< 1	< 1	< 1	< 1	< 1
3.7	2.1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	3.2
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
14	< 2	< 2	9	5	3	< 2	3
1.8	1.3	0.3	< 0.1	0.5	< 0.1	0.1	0.3
- -	- -	- -	- -	- -	- -	- -	- -
22.9	15.1	4.3	< 0.5	3.9	< 0.5	1.4	3.4
12	9	10	9	11	8	9	7
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
2	6	3	106	3	2	1	1
2	5	8	82	6	3	4	< 1
29.6	7	3.2	3.6	2.7	< 0.5	1.6	5.2
180	17.6	6.8	56	17.8	7.1	11.1	3.6
< 2	2	- -	- -	- -	- -	- -	< 2
< 3	5	< 3	4	< 3	< 3	< 3	4
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
134	69.4	41.5	16.7	63.3	33.6	30.3	75.9
4.7	4.8	1.3	6.3	2.1	0.4	0.7	0.6
4.1	6.7	6.7	9	8.5	2.1	3.2	0.6
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
- -	- -	- -	- -	- -	- -	- -	- -
< 0.1	< 0.1	0.2	0.5	0.1	< 0.1	< 0.1	< 0.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
1.7	< 0.5	- -	- -	- -	- -	- -	< 0.5
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
302	19	26	23	28	22	26	4
< 2	< 2	- -	- -	- -	- -	- -	< 2
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
- -	- -	- -	- -	- -	- -	- -	- -
181	6	5	14	4	< 2	< 2	2
- -	- -	1.40	0.90	0.90	0.50	0.70	- -

APPENDIX I continued.

90-JP-043-R	90-JP-044-R	90-JP-045-R	90-JP-046-R	90-JP-047-R	90-JP-048-R	90-JP-050-R	90-JP-051-R
11	11	11	11	10	10	10	10
7562370	7665260	7685500	7685500	7586950	7586950	7587550	7587650
437450	400500	395200	395200	587500	587500	587000	588100
- -	- -	- -	- -	- -	- -	- -	- -
< 5	< 5	< 5	< 5	- -	- -	< 5	- -
< 1	< 1	< 1	< 1	< 1	11	< 1	< 1
3	< 0.5	2.6	1.6	< 0.5	0.7	2.4	< 0.5
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
< 2	3	< 2	2	9	6	< 2	8
< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	3	0.4	0.2
- -	- -	- -	- -	- -	- -	- -	- -
4	< 0.5	< 0.5	1.9	< 0.5	15.6	0.6	0.8
6	8	6	7	7	20	6	9
- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -
< 1	< 1	< 1	< 1	< 1	6	< 1	< 1
< 1	< 1	< 1	< 1	< 1	9	2	2
4.6	1.8	4.6	3.2	2.2	831	5	< 0.5
2	1.1	1.6	1.6	2.3	43.3	3.3	0.8
2	2	< 2	< 2	- -	- -	< 2	- -
4	< 3	< 3	< 3	< 3	< 3	< 3	< 3
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
57.6	9.6	32	26.6	2.8	7	53.8	25.8
0.3	< 0.1	< 0.1	< 0.1	< 0.1	0.4	1.1	0.5
< 0.5	< 0.5	< 0.5	< 0.5	1.6	30.3	0.7	1.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
- -	- -	- -	- -	- -	- -	- -	- -
< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
< 0.5	< 0.5	< 0.5	< 0.5	- -	- -	< 0.5	- -
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
4	20	2	5	2	65	2	11
< 2	< 2	< 2	< 2	- -	- -	< 2	- -
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
- -	- -	- -	- -	- -	- -	- -	- -
< 2	< 2	< 2	< 2	< 2	6	< 2	< 2
- -	- -	- -	- -	0.50	6.30	0.30	- -

APPENDIX I continued.

90-JP-052-R	90-JP-053-R	90-JP-054-R	90-JP-055-R	90-JP-057-R	90-JP-058-R	90-JP-059-R	90-JP-060-R
10	10	11	11	11	11	10	10
7587850	7588050	7694950	7694950	7692760	7692450	7662700	7662700
588200	588250	383800	383800	385500	384400	591100	591100
--	--	--	--	--	--	--	--
--	--	--	--	--	< 5	< 5	--
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1.8	2.3	< 0.5	< 0.5	2.3	0.6	< 0.5	< 0.5
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14	< 2	< 2	< 2	3	< 2	< 2	< 2
4.2	0.6	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
--	--	--	--	--	--	--	--
12.2	3.2	< 0.5	< 0.5	< 0.5	1.2	< 0.5	4.9
12	8	8	7	6	9	12	13
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--	--	--	--	--	--	--	--
6	< 1	< 1	< 1	< 1	< 1	< 1	< 1
7	3	2	2	2	< 1	< 1	< 1
6.6	5.4	< 0.5	1	5.3	< 0.5	0.7	< 0.5
5.8	2.7	< 0.5	1.5	9.4	1.9	2.5	1
--	--	--	--	--	2	< 2	--
6	5	8	3	< 3	< 3	< 3	< 3
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
52.3	65.8	6.5	46.9	67.8	3.4	1.8	4
8.8	5	< 0.1	0.2	0.4	< 0.1	0.4	0.5
7.1	2.5	< 0.5	0.5	1.1	< 0.5	4.3	7.5
< 1	< 1	< 1	< 1	< 1	2	< 1	< 1
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< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	0.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	--	--	< 0.5	< 0.5	--
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
17	14	15	11	4	15	3	5
--	--	--	--	--	< 2	< 2	--
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	--	--	--	--	--
3	5	2	4	3	< 2	< 2	< 2
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APPENDIX I continued.

90-JP-061-R	90-JP-062-R	90-JP-063-R	90-JP-064-R	90-JP-065-R	90-JP-066-R	90-JP-067-R	90-JP-068-R
10	10	10	10	10	10	10	10
7662700	7657770	7660300	7619200	7737590	7737590	7737590	7673000
591100	597680	591000	574300	496410	496410	496410	485800
--	--	--	< 1	--	--	--	--
--	< 5	--	--	< 5	< 5	--	< 5
< 1	< 1	< 1	17	1	< 1	15	< 1
< 0.5	< 0.5	< 0.5	< 0.5	3	2.5	< 0.5	< 0.5
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6	< 2	4	< 2	5	< 2	< 2	< 2
< 0.1	< 0.1	< 0.1	1.2	3.1	1.7	3.2	< 0.1
--	--	--	--	--	--	--	--
< 0.5	< 0.5	4.2	105	< 0.5	< 0.5	2.9	< 0.5
8	6	11	14	7	7	10	8
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
< 1	< 1	< 1	13	2	17	15	< 1
2	< 1	2	34	< 1	6	14	< 1
< 0.5	< 0.5	0.6	158	45.9	14.6	23.6	< 0.5
< 0.5	< 0.5	1.4	22.4	58.6	27.3	54	2
--	< 2	--	--	< 2	7	--	< 2
< 3	< 3	< 3	< 3	< 3	9	7	< 3
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
4.2	2	1.3	25.6	38.2	159	14	6.8
0.4	1.1	1.1	4.9	34	20.6	5.3	0.2
2.5	1.4	6.2	3	2.7	3.5	4.8	2
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
--	--	--	17	--	--	--	--
< 0.1	< 0.1	< 0.1	< 0.1	0.6	0.7	< 0.1	< 0.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	< 0.5	--	--	< 0.5	1.2	--	< 0.5
< 5	< 5	< 5	5	< 5	< 5	< 5	< 5
5	6	2	54	74	28	72	20
--	< 2	--	--	< 2	< 2	--	< 2
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	< 10	--	--	--	--
2	< 2	8	< 2	57	75	33	2
--	--	--	--	--	--	--	--

APPENDIX I continued.

90-JP-069-R	90-JP-070-R	90-JP-071-R	90-JP-072-R	90-JP-073-R	90-JP-075-R	90-JP-078-R	90-JP-079-R
10	10	10	10	10	10	10	10
7673000	7673000	7673000	7673000	7672900	7672900	7743990	7743990
485800	485800	485800	485800	485700	485700	512140	512140
< 1	< 1	< 1	< 1	< 1	--	--	--
--	--	--	--	--	--	< 5	< 5
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1.4	< 0.5	< 0.5	< 0.5	3.7	3.4	1.5	2.5
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--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
< 2	10	6	< 2	31	30	< 2	< 2
5.9	0.3	< 0.1	< 0.1	0.3	< 0.1	0.1	< 0.1
--	--	--	--	--	--	--	--
28	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.1	1.1
21	7	7	6	5	6	6	5
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
5	< 1	2	3	< 1	< 1	3	3
8	2	11	6	1	2	< 1	< 1
8.9	0.8	4.7	0.7	6	7	13.1	4
76.5	2	19.5	13.6	< 0.5	< 0.5	1.4	0.6
--	--	--	--	--	--	< 2	< 2
< 3	< 3	47	3	< 3	4	< 3	5
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
65.3	32.5	5.3	17.4	264	260	18.9	41.1
22.6	0.6	< 0.1	0.1	0.6	< 0.1	0.6	0.9
32.2	2.1	6.7	2.8	< 0.5	< 0.5	0.6	< 0.5
< 1	< 1	59	3	1	< 1	< 1	< 1
< 1	< 1	< 1	< 1	1	--	--	--
0.9	0.2	0.4	0.1	0.2	< 0.1	< 0.1	< 0.1
< 1	< 1	2	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	--	--	--	< 0.5	< 0.5
13	< 5	7	< 5	< 5	< 5	< 5	< 5
498	45	27	16	8	6	7	3
--	--	--	--	--	--	< 2	< 2
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
< 10	< 10	10	< 10	< 10	--	--	--
48	< 2	28	8	< 2	3	< 2	< 2
--	--	--	--	--	--	--	--

APPENDIX I continued.

90-JP-080-R	90-JP-081-R	90-JP-082-R	90-JP-083-R	90-JP-084-R	90-JP-085-R	90-JP-086-R	90-JP-087-R
10	10	10	10	10	10	10	10
7744430	7691790	7691790	7691790	7736270	7736150	7736150	7736150
511690	504930	504930	504930	524940	525330	525330	525330
--	--	--	--	--	2	6	1
< 5	--	--	--	--	--	--	--
< 1	< 1	< 1	< 1	< 1	9	9	15
2.7	< 0.5	< 0.5	1.2	0.6	< 0.5	< 0.5	< 0.5
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
< 2	4	< 2	2	11	6	6	12
0.2	< 0.1	< 0.1	1.1	0.8	2.6	2	3.8
--	--	--	--	--	--	--	--
2.2	< 0.5	< 0.5	4	3.5	80.7	115	121
6	8	8	8	8	23	11	11
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
5	< 1	< 1	4	< 1	16	14	17
< 1	< 1	1	3	2	34	18	29
3.9	< 0.5	< 0.5	3.5	2.2	146	135	176
2.5	< 0.5	< 0.5	5.3	8.1	24.5	28.7	37.8
< 2	--	--	--	--	--	--	--
< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
33.4	1.5	1.5	10.1	3.4	31.4	24.2	26.9
1.6	0.9	0.6	4.8	2.2	3.7	6.5	7.6
< 0.5	2.9	6.2	2.3	3.8	3.8	4.8	6.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
--	--	--	--	--	16	19	17
< 0.1	0.2	0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
< 0.5	--	--	--	--	--	--	--
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
4	4	5	4	10	54	25	37
< 2	--	--	--	--	--	--	--
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	--	--	10	< 10	< 10
< 2	< 2	< 2	< 2	4	< 2	< 2	< 2
--	0.70	10.	0.90	--	--	--	--

APPENDIX I continued.

90-JP-088-R	90-JP-089-R	90-JP-091-R	90-JP-092-R	90-JP-093-R	90-JP-094-R	90-JP-096-R	90-JP-097-R
10	10	10	10	10	10	10	10
7736150	7736150	7742380	7644460	7644490	7644490	7643710	7644370
525330	525330	524930	547280	547790	547790	546690	545930
1	1	< 1	--	--	--	--	--
--	--	--	< 5	--	--	--	--
13	18	22	< 1	< 1	< 1	< 1	< 1
< 0.5	< 0.5	< 0.5	2.3	2.7	< 0.5	< 0.5	< 0.5
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
15	2	4	< 2	4	< 2	7	< 2
2.9	2	8	3.4	0.3	< 0.1	0.2	< 0.1
--	--	--	--	--	--	--	--
110	96.4	127	4.3	2.6	< 0.5	< 0.5	< 0.5
12	12	22	9	6	7	8	7
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
16	18	23	5	2	< 1	< 1	< 1
33	54	36	7	3	1	< 1	< 1
175	109	184	13.5	7.8	1.6	< 0.5	0.8
36.6	29.4	25.1	10.1	3	1.1	< 0.5	4.7
--	--	--	9	--	--	--	--
< 3	< 3	< 3	10	3	7	< 3	< 3
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
29.7	32.1	16.4	17.6	39.8	1.6	1.3	1.6
6.1	5.1	10.7	9.8	4.2	0.9	1.1	0.4
4.2	3.4	9.2	3.9	1.3	1.5	5	2.4
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
16	17	19	--	--	--	--	--
< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.2	0.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	< 0.5	--	--	--	--
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
53	54	35	12	5	6	8	4
--	--	--	< 2	--	--	--	--
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
10	< 10	< 10	--	--	--	--	--
< 2	< 2	< 2	6	4	< 2	< 2	< 2
--	--	--	--	--	--	--	--

APPENDIX I continued.

90-JP-098-R	90-JP-099-R	90-JP-100-R	90-JP-102-R	90-JP-103-R	90-JP-104-R	90-JP-105-R	90-JP-106-R
10	10	10	10	10	10	10	10
7615610	7611300	7611300	7605620	7605570	7605120	7605120	7605120
590620	593500	593500	562840	563380	564570	564570	564570
--	--	--	--	--	--	--	--
--	--	--	< 5	< 5	--	--	--
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3.3	2.6	2.3	2.7	< 0.5	< 0.5	< 0.5	< 0.5
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
4	< 2	3	< 2	< 2	9	9	4
< 0.1	1.3	2.8	0.2	< 0.1	0.2	0.2	0.2
--	--	--	--	--	--	--	--
1.3	6.2	7.1	< 0.5	< 0.5	15.2	11.3	1.4
6	12	11	8	8	17	16	18
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
< 1	3	5	< 1	< 1	2	3	< 1
< 1	4	7	< 1	1	5	7	1
7.9	108	19.3	4.6	< 0.5	5.5	5.1	3.6
3	10.2	7.9	2.2	< 0.5	12	17.8	5.9
--	--	--	< 2	< 2	--	--	--
4	< 3	10	< 3	< 3	5	5	< 3
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
39.8	40.4	33.4	18.9	1.7	2.6	2.1	2
0.5	2.8	3.8	5.5	0.4	0.3	0.5	0.1
0.7	3.2	8.9	0.9	6.6	3.6	3.5	4
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
--	--	--	--	--	--	--	--
< 0.1	0.2	< 0.1	< 0.1	< 0.1	0.2	0.2	< 0.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	< 0.5	< 0.5	--	--	--
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
5	15	14	3	2	16	12	21
--	--	--	< 2	< 2	--	--	--
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	--	--	--	--	--
< 2	< 2	< 2	< 2	< 2	3	3	3
--	--	--	--	--	0.50	0.50	0.40

APPENDIX I continued.

90-JP-107-R	90-JP-108-R	90-JP-109-R	90-JP-110-R	90-JP-111-R	90-JP-112-R	90-JP-113-R	90-JP-114-R
10	10	10	10	10	10	11	11
7604960	7517390	7517390	7517240	7517240	7647130	7568300	7568300
564460	548790	548790	548430	548430	465160	426350	426350
--	--	--	--	--	--	--	--
--	--	--	--	--	--	< 5	< 5
< 1	< 1	< 1	3	10	< 1	5	< 1
3.1	1.5	2	0.6	0.9	4.1	2.9	< 0.5
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
8	< 2	7	18	15	< 2	6	< 2
0.2	1.7	2.9	5.3	3.6	< 0.1	0.6	3
--	--	--	--	--	--	--	--
< 0.5	6.6	7.5	12.4	22.3	6.1	2.3	8.2
8	10	11	21	40	5	8	13
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
< 1	2	3	7	8	< 1	2	2
1	2	5	14	20	4	3	3
5.7	2.6	3.8	22.7	2.7	9.7	5.7	< 0.5
1.8	2.2	8.5	25.4	42.6	3.5	5.7	8.1
--	--	--	--	--	--	< 2	2
< 3	3	7	5	6	6	< 3	< 3
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
28.8	26.8	43.6	44	37.4	219	61.1	10.9
4	4.6	6.1	6.9	4.3	0.7	2	2.5
0.7	5	6.3	13	16.2	< 0.5	1.6	11.5
< 1	< 1	< 1	3	< 1	5	< 1	< 1
--	--	--	--	--	--	--	--
0.2	< 0.1	< 0.1	0.1	< 0.1	0.1	< 0.1	0.1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	--	--	--	< 0.5	< 0.5
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
5	14	21	104	124	10	4	25
--	--	--	--	--	--	< 2	< 2
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	--	--	--	--	--
< 2	< 2	< 2	5	< 2	< 2	2	< 2
0.10	--	--	--	--	--	--	--

APPENDIX I continued.

90-JP-115-R	90-JP-116-R	90-JP-117-R	90-JP-118-R	90-JP-119-R	90-JP-120-R	91-JP-018-R	91-JP-031-RA
11	11	11	11	11	10	10	10
7553850	7548530	7548530	7548530	7548530	7734130	7620650	7691400
448450	451300	451300	451300	451300	496980	598290	506730
< 1	< 1	< 1	1	< 1	< 1	--	--
--	--	--	--	--	--	< 5	< 5
6	15	9	1	< 1	10	< 1	3
< 0.5	< 0.5	< 0.5	2.3	2.9	< 0.5	< .5	4.7
--	--	--	--	--	--	.03	.05
--	--	--	--	--	--	.16	8.98
--	--	--	--	--	--	.06	.38
--	--	--	--	--	--	< .01	.21
--	--	--	--	--	--	.02	.09
--	--	--	--	--	--	2.76	15.0
6	8	11	60	104	6	--	--
1	1.9	0.8	0.2	0.3	1.8	< .5	5.9
--	--	--	--	--	--	< .01	< .01
131	164	130	< 0.5	1.4	108	8	10
10	9	23	5	5	8	1	8
--	--	--	--	--	--	< .01	.03
--	--	--	--	--	--	.11	5.53
14	14	15	2	< 1	23	2	36
15	27	22	1	< 1	37	< 1	38
167	202	200	7.2	10.1	198	2.0	42.3
17.1	27.5	26.3	16.2	13.1	43.7	< .5	123.
--	--	--	--	--	--	3	25
< 3	< 3	< 3	< 3	< 3	< 3	< 3	17
< 20	< 20	< 20	< 20	< 20	< 20	--	--
26.5	22.9	13.9	59.2	57.9	23.3	33.6	37.2
7.1	6.4	3.2	5.2	1.3	9.8	1.7	34.9
5.9	3	4.6	0.9	1.4	4.3	2.3	6.2
< 1	< 1	< 1	< 1	< 1	< 1	< 1	3
14	18	17	3	2	17	--	--
< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< .1	< .1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
--	--	--	--	--	--	< .5	< .5
< 5	< 5	< 5	6	< 5	< 5	< 5	< 5
38	36	16	10	31	43	6	19
--	--	--	--	--	--	< 2	< 2
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
< 10	< 10	< 10	< 10	< 10	< 10	< 2	6
< 2	< 2	5	55	< 2	8	< 3	5
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APPENDIX I continued.

91-JP-031-RB	91-JP-034-R	91-JP-038-R	91-JP-048-R	91-JP-053-R	91-JP-058-R	91-JP-059-R	91-JP-127-R
10	10	10	10	10	10	10	10
7691400	7732250	7713340	7728140	7588050	7625100	7622500	7691170
506730	522450	588580	518540	573770	596500	597350	506250
- -	- -	- -	- -	- -	- -	- -	- -
< 5	< 5	17	< 5	< 5	< 5	< 5	< 5
< 1	< 1	12	< 1	70	6	4	< 1
< .5	1.0	.9	< .5	2.6	.9	< .5	< .5
.03	.04	.03	.03	.04	.03	.03	.03
.34	1.10	.34	.09	5.48	.22	.02	.03
.24	.38	.88	.15	2.03	.48	.04	.19
.03	.01	< .01	< .01	.02	< .01	< .01	< .01
.26	.30	.46	.10	.53	.21	< .01	.15
.60	1.89	.08	.10	13.2	.33	.15	.03
- -	- -	- -	- -	- -	- -	- -	- -
.6	3.5	3.1	< .5	2.8	2.8	< .5	< .5
< .01	< .01	.04	< .01	.05	< .01	< .01	< .01
4	< 2	17	4	30	9	9	11
2	2	14	3	20	5	3	8
< .01	< .01	< .01	< .01	.02	< .01	< .01	< .01
.79	.66	1.2	1.36	1.07	3.11	.83	.85
< 1	8	7	24	3	11	< 1	< 1
< 1	3	10	2	< 1	< 1	< 1	5
6.3	69.8	665.	17.8	6.8	27.1	5.4	< .5
3.8	3.1	47.4	4.8	16.7	9.1	3.4	2.0
18	5	3	33	< 2	7	9	< 2
9	< 3	< 3	28	< 3	< 3	< 3	< 3
- -	- -	- -	- -	- -	- -	- -	- -
17.5	24.3	12.1	3.6	185.	7.7	1.7	3.4
2.9	4.0	1.0	.9	3.9	14.4	.3	1.5
8.2	6.3	33.1	5.3	5.3	13.0	2.3	9.7
2	< 1	< 1	1	< 1	< 1	< 1	< 1
- -	- -	- -	- -	- -	- -	- -	- -
< .1	< .1	.1	.6	.1	.2	.1	< .1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
2.1	1.0	.9	.9	< .5	.9	< .5	.7
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
39	17	61	22	37	54	4	27
< 2	2	2	< 2	< 2	2	< 2	< 2
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
12	13	14	72	< 2	5	< 2	4
< 3	4	< 3	< 3	< 3	< 3	< 3	< 3
- -	- -	- -	- -	- -	- -	- -	- -

APPENDIX I continued.

91-JP-128-R	91-JP-129-R	91-JP-130-R	91-JP-131-R	91-JP-132-R	91-JP-133-R	91-JP-134-R	91-JP-135-R
						(?139-R)	
10	10	10	10	10	10	10	10
7691170	7744320	7744320	7744320	7691170	7714130	7586920	7715710
506250	498700	498700	498700	506250	588160	587530	588590
--	--	--	--	--	--	--	--
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 1	26	5	< 1	< 1	< 1	5	< 1
< .5	1.2	2.1	1.6	< .5	1.5	.9	.7
.03	.08	.07	.05	.04	.04	.04	.04
.03	1.33	4.80	7.40	.30	10.2	3.04	4.25
.19	2.13	.60	.16	.88	.16	.88	.34
< .01	.04	.01	< .01	.02	< .01	.01	.02
.13	.30	.20	.09	.48	.10	.69	.25
.03	.34	10.3	12.8	.18	16.0	4.27	7.00
--	--	--	--	--	--	--	--
< .5	2.5	4.3	< .5	2.5	.6	4.3	2.2
<.01	< .01	< .01	< .01	< .01	< .01	< .01	< .01
12	13	4	< 2	40	11	8	9
9	23	8	1	31	3	12	7
< .01	.04	.57	.84	.02	.04	.02	.03
.93	4.2	11.3	9.83	3.1	.70	1.02	1.40
< 1	20	38	68	3	1	4	2
5	20	15	26	2	< 1	8	3
181.	86.7	256.	625.	3.0	3.0	< .5	< .5
1.2	39.4	32.4	934.	42.1	1.5	20.9	6.1
< 2	3	42	120	6	2	2	< 2
< 3	< 3	38	107	< 3	< 3	< 3	< 3
--	--	--	--	--	--	--	--
3.5	9.3	31.4	51.0	12.6	43.6	30.6	32.8
2.1	7.2	23.7	39.9	9.6	2.1	5.8	6.8
6.5	6.9	7.2	2.8	13.1	2.2	9.1	7.7
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
--	--	--	--	--	--	--	--
< .1	< .1	.7	1.2	< .1	< .1	< .1	< .1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
.8	.6	18.0	42.0	2.0	< .5	< .5	< .5
< 5	< 5	10	26	< 5	< 5	< 5	< 5
16	71	120	147	86	8	47	27
< 2	2	< 2	< 2	2	< 2	< 2	< 2
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
3	7	58	619	6	7	< 2	3
< 3	5	11	6	< 3	< 3	4	3
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APPENDIX I continued.

91-JP-137-R	91-JP-138-R	91-JP-139-R	91-JP-140-R	91-JP-141-R	91-JP-142-R	91-JP-143-R	91-JP-144-R
		(?134-R)					
10	10	10	10	10	10	10	10
7656340	7587340	7587680	7588320	7588090	7588680	7666620	7687350
598020	586830	588090	588580	587840	588130	605320	605700
--	--	--	--	--	--	--	--
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 1	6	3	5	3	11	59	< 1
< .5	.6	.8	.5	< .5	< .5	1.1	.6
.03	.04	.04	.04	.03	.03	.04	.03
.06	1.89	4.38	1.47	1.14	.56	7.54	.17
.21	1.24	.85	1.02	.66	1.07	2.08	.33
< .01	.02	.01	< .01	< .01	< .01	.03	.21
.12	.78	.58	.74	.42	.80	.92	.13
.05	2.34	5.84	2.10	1.42	.21	7.68	7.21
--	--	--	--	--	--	--	--
< .5	6.3	4.8	4.0	5.2	3.5	2.2	1.0
< .01	.01	< .01	< .01	.03	< .01	.04	< .01
5	14	13	10	14	12	24	20
4	16	11	12	12	23	15	25
< .01	.04	.04	.02	.02	.01	.02	.01
.10	1.92	1.3	.83	1.20	2.0	.85	4.2
< 1	14	7	6	7	6	7	10
2	18	10	9	8	14	5	11
< .5	27.0	9.5	9.4	5.9	< .5	6.8	9.7
1.9	36.8	25.3	24.0	23.9	41.0	12.8	16.4
< 2	3	< 2	2	2	5	5	23
< 3	< 3	< 3	< 3	< 3	< 3	5	22
--	--	--	--	--	--	--	--
10.6	22.8	32.6	576.	23.2	147.	19.5	53.3
1.7	6.1	4.8	10.3	3.4	7.7	4.7	3.1
5.8	9.8	6.6	20.3	18.0	10.6	10.0	7.3
< 1	< 1	< 1	3	< 1	< 1	< 1	< 1
--	--	--	--	--	--	--	--
< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
25	73	108	198	110	55	75	114
< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
17	5	< 2	< 2	4	< 2	< 2	< 2
< 3	< 3	5	5	3	< 3	< 3	< 3
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APPENDIX I continued.

91-JP-145-R	91-JP-146-R	91-JP-147-R	91-JP-148-R
10	10	10	10
7616490	7616640	7616950	7714130
600350	600540	600630	588160
- -	- -	- -	- -
< 5	< 5	< 5	< 5
< 1	< 1	< 1	< 1
1.2	1.2	1.1	.8
.04	.04	.04	.04
10.6	11.0	10.2	9.20
.20	.08	.13	.16
< .01	< .01	< .01	.01
.13	.04	.06	.10
14.2	14.9	15.4	12.5
- -	- -	- -	- -
.9	< .5	< .5	< .5
< .01	< .01	< .01	.02
6	3	< 2	47
4	2	< 1	12
.02	.12	.10	.03
.42	.75	2.7	3.11
2	2	2	2
2	< 1	< 1	< 1
< .5	< .5	2.0	2.0
3.3	< .5	8.0	4.8
< 2	< 2	< 2	2
< 3	< 3	< 3	< 3
- -	- -	- -	- -
38.0	35.2	15.7	42.7
2.5	1.4	3.7	2.4
1.9	< .5	1.8	5.5
< 1	< 1	< 1	< 1
- -	- -	- -	- -
< .1	< .1	< .1	< .1
< 1	< 1	< 1	< 1
< 10	< 10	< 10	< 10
< .5	< .5	< .5	< .5
< 5	< 5	< 5	< 5
11	4	9	15
< 2	< 2	< 2	< 2
< 10	< 10	< 10	< 10
< 2	< 2	< 2	4
< 3	< 3	< 3	< 3
- -	- -	- -	- -

APPENDIX II. CHEMICAL ANALYSES OF STREAM SEDIMENT SAMPLES AND TILLS.

		90-JP-001-S	90-JP-002-S	90-JP-003-S	90-JP-004-S	90-JP-005-S	90-JP-006-S
Al	ICP (%)	0.35	0.52	0.27	0.58	0.53	0.44
Fe Tot	ICP (%)	1.14	1.15	0.74	1.67	1.34	1.27
Mn	ICP (ppm)	136	147	108	205	201	310
Mg	ICP (%)	5.97	5.68	6.54	5.81	5.03	3.27
Ca	ICP (%)	> 10.00	> 10.00	> 10.00	> 10.00	8.46	5.23
Na	ICP (%)	< 0.05	< 0.05	< 0.05	0.06	< 0.05	< 0.05
K	ICP (%)	< 0.05	0.06	< 0.05	0.07	0.07	0.13
Sc	ICP (ppm)	--	--	--	--	--	--
V	ICP (ppm)	64	58	33	89	60	46
Cr	ICP (ppm)	7	7	3	10	9	6
Co	ICP (ppm)	2	2	< 1	4	3	3
Ni	ICP (ppm)	8	11	4	14	8	7
Cu	ICP (ppm)	14	33	12	22	14	11
Zn	ICP (ppm)	22	26	15	25	21	27
As	ICP (ppm)	< 5	< 5	< 5	6	< 5	< 5
Sr	ICP (ppm)	42	60	48	44	34	27
Y	ICP (ppm)	5	5	4	6	6	6
Mo	ICP (ppm)	2	< 1	< 1	1	< 1	< 1
Ag	ICP (ppm)	< 0.5	< 0.5	< 0.5	< 0.5	0.5	< 0.5
Cd	ICP (ppm)	1	< 1	< 1	< 1	< 1	< 1
Sn	ICP (ppm)	< 20	< 20	< 20	< 20	< 20	< 20
Sb	ICP (ppm)	< 5	< 5	< 5	< 5	< 5	< 5
Te	ICP (ppm)	< 10	< 10	< 10	< 10	< 10	< 10
Ba	ICP (ppm)	30	50	24	45	47	51
La	ICP (ppm)	7	7	4	9	12	8
Ce	ICP (ppm)	< 5	< 5	< 5	< 5	27	20
W	ICP (ppm)	< 10	< 10	< 10	< 10	< 10	< 10
Pb	ICP (ppm)	12	12	8	10	7	5
Bi	ICP (ppm)	< 5	< 5	< 5	< 5	< 5	< 5

APPENDIX II continued.

90-JP-007-S	90-JP-008-S	90-JP-009-S	90-JP-010-S	90-JP-011-S	90-JP-012-S	90-JP-013-S	90-JP-014-S
0.44	0.48	0.29	0.22	0.42	0.43	0.58	0.32
1.57	1.68	0.49	0.89	1.13	1.10	1.49	1.31
252	183	87	130	143	229	191	270
3.96	6.15	4.67	2.39	1.92	2.08	5.35	4.74
6.45	> 10.00	7.79	3.83	2.99	3.44	9.12	8.25
< 0.05	0.09	< 0.05	< 0.05	< 0.05	< 0.05	0.09	< 0.05
0.14	0.06	< 0.05	0.06	0.12	0.11	0.13	0.05
--	--	--	--	--	--	--	--
69	101	14	11	32	19	70	54
9	10	3	2	5	6	8	5
3	4	< 1	2	4	3	3	3
7	11	5	4	6	6	8	8
11	16	16	10	10	13	25	21
20	24	15	15	13	11	34	20
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
32	44	32	21	18	17	41	27
8	5	4	3	5	6	6	5
< 1	1	< 1	< 1	< 1	< 1	< 1	< 1
< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6
< 1	< 1	< 1	< 1	< 1	< 1	1	< 1
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
186	42	28	64	31	41	135	44
14	8	7	5	8	7	8	7
28	< 5	9	14	23	20	20	17
< 10	< 10	13	< 10	< 10	< 10	< 10	< 10
6	10	6	5	4	4	10	11
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

APPENDIX II continued.

90-JP-015-S	90-JP-016-S	90-JP-017-S	90-JP-018-S	90-JP-019-S	90-JP-020-S	90-JP-021-S	90-JP-022-S
0.42	0.35	0.41	0.30	0.48	0.43	1.00	0.56
0.74	0.78	0.88	0.61	1.67	1.19	1.86	1.04
130	119	152	194	245	218	285	169
5.16	5.37	5.31	4.14	2.18	2.05	1.84	4.44
8.90	9.18	8.92	6.87	3.33	3.08	2.61	7.58
< 0.05	< 0.05	< 0.05	< 0.05	0.06	< 0.05	< 0.05	0.05
0.08	< 0.05	0.06	< 0.05	0.14	0.08	0.20	0.11
--	--	--	--	--	--	--	--
26	29	32	13	49	36	23	19
8	4	4	3	9	6	9	7
2	1	2	< 1	3	3	7	3
6	5	5	4	34	6	12	7
11	10	14	7	14	12	22	18
13	12	19	11	24	18	37	28
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
36	34	34	25	20	18	21	38
4	4	5	4	7	7	8	6
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
0.6	0.5	0.7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
38	32	29	22	30	38	61	47
7	7	9	5	13	25	13	9
16	16	22	6	31	57	34	12
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
5	8	4	5	7	8	11	8
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

APPENDIX II continued.

90-JP-023-S	90-JP-024-S	90-JP-025-S	90-JP-026-S	90-JP-027-S	90-JP-028-S	90-JP-029-S	90-JP-030-S
0.59	0.66	1.23	0.33	0.50	3.49	1.10	0.48
1.07	3.20	2.19	1.07	1.63	4.23	3.19	1.83
178	313	404	135	206	680	3310	366
3.71	2.45	1.43	6.11	5.72	1.34	0.64	0.50
5.96	3.71	1.76	> 10.00	> 10.00	1.11	1.40	6.13
< 0.05	< 0.05	0.06	< 0.05	< 0.05	0.07	< 0.05	< 0.05
0.19	0.08	0.19	< 0.05	0.06	0.17	0.05	< 0.05
34	193	52	61	90	59	44	22
8	16	16	5	9	51	23	10
2	8	9	2	4	18	13	6
6	16	17	7	15	51	17	11
8	18	22	12	18	47	35	46
15	47	37	18	22	207	137	286
< 5	< 5	< 5	< 5	< 5	22	20	24
32	26	22	41	37	150	29	67
5	7	8	4	5	23	25	12
< 1	< 1	< 1	< 1	< 1	10	< 1	9
< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
< 1	< 1	< 1	< 1	< 1	1	1	3
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
35	143	98	28	45	112	268	97
8	15	18	7	7	39	22	11
13	30	39	< 5	< 5	65	40	16
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
6	10	8	8	9	67	34	79
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

APPENDIX II continued.

90-JP-032-S	90-JP-033-S	90-JP-049-S	90-JP-095-S	90-JP-101-S	91-JP-023-T	91-JP-026-T	91-JP-60-S
0.27	0.46	0.94	0.90	0.62	0.36	0.61	0.49
0.87	1.13	1.15	2.05	1.45	1.29	1.52	1.36
124	181	259	232	274	311	351	426
2.17	4.37	2.47	1.24	4.02	0.37	3.59	4.63
3.48	7.40	3.80	2.00	7.02	0.12	2.98	4.10
< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.04	0.05	0.05
0.07	0.08	0.48	0.40	0.24	0.09	0.22	0.13
--	--	--	--	--	< 5	< 5	< 5
11	19	14	19	43	23	20	16
3	6	11	8	8	11	11	8
2	3	5	9	4	9	4	5
4	7	9	9	9	9	12	11
10	13	12	21	13	12	14	17
12	21	17	19	18	16	20	19
< 5	< 5	< 5	11	< 5	< 5	< 5	< 5
21	35	43	20	42	7	17	19
4	5	6	13	6	5	5	5
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.2	< 0.2	< 0.2
< 1	< 1	< 1	< 1	< 1	2.1	< 0.2	< 0.2
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
72	47	154	105	81	42	58	75
6	7	8	6	11	12	9	7
17	6	20	18	17	--	--	--
< 10	< 10	< 10	< 10	< 10	< 20	< 20	< 20
6	8	10	13	8	10	< 2	< 2
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

APPENDIX II continued.

91-JP-62-S	91-JP-66-S	91-JP-101-S	91-JP-102-S	91-JP-103-S	91-JP-104-S	91-JP-105-S	91-JP-106-S
0.36	0.49	0.91	0.81	0.79	0.82	0.96	0.94
1.69	1.27	2.34	1.97	2.14	2.05	2.59	2.66
463	363	642	480	544	644	550	606
7.28	6.33	3.63	5.02	4.53	4.32	3.18	2.60
> 10.00	7.99	2.28	4.15	3.32	3.54	1.81	1.37
0.06	0.05	0.04	0.05	0.05	0.05	0.04	0.05
0.08	0.14	0.15	0.14	0.12	0.12	0.12	0.14
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
61	16	19	24	21	25	19	15
7	8	11	11	10	11	13	12
5	4	11	8	10	9	11	12
11	11	17	15	17	17	20	18
12	13	18	20	18	15	18	23
33	25	49	40	45	40	56	57
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
70	50	14	19	15	18	12	14
5	5	7	6	6	5	7	8
2	1	< 1	< 1	< 1	1	< 1	< 1
< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
36	63	50	47	45	41	49	61
8	8	13	14	12	14	12	13
--	--	--	--	--	--	--	--
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
< 2	< 2	4	< 2	< 2	< 2	7	12
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

APPENDIX II continued.

91-JP-107-S	91-JP-108-S	91-JP-109-S	91-JP-110-S	91-JP-111-S	91-JP-112-S	91-JP-113-S	91-JP-114-S
0.73	1.23	0.71	0.98	0.89	1.08	1.09	1.00
2.10	3.17	1.77	2.38	2.24	2.52	2.90	2.88
415	602	1004	712	857	823	808	865
3.22	2.13	5.54	4.89	4.15	3.27	1.54	2.07
2.23	0.77	4.74	3.63	2.92	1.84	0.38	0.86
0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05
0.15	0.16	0.11	0.11	0.10	0.15	0.15	0.16
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
14	17	32	29	21	19	14	14
9	16	10	12	11	15	15	13
11	14	7	9	9	13	15	14
17	24	14	17	15	19	20	19
27	30	16	13	14	18	19	25
44	67	40	48	44	59	61	56
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
22	15	19	14	12	11	7	14
8	10	5	6	6	8	8	8
< 1	< 1	< 1	< 1	1	< 1	< 1	< 1
< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
57	103	53	51	52	57	85	189
9	13	13	21	18	29	31	23
--	--	--	--	--	--	--	--
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
8	24	< 2	< 2	< 2	13	17	18
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

APPENDIX II continued.

91-JP-115-S	91-JP-116-S	91-JP-117T	91-JP-118-S	91-JP-119-S	91-JP-120-S	91-JP-150-S	91-JP-151-S
0.68	1.25	1.35	0.29	0.43	0.53	0.28	0.24
1.84	3.52	3.67	1.15	1.01	2.54	1.13	0.90
499	412	537	357	247	424	746	1133
2.59	5.70	1.53	6.35	6.25	7.07	2.03	1.59
1.55	4.76	0.71	6.74	6.09	8.04	1.42	1.06
0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05
0.10	0.11	0.15	0.07	0.15	0.08	0.07	0.06
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
14	19	24	18	19	125	28	12
10	12	18	6	8	13	6	6
9	10	11	2	2	6	3	4
14	20	19	8	8	17	7	6
12	13	18	9	5	19	6	7
44	66	59	15	18	39	18	19
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
12	20	9	21	26	30	7	6
5	7	6	3	5	5	4	2
< 1	1	< 1	< 1	1	1	< 1	< 1
< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
74	59	133	26	32	48	36	44
13	21	19	5	11	12	7	5
--	--	--	--	--	--	--	--
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
6	< 2	13	< 2	< 2	< 2	< 2	< 2
< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

APPENDIX II continued.

91-JP-152-S	91-JP-153-S	91-JP-154-S	91-JP-155-S	91-JP-156-S
0.55	0.34	0.46	0.68	0.37
1.42	1.29	1.69	1.40	1.31
576	824	1063	531	763
6.09	7.06	6.39	2.01	6.93
6.31	8.26	6.64	1.21	7.90
0.05	0.05	0.06	0.05	0.05
0.10	0.11	0.13	0.23	0.12
< 5	< 5	< 5	< 5	< 5
36	13	15	15	14
10	5	7	11	6
4	2	5	9	3
12	8	10	13	7
17	7	8	20	8
26	13	27	22	14
< 5	< 5	< 5	< 5	< 5
17	21	18	7	20
7	4	5	9	5
1	2	2	< 1	1
< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
< 20	< 20	< 20	< 20	< 20
< 5	< 5	< 5	< 5	< 5
< 10	< 10	< 10	< 10	< 10
60	39	62	62	45
11	6	8	7	7
--	--	--	--	--
< 20	< 20	< 20	< 20	< 20
< 2	< 2	< 2	< 2	< 2
< 5	< 5	< 5	< 5	< 5

APPENDIX III. CHEMICAL ANALYSES OF HEAVY MINERAL CONCENTRATES FROM BULK STREAM SEDIMENT SAMPLES.

Sample #	90-JP-001-H	90-JP-002-H	90-JP-003-H	90-JP-004-H	90-JP-005-H	90-JP-006-H	90-JP-007-H
Na (%)	0.27	0.43	0.26	0.44	0.29	0.13	0.15
Sc (ppm)	20.0	16.0	20.0	20.0	38.0	14.0	69.1
Cr (ppm)	200	120	190	150	750	110	930
Fe (%)	8.1	4.3	7.7	5.8	18.0	5.3	17.0
Co (ppm)	28	23	24	25	46	14	33
Ni (ppm)	45	48	37	38	81	26	38
Zn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
As (ppm)	22	6	19	7	12	8	7
Se (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Br (ppm)	9	6	10	6	4	3	2
Rb (ppm)	15	22	< 10	19	< 10	< 10	< 10
Zr (ppm)	800	< 500	2000	< 500	9900	7700	81500
Mo (ppm)	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Ag (ppm)	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Cd (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Sn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
Sb (ppm)	0.8	0.4	0.7	0.5	2.1	0.7	2.5
Te (ppm)	< 20	< 20	< 20	< 20	< 20	< 20	< 20
Cs (ppm)	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ba (ppm)	230	300	290	230	370	110	3000
La (ppm)	26	11	23	15	84	15	180
Ce (ppm)	48	27	46	30	160	44	390
Sm (ppm)	5.6	3.1	5.5	3.8	16.0	6.1	42.4
Eu (ppm)	< 2	< 2	< 2	< 2	< 2	< 2	4
Tb (ppm)	1	< 1	1	1	3	2	15
Yb (ppm)	< 5	< 5	< 5	< 5	15	9	71
Lu (ppm)	< 0.5	< 0.5	< 0.5	< 0.5	2.0	0.9	11.0
Hf (ppm)	14	3	35	4	170	150	1530
Ta (ppm)	2	< 1	2	1	8	1	11
W (ppm)	< 2	< 2	2	< 2	5	< 2	6
Ir (ppb)	< 100	< 100	< 100	< 100	< 100	< 100	< 100
Au (ppb)	< 5	< 5	< 5	< 5	< 5	< 5	140
Th (ppm)	15.0	4.9	13.0	7.3	50.3	21.0	203.0
U (ppm)	2.7	1.0	4.0	1.4	14.0	12.0	104.0
WT (gm)	10.10	9.63	9.96	9.02	11.94	11.76	8.99

APPENDIX III continued.

Sample #	90-JP-008-H	90-JP-009-H	90-JP-010-H	90-JP-011-H	90-JP-012-H	90-JP-013-H	90-JP-014-H
Na (%)	0.43	0.28	0.12	0.17	0.15	0.35	0.22
Sc (ppm)	11.0	21.0	24.0	34.0	100.0	12.0	27.0
Cr (ppm)	78	160	180	310	610	100	210
Fe (%)	2.6	4.1	12.0	7.9	17.0	2.9	10.0
Co (ppm)	16	15	21	21	30	15	41
Ni (ppm)	25	< 20	30	34	< 20	24	75
Zn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
As (ppm)	4	3	31	5	17	2	98
Se (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Br (ppm)	6	8	3	3	2	7	5
Rb (ppm)	22	< 10	< 10	10	< 10	15	< 10
Zr (ppm)	< 500	2400	12000	28000	>90000	550	4600
Mo (ppm)	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Ag (ppm)	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Cd (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Sn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
Sb (ppm)	< 0.2	0.3	1.3	1.4	5.6	< 0.2	0.7
Te (ppm)	< 20	< 20	< 20	< 20	< 20	< 20	< 20
Cs (ppm)	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ba (ppm)	150	320	2800	< 100	390	610	360
La (ppm)	7	39	58	51	110	9	35
Ce (ppm)	19	87	140	140	340	23	70
Sm (ppm)	2.0	7.2	15.0	18.0	65.6	2.6	7.6
Eu (ppm)	< 2	< 2	< 2	3	12	< 2	< 2
Tb (ppm)	< 1	1	4	7	31	< 1	2
Yb (ppm)	< 5	5	22	38	170	< 5	7
Lu (ppm)	< 0.5	0.8	2.7	5.0	28.0	< 0.5	0.7
Hf (ppm)	< 2	44	237	541	2010	7	89
Ta (ppm)	< 1	2	4	5	18	< 1	6
W (ppm)	< 2	< 2	< 2	3	10	< 2	2
Ir (ppb)	< 100	< 100	< 100	< 100	< 100	< 100	< 100
Au (ppb)	< 5	< 5	8	7	61	< 5	< 5
Th (ppm)	2.4	19.0	44.0	64.1	229.0	3.8	25.0
U (ppm)	0.7	4.7	20.0	37.0	152.0	1.2	7.8
WT (gm)	9.35	10.78	9.01	9.23	9.28	11.83	9.32

APPENDIX III continued.

Sample #	90-JP-015-H	90-JP-016-H	90-JP-017-H	90-JP-018-H	90-JP-019-H	90-JP-020-H	90-JP-021-H
Na (%)	0.31	0.25	0.21	0.27	0.12	< 0.23	0.39
Sc (ppm)	24.0	65.1	59.6	21.0	5.9	34.0	8.0
Cr (ppm)	240	820	630	190	< 50	430	51
Fe (%)	5.8	19.0	16.0	3.9	1.7	5.4	2.5
Co (ppm)	23	53	58	13	< 10	11	12
Ni (ppm)	23	56	54	< 20	< 20	< 20	< 20
Zn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
As (ppm)	4	9	13	2	3	7	4
Se (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Br (ppm)	8	3	4	6	2	2	4
Rb (ppm)	< 10	< 10	< 10	16	11	< 10	29
Zr (ppm)	1900	23000	25000	13000	< 500	28000	650
Mo (ppm)	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Ag (ppm)	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Cd (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Sn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
Sb (ppm)	0.3	1.9	1.9	0.5	< 0.2	1.6	0.4
Te (ppm)	< 20	< 20	< 20	< 20	< 20	< 20	< 20
Cs (ppm)	< 1	< 1	< 1	< 1	< 1	< 1	1
Ba (ppm)	250	350	180	< 100	< 100	< 100	190
La (ppm)	27	130	140	36	10	270	13
Ce (ppm)	61	300	310	81	25	530	27
Sm (ppm)	5.6	29.9	29.3	10.0	2.4	57.6	3.3
Eu (ppm)	< 2	3	3	< 2	< 2	3	< 2
Tb (ppm)	1	8	7	4	< 1	11	< 1
Yb (ppm)	< 5	40	36	18	< 5	29	< 5
Lu (ppm)	0.7	5.2	5.3	1.9	< 0.5	3.8	< 0.5
Hf (ppm)	39	457	496	254	8	462	10
Ta (ppm)	2	10	9	4	< 1	12	< 1
W (ppm)	< 2	7	3	< 2	< 2	< 8	3
Ir (ppb)	< 100	< 100	< 100	< 100	< 100	< 100	< 100
Au (ppb)	< 5	< 5	< 5	< 5	< 5	18	< 5
Th (ppm)	14.0	92.7	93.9	33.0	3.6	175.0	5.5
U (ppm)	3.9	37.0	35.0	16.0	1.1	46.0	1.8
WT (gm)	9.52	9.21	9.71	9.30	9.69	9.73	10.70

APPENDIX III continued.

Sample #	90-JP-022-H	90-JP-023-H	90-JP-024-H	90-JP-025-H	90-JP-049-H from 90-JP-049-S	90-JP-095-H from 90-JP-095-S	90-JP-101-H from 90-JP-101-S
Na (%)	0.32	0.30	0.67	0.43	< 0.05	0.15	0.26
Sc (ppm)	11.0	5.6	33.0	9.4	0.7	8.2	5.7
Cr (ppm)	77	< 50	310	70	< 50	54	52
Fe (%)	6.1	1.4	9.1	2.6	< 0.5	2.5	1.6
Co (ppm)	26	< 10	38	13	< 10	< 10	< 10
Ni (ppm)	36	< 20	66	< 20	< 20	< 20	< 20
Zn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
As (ppm)	41	1	5	1	< 1	6	2
Se (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Br (ppm)	1	2	2	< 1	< 1	1	2
Rb (ppm)	< 10	15	26	25	< 10	100	20
Zr (ppm)	< 500	< 500	1300	< 500	< 500	< 500	< 500
Mo (ppm)	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Ag (ppm)	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Cd (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Sn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
Sb (ppm)	0.5	< 0.2	0.7	0.3	< 0.2	0.4	< 0.2
Te (ppm)	< 20	< 20	< 20	< 20	< 20	< 20	< 20
Cs (ppm)	< 1	< 1	< 1	< 1	< 1	3	< 1
Ba (ppm)	< 100	140	1000	180	110	290	230
La (ppm)	6	8	25	12	8	29	10
Ce (ppm)	< 10	17	49	25	19	65	21
Sm (ppm)	1.8	1.7	6.0	2.5	1.5	5.5	2.3
Eu (ppm)	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Tb (ppm)	< 1	< 1	2	< 1	< 1	< 1	< 1
Yb (ppm)	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Lu (ppm)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Hf (ppm)	< 2	< 2	23	3	< 2	4	< 2
Ta (ppm)	< 1	< 1	2	< 1	< 1	< 1	< 1
W (ppm)	< 2	< 2	< 6	< 2	< 2	< 2	< 2
Ir (ppb)	< 100	< 100	< 100	< 100	< 100	< 100	< 100
Au (ppb)	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Th (ppm)	1.5	2.3	12.0	3.5	2.3	8.8	3.3
U (ppm)	0.9	0.6	3.1	0.9	0.5	2.3	0.7
WT (gm)	7.31	11.41	10.30	9.14	10.12	8.80	8.98

APPENDIX III continued.

Sample #	90-JP-026-H duplicate 90-JP-001-H	90-JP-027-H duplicate 90-JP-004-H	90-JP-032-H duplicate 90-JP-010-H	90-JP-033-H duplicate 90-JP-022-H	90-JP-034-H duplicate 87-JP-026-H	91-JP-060-H	91-JP-062-H
Na (%)	0.29	0.41	< 0.12	0.15	< 0.61	0.14	0.52
Sc (ppm)	27.0	24.0	25.0	12.0	12.0	11.00	27.00
Cr (ppm)	220	180	220	84	440	83	150
Fe (%)	10.0	6.7	11.0	6.7	26.0	1.6	6.6
Co (ppm)	32	31	22	27	300	< 10	25
Ni (ppm)	34	43	27	47	150	< 20	32
Zn (ppm)	< 200	< 200	< 200	< 200	1100	< 200	< 200
As (ppm)	16	7	31	40	753	2.4	5.0
Se (ppm)	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Br (ppm)	8	6	3	2	< 4	3.1	4.3
Rb (ppm)	< 10	20	< 10	< 10	< 10	14	20
Zr (ppm)	1000	< 500	12000	< 500	6200	3400	< 500
Mo (ppm)	< 2	< 2	< 2	< 2	< 5	4	7
Ag (ppm)	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Cd (ppm)	< 10	< 10	< 10	< 10	90	< 10	< 10
Sn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200	< 200
Sb (ppm)	0.9	0.6	1.3	0.5	41.4	0.3	0.4
Te (ppm)	< 20	< 20	< 20	< 20	< 20	< 20	< 20
Cs (ppm)	< 1	< 1	< 1	< 1	3	< 1.0	< 1.0
Ba (ppm)	330	230	2700	100	>90000	160	160
La (ppm)	37	13	61	6	2020	20	16
Ce (ppm)	58	22	130	< 10	3800	52	34
Sm (ppm)	5.5	3.1	15.0	1.9	219.0	4.90	3.30
Eu (ppm)	< 2	< 2	< 2	< 2	69	< 2	< 2
Tb (ppm)	< 1	< 1	4	< 1	17	1.2	< 1.0
Yb (ppm)	< 5	< 5	22	< 5	9	9	< 5
Lu (ppm)	0.6	< 0.5	2.3	< 0.5	1.0	2.1	0.6
Hf (ppm)	15	4	237	< 2	84	87	10
Ta (ppm)	3	1	4	< 1	8	< 1.0	< 1.0
W (ppm)	< 5	< 5	< 6	< 4	45	< 2	< 2
Ir (ppb)	< 100	< 100	< 100	< 100	< 100	< 100	< 100
Au (ppb)	< 5	< 5	< 5	< 5	< 21	10	< 5
Th (ppm)	18.0	4.6	45.0	1.5	229.0	13.0	5.2
U (ppm)	2.7	1.3	22.0	0.9	37.0	5.9	1.5
WT (gm)	10.93	10.15	10.44	7.90	13.18	9.58	9.94

APPENDIX III continued.

Sample #	91-JP-066-H	91-JP-100-H	91-JP-101-H	91-JP-118-H	91-JP-119-H	91-JP-120-H
Na (%)	0.15	< 0.05	0.21	0.19	0.35	0.44
Sc (ppm)	27.00	33.00	42.00	21.00	25.00	57.20
Cr (ppm)	200	150	310	150	240	460
Fe (%)	4.9	4.7	10.0	4.0	5.6	16.0
Co (ppm)	12	15	37	11	17	50
Ni (ppm)	< 20	36	80	< 20	26	84
Zn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200
As (ppm)	5.0	2.7	8.2	2.2	1.5	5.5
Se (ppm)	< 10	< 10	< 10	< 10	< 10	< 10
Br (ppm)	2.1	1.9	2.6	4.3	< 1.0	3.4
Rb (ppm)	< 10	27	< 10	22	< 10	< 10
Zr (ppm)	13000	18000	7500	7200	7600	3000
Mo (ppm)	6	4	10	5	6	12
Ag (ppm)	< 5	< 5	< 5	< 5	< 5	< 5
Cd (ppm)	< 10	< 10	< 10	< 10	< 10	< 10
Sn (ppm)	< 200	< 200	< 200	< 200	< 200	< 200
Sb (ppm)	0.5	1.0	1.4	0.8	0.4	1.1
Te (ppm)	< 20	< 20	< 20	< 20	< 20	< 20
Cs (ppm)	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ba (ppm)	570	< 100	250	< 100	110	520
La (ppm)	43	22	50	46	59	44
Ce (ppm)	120	54	110	100	140	96
Sm (ppm)	16.00	13.00	11.00	11.00	11.00	9.10
Eu (ppm)	3	2	< 2	< 2	< 2	< 2
Tb (ppm)	3.5	5.4	3.0	2.5	2.9	1.5
Yb (ppm)	19	32	18	17	13	9
Lu (ppm)	4.9	7.4	4.1	4.1	3.5	2.1
Hf (ppm)	277	389	150	150	170	60
Ta (ppm)	2.1	2.2	3.8	3.0	3.2	3.2
W (ppm)	< 2	2	4	< 2	< 2	2
Ir (ppb)	< 100	< 100	< 100	< 100	< 100	< 100
Au (ppb)	46	< 5	< 5	< 5	< 5	< 5
Th (ppm)	48.0	56.6	31.0	31.0	42.0	20.0
U (ppm)	23.0	36.0	13.0	12.0	13.0	6.0
WT (gm)	9.89	9.84	9.68	9.93	9.95	9.87