



GEOLOGICAL SURVEY OF CANADA

OPEN FILE 2480

**ASSESSMENT OF MINERAL RESOURCE POTENTIAL,
PHASE I, IN THE PROPOSED AREA OF
GWAII HAANAS / SOUTH MORESBY
NATIONAL MARINE PARK RESERVE**

**C.W. Jefferson
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April, 1992

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EXECUTIVE SUMMARY

The proposed area of the Gwaii Haanas / South Moresby National Marine Park Reserve includes marine waters and sea bottom within about 10 to 15 km of the shoreline south of Tasu Inlet on the west and south of Laskeek Bay on the east (Figure 1). The bedrock area on adjacent land and under water is divided into seventeen mineral resource assessment domains for this study (Table 1, Figure 1). The terrestrial parts of these domains are the main sources of the marine surficial sediments and their contained minerals. This report assesses the mineral, coal and geothermal energy potential of the surficial deposits and bedrock in the marine area of interest. Dietrich et al. (1992, in preparation) assess the petroleum resource potential of the same area.

A qualitative rating scheme developed for northern Canadian resource assessments (Table 2) has been consistently applied to available literature data on each domain. Very high to high potential (1-2) is inferred in the marine parts of domains BU, CU, LO, LY, RS, SH, SK and TA for gold and titanium in marine placer deposits which could have been reworked from drowned alluvial placers and from bedrock deposits. The known and inferred bedrock gold deposits are also assigned high potential (2). These include disseminated gold in sedimentary rocks; gold in veins and shear zones; skarn-hosted iron-copper, copper+/-silver, gold and tungsten; and porphyry copper - molybdenum +/- gold - rhenium. Moderate to high potential (3) in BI, SC and SH domains is inferred for bedrock deposits of the above skarn-hosted metals. The QC domain has moderate to high potential (3) for seafloor hydrothermal polymetallic resources of copper, zinc, lead, gold and silver.

Potential for traditional carving stone (Haida Argillite) is moderate (4) in TA Domain. Building stone (mainly limestone)

and aggregates are rated as very high (1) in BU, CU, LO, LY, RS, SK and TA domains. Limestone quarries, if developed, would most likely be on tidewater. High (2) and moderate to high potential (3) are rated in eastern domains and in QC for geothermal energy.

The resource potential ratings are summarized by domain in Table 1, and illustrated in Figure 1. The rating categories and domains are summarized in Tables 2 and 3 respectively; and discussed in more detail in the body of this report. Appendix I and Figure 2 summarize known mineral occurrences in the terrestrial parts of the domains.

The assessments are derived by application of mineral deposit models to a geoscience data base that is virtually absent in the specific marine area of park interest, even though the extrapolated data base from adjacent land areas and the deeper offshore has been much improved under the Frontier Geoscience Program by on-land mapping, marine geoscience studies and re-interpretation of old geophysical data. Phase II studies are recommended to document the preliminary resource assessments given here and to provide definitive information in the areas of higher detrital mineral potential (e.g. placer gold).

Gold is now being recovered from beach placers on northern Graham Island by local cooperatives. Gold placers in shallow marine environments in Alaska; diamond placers along the southwest coast of Africa; and a variety of heavy minerals placers including ilmenite (titanium) in Australia, along the southeast coast of USA and the southeast coast of Brazil; are currently being mined. Canadian research has shown that the relatively simple mining techniques used for these deposits could be viable in the study area.

Table 1. Summary mineral potential ratings (explained in Tables 2, 3; figures 1 and 2; derived in text). Abbreviations explained in Appendix I.

Part I									
Domain	Marine Placer Au,Ti	Aggregates	Geothermal Energy	Carving Stone	Industrial Stone	Coal	Skarn Fe-Cu-Au-Ag	Porphyry Cu-Mo-Au	
Barber Point (BP)	4	5	5	7	7	7	6	7	
Barry Inlet (BI)	3	2	5	6	6	7	3	4	
Bumaby (BU)	2	2	2	6	2	7	4	4	
Cumshewa (CU)	2	2	3	5	6	4	4	4	
Garcin (GA)	3	5	3	7	7	7	5	6	
Hecate (HE)	3	2	3	7	7	7	5	6	
Lost Islands (LI)	3	2	3	7	7	5	5	6	
Lousoone Inlet (LO)	2	2	3	6	2	7	2	6	
Lyell (LY)	2	2	2	5	2	4	3	2	
Pacific (PA)	6	6	5	7	7	7	6	7	
QCFZ (QC)	7	7	2	7	7	7	6	7	
Rennell Sound (RS)	2	2	3	5	1	4	4	5	
San Christoval (SC)	3	2	5	5	6	7	3	4	
Shuttle (SH)	1	2	3	5	6	7	4	4	
Skincuttle (SK)	2	2	3	5	2	6	1	2	
Tasu (TA)	2	2	3	3	2	4	1	4	
Wells Cove (WC)	4	5	5	7	7	7	6	7	
Part II									
Domain	Volcanic- Redbed Cu-Ag	Volcanic- Associated Vein Au-Ag	Disseminated Au-Ag (Cinola)	Seafloor Hydrothermal Cu-Zn-Pb-Au-Ag (Juan de Fuca Ridge)	Volcanogenic Massive Sulphide Cu-Zn-Pb- Au-Ag (Westmin type)				
Barber Point (BP)	6	5	6	4	6				
Barry Inlet (BI)	4	4	7	6	6				
Bumaby (BU)	3	2	5	5	4				
Cumshewa (CU)	7	3	2	5	6				
Garcin (GA)	7	6	6	4	6				
Hecate (HE)	7	6	6	4	6				
Lost Islands (LI)	7	5	6	4	6				
Lousoone Inlet (LO)	3	2	6	4	4				
Lyell (LY)	4	2	2	5	6				
Pacific (PA)	5	6	7	4	6				
QCFZ (QC)	6	6	7	3	6				
Rennell Sound (RS)	5	3	2	5	6				
San Christoval (SC)	5	4	7	6	6				
Shuttle (SH)	3	2	2	4	6				
Skincuttle (SK)	4	2	5	5	6				
Tasu (TA)	3	3	2	5	6				
Wells Cove (WC)	5	6	7	5	6				

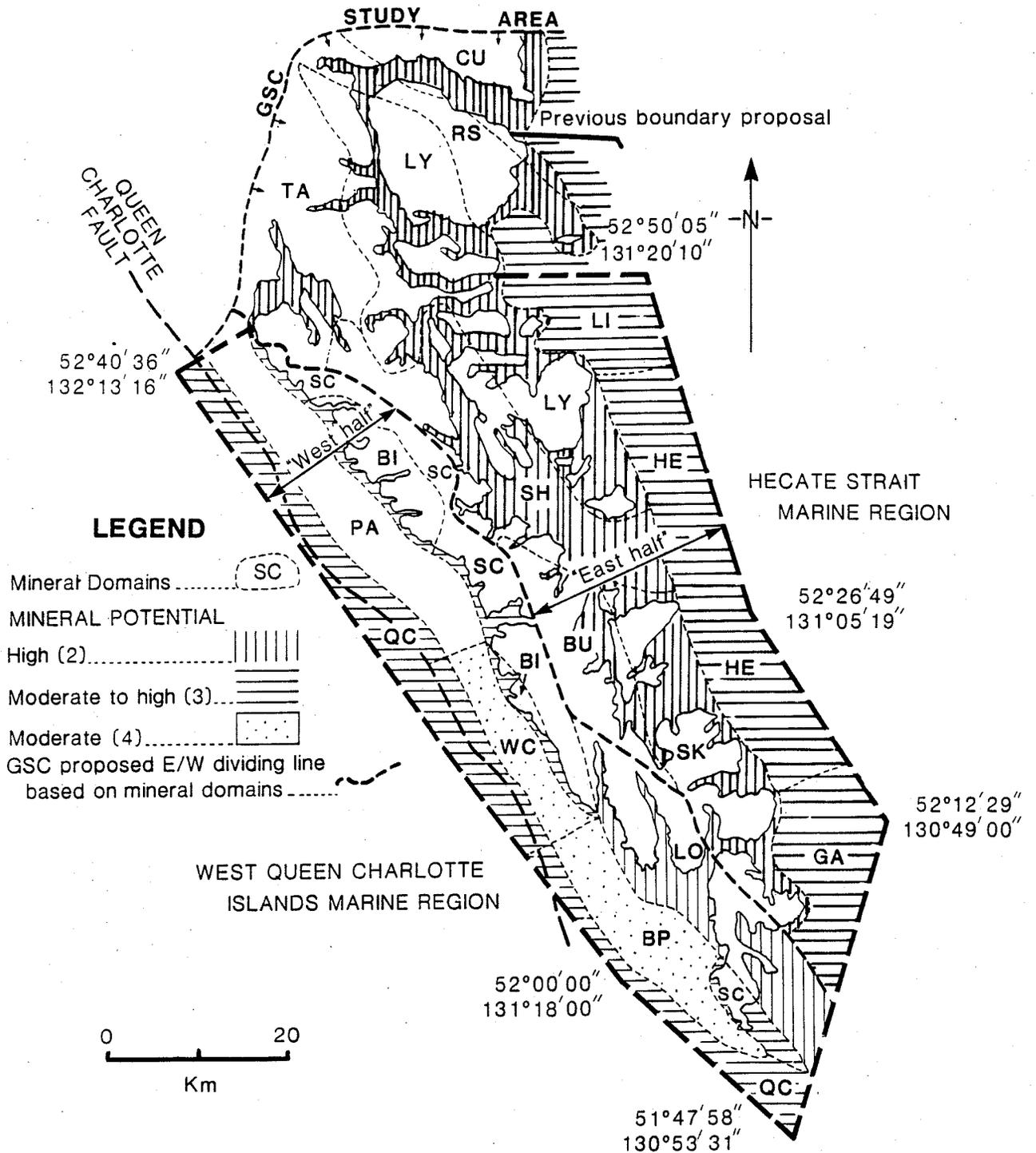


Figure 1. Summary sketch map of mineral resource potential in the proposed area of Gwaii Haanas / South Moresby National Marine Park Reserve as outlined by heavy dashed line. Scale is approximately 1:700,000. Figure 2 shows these domains more accurately, and terrestrial mineral occurrences at a scale of 1:250,000. See Figure 3 for regional setting.

Table 2. Explanation of mineral potential rating categories (after Jackson and Sangster, 1987 and Jefferson et al., 1988), based on the application of deposit-type¹ models (e.g. Eckstrand, 1984) to data bases that include only geology, mineral occurrences and sparse geochemical data.

<u>Symbol</u>	<u>Potential</u>	<u>Criteria</u>
1	Very High	<ul style="list-style-type: none"> - Geological environment is very favorable - Significant deposits¹ are known - Presence of undiscovered deposits very likely
2	High	<ul style="list-style-type: none"> - Geological environment is very favorable - Occurrences² are known - Presence of undiscovered deposits is likely
3	Moderate to High	<ul style="list-style-type: none"> - Between moderate and high potential - Reflects more uncertainty due to fewer data
4	Moderate	<ul style="list-style-type: none"> - Geological environment is favorable - Occurrences may or may not be known - Presence of undiscovered deposits permissible
5	Low to Moderate	<ul style="list-style-type: none"> - Between low and moderate potential - Reflects more uncertainty due to fewer data
6	Low	<ul style="list-style-type: none"> - Some aspects of the geological environment are favorable but are limited in extent - Few occurrences may or may not be known. - Presence of undiscovered deposits unlikely.
7	Very low	<ul style="list-style-type: none"> - Geological environment is unfavorable. - No occurrences are known. - Presence of undiscovered deposits very unlikely.

¹ "Deposit" is a mineral resource with measured reserves of a size that could be developed; includes past producers and producing mines.

² "Occurrence" is a drilled or exposed mineral resource (showing, prospect) that may be part of a hidden deposit.

Table 3. Summary descriptions of mineral resource assessment domains (Figure 1; Table 1) for the proposed area of Gwaii Haanas / South Moresby National Marine Park Reserve. Domains are defined on the basis of on-land geology and marine geography. Boundaries of domains are arbitrary and approximate; for this reason mineral occurrences located close to domain boundaries (Figure 2, Appendix I) are considered as part of each of any two adjoining domains. Bedrock and surficial sediments have not been studied in any of these domains except seismic sections on the west side give some indications of thickness; all comments on surficial sediments are therefore based on inference.

BI **BARRY** Post-tectonic plutons in contact with Karmutsen volcanic and syntectonic plutons (Anderson and Reichenbach, 1991). About twenty percent of this domain consists of marine environments including several large east-west fjords and an irregular, high-energy nearshore coastal environment. Much of the intertidal zone comprises well exposed rock although adjacent to inlet entrances and in the lee of prominent headlands, pockets of reworked unconsolidated sediments likely occur. The nature of unconsolidated sediments at the bottom of Sunday, Pocket, Barry and Mike Inlet is unknown.

INLET

....Table 3 continued

Table 3 continued.

BP	BARBER POINT	Moderately deep marine, high wave-energy, east of the QC Domain under the continental slope, and including the western fringe of the Louscoone Inlet Fault Zone (see LO below). A linear aeromagnetic high (Geological Survey of Canada, 1987a) extends from Nagas Point to Barber Point, suggesting that the continental slope is here underlain by San Christoval Plutonic Suite. The petrological similarity of intrusive rocks exposed on Kunghit Island, Anthony Island and Nagas Point area support this hypothesis (Sutherland Brown, 1968). Surficial deposits of glacial till, sand and gravel, were probably reworked at times of low sea level.
BU	BURNABY	Burnaby Strait, Huston Inlet, head of Hutton Inlet. Encompasses both north- and NW-trending faults in the middle sector of the Louscoone Inlet Fault Zone (see LO below) in Karmutsen Formation basalts; western boundary at height of land. Gold occurrences and soil anomalies are close to faults. The northern boundary is drawn to exclude NW-trending faults of SH (Juan Perez Sound). Surficial deposits of glacial till, sand and gravel, were probably reworked at times of low sea level.
CU	CUMSHEWA	Cumshewa Inlet Domain is characterized by extensive unconsolidated deposits derived from Moresby and Louise islands, underlain by dominantly sedimentary bedrock strata intruded by the Burnaby Plutonic Suite, between RS (west) and Sandspit Fault (east). Surficial deposits of glacial till, sand and gravel, were probably reworked at times of low sea level and are now being reworked under conditions of moderate-to-high wave and tidal energy.
GA	GARCIN	Narrow high wave-energy shelf, mainly >50 m, off-shore marine extension of SK. Topographic map by B. Sawyer on the cover of Woodsworth (1991) indicates that this is the deepest of the eastern offshore domains, and suggests that marine currents and movement of clastic sediments are toward the south, through canyons in this domain.
HE	HECATE	Moderately wide shelf, mainly <50 m, moderate wave-energy; offshore extensions of LY, SH, SK bedrock geology are indicated by the aeromagnetic pattern. Surficial deposits include Pleistocene tills and sands to gravels which were subaerially reworked from the glacial deposits and continue to be reworked in the present environment (Barrie et al., 1991).
LI	LOST ISLANDS	Laskeek Bay to Hecate Strait: shallow marine shelf with extensive glacial deposits, underlain by southeastern extension of RS Fold Belt and Sandspit Fault Zone, and offshore extension of LY. Surficial deposits of glacial till, sand and gravel, were probably extensively reworked at times of low sea level and are now being reworked by moderate waves and tides.
LO	LOUSCOONE INLET	Encompasses northerly structural lineaments, faults and shears of the Louscoone Inlet Fault Zone (dextral and normal offsets) from Louscoone Inlet SE to Ballard Point on Kunghit Island; northern boundary with BU placed at height of land. About forty percent of the Domain consists of near-shore to moderately deep marine environments. Submerged geology within the Domain is probably very similar to adjacent on-land exposures, and likely mantled by a diverse assortment of unconsolidated sediments: moderately low-wave-and-tide energy to high-wave-and-tide-energy, estuarine to continental slope, derived largely from source areas within Flamingo and Louscoone Inlet, Houston Stewart Channel, and Luxana and Howe Bays. The present distribution of these sediments may have been subject to a complex interaction of tidal and longshore currents.
LY	LYELL	Sequence of east-west inlets from Carmichael Passage to Ramsay Island, including Gogit Passage and shorelines: encompasses the northern end of the Louscoone Inlet Fault Zone (see LO above) transecting Tertiary sub-aerial volcanic rocks of the Massett Formation, the contemporaneous Kano Plutonic suite, the underlying older strata and the Burnaby Island plutonic suite. Surficial sediments are probably very similar to those of the Hecate (HE) Domain but are being more actively reworked by waves and tides in the shallow marine environment, particularly along its narrow straits and fjords.
PA	PACIFIC	Deep offshore, includes outermost mouth of Tasu Inlet; underlain almost entirely by rocks of Wrangellia terrane: tholeiitic submarine basalts of the Triassic Karmutsen Formation and relatively minor overlying calcareous sediments of the upper Triassic to Sinemurian Kunga Group. Unconsolidated glacial and post-glacial sediments of variable thickness are thought to mantle the continental slope. These may be prone to extensive slumping due to the steepness of the slope and high incidence of local seismic activity. Unconsolidated sediments may have been re-worked in the high-wave-energy near-shore environment.

...Table 3 continued

Table 3 continued.

QC	QCFZ	Queen Charlotte Fault Zone, deep marine, includes bathymetric complexities associated with fault splays and continental rise. The QC Domain is a narrow zone along the westernmost part of the marine park study area, underlain by the seismically active Queen Charlotte Fault Zone which is the locus of principal dextral transform motion between the Pacific Plate and North American Plate along which Wrangellia terrane is juxtaposed (Yorath and Chase, 1981; Monger and Berg, 1984). Small elongate sedimentary basins, likely to contain Tertiary or older marine turbidites, are present on the down-thrown side of certain segments of the fault zone (Morrell and Fortier, 1987). Farther west a thick wedge of consolidated sediments tectonically thickened by landward underthrusting and compression rests on an eastward subducting slab of oceanic crust (Hyndman and Ellis, 1981; Hyndman et al., 1982; Dehler et al., 1986).
RS	RENNELL SOUND	Gillat Arm, head of Cumshewa Inlet, waters around Limestone and Reef islands. Named for Rennell Sound Fold Belt (Thompson and Thorkelson 1989); imbricated and folded Karmutsen volcanics and Kunga limestones on west, unconformably overlain on the east by variably dipping Longarm conglomerate-sandstone-shale, Honna conglomerate, Haida sandstone and shale. Surficial sediments and marine conditions are probably very similar to those of the Lyell (LY) Domain.
SC	SAN CHRISTOVAL	Syntectonic plutons of San Christoval Batholith and slivers of Karmutsen volcanics. The western margin of the San Christoval Domain, except where it contacts the Barry Inlet Domain, includes a uniform to irregular high-wave-and-tide-energy coastal zone punctuated by Sunday Inlet, Gowgaia Bay and Wells Cove. Unconsolidated sediment distribution and characteristics have not been documented along the coast or within the various inlets.
SH	SHUTTLE	Darwin and Juan Perez Sounds and feeder inlets. Encompasses extensive northwest- and west-northwest-trending faults of the Louscoone Inlet Fault Zone which transects Karmutsen and (on the eastern fringe) Masset volcanic rocks, Kunga limestones, minor Burnaby and Kano plutonic suites. Named for the several lode gold occurrences and placer gold at Shuttle Island which may be provenance for placer deposits in Juan Perez Sound. Unconsolidated sediment distribution and characteristics have not been documented along the coast or within the various inlets. Marine conditions and surficial deposits are probably much like those of the Lyell (LY) Domain.
SK	SKINCUTTLE	Skincuttle Inlet, Carpenter Bay, east Houston-Stewart Channel and nearshore waters containing numerous small islands. Underlain by Karmutsen volcanics and Kunga limestones cut by Kano and Burnaby plutonic suites; transected by numerous N-S and E-W faults; host to numerous skarn Fe-copper and gold-silver deposits. Unconsolidated sediment distribution and characteristics have not been documented along the coast or within the various inlets. Marine conditions and surficial deposits are probably much like those of the Lyell (LY) Domain.
TA	TASU	Tasu Sound, feeder inlets and head of Sewell Inlet. Underlain by Karmutsen volcanics, Kunga limestones, Yakoun clastic and volcanic rocks, which are cut and altered by San Christoval Plutonic Suite and host Tasu Mine and other skarn deposits. In Sewell Inlet area the Burnaby Island Plutonic Suite intrudes and is unconformably overlain by Haida and Honna clastic rocks and Massett volcanics. NW-trending faults of SH continue into TA. Unconsolidated sediment distribution and characteristics have not been documented along the coast or within the various inlets, but would be subject to highly variable wave and tidal energy conditions depending on location within the inlet; highest at the mouth.
WC	WELLS COVE	Moderately deep, high-wave-energy marine; Its bedrock geology is generally similar to that of the Pacific Domain: Karmutsen Formation tholeiitic basalts appear to underlie most of the steep continental slope to perhaps six to eight kilometres offshore, where the Wrangellia terrane is terminated by the Queen Charlotte Fault Zone. A bathymetric high and pronounced northwest trending aeromagnetic high (Geological Survey of Canada, 1987a) are coincident adjacent to the east side of the Queen Charlotte Fault Zone trace. These features suggest an area of complex geology related to the dextral transform or oblique convergent(?) processes along the Pacific Plate - North American Plate suture zone (Hyndman et al., 1982), or a western extension of the San Christoval Batholith truncated by the Queen Charlotte Fault Zone. The continental slope of the Domain is mantled by unconsolidated sediments which are thickest in the northwest-striking linear depression marking the trace of the Queen Charlotte Fault Zone. Slope sediments may have been reworked in the high wave-energy nearshore environment.

INTRODUCTION

Terms of Reference

Canadian Parks Service (CPS) completed work in 1986 to define the proposed area of Gwaii Haanas / South Moresby National Marine Park Reserve (Figures 1, 2, 3). In 1988 this area became part of the comprehensive agreement for the establishment of Gwaii Haanas / South Moresby National Park Reserve and National Marine Park Reserve. This represented the culmination of 15 years of integrated resource planning involving numerous federal and provincial agencies, public interest groups and native organizations (e.g. South Moresby Resource Planning Team, 1983).

An assessment of mineral potential, along with other natural resources on the land area of Gwaii Haanas / South Moresby Island, has been published by South Moresby Resource Planning Team (1983), and was considered in establishing the terrestrial portion of Gwaii Haanas / South Moresby National Park Reserve.

Assessment of mineral and energy resource potential in marine lands is required by the agreement between Canada and British Columbia before a marine park boundary is finalized. It was agreed that a preliminary (Phase I) assessment would be done first, based on literature research only. The agreement also stipulates that further review work will be considered for all areas rated as moderate or higher in mineral and/or energy potential by the Phase I assessments. This Open File presents the Phase I assessment of the mineral, coal and hydrothermal energy resource potential in the proposed area of the national marine park, as well as in terrestrial areas which both serve as reference and have influence on the mineral potential of adjacent marine lands. Dietrich et al. (in preparation, 1992) assess the petroleum resource potential of the marine area of interest.

The mineral and energy resource assessments for the study area have been guided by senior representatives from Canadian Parks Service and Energy, Mines and Resources Canada (Senior MERA Committee for Gwaii Haanas / South Moresby). These Phase I assessments are based on reviews of all available literature relevant to the area of interest, which in this case includes new field work done under the Frontier Geoscience Program in the Queen Charlotte Islands region. The Frontier Geoscience Program (FGP) did not,

however, collect any new data specifically for the marine part of the study area. We have attempted to apply the new FGP information by inference to the study area.

High mineral potential and a fundamental lack of information are identified by this Phase I report in the marine area of interest. Considering the Canada - British Columbia Agreement, it is therefore recommended that Phase II field studies be undertaken in order to provide definitive information in the areas of high mineral potential.

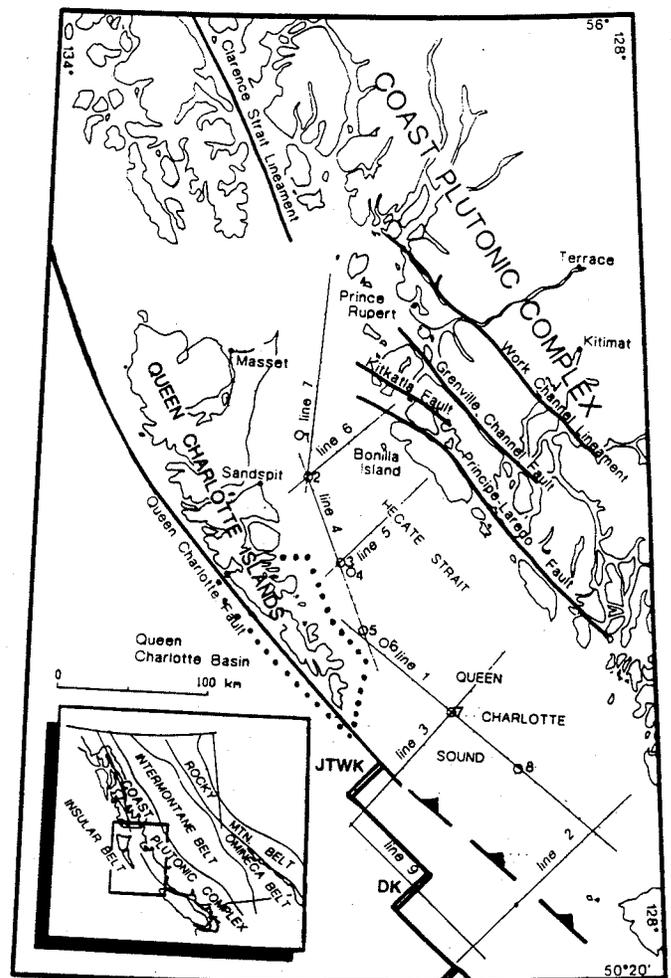


Figure 3. Index of marine resource assessment area (heavy dotted line), Queen Charlotte Islands. Stipple: Queen Charlotte Basin. Heavy lines: major boundary faults. JTWK and DK: J.T. Wilson and Dellwood knolls (northernmost offsets of the Juan de Fuca - Explorer spreading ridge). Circles: offshore wells. Fine lines: seismic structure lines. After figures 1 of P.D. Lewis et al. (1991) and Mackie et al. (1989).

Hereafter the terms "study area" and "area of interest" will refer to combined terrestrial and marine lands enclosed by the proposed boundary of the Gwaii Haanas / South Moresby National Marine Park Reserve (Figure 1). Individual discussions will differentiate between "marine area of interest" and "terrestrial area of interest".

History of Assessments and the Boundary Between East and West Assessment Areas

Scoates et al. (1986) have summarized the history and methodology of on-land mineral and energy resource assessments in northern Canada. By comparison, marine resource assessment is in its infancy, with only Hale and McLaren (1984), Proudfoot (1989) and a few deposit descriptions such as Carpenter and Carpenter (1991) available as examples. Franklin's (1987, unpublished) assessment of mineral resource potential of the Juan de Fuca and Explorer ridges dealt with abyssal and non-shelf areas which are covered by only the westernmost part of the study area. The assessment of on-land mineral resources by South Moresby Resource Planning Team (1983) provides some guidance regarding resources that might be mined by conventional tunnelling in the very shallow offshore. An early unpublished review of available minerals information (Hale, 1987a) suggested low mineral potential in the Pacific offshore in general.

The study area was originally divided by Canadian Parks Service into eastern and western parts (Figures 1 and 2), based on the broad understanding that hydrocarbon potential is high in Hecate Strait and Queen Charlotte Sound, but low in the Pacific offshore. Based on this assumption, and the very preliminary assessment by Hale (1987a), it was proposed that only Phase I assessment might be required to finalize the western area, and the Canada - British Columbia Agreement left open the possibility of establishing the marine park reserve in two phases.

Phase II studies were initially considered only for the eastern area. Because of the cost of conducting Phase II studies over the entire eastern area, it was decided that a delayed Phase I eastern assessment would be done utilizing data from the Frontier Geoscience Program, and that more specific Phase II studies would be considered later, depending on results of the Phase I study and any other new data that were obtained during the delay.

The second very preliminary assessment of non-renewable resource potential of the western part of the study area, by Schmitt et al. (1987), assigned high mineral potential to the Louscoone Inlet domain and moderate to high potential to several other domains. The 1987 report also assessed hydrocarbon potential in the western area as overall very low, but low-to-moderate potential was speculated for restricted basins in the QC Domain. The 1987 report recommended Phase II studies for minerals.

Assessment of the Tasu Inlet and eastern domains was delayed until results of on-going research for the Queen Charlotte Frontier Geoscience Program (FGP) (for example Thompson, 1989 to Thompson et al., 1991; Woodsworth, 1990, Lewis et al., 1991) became available. Jefferson and Schmitt (1989) provided a third very preliminary assessment of the mineral and geothermal energy potential in the eastern area, rating much of its mineral potential as high (2) and recommending Phase II field studies in order to provide more definitive information.

Dietrich et al. (1989) provided an interim assessment of the hydrocarbon potential in the eastern area. They used different domains based on regional bedrock geology, and rated most of the area as low or moderate to low, with a small domain crossing our LI and HE domains being rated as moderate. No further Phase II work on hydrocarbons was recommended, however their assessment was to be updated as the Frontier Geoscience Program proceeded. Dietrich et al. (1992, in preparation) will provide the latest hydrocarbon assessment for the study area.

Scope of Present Study

This report concerns both east and west sides of the study area. It includes all land south of the line labelled "GSC STUDY AREA", and it includes marine waters within about 10 to 15 km of the shoreline south of Tasu Sound on the west, and south of Laskeek Bay on the east (Figures 1, 2). The marine boundary outline is taken from the Canada - British Columbia Agreement of 1988.

This assessment is concerned only with mineral, coal and geothermal energy resource potential. It is still preliminary but combines and updates the mineral portions of previous very preliminary assessment documents (Northcote and Schmitt, 1982; Schmitt et al., 1987; Schmitt and Jefferson, 1989).

The study area is large and includes land for two reasons:

- (1) The study area covers extensions of mineral resource assessment domains which are known from mapping on the land and have unique mineral resource potentials that are distributed throughout the entire domains;
- (2) Unless a large study area is outlined initially, discussion of the final park boundaries may result in parts of the park boundaries being positioned outside of the area studied, thereby requiring additional resource assessments.

The mineral resource assessments given here are generalized over entire domains and include moderate to high potential (categories 1 to 4, Table 2) for one or more commodities in most of the eastern domains. The Canada - British Columbia Agreement states that, upon completion of this and the petroleum Phase I review, Canada, in consultation with British Columbia, may determine that further review work involving field studies (here termed Phase II) is required in those areas of the Marine Park Land rated as category 1, 2, 3, or 4 mineral or energy resource potential (see Table 2). Therefore, if more precise assessments are required before a final decision can be made on the proposed boundaries of the marine park, Phase II field work for the assessment process would be necessary to obtain specific information which could better delineate areas of high and low potential.

Phase II field work would be directed toward obtaining information specifically for resource assessment purposes. Sufficient data could be acquired by a 21-day cruise by small boat to map, collect and determine the minerals in some 200 samples of surficial gravel, sand and mud; to map the sea-floor topography by sidescan sonar (sound waves); and possibly to examine a few submarine rock outcrops. The cruise would cover all eastern domains, as well as LO and SC. Sediment samples would be 2-5 kg in weight, about the size of one or two milk cartons. Samples would be processed using water passed over a flat shaker table; no chemicals would be required (e.g. Stewart, 1986). Any activities associated with such field work would be subject to appropriate environmental screening so that the natural values of the study area would not be impaired.

Confidence and Temporal Value in this Assessment

Any resource estimates of any land being considered for specialized use should be regarded as time-limited and approximate. Their scope in the case of Gwaii Haanas / South Moresby marine areas is severely limited by a lack of information as noted above. The assessments provided here are based only on reviews of available geoscience information in the study area and some examples in other parts of the world. Such external data are only partially relevant to this resource assessment.

Much of this assessment is based on regional geological maps that are nearly 25 years old (Sutherland Brown, 1968). These maps are in the process of being completely up-dated at the scale of 1:50,000 for the Frontier Geoscience Program (FGP) (Haggart, 1992a). The FGP has been a multi-disciplinary federal contribution to the understanding of hydrocarbon accumulations beneath Hecate strait. This FGP has included much work on land because some types of information on the various formations are easier to gather on land than at sea, and many of the formations with their geological histories are directly linked to those with hydrocarbon potential beneath Hecate Strait.

The same FGP information, which will soon encompass the entire on-land area of the Queen Charlotte Islands, is a very important part of understanding mineral resource potential. The new data base is enormous, still growing and revolutionary; the geological history is being rewritten in contemporary tectonic and geophysical syntheses (e.g. Woodsworth, 1991, P.D. Lewis et al., 1991). Our confidence in the geologic history of the region has been increased in a number of sub-disciplines of geology, as follows.

Sedimentation is closely linked to the plate-tectonic history of the region (Fogarassy and Barnes, 1991; Haggart, 1991, 1992b and *in* P.D. Lewis et al., 1991; and Higgs, 1991a, b). Volcanism (e.g. Hickson, 1991 and *in* P.D. Lewis et al., 1991) and plutonism (e.g. Anderson, 1991 and *in* P.D. Lewis et al., 1991) are similarly linked to tectonism and provide events for radiometric dating. Paleontological studies (e.g. Cameron and Tipper, 1985; Desrochers and Orchard, 1991; Carter et al., 1991; Tipper et al., 1991; Poulton et al., 1991 and Tipper et al., 1991) have resolved stratigraphic problems and the timing of the various geological events. Paleomagnetic (Irving

et al., 1985) and paleontology studies also have demonstrated that Wrangellia was built in a more tropical climate. A host of other equally valuable contributions are reported in Woodsworth (1991) and a series of Geological Survey of Canada Current Research volumes (1988-1E, 1989-1H, 1990-1F, 1991-1A and 1992-1A).

Although the above studies have vastly improved our detailed knowledge of what the map patterns mean, both in terms of the geologic history and the mineral contents of the map units, the FGP re-mapping is areally incomplete, and new surprises are discovered every year in the FGP (Haggart 1992a; see for example the discussion in this report on volcanogenic massive sulphide deposits of copper, zinc, lead, gold and silver). Furthermore, new data are still being acquired, processed and synthesized. Sutherland Brown (1968) thus remains, for a short time longer, the major regional geological compilation map for Gwaii Haanas / South Moresby Island.

The above data base concerns the geological settings within which mineral deposits could be found, but little of the field work has been directed toward mineral deposit studies because the focus for FGP is on hydrocarbons. Because of this focus, petrologic and trace-element geochemical data on bedrock and unconsolidated sediments which are applicable to mineral deposits are non-uniform on land and unavailable for the marine part of the study area. Little information concerning mineral deposits has been published since the on-land assessments were done by South Moresby Resource Planning Team (1983). Work by Christie (1989) on the Cinola gold deposit, by Hickson (1991) on the relationship of Massett Formation volcanism to Cinola, by Anderson (1989) on which granites have mineral deposits associated with them, and by Barrie (1991 and earlier references) on marine placer deposits are exceptions, but none of these are directly applicable to the study area. Minfile maps (Ministry of Energy, Mines and Petroleum Resources, 1989; Jones, 1989) which place mineral deposits on a partially updated geologic base, have been valuable to this assessment, but are generalized and must be used in conjunction with Sutherland Brown (1968).

Brobst and Goudarzi (1984) have stated that assessments of mineral resource potential are of a dynamic nature regardless of how they are conducted, or of the methods that are used. Final, once-and-for-all assessments of mineral resource

potential cannot be made. Areas should be reassessed periodically as new data become available, as new concepts of the factors that influence the concentration of minerals are developed, as new uses and extractive technologies for minerals are devised, as the local and world economies change, and as local to national political needs change.

To say that an area has no mineral resource potential is inadvisable, even though some areas may be classified as having low potential for the occurrence of resources of a particular mineral (Brobst and Goudarzi, 1984). Some of the areas that have no identifiable resource potential may contain new types of mineral deposits, recognizable and exploitable only in the future. Similar statements have been made by many others (e.g., Scoates et al., 1986). For example, a new type of deposit containing nickel, zinc and platinum group elements has recently been discovered (Hulbert et al., 1992). These comments apply to all mineral resource evaluations and must be borne in mind by both producers and users of mineral resource assessment studies.

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TECTONIC HISTORY AND STRUCTURE OF THE QUEEN CHARLOTTE REGION

The following summary draws mainly from the recent synthesis by P.D. Lewis et al. (1991) of the nearly completed Frontier Geoscience Program (FGP) in the Queen Charlotte Basin. Figures 3 to 5 summarize the map pattern and the most recent regional stratigraphy. Figure 6 reproduces two older regional stratigraphic summaries. The different stratigraphic columns (figures 5 and 6) illustrate the enormous improvements in knowledge that can be achieved by new regional field studies 25 years after the last major mapping project. Despite this progress, our understanding of the stratigraphy of latest Cretaceous and early Tertiary rocks is still fragmentary (*ibid.*, p. 151). Furthermore the data base in the specific marine area of interest is even less than fragmentary, because virtually no geological work has ever been done there.

The Queen Charlotte Islands and adjacent Queen Charlotte Basin are components of the North American Cordillera (the mountain chain which includes the Rocky Mountains and Coast Mountains). These mountains are the product of intermittent convergence and pulling apart of segments (plates) of the earth's crust, termed plate tectonics. Plate tectonics causes the intrusion of granitic rocks, volcanic eruptions and deposition of sedimentary rocks. These events are recorded in rocks of Gwaii Haanas / South Moresby Island from the Permian time period (at least 260 million years ago) to the present.

Plate tectonics in the area of interest (Figure 1) has involved interactions between the western margin of the North American Plate (continental crust) and various Pacific plates (oceanic crust) (Hyndman and Hamilton, 1991). The Pacific plates have been partially subducted (shoved underneath) and/or amalgamated (squashed together) with continental crust, folded and thrust-repeated to cause overthickening, uplifting, volcanism, and hence the mountainous topography that defines the Cordillera.

Plate convergence has caused the joining of blocks of oceanic and continental crustal material of various origins (allochthonous = exotic terranes) along fault zones termed interplate sutures. Hundreds of such blocks make up the Cordillera, but many of these blocks have similar, internally coherent structures and stratigraphy. Groups of similar blocks are considered to represent parts of

single parent blocks (terrane) which have been dismembered and then re-assembled (Monger and Berg, 1984) into the Cordilleran collage. Four such terranes (Alexander, Wrangellia, Peninsular and northern Taku) have been amalgamated into the composite Insular Superterrane which underlies the continental shelf and offshore islands of British Columbia (Jones et al., 1977; Yorath and Chase, 1981; Monger and Berg, 1984; P.D. Lewis et al., 1991). The Queen Charlotte Islands are underlain by only Wrangellia, which at this latitude stretches from Banks Island on the east side of Hecate Strait (Woodsworth, 1988) to the Queen Charlotte Fault Zone 10 km west of the islands.

The stratigraphic and volcanic history in Queen Charlotte Islands comprises five major tectonostratigraphic subdivisions (after P.D. Lewis et al., 1991). Pre-Cretaceous rocks (older than 144 million years) constitute Wrangellia and form the lowest three major subdivisions.

1) The lowest subdivision of Wrangellia was recently discovered in exposures only in the Englefield Bay area (west coast of northern Moresby Island, outside of the study area). Here, Permian (Hesthammer et al., 1991) and Paleozoic or lower Mesozoic (Indrelid and Hesthammer, 1991) felsic volcanic rocks and variegated limestones which resemble the Sicker Group of Vancouver Island (see assessment of volcanogenic massive sulphide deposits).

2) The middle and most extensive subdivision of Wrangellia is characterized by thick (4600 metres) pillow basalts of the Karmutsen Formation, conformably overlain by a variety of limestones, sandstones and shales (Kunga and Maude groups) totalling about 900 m. These rocks constitute a very large proportion of the exposed non-plutonic rocks in the study area.

3) The upper subdivision of Wrangellia comprises unconformity - bounded andesitic extrusive rocks (Yakoun Group) and volcanic-derived clastic rocks (Moresby Group) which total about 1300 metres and are intruded by two plutonic suites (San Christoval and Burnaby Island) spanning 172-171 and 168-158 million years respectively (Anderson and Reichenbach, 1991). On the northwest corner of Graham Island, Haggart (1992b) has documented Late Jurassic clastic rocks which were apparently being deposited while in the south the plutonic suites were being emplaced.

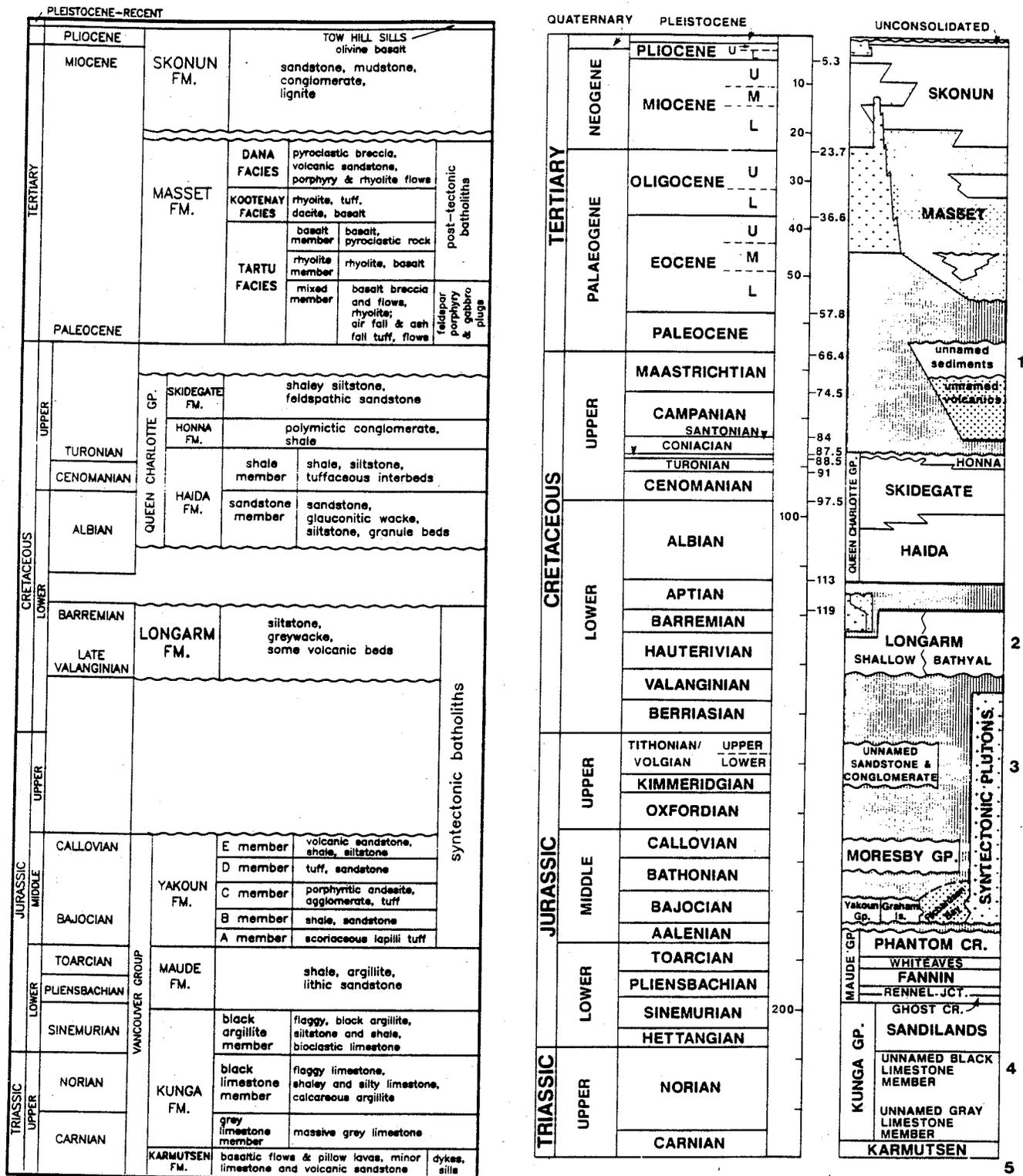


Figure 6. Two steps in the long history of stratigraphic change summarized by Woodsworth and Tercier (1991). Left: the first comprehensive stratigraphy for the region, from Sutherland Brown (1968). Right: initial results of the Frontier Geoscience Program, from Cameron and Hamilton (1988). Some of the more significant changes since 1988 are highlighted on the far right as follows. (1) Two different sets of unnamed sedimentary and volcanic rocks are shown in Figure 5; one Cretaceous, the other Tertiary. (2) Longarm Formation is now known to overlie plutons which are concisely dated at 440 million years older. (3) The unnamed sequences of Jurassic-Cretaceous strata have been precisely dated and named Skidegate Channel and White Point beds; and additional strata conformably underlying Longarm Formation have been dated as old as Late Jurassic. (4) The unnamed limestone members are now known as the Sadler and Peril formations. (5) Permian and possibly older sedimentary and plutonic rocks have been recognized.

Divisions 2 and 3 of the stratigraphy have been interpreted in two ways:

- a) they were completely assembled and then accreted to the Cordilleran collage during Cretaceous time (Monger et al., 1982; Crawford et al., 1987) or
- b) they were accreted into the Insular Belt by Middle Jurassic time, and Cretaceous tectonism was superimposed on the accreted terranes (van der Heyden, 1989; P.D. Lewis et al., 1991).

Divisions 1 to 3, the Moresby Group and older rocks, have similar counterparts on Vancouver Island which are also considered to be parts of Wrangellia. Information on mineral deposits of Vancouver Island is therefore roughly applicable to the Queen Charlotte Islands.

4) Since the "docking", uplift and erosion of the Insular Superterrane during the Jurassic (from about 145 to 74 million years ago), a fourth division of sedimentary and lesser volcanic rocks (~2800 metres) has recorded marine transgression across the region from west to east. These Cretaceous strata include the Longarm Formation and Queen Charlotte Group (Haida, Skidegate, Honna and some un-named formations). The present-day mountains that form the backbone of Moresby Island used to be a relatively flat shallow shelf sloping toward the Pacific Ocean. Recent stratigraphic studies (Haggart, 1992b) indicate that the separation in time of sedimentation between Divisions 2 and 3 was not very long in the area of northwest Graham Island.

5) The youngest lithified tectono-stratigraphic subdivision comprises still un-named Tertiary (66.4 to ~3 millennia) basalts to rhyolites and their sedimentary derivatives which were intruded by the Kano Plutonic Suite from 46 to 27 million years ago, conformably overlain by the Massett Formation basalts to rhyolites (27-5.3 Ma) and reworked into coal-bearing conglomerates, sandstones and shales of the Skonun Formation. The depositional basin architecture, and centres of volcanism were controlled by directions of movement of Pacific Plates (Hickson, 1991; Hyndman and Hamilton, 1991). Strike-slip faulting accompanied the dominant extensional faulting (generating rifts and variable subsidence) and lesser compressional tectonism (causing folding, reversal of extensional faults and uplift) (Lewis and Ross, 1991).

Quaternary alluvium and till cover much of the eastern side of Graham Island and the floor of Hecate Strait. Dominant convergence of Pacific plates during the Quaternary (1.6 million years to the present) has caused the uplift of the mountainous Queen Charlotte Island chain. Glaciers flowing from these ranges eastward, and

from the Coast Plutonic Complex westward, have deposited tills and glacial-marine sediments which record a variety of emergent periods and still-active shallow marine reworking of the sediments into large ripples, dunes and related bedforms, some of which contain significant heavy mineral laminae (Barrie 1991; Barrie and Luternauer, 1986; Barrie et al., 1988). Well preserved pieces of wood dredged from greater than 100 metre water depths, together with Haida legends of drowned forests, testify to the scale of local sea-level changes that have taken place since the Haida began to live in this region (Barrie et al., 1988 and personal communication 1992).

Fault and Fold Zones

A detailed study of the kinematic history of major faults in the Queen Charlotte Islands has been undertaken by the Geological Survey of Canada and other researchers under the Frontier Geoscience Program (Thompson et al., 1991; Lewis and Ross, 1991; P.D. Lewis et al., 1991; and earlier references therein). This has already allowed more detailed reconstruction of stratigraphy, paleogeography and basin tectonics as summarized above. Lewis and Ross (1991) have subdivided the structural history into four main periods which are temporally linked to the latter four main tectonostratigraphic divisions summarized above. The following provides information on specific geographic zones of faults which are but one part of the structural history.

Major faults of the Queen Charlotte Islands follow the dominant trends of the Cordillera, and strike northwesterly (Figure 4). Principal among these is the Queen Charlotte Fault Zone which marks the western edge of the continental shelf and is located about 10-15 kilometres west of Moresby and Graham islands. Dextral transform movement occurs along this fault system at the interface of the North American and Pacific plates. In 1949 an earthquake of 8.1 magnitude resulted in 6 metres of motion along this fault system. Recent seismic studies by Rogers et al. (1988) indicate the presence of a "stuck" zone, along the Queen Charlotte Fault Zone off southwest Moresby Island, which could be the locus of a large future earthquake, although Mackie et al. (1989) suggest that oblique subduction could be accomplished aseismically.

The Rennell Sound Fold Zone, which strikes southeasterly from Rennell Sound to Louise Island and into Hecate Strait, has been identified as a major zone of southwest to northeasterly directed compression and extensional block faulting (Lewis and Ross, 1991; Thompson et al. 1991). The Rennell Sound Fault Zone truncates obliquely both

Sandspit and Louscoone Inlet fault zones. Rennell Sound Fault Zone has been activated repeatedly as a zone of slippage for both compressional and translational strain, and extensional faulting along a profound structural weakness which developed early in the history of the region. A complex history of folding is also particularly evident in rocks of Cretaceous and Jurassic age of northern Moresby and southern Graham Island, and appears to be related to this compressional regime (Thompson, 1989).

The Sandspit Fault, another major northwest-trending fault zone parallel to the Queen Charlotte Fault in central Graham Island, can be traced on seismic lines and as a linear gravity low (Seeman et al. 1988) offshore along eastern Louise Island. It was previously considered to be a major regional strike-slip fault accommodating oblique plate motion (Yorath and Chase, 1981). Recent interpretations of regional gravity data (Sweeney, pers. comm. 1987), combined with regional mapping in the northwest Graham Island area by Hickson (1991) suggest that the fault is listric normal (east-side down) with parallel east- and west-facing subvertical components (graben-like). The Sandspit Fault includes a number of splays; the Cinola gold deposit is located on one of these (Christie, 1989), as are two vent areas for the Massett Formation volcanic rocks (Hickson, 1991).

The Louscoone Inlet Fault Zone (Sutherland Brown, 1968) which obliquely transects Moresby Island from Louise Island southerly through Kunghit Island appears to be another regional fault system related to translational and compressional plate tectonics. Yorath and Chase (1981) suggested that this fault zone was once the southern continuation of the Sandspit Fault Zone and was displaced right-laterally along the Rennell Sound Fault Zone during late Tertiary reactivation. Thompson (1989) has rejected this interpretation, noting the predominantly fold-structural style of the Rennell Sound Fault Zone. Nevertheless the Louscoone Inlet Fault Zone remains a significant feature, includes faults (P.D. Lewis et al., 1991) and terminates against the Rennell Sound Fault Zone. The Rennell Sound Fault Zone may be interpreted as being a zone of accommodation developed at the termination of the strike-slip movement on the Louscoone Inlet Fault Zone.

A set of shorter northeasterly to easterly trending faults transect the Queen Charlotte Islands between the main strands of the Queen Charlotte Fault Zone, Louscoone Inlet Fault Zone and Sandspit Fault, and appear to be zones of weakness which were scoured by glaciation into several of the major fjords which penetrate the interior of the islands. These faults are extensional, showing

normal and some left-lateral strike-slip displacement (Sutherland Brown, 1968). They appear to be genetically related to the major translational strain of the Queen Charlotte Fault Zone and Louscoone Inlet Fault Zone systems. Possible examples of this class of fault have been identified on seismic lines offshore along the eastern side of Moresby Island.

Structures of considerably more significance to hydrocarbon exploration offshore, on the eastern side of Moresby Island are associated with a different class of faults. These are extensional faults which developed during periods of rifting that took place through much of the Queen Charlotte Basin beneath Hecate Strait and the Queen Charlotte Sound but generally seaward of the study area.

Extensional faults within the Cordillera are associated with differential subsidence and volcanic centres. Crustal components of various densities were thus redistributed during periods of extension. Volcanic rocks of the Masset Formation might be related to rifting of the Wrangellian landmass (see description in previous section) during the Late Oligocene and Early Miocene (Yorath and Hyndman, 1983), although a variety of alternatives are possible (Hickson, 1991). Volcanism is recorded by accumulations of volcanic rocks in the rift basins (in Hecate Strait and Queen Charlotte Sound), by accumulations of volcanic rocks along previously established lines of weakness, i.e., Queen Charlotte Fault Zone, Louscoone Inlet Fault Zone, Rennell Sound Fault Zone (Yorath and Chase, 1981), by dyke swarms (Souther and Jessop, 1991) and by non-marine mafic flows localized along fissures on northern Graham Island (Hickson, 1991). Vent areas of Massett volcanism on northern Graham Island are spatially associated with gold and silver concentrations at Cinola (Christie, 1989; Hickson, 1991); this association is inferred in other areas of Masset volcanism.

An understanding of extensional tectonic processes and the distribution of related volcanic and intrusive rocks is important to be able to predict their effects on thermal maturation of coal-bearing rocks, as well as fluid hydrocarbons, in adjacent parts of Hecate Strait. The highly faulted appearance of a strong reflector interpreted on seismic lines in central Hecate Strait, and the coarse clastic nature of this continental margin facies, suggest that rifting continued (strike-slip pull-apart or back-arc basin?) (Higgs, 1991b) after the cessation of Masset volcanism, causing significant faulting and folding of the younger Skonun Formation as late as the Mio-Pliocene unconformity in Hecate Strait.

MINERAL RESOURCE ASSESSMENTS

Mineral Resource Assessment Domains

The dividing line between eastern and western assessment areas (Figure 1) follows mineral resource assessment domain boundaries. Ten eastern domains and seven western domains were delineated solely for mineral resource assessment purposes, on the basis of on-land geology and overall geography. The domains are summarized in Table 3 and Figures 1 and 2. Boundaries were chosen somewhat arbitrarily in order to compartmentalize the assessments. Domain boundaries correspond broadly to major geological units where possible but are locally placed at the height of land because the terrigenous component of surficial deposits in the marine lands off a particular shoreline would be affected mainly by the composition of bedrock on that side of the drainage divide. Detailed discussions of specific geological features in the Phase I domains are included in the resource assessments below. Domains could be defined in greater detail and could use more specific marine geographical and geological parameters in a Phase II assessment.

Geological units and faults transect the east-west boundary as well as each domain boundary. In particular, the Rennell Sound fold-fault belt and Louscoone Inlet Fault Zone transect the study area obliquely from south to north, and their environs are prospective for gold (see further discussions in assessments). For assessment purposes these fault zones are dominant in six mineral resource assessment domains (BU, LI, LO, LY, RS and SH). Splays from these zones also affect domains SK and TA (Figures 1 and 2; Table 3). Nearly all eastern inlets, straits and sounds are affected by these fault zones.

General Approach

The following assessments of mineral resources consider the potential for the occurrence of specific types of mineral deposit within each domain. The assessments adopt the general approach reviewed by Scoates et al. (1986) and used in recent resource assessment studies of Jefferson et al. (1988, 1991) and Jackson and Sangster (1987) for new national park proposals. Insufficient data are available and the area is too large to apply the more quantitative methods used by McLaren (1990). Only one occurrence (Shuttle

Island beach placer gold) is known within the marine study area.

The commodities and deposit types considered here use the classifications summarized in Eckstrand (1984) with additional information included from Cox and Singer (1986) and from mineral deposit investigations which have implications for the study area (e.g. Ettlinger and Ray, 1989; Dawson et al., 1991; Getsinger et al., 1990; Hale, 1990; Northcote et al., 1983; and Ray et al., 1990).

The Queen Charlotte Islands have long been known for their mineral potential. Gold, historically the most important metal in the Cordillera, was long ago mined from placer deposits by the Haida (Barry, personal communication, 1992). Lode gold was first mined in British Columbia in 1852 in the Queen Charlotte Islands (Dawson et al., 1991).

Despite this long history of mining, the Queen Charlotte Islands have been relatively unexplored and less well documented than areas closer to centres of dense population. Vancouver Island therefore serves as the most direct geographic and geological analogue for the metallogeny of the Queen Charlotte Islands region. Both of these island regions are considered uniquely fertile for metallic mineralization, because of their diverse, voluminous and long-lasting volcanism, related plutonism, intercalated reactive carbonate rocks, and repeated tectonic activity (Dawson et al., 1991). Nine producing and potentially producing mines are located in the area of northern Vancouver Island (Table 5-2-2 of Gravel and Matysek, 1989; based on Muller et al., 1974).

Exploration targets in the Queen Charlotte and Vancouver islands region (Insular Belt) include the following, listed by page in this Open File:

18. Beaches and shallow marine sands and gravels which may contain gold, titanium, or may be utilized directly as construction aggregates.
20. Hot springs which may be utilized for power or recreation.
21. Stone which may be used for carving or building.
22. Coal which may be used directly for generating power or which may be a source of gas.

Margins / roof pendants in Jurassic Island intrusions with potential for:

23. skarn,
 25. porphyry copper and gold,
 26. gold in veins and shear zones, and
 30. gold - silver - rich volcanogenic copper-zinc sulphide deposits.
25. Subaerial volcanic rocks of the Karmutsen Formation with unrecognized potential for viable copper - silver deposits of the volcanic - redbed type;
 26. Faults and splays in the Louscoone Inlet and Rennel Sound fault and fold zones transecting volcanic and intrusive rocks, for gold and silver in quartz veins.

Jurassic Island Intrusions reclassified as Tertiary intrusions with the possibility of:

25. porphyry copper (Island Copper type) and
28. disseminated epithermal gold;

Unrecognized outliers of Sicker Group volcanic rocks with potential for:

26. gold and silver in quartz veins, and
28. gold-silver-rich volcanogenic copper - zinc sulphide deposits.

The characteristics of these deposit types are summarized in the relevant evaluations below. Some potential exists in each domain of the marine study area for a wide range of commodities and deposit types. Some deposit types are probably present which have not been considered here, either because the science has not recognized them, or because they have not yet been recognized to be significant in the Insular Terrane. Future research and resource assessments are expected to make revisions to this list of deposit types and to the interpretations made here.

The authors emphasize that the following assessments are preliminary (see Introduction: Scope; Confidence and Temporal Value). The mineral resource assessments rely on the known distribution of mineral deposits and showings immediately adjacent to and in the terrestrial parts of the study area (Appendix I), the distribution of mineral deposits in analogous geological environments in other regions, and on indirect geological inferences bearing on genetic concepts for the various types of mineral deposits ("mineral deposit models"). The assessments are provided here in the pure geological sense, with no consideration or advocacy implied regarding political and economic constraints on the viability of extraction.

The mineral resource potential ratings for all domains are listed in Table 1 and the rating scheme is explained in Table 2. Appendix I summarizes known metallic and non-metallic mineral occurrences in the terrestrial lands of each domain.

Detrital Deposits in the Offshore (Placer Gold, Titanium; Industrial Aggregates and Minerals)

Offshore marine detrital deposits with commercial potential are grouped into industrial and placer minerals (Hale and McLaren, 1984; Hale, 1990). Current mining technology limits economic extraction of commodities to water depths of about 100 metres or less (Hale, 1990).

Industrial mineral resources include detrital (sand and gravel) and chemical types (e.g quartz sands and calcium carbonate in shell beds). The sand, gravel and quartz are derived from the disintegration of pre-existing rock which has been transported to and re-concentrated in the marine environment. The shells are important for their chemical composition (e.g., in cement making).

Placer mineral resources occur in a wide variety of marine environments, and typically comprise rich concentrations of gold, platinum, diamonds, cassiterite, chromite, magnetite and other minerals that are concentrated by fluvial, coastal and marine current processes. Placers may be actively forming by contemporary processes (e.g., Kilby, 1991) or may be preserved as unconsolidated to lithified deposits that were formed under past conditions of higher (e.g., Carpenter and Carpenter, 1991) or lower sea level.

Economic concentrations of placer gold have been documented in lodgement tills and other subglacially deposited facies in the Cariboo area of central British Columbia (Eyles and Kocsis, 1989). Drowned placer gold deposits of this type could easily be preserved in the extensive Quaternary sediments located in the marine area of interest, especially because of the documentation of lower sea levels in Recent history (Barrie et al., 1991). Eyles and Kocsis (1989) noted that the most prospective strata are older tills related to colder intervals between 125,000 and 30,000 years ago. They called for reflection seismic work to identify thin lodgement tills overlying bedrock of moderate to high relief. Such surveys are a common procedure in shallow marine environments.

Only one known occurrence of unconsolidated offshore mineral resources is located within the study area (Shuttle Island, Minfile occurrence #10, Appendix I). At least three other examples located nearby or in very similar environments have been documented recently:

- a) Haida cooperatives are now recovering gold from beach placers on northeastern Graham Island (J.V. Barrie, personal communication, 1992). These are small, simple operations, involving trucks and light equipment to access the upper shoreface of a broad beach;
- b) Gold placers are currently forming on the west coast of Vancouver Island close to terrestrial sources of gold and platinum (Kilby, 1991);
- c) Barrie (1991) and Barrie et al. (1988) have documented potentially significant titaniferous placer deposits on the continental shelf 200 kilometres southeast of the study area. Based on limited sampling, they identified concentrations of titanium up to 1.1% by volume, vanadium up to 0.04%, and zirconium up to 0.2%. These grades compare favorably with those of economic beach deposits along eastern Australia (Jones and Davies, 1979), Brazil (Mining Journal, 1990), southeastern United States and other parts of the world (Carpenter and Carpenter, 1991). Such deposits would be economically viable for marine mining in offshore areas of western Canada. The sizes of the placer deposits southeast of the study area are not constrained by the available data.

Hale (1990) and Proudfoot (1989) have demonstrated the viability of mining placer gold in the eastern Canadian offshore, in environments similar to those of the study area. Hale (1990) has also documented a direct benefit of placer exploration to the fishing industry, in that clam beds have been discovered during sea-bed mapping of the coastal marine lands off Nova Scotia. The environmental neutrality of marine placer mining is also clearly documented (ibid.) by the rapid and dramatic spatial shifting of marine aggregates which is caused by natural marine currents. Processing of marine placer deposits can be done without the use of chemicals, utilizing entirely hydraulic methods. Phase II research in this study area would use the same hydraulic methods (e.g., Stewart, 1986).

Despite the paucity of direct evidence for offshore mineral resources in the study area, Hale (1987b, 1990) and Hale and McLaren (1984) list

criteria by which it is possible to assess resource potential. The following features are either identified or likely to occur in the marine study area, and provide the basis for inferences about the potential for occurrence and possible economic significance of offshore mineral placer deposits.

Source Geological Environments. Areal extensive I-type granitic suites intrude widespread tholeiitic basalts and less extensive calcareous sedimentary rocks in structurally complex settings. Major northwesterly faults may have been long lived and subject to hydrothermal or related magmatic events.

Known and Potential Deposit Types and Commodities in Provenance Areas. Skarn (iron-copper, gold, silver; minor vanadium, titanium, tungsten); porphyry (copper, molybdenum, gold); volcanic- and intrusion-associated veins and shear zones (gold, silver, platinum); disseminated Cinola-type precious metals (gold, silver), volcanogenic massive sulphides (copper, zinc, lead, gold) and alluvial placers (gold).

Principal Economic Minerals. Native gold (trace); titanium in ilmenite + titaniferous magnetite + sphene (5-25% of heavy minerals).

Other Detrital Heavy Minerals Totals average 10% of the sand fraction, with maximum concentrations of up to 15% in Hecate Strait and 28% in Queen Charlotte Sound. Individual minerals listed in decreasing order of abundance given as a percentage of the total heavy mineral suite: amphibole (30-50%), opaques (not described other than dominantly ilmenite and >5% magnetite), garnet (undivided grossularite + andradite >5%), epidote (>5%), chlorite (>5%), and lesser rutile, scheelite, zircon (Barrie et al., 1988). Other, deleterious accessory elements listed with the above bedrock gold deposits are not found in stable heavy minerals, and have been removed before creation of the placers by natural weathering processes.

Physiographic Features. Glaciation, possible limited drowned river channels, high-energy fiords, possible unglaciated 'nunataks' (regoliths?) in source areas, coarse unconsolidated sediments in high-energy nearshore environments, fine-grained sediments in lower energy estuarine environments.

Marine Features and genesis. General high- to moderate-energy, youthful, glaciated coastal environment; complex tidal current and wave forms down to 100 m and greater water

depths; steep continental slope commencing near intertidal zone; twelve months ice-free. The anomalous concentrations are interpreted by Barrie et al. (1988) to result from continuous differential sorting by strong wave currents during extreme yearly storms. They are not considered to be relict.

Resource Assessments of Domains. Based on the above criteria, virtually all of the eastern study area has high potential (2) for marine placer mineral deposits and for industrial aggregates. The nearshore domains are clearly sites of high current activity due to waves and tides, and would be high in prospectivity for gold. The Shuttle Domain (SH) is assigned a very high potential (1) for gold because it contains past-producing beach-placer and lode gold deposits on Shuttle Island (Appendix I, Minfile #10, 12) and is adjacent to several precious-metal-enriched fault and hydrothermal zones.

Reinforcing the high mineral potential of SH is the presence of the Swede occurrence (Appendix I, LYSH MINFILE #103B-12W/ 09) which contains unsubstantiated platinum in a copper-enriched volcanic flow environment. Recent work on Vancouver Island, primarily in Paleozoic rocks but including the base of the Karmudsen Formation (Getsinger et al., 1990), has outlined economically attractive gold-platinum - group - element - nickel - chrome concentrations. Erosion of the Swede occurrence could have supplied these elements northward into Logan Inlet, or southward into Darwin Sound (both within SH).

The offshore marine domains (GA, HE, LI) are interpreted as too distal for high gold prospectivity. Instead, work by Barrie et al. (1988) and Barrie and Bornhold (1989) has shown that offshore marine domains in Hecate Strait contain anomalous titaniferous heavy mineral placer concentrations (10-25% heavy minerals) that are in equilibrium with present hydrodynamic conditions. Regional seabed mapping and geochemical sampling would be necessary to subdivide both shallower and deeper marine domains into smaller areas of higher and lower potential.

Geothermal Energy

Geothermal energy resources represent the earth's natural heat that is released through concentrated discharge points under favorable geological conditions. In the Cordillera and adjacent tectonically active offshore areas, relatively young geological environments with high

thermal gradients are ideal environments for deep circulation of meteoric or marine waters, giving rise to major geothermal fluid systems (Souther and Halstead, 1973; Geothermal Resources Council, 1980). Hot springs on land areas are recharged at high topographic levels; the water passes through deeper aquifers through the source of heat, and returns to surface. Depending on the hydraulic head and nature of the aquifers, meteoric waters could be a significant source for shallow submarine hot springs. Of the six possible types of geothermal reservoirs: hot water, natural steam, geopressurized, normal heat gradient, hot dry rock and molten magma, only the first is considered to provide potential opportunities in the Study area.

Hyndman et al. (1982) conducted reconnaissance heat flow measurements from 20 marine sites in the Pacific offshore and one terrestrial site. They recorded a continuous transition from very high heat flow (270 mW m^{-2}) at the western terrace/ocean plate margin, through intermediate values on the terrace ($66\text{-}128 \text{ mW m}^{-2}$), to low continental heat flow (47 mW m^{-2}) at one terrestrial site at Tasu, just north of the SC Domain. They made no heat flow measurements within the study area, on the Queen Charlotte Fault Zone or Louscoone Fault Zone.

T.J. Lewis et al. (1988, 1991) subsequently conducted field measurements of heat flow to model present crustal temperatures. Preliminary results of their studies indicate generally lower heat flux than Hyndman et al. (1982). The low heat flux could be attributed to crustal thickening caused by eastward-directed oblique subduction along the Queen Charlotte Fault Zone. It could also be attributed to blanketing by sediments, resulting in focussing of flow toward clusters of springs such as those on Hot Spring and Lyell Island.

The extensive fault and fold zones described above (Queen Charlotte, Louscoone Inlet and Sandspit fault zones, and Rennel Sound Fold/Fault Zone) are considered potential aquifers for hydrothermal circulation. The set of springs documented at Hotspring Island, southernmost LY Domain (Minfile #14 of Figure 2 and Appendix I), and an additional hot spring in Haswell Bay of the BU Domain (J. Haggart, personal communication, 1992; not shown in Figure 2) are the two known examples of this probably abundant resource.

Geothermal potential for the domains is summarized in Table 1. The LY and BU domains are rated at high potential (2) because of the known hot springs on Hotspring Island and in Haswell Bay.

The QC Domain is also rated as high because of its active nature (arguments as presented under Seafloor Hydrothermal Polymetallic Sulphide Deposits). All other domains in the eastern part of the study area (CU, GA, HE, LI, LO, RS, SH, SK, and TA) are assigned moderate-to-high potential (3) for the presence of geothermal energy sources, because this region is transected by faults.

The remaining domains in the western area of interest are assigned an uncertain moderate-to-low potential (5) because the active tectonic setting favors geothermal activity but faults are less prevalent and no thermal anomalies have been determined in similar environments outside the study area. Hyndman et al. (1982, p. 1666-1667) suggested that any thermal anomaly generated by the Queen Charlotte Fault Zone may be masked by the main regional heat flow transition and complex structure of the crustal regime.

Geothermal energy sources have mixed potential to contribute to National Park infrastructure. They are likely to be sites of unique fauna and flora both on land and at sea, and therefore would be sites of visitor interest. Conversely, it may be necessary to limit visitor access, because such small unique ecosystems are extremely sensitive to disruption by human activity. If included in the park, such sites would require base-line documentation and special care for their preservation.

Carving and Industrial Stone: Haida Argillite, Limestone, Perlite

The famed Haida argillite, which is quarried at Slatechuk Creek, is a readily traceable member of an un-named Early Tertiary (Paleogene) assemblage of black shale and sandstone, previously thought to be Cretaceous (Haggart 1991). The Cretaceous Haida Formation thus does not include the main Haida carving-stone quarry. Haggart (personal communication, 1992) has provided the following information regarding resource potential of the argillite. The Haida Argillite is present in lacustrine deposits which do not appear to have been very widespread on the Queen Charlotte Islands. The only known occurrences of these rocks outside of the "type locale" in Slatechuk Creek are nearby, SW of Yakoun Lake (Haggart et al., 1990) and on the ridges to the west (Haggart, 1992b). All other exposures of older Tertiary strata mapped in the CU, RS, LY, SH and TA domains, are of coarser

facies, typically conglomerates. Geologists mapping for the Frontier Geoscience Program have traversed these domains extensively over the past few years, and have found no carvable argillites in them. Only TA has known argillite which might have some potential for carving; this is developed in Cretaceous mudstone intruded by plutons, and is located north of the proposed boundary of the park.

Low-to-moderate potential (5) at best, is therefore assigned to all domains except TA (moderate potential, 4) for traditional carving stone. As noted by Jefferson et al. (1991) however, with modern tools any attractive stones of any hardness can be carved to the artists' tastes. Potential for other carving material would therefore be subject to the preferences of any prospective carvers and might require experimentation.

Other industrial minerals and rocks as noted by Sutherland-Brown (1968) include limestone (suitable for building, carving and cement-making), perlite (a kind of volcanic glass which is expandible for use as a light aggregate in cement), bentonite (used for diamond drilling) and diatomaceous clay (an absorbent material used for cleaning purposes).

Sutherland-Brown (1968) noted tidewater exposures of limestone and marbles derived from the limestone in the Tasu Mine area (TA), on Kunga Island (LY), on southeast Burnaby and Copper islands (SK). Ministry of Energy Mines and Petroleum Resources (1989) considered the Kunga Formation limestone units, which trend through the LO and BU domains, as the principle limestone resources of the Queen Charlotte Islands. Rennell Sound Domain (RS) is rated very high because it includes the Gillatt past producer (Appendix I, Minfile #38). All of the other domains noted above are rated as high in potential for industrial stone.

The perlite is most common in Masset Formation rhyolites which are mapped in the LY, SH and TA domains. These three domains are therefore also rated high in potential for industrial stone.

Coal

Coal and carbonaceous shales occur in the Jurassic (Bajocian Yakoun Group), are minor in the Cretaceous (Albian Haida Formation), and are documented in the Tertiary (Neogene Skonun Formation) (Sutherland Brown, 1968).

Yakoun Group rocks underlie the head of Tasu Sound (TA), easternmost Tanu Island and parts of central Lyell Island (LY), and various islands in SK Domain (*ibid.*). Yakoun Group strata contain very few confirmed coal seams in the Queen Charlotte Island region. According to Haggart (personal communication, 1992) the TA and LY domains have been exhaustively examined during the FGP; no occurrences of coal-bearing strata have been found on land anywhere in these domains. Geological relations indicate that the zero-edge of the Skonun Formation is to the east of these areas, and virtually all of the Tertiary rocks in these domains are intermediate volcanic strata.

The Haida Formation is exposed between Tasu Sound and the head of Sewell Inlet in TA Domain. The Haida Formation consists of dark grey to black shales and argillites (Taite, 1990) which are a famous Haida carving stone (Haggart, 1991). Lowermost Haida facies locally contain carbonaceous sandstones and coal pebbles, the latter of which are thought to be derived from the underlying Yakoun Formation (Sutherland Brown, 1968; Fogarassy and Barnes, 1988). Haggart (1991) has documented minor coal in marginal marine facies of basal Cretaceous strata on NW Graham Island, but has also shown that the known past-producing coal deposits in Skidegate Inlet and Yakoun Lake areas are Paleogene (Tertiary), not Cretaceous, in age. Haggart (1991) has also compiled evidence supporting a marine depositional model for Cretaceous clastic rocks. Submarine fan complexes were shed westward from an easterly source terrain. He constructed paleogeographic models showing west to east shoreline transgression during Early Cretaceous time. The marine paleogeography does not favor the accumulation of significant coal resources in Cretaceous strata (*ibid.*)

The Neogene Skonun Formation is exposed almost exclusively on Graham Island; it extends offshore beneath Queen Charlotte Sound and Hecate Strait where it is at least 4500 metres thick (Shouldice, 1973). The Skonun Formation consists of interbedded marine, transitional and non-marine sandstone, siltstone, shale and thin coals. The

Skonun Formation is projected to extend beneath Hecate Strait under the three eastern marine domains: LI, HE and GA, and should be at least 1500 metres thick (Bustin et al., 1990).

Exploratory boreholes drilled in Hecate Strait and on Graham Island encountered up to 9 coal seams (Rowling, personal communication, 1990). Information on the maximum thicknesses and lateral continuity of coal seams is sparse. Individual seams exposed on Graham Island are generally less than 1 metre thick; a section measured by Higgs (1989) at Miller Creek on the east coast of Graham Island consists of a series of lignite beds up to 20 cm thick alternating with massive grey mudstones. Higgs (1991b) and Bustin et al. (1990) studied the Skonun Formation for its potential as a petroleum source rock. Their preliminary findings indicate that the organic matter is mainly gas-prone Type III and Type II; offshore strata have variable thermal maturations, and vitrinite reflection values ranging from 0.18% $R_{o_{rand}}$ to 1.38% $R_{o_{rand}}$. Based on a limited review of these Skonun data, C. Kenyon (personal communication, 1990) considers the Skonun Formation to represent a significant prospective reservoir for coal-bed methane deposits. Coal bed methane deposits have attracted considerable industry interest in the Cretaceous Nanaimo and Comox basins, where significant, potentially economic deposits are known. (C. Kenyon, personal communication, 1990).

The Tasu (TA) and Lyell (LY) domains are rated moderate (4) for the discovery of coal deposits. The Lost Islands (LI), Hecate (HE) and Garcin (GA) marine domains are rated as moderate to high (2) for coal-bed-methane deposits. Their overall geological environments are favorable, and yet uncertain due to lack of data, therefore the highest rating for coal is (3).

Coal is considered here as being potentially extractable by conventional tunnelling from on-shore sites with possible ventilation or extended access from existing and/or man-made islands (e.g., Hale, 1990). Coal bed methane is considered to be in the realm of fluid hydrocarbons, therefore its assessment is left to the hydrocarbon assessment in progress.

Skarn Deposits: Iron-Copper, Copper-Gold, Silver, Zinc, Tungsten

Intrusion - associated (contact - metasomatic) cupriferous iron - skarn deposits have been mined at two locations in the study area: Tasu and Jedway (adjacent to the study area). The Tasu Mine between 1963 and 1982 produced 20.9 million tonnes containing 5.5 million tonnes of magnetite concentrate, 56,084 tonnes of copper, plus significant precious metals (Dawson et al., 1991).

Skarns have also been mined at several locations on Vancouver and Texada Island in similar stratigraphic settings (Sangster, 1969; Sutherland Brown, 1968; Meinert, 1984; Webster and Ray, 1990) and on Banks Island to the east (Ettlinger and Ray, 1989). On the mainland adjacent to northern Vancouver Island, the Lucky Jim skarn deposit has reported reserves of 12,700 tonnes of 2% copper, 11 grams/tonne silver and 17 grams/tonne gold (Muller et al., 1974).

Intermittent exploration for skarn deposits up to the mid-1960s led to the discovery of numerous sub-economic deposits and occurrences north of, and along the east coast of, the study area. Aeromagnetic surveys were the primary exploration tool. Japanese markets for magnetite were a factor in the exploration interest at that time (R.V. Kirkham, personal communication 1988). Skarn iron-copper occurrences have been documented at Treat Bay within the terrestrial part of Louscoone Inlet Domain, and at several other locations within a few kilometres of this and other domains. Skarns constitute the principal proven metallic mineral resources in the southern Queen Charlotte Islands (South Moresby Resource Planning Team, 1983).

In addition, gold-bearing skarns have been described as related to Tertiary block faulting in southern British Columbia (Einaudi et al., 1981 and Ray et al., 1990).

The geological setting, mineral deposit environment, mineralogy and genetic models of skarn deposits are reviewed by Gross (1984), Einaudi and Burt (1982), Cox (1986a), Ettlinger and Ray, (1989), Dawson et al. (1991). Sutherland Brown (1968), Sangster (1969), and Meinert (1984) have provided detailed geological information on the deposits within the study area. Anderson (1989) has noted the spatial association of the Burnaby Island Plutonic Suite with most of the known skarn deposits in the study area. The following features taken from the above authors characterize these

deposits in Wrangellia terrane underlying the study area:

Commodities Extracted. iron, copper, gold, silver, tungsten.

Accessory Elements. titanium, vanadium, arsenic, cobalt.

Grade and Tonnage. Up to 30 million tonnes averaging 35 - 60% iron; other elements have undefined grades.

Geological Setting and Host Rocks. Deposits are hosted predominantly in Triassic Karmutsen Formation tholeiitic basalt, and less commonly within overlying Kunga Group calcareous strata at or near the contact with granitic plutons. The most favorable plutons are heterogeneous, sequentially intruded, mafic, intermediate and felsic variants of the Burnaby Island Plutonic Suite. In Tasu Inlet area, the skarns are associated with unusually heterogeneous representatives of the San Christoval Plutonic Suite. Deposits are commonly located in structurally complex environments.

Form of Occurrences. Irregular, massive, disseminated patchy veins, concordant to discordant tabular, lenticular or pipe-like, with sharp contacts, and common evidence of brecciation.

Metallic Minerals. Magnetite, hematite, martite, chalcopyrite, pyrite, pyrrhotite, iron-rich sphalerite. Gold and silver are located in sulphide minerals, associated mainly with calcic skarns.

Associated Skarn Minerals. Andradite-grossularite, chlorite, actinolite, diopside, epidote, apatite, calcite, dolomite, (calc-silicate skarn assemblage); possible late scapolite alteration.

Genetic Model. Hydrothermal metasomatic replacement of wall rocks contemporaneous with emplacement of intrusions. Limestone (and in some cases volcanic rocks and the intrusions themselves) localizes precipitation of magnetite by reacting to increasing ore fluid pH. The majority of gold skarns are associated with relatively small mafic plutons (Dawson, in press). The highest gold content occurs in zones of coincident high sulphide content and intense retrograde alteration of skarn (Meinert, 1986)

Exploration Guidelines.

- a) Karmutsen Formation pillow volcanic rocks in contact with Kunga Group limestones.

- b) Intrusive rocks of Burnaby Island Plutonic Suite nearby.
- c) Faults, breccias, fractures.
- d) Associated skarn minerals
- e) Pronounced magnetic anomaly (see Geological Survey of Canada, 1987a,b).
- f) Gold in copper-iron-sulphide-rich parts of skarn.

Skarn deposit potential for the domains is summarized in Table 1 and discussed in the following. Both precious metal enriched and iron-copper-dominated skarn types are present, and the potential for these two types is very similar. Attempts to rigorously classify and predictively distinguish between the two have not yet been successful. Ettlinger and Ray (1989, p. 4) suggest that British Columbia has excellent potential for new discoveries of precious metal enriched skarn deposits, the most prospective terranes being Quesnellia, Wrangellia, Alexander or Stikinia. Particular areas of interest are fracture-controlled, island-arc or back-arc basins that contain Late Triassic to Early Jurassic limy supracrustal rocks and varied suites of subalkalic, calc-alkaline, arc-related intrusions of Jurassic to Cretaceous age. Areas with ferrous or base-metal skarns enriched in arsenic, bismuth, tellurium and/or cobalt are particularly favorable. Dawson (personal communication, 1992) cautions that the high gold potential applies only to the sulphide-rich parts of calcic magnetite-copper skarns. These parameters are directly applicable to much of the eastern terrestrial and shallow marine study area.

Very high potential (1) for the occurrence of both precious-metal-enriched and iron-copper skarns is assigned to the SK and TA domains because of the coincidence of favorable geology, the abundance of showings and some past-producers. The San Christoval Plutonic Suite is anomalous in the TA Domain because here it is relatively heterogeneous.

LO Domain contains Karmutsen volcanic rocks in contact with Kunga Group limestone on Kunghit Island and along Louscoone Inlet, transected by the Louscoone Fault Zone and locally intruded by small fault-related quartz diorite to granitic bodies. A small (?) poorly described iron-copper skarn occurrence is located in Treat Bay on Kunghit Island (Appendix I, Minfile #51). Considerable aeromagnetic complexity (Geological Survey of Canada, 1987a) extends throughout the

domain. Five kilometres to the northeast of the domain many skarn deposits are concentrated adjacent to the former Jedway Mine. The LO Domain is thus assigned a high potential (2) for skarn deposits.

CU, LY and RS domains are assigned moderate-to-high potential (3) because of the favorable geological association of abundant limestone-basalt contacts and the Burnaby Island Plutonic Suite. The potential is not rated more highly in these domains because of their small number of occurrences.

BI and SC domains share similar geological features that are conducive to skarn deposit formation and thus can be assessed together. Neither of these domains contain any known skarn deposits, yet both domains contain Karmutsen Formation basalts, a range of intrusive rock types, very minor Kunga Group and some faulted or fractured contact relationships. San Christoval plutonic rocks are associated with the Tasu skarn-iron-copper deposit several km north of the San Christoval domain, whereas younger intrusive rocks of the Pocket Inlet Pluton have some similarities to mineralizing intrusives in the Harriet Harbour area (Sutherland Brown, 1968). Regional aeromagnetic data south of Sunday and Barry Inlets and west of Lower Victoria Lake exhibit prominent highs where Karmutsen volcanic rocks contact plutonic rocks. Although no Kunga Group limestone is mapped (Sutherland Brown, 1968) the areas are prospective for exploration. The ruggedness of terrain and logistic difficulties may have inhibited a thorough examination of these areas during past exploration cycles. Based on these considerations, skarn deposit potential is assessed as moderate overall with limited areas of moderate to high potential (3).

The BU and SH domains are assigned moderate potential (4) because, although some occurrences and many intrusions are present, the occurrences have been well prospected, limestones are rare and most intrusions are of the homogeneous San Christoval Plutonic Suite which is associated with skarns only in the Tasu Domain. Skarns are still possible in these volcanic-dominated terranes because the necessary calcium and carbon dioxide could have been provided by thin interflow limestones (Sangster, 1969).

Domains BP, GA, HE, LI, PA, QC and WC are assigned moderate-to-low (5) and low potential (6) because of their inaccessibility (deep water) and cover by Tertiary and Quaternary sediments.

Porphyry Deposits: Copper, Molybdenum, Gold, Silver, Rhenium

Porphyry copper deposits with variably recoverable amounts of molybdenum, gold and silver (Kirkham and Sinclair, 1984; Sutherland Brown, 1976) are considered for all on-land domains because they would be associated with the many mesozonal to epizonal intermediate to felsic intrusions which are present in favorable geological environments as described by Anderson (1991). Although no porphyry deposits have yet been discovered in these domains, Carson (1960), and Muller et al. (1974 and 1981), have documented numerous porphyry copper and copper-molybdenum deposits on Vancouver Island in similar tectono-stratigraphic environments to those of the study area.

The most significant of the Vancouver Island deposits is Island Copper, situated 12 km south of Port Hardy (Cargill et al., 1976). The original ore zone is reported to have contained 257 million tonnes grading 0.52% copper, 0.017% molybdenum, 0.24 grams/tonne gold and important by-product rhenium and silver. This deposit is the largest recorded gold producer in British Columbia (K. Dawson, personal communication, 1992). The deposit is located in an area where Early to Mid-Jurassic quartz-feldspar porphyry intrudes comagmatic andesitic brecciated tuff, lapilli and tuff breccia of the Bonanza Group (Cargill et al., 1976). The deposit was discovered after nearly four years of exploration that utilized regional aeromagnetic data, induced polarization magnetometer surveys, soil geochemistry (Witherly, 1979) and, most important, prospecting (R.V. Kirkham, personal communication, 1988). A small island 2 km away was known to have copper and magnetite in volcanic rocks but had been previously considered to be insignificant as a guide to this type of deposit (Witherly, 1979).

The adjacent, similar Hushamu Creek prospect of BHP-Utah and Morgana Resources has recently determined resources of 100 million tonnes grading 0.32% copper, 0.01% molybdenite and 0.41 grams/tonne gold. The Hushamu and similar Red Dog prospects are located within extensive zones of advanced argillic alteration in Early Jurassic Bonanza Group volcanic rocks, 25 to 35 km NW of Island Copper (K.M. Dawson, personal communication, 1992).

The Catface copper - molybdenum porphyry deposit adjacent to the Nootka Sound map

area provides another example of a deposit environment that may also be present in the study area. At Catface, mineralized Tertiary quartz diorite and associated porphyritic rocks (Catface Intrusions) intrude Jurassic granodiorite, quartz monzonite and older migmatitic rocks (McDougall, 1976; Muller et al., 1981) which have been interpreted as meta-basalt of the Karmutsen Formation by Dawson et al. (1991).

In SK Domain west of Point Langford the Raspberry Cove showing (Minfile #55) contains chalcopyrite veinlets in basalts and quartz monzonite with one assay of 7% copper across a 60 cm sample width. The Raspberry Cove showing, similar occurrences in LY domain, and the abundant granitic intrusions of both major suites suggest high potential (2) for porphyry copper deposits in LY and SK domains.

Lower potentials assigned to the other domains (Table 1) reflect lesser numbers of intrusions and less favorable host rock geology as in the case of the skarn deposit type assessed above. The moderate potentials (4) assigned to domains BI, BU, CU, SC, SH and TA reflect the presence of numerous intrusions. These moderate ratings are tempered by the fact that most major porphyry deposits occur on the tops of small, in places buried, intrusions (Kirkham and Sinclair, 1984). They are relatively invisible and require intensive exploration to be found. The area of interest has not been intensively explored for porphyry copper deposits, and the more recently recognized porphyry gold-copper deposits (e.g., DeLong et al., 1991; Kirkham et al., 1992; Thompson et al., 1992) were of course never explored for in the southern Queen Charlotte Islands because they were not known as viable deposit types until recently.

Volcanic Redbed: Copper, Silver, Vanadium

Copper and trace amounts of vanadium are reportedly widespread as disseminations and minor veinlets in Triassic Karmutsen Formation flow-top amygdules, and in interlava sedimentary interbeds (Kirkham, 1984) in the study area (Northcote et al., 1983), on Vancouver Island (Muller et al., 1974), in southern Alaska (Cox, 1986b), and in several other places, all within sub-aerial basalts of Wrangellia terrane. On a world scale this is a minor deposit type, but in similar geological settings at Sustut Copper Mine, north-central British Columbia (Kirkham, 1984), and on Keeweenaw Peninsula (central Great Lakes) some of these deposits have

been economically viable; they range from one to fifty millions of tonnes in size and from 0.6 to 4 percent copper as native copper, chalcopyrite, chalcocite, bornite, with local native silver, and minor zinc and cobalt enrichment (Kirkham, 1984; Cox, 1986b). Usually the higher grades are in smaller deposits and vice-versa.

Karmutsen Formation sub-aerial basalts occur in nearly all domains of the study area, although only one occurrence of native copper, cuprite and tetrahedrite is reported in basaltic rocks just west of the north end of Louscoone Inlet (British Columbia Minfile #103B-48, Appendix I). Many other occurrences may not have been recognized because of their pervasive, low grade nature or limited areal extent. For this reason the following additional occurrences were interpreted from Minfile descriptions to be volcanic-red-bed-copper types of deposit (vrc, Appendix I): LYSH, #03, #09, #58. These are all from the Darwin Sound area. The mineral potential ratings for each domain given in Table 1 were thus derived from an examination of the actual and inferred areal extent of Karmutsen Formation: those rated as moderate-to-high (3) contain the highest proportion of basalts.

Volcanic- and Intrusion - Associated Veins and Shear Zones: Gold, Silver

Volcanic- and intrusion-associated gold deposits have accounted for over half of Canadian gold production (Thorpe and Franklin, 1984a,b) and over 86% of British Columbia lode gold production (Hodgson et al., 1982, p. 186). Lode gold is here considered to be important not only as a primary deposit type but also as a potential source for marine placer deposits in the nearshore environment.

Thorpe and Franklin (1984a,b) distinguished volcanic- and intrusion-associated deposit types. This assessment considers a composite type which includes volcanic-intrusion dominated and intrusion-dominated end members.

Studies of gold deposits along the east coast of the area of interest (Sutherland Brown, 1968; Northcote et al., 1983), in the Zeballos area of western Vancouver Island (Muller et al., 1981; Muller, 1989), the Port Alberni-Saltspring Island area (Getsinger et al., 1990) and British Columbia in general (Dawson et al., 1991; Hodgson et al., 1982) provide type examples and the basis for

establishing mineral potential ratings in the present study area as outlined below.

For the Queen Charlotte Islands Dawson et al. (1991) outline two prospects of this type. The Court, on southwestern Graham Island, consists of a zone of westerly trending small veins in an area of argillic alteration in the Yakoun Formation close to the Tertiary Masset Formation volcanic rocks. Sulphide minerals consist of pyrite and gold-bearing stibnite. A host of similar small prospects are associated with Tertiary fault zones on Vancouver Island. The Inconspicuous prospect on northern Graham Island and the April prospect on Lyell Island (SH-LY, Minfile #64, Appendix I and Figure 2) are also of this class. The April prospect is hosted by felsic lapilli tuff of the Massett Formation which is in fault contact with Karmutsen volcanic rocks within the Louscoone Inlet Fault Zone; a broad zone of argillic alteration encloses small veinlets of chalcedony with minor pyrite and gold (Dawson et al., 1991). The Inconspicuous prospect also is located in the Massett Formation in marine mixed pyroclastic breccias near the Beresford Fault on northwestern Graham Island; a silicified and pyritized zone contains small gold-bearing veins (ibid.). The Ellen/Bud/Aeroplane/Shuttle prospect (British Columbia Minfile #12 in the SH Domain; Appendix I, Figure 2) also appears to be of this deposit type: auriferous brecciated quartz veins are hosted by greenstones, limestone, tuff and argillite.

In the Zeballos camp, the Privateer and Spud Valley mesothermal gold-quartz vein deposits have reported proven and probable reserves of 123,000 tonnes of 9.15 grams/tonne gold and 224,000 tonnes of 14.1 grams/tonne gold, respectively (Muller et al., 1981). These veins are hosted by Early Jurassic pyroclastic volcanic rocks of the Bonanza Group. The veins are steep, thin, ribbon quartz with abundant pyrite and arsenopyrite, lesser amounts of sphalerite, chalcopyrite, galena and pyrrhotite, and rare free gold (Stevenson, 1950). The mine produced 282,000 tonnes containing 18.8 grams/tonne gold with some silver, lead and zinc (Dawson et al., 1991).

The Mount Washington area of east-central Vancouver Island has been the site of minor production (335,600 tonnes of ore grading 1.16% copper, 0.34 grams/tonne gold and 17.1 grams/tonne silver) from the Domineer-Lakeview Prospect. Host rocks are sheared Karmutsen Formation basalts, Nanaimo Group sandstones and

conglomerates, and Catface sills of hornblende quartz diorite and quartz feldspar porphyry (Muller, 1989). The Mount Washington area is now being further explored for precious and base metals in breccias related to low-angle extensional faults. The most prospective zones for epithermal gold are indicated to be adjacent to Tertiary intrusions and/or associated Tertiary volcanic rocks. (ibid.).

Gold occurs in six specific settings within volcanic rocks of the Sicker Group in the Port Alberni area (details in Getsinger et al., 1990):

- a) Structurally controlled quartz veins (e.g., Mineral Creek: 438 tonnes averaging 27.26 grams/tonne gold, 3.69 grams/tonne silver, and 0.02% copper).
- b) Stockwork quartz veins (e.g., Debbie: diamond drill-hole intersections of up to 139.82 grams/tonne gold over 14.36 m).
- c) Skarn (e.g., Rift Creek: diamond drill intersections of up to 2.35 grams/tonne gold over 6.59 m).
- d) Quartz-carbonate-sericite-pyrite altered zones (e.g., Peak Lake: diamond drill intersections of up to 3.53 grams/tonne gold over 21 m).
- e) Pyritic iron formation (e.g., grab samples in Sicker Group up to 4.8 grams/tonne gold).
- f) With platinum in podiform and disseminated sulphides in sheared mafic volcanic and intrusive rocks (e.g., Kitkat: grab samples yield assays of up to 1.65 grams/tonne platinum, 5.31 grams/tonne palladium, 100 ppb gold, 6500 ppm copper and 2012 ppm nickel).

The following features taken from the above authors characterize these deposits in Wrangellia terrane underlying the study area:

Commodities Extracted. gold, silver.

Accessory Elements. platinum, tellurium (as tellurides), chrome (as fuchsite), copper, zinc, lead, and arsenic (as sulphides).

Grade and Tonnage. Generally 1 to 6 million tonnes of 7 grams/tonne gold, up to 40 million tonnes averaging 8.6 grams/tonne gold.

Geological Setting and Host Rocks. Deposits occur predominantly in Tertiary or Paleozoic heterogeneous volcanic rocks with related intrusions. Deposits are commonly located in structurally complex environments.

Form of Occurrences. Quartz veins, stockwork quartz veins, skarns, disseminated in quartz-carbonate-sericite-pyrite altered zones, and irregular bodies of quartz along fractures and faults.

Metallic Minerals. Native gold, tellurides.

Associated Minerals. Pyrite, arsenopyrite, minor other sulphides, quartz, sericite, carbonates, scheelite, fuchsite.

Genetic Model. Hydrothermal alteration of wall rocks contemporaneous with vein formation. Fault movements open and close spaces at depth, pumping fluids and causing dramatic pressure and temperature changes, thereby precipitating gold.

Exploration Guidelines.

- a) Volcanic rocks of the Sicker Group and equivalents in Wrangellian terranes; and/or post-accretionary Tertiary volcanic rocks.
- b) Faults, breccias, fractures.
- c) Sericite alteration zones and presence of associated minerals listed above.

Potential for vein and shear-zone gold associated with volcanic rocks and intrusions in each domain is summarized in Table 1 and discussed in the following.

Ratings in terrestrial parts of the study area in general are high (2) because:

- a) extensive fault systems transect the eastern part of the terrestrial area of interest;
- b) epithermal gold (Cinola, Inconspicuous, April) is associated with similar faults on Graham and Lyell islands, and
- c) Hesthammer et al. (1991) and Indrelid and Hesthammer (1991) recently discovered in the Queen Charlotte Islands possible equivalents to the Sicker Group rocks which host a number of such deposits on Vancouver Island as listed above (see also comments below on Sicker Group in Volcanogenic Massive Sulphide Deposits).

High potential (2) for gold is proposed in Tertiary volcanic rocks which are cut by low-angle extensional faults near related intrusions (like Mount Washington), especially where these are cut by complexes of high-angle reverse faults, brittle transcurrent faults, and fault-localized intrusions (e.g., Journeay and Csontos, 1989; Getsinger et al., 1990). Domains CU, RS and TA satisfy these conditions and only lack significant showings; these

are therefore rated moderate-to-high in potential (3). The LY and SH domains are rated at high (2) because they satisfy the above conditions and contain significant showings (April and Ellen/Shuttle respectively).

Domains BU and LO are assigned high (2) potential even though they lack the Tertiary volcanic record, because they are transected by the Louscoone Inlet Fault Zone which is a broad north-west trending zone of steep easterly dipping dextral faults and shears that cross-cut all rock types. Locally this fault zone is characterized by carbonatization, quartz-sericite schist development, and intense penetrative deformation (Sutherland Brown, 1968). The fault zone had been the focus for progressively more active gold exploration in recent years, which resulted in the discovery of one and possibly three new Au occurrences (British Columbia Minfile No. 103B-65; British Columbia Assessment Report Index Nos. 9650, 11531, 12657, and 8072). At all three locations northwest trending zones of variably sheared, carbonatized and silicified Karmutsen Formation 'greenstone' contains variable amounts of quartz veins and sulphide minerals. Imposition of the Gwaii Haanas / South Moresby National Park Reserve curtailed exploration at an early stage.

Domains BI and SC are assigned moderate potential (4) because they are less intensely affected by the fault zones and lack the Tertiary volcanic record, yet still meet the criterion of numerous intrusions.

Other domains which are completely marine (BP, GA, HE, LI, PA, QC and WC) are assigned low (6) and moderate-to-low (5) potential based on their relative inaccessibility for bedrock mining.

Disseminated Precious Metals, Cinola-Type: Gold, Silver

The Cinola deposit on Graham Island in the northern Queen Charlottes is a large disseminated gold and silver deposit interpreted as the product of an epithermal (near-surface) hot-spring-type precious metal system by Tolbert et al. (1987) and Christie (1989). It is similar in scale, associated elements and its disseminated nature with the Carlin type (Thorpe, 1984; Berger, 1986) of gold deposits but differs in that the latter were formed at depth by selective replacement of carbonaceous carbonate turbidites adjacent to and along high- and low-angle

faults and bedding; the association of Carlin deposits with intrusive rocks is much less direct than at Cinola.

The following geological, geochemical and structural features are found at Cinola (Champigny and Sinclair, 1982; Christie, 1989) and may be used as exploration guidelines when assessing mineral potential for similar deposits elsewhere on the Queen Charlottes:

Commodities Extracted. gold, silver.

Accessory Elements / Geochemical Signatures. gold, silver, arsenic, mercury, copper, zinc, lead, antimony, tungsten, molybdenum, tellurium. At Cinola silver shows a more confined primary dispersion than gold; mercury shows a broad secondary dispersion in soil and peat.

Grade and Tonnage. The mineable reserves at Cinola have been quoted as 23.8 million tonnes of 2.43 grams /tonne gold (City Resources (Canada) Ltd. News Release, 1987/12/04). Economically viable deposits of similar scale (different genesis as noted above) in the Carlin area of Nevada have combined production and reserves of 16 million tonnes with grades from 1.0 to 10 grams gold / tonne.

Tectonic Setting. Cinola occurs adjacent to the Specogna Fault, a splay of the Sandspit Fault which is a major high-angle dip-slip zone with minor dextral strike-slip offset. The Sandspit and Specogna faults were active in early Tertiary time during development of the extensional Queen Charlotte Basin. These faults were loci of Masset Formation volcanism (expressed in part by stocks and dykes of porphyritic rhyolite) in at least two places, one of which is the rhyolite stock at the Cinola gold deposit.

Local Geological Setting has been summarized by Dawson et al. (1991) and detailed by Christie (1989). Skonun Formation conglomerate and sandstone are juxtaposed across the Specogna Fault (a splay of the Sandspit Fault) against the Queen Charlotte Group and unconformably overlying Massett Formation. A 40 m-wide quartz porphyry dyke is enveloped by silicic and argillic alteration, cut by quartz veins, and all are brecciated. The gold grade correlates with the intensity of multiple hydrothermal brecciation and silicification (Tolbert et al., 1987)

The linkage among faults, sedimentation and gold mineralization was documented by Christie (1989):

- a) most of the hydrothermal alteration, veins and breccias which host the gold post-date the intrusion of the rhyolite stock;
- b) the stock is one of a series which are localized along the Specogna fault, and
- c) hydrothermal alteration was multistage and partly syn-sedimentary. Clastic rocks of the Skonun Formation were apparently bounded by and shed from the fault scarps.

Form of occurrences. Gold is widely disseminated as grains <0.5 micron in size in silicified clastic sedimentary rock and in drusy and banded veins of quartz and chalcedony. Locally gold >100 microns is located in quartz veins in brecciated porphyritic rhyolite.

Metallic Minerals. Pyrite, marcasite, chalcopyrite, sphalerite, galena, pyrrhotite, arsenopyrite, cinnabar, tiemannite (mercury selenide), rutile, magnetite, hematite, limonite, native gold and electrum (silver ~6.2 to 24.2 weight %).

Alteration. Sericite, illite, kaolinite and chlorite, with abundant multi-stage quartz.

Genetic Model. The Cinola deposit has been interpreted by Tolbert et al. (1987) as an epithermal hot-spring-type precious metal system. Christie (1989) has documented the important link between fault movement and generation of the hydrothermal alteration and brecciation.

Potential for the occurrence of Cinola-type gold deposits is rated, according to the above parameters, as high (2) in CU, LY, RS, SH (northern part) and TA domains, because they contain Massett Formation volcanic rocks as well as numerous epithermal gold occurrences (epi, Appendix I). Other domains are rated lower for this particular type of gold deposit not because of the lack of gold showings, but because of the lack of Massett Formation mapped by the Frontier Geoscience Program (e.g., Figure 4) and Sutherland Brown (1968), and or inaccessibility in the marine environment. Bedrock gold potential in other domains is mainly for the volcanic- and intrusion-associated deposit type (see above).

Seafloor Hydrothermal Polymetallic Sulphide Deposits: Copper, Zinc, Lead, Gold, Silver, Cobalt, Platinum

Base and precious metal resource-potential assessments are being conducted at present off the west coast of British Columbia in spreading oceanic ridge environments with high heat flow (Franklin, 1987; Kappel and Franklin, 1989). This work has led to a better understanding of the volcanic and geochemical processes responsible for seafloor deposition of polymetallic sulphide deposits from metalliferous brines. It has also documented the presence of copper-zinc sulphide deposits that were documented using shallow cores and grab samples to be 1 to 5 million tonnes in size. Forty nine grab samples from Middle Valley graded on average 0.42% copper, 3.43% zinc, 0.05% lead, and 10 ppm silver (ibid.). Fourteen grab samples from Explorer Ridge (close to Dellwood and J.T. Wilson Knolls, Figure 3) averaged 5.11% copper, 9.09% zinc, 0.029% lead and over 2 grams/tonne gold. These deposits are probably an order of magnitude larger if thicknesses are 10 to 50 metres (ibid.). The largest of these deposits are located in parts of the spreading ridges that are mantled by turbiditic sediments (Davis et al., 1987).

The following discussion is very speculative because no studies have been done which could provide definitive data in the study area. Nevertheless, the experience of the senior author on Devonian base metal deposits, and discussions with J.M. Franklin, W.D. Goodfellow and D.E. Ames (personal communications, 1989 and 1992) on seafloor minerals research support an optimistic assessment of seafloor mineral potential in regions of combined active faulting and sedimentation such as this.

Although no active spreading ridge environments are present in the study area, the Queen Charlotte Fault Zone Domain contains the Queen Charlotte transform fault and other geological attributes that may be conducive to deposition of metals from hydrothermal fluids. In addition, deposits which may have formed at active spreading ridges could have been preserved by burial under turbidites originating from the continental shelf.

Within the Queen Charlotte Basin itself, evidence of Tertiary rifting in Hecate Strait (Higgs, 1991b) is the basis for moderate potential (4) being assigned to the GA, HE and LI domains (Table 1). The following favorable geological features (discussed by Davis et al., 1987; Franklin, 1987;

and Kappel and Franklin, 1987) are thought to be present at depth in Hecate Strait:

Copper and iron-rich volcanic rocks (Karmutsen Formation);

Oceanic turbidite sediments, up to 3.5 km thick, in direct contact with volcanic rocks; these may contain or may have contained unstable high-pressure formational waters with potential for extracting metals from sediments and basalts, and for depositing metals at vents;

Void spaces likely contain seawater;

Deep crustal faults and rift structures are indicated by seismic records (e.g., P.J. Lewis et al., 1991, Fig. 6). A typical zone of subsidiary fault splays and fractures would provide conduits for upward migration of hydrothermal fluids;

Sufficient water depth (80-1100 metres) to prevent boiling of hydrothermal fluid discharge;

Known hot springs on land (Minfile #14, LY Domain; Figure 2 and Appendix I).

Genetic models. Four different mechanisms are speculated for the generation of hydrothermal metal-enriched fluids, their migration along the Queen Charlotte Fault and subsequent precipitation of sulphides on the seafloor:

- a) Consolidation and eastward-directed compression of terrace sediments; lateral migration of metal-enriched trapped seawater to the fault zone; upward migration along a thermal gradient;
- b) Thermal metamorphism of deep terrace sediments; expulsion of structural waters; dehydration at elevated temperatures; leaching of metals from surrounding sediments and volcanic rocks while the hydrothermal fluids migrate upward along the fault;
- c) Meteoric groundwaters in the Queen Charlotte Islands under considerable hydrostatic head may percolate downward and seaward through permeable units of the Karmutsen Formation; leaching metals along the way; fluids eventually expelled from the Queen Charlotte Fault or other landward parallel fracture zones by hydrostatic pressure;
- d) Hydrothermal fluids generated by dehydration of the subducting Pacific Plate below the Queen Charlotte Fault; fluids remobilize metals from the subducted oceanic slab or overlying volcanic rocks and sediments; fluids rise to a point of

discharge along or adjacent to the Queen Charlotte Fault Zone.

Potential for seafloor hydrothermal polymetallic sulphides in the Queen Charlotte Fault Zone (QC) Domain is speculated to be moderate-to-high (3) because its active strike-slip motion provides more opportunity for fluid movements according to the above criteria. In addition, the spreading ridges represented by J.T. Wilson and Dellwood knolls are very close to the marine area of interest (Figure 3); deposits formed at these centres could have been moved by continued spreading into the present study area along the Queen Charlotte transform fault trace.

The presence of the above criteria, despite the lack of known showings and paucity of on-site data, suggests moderate potential (4) for this deposit type in both the eastern and western deeper offshore domains (BP, GA, HE, LI, LO, PA, SH and WC) of the study area.

The other, more shallow domains on the east side (BU, CU, LY, RS, SK, TA) are rated as low-to-moderate (5). The uncertainty here results from the on-land evidence of active fault movements, but shallow water limitations on the pressure criterion. The shallow marine domains on the west side (BI, SC), being tectonically less active and associated with less evidence of mineralization on land, are rated as low (6) in potential for seafloor sulphide deposits.

Unlike the detrital surficial deposits, these ratings are tempered by the uncertainty as to whether this deposit type will be economically recoverable in the near future (Scott, 1987).

Volcanogenic Massive Sulphide Deposits, Westmin-Type: Copper, Zinc, Lead, Gold, Silver

The Westmin Resources massive sulphide deposits are significant resources which must be considered here because they occur in the Sicker Group, equivalents of which probably underlie much of the Queen Charlotte Islands. The following key attributes are summarized mainly from Walker, *in* Fleming et al., (1983) and from Dawson et al. (1991).

Grade and Tonnage. Westmin's 1990 Annual Report cites total production since start-up of 11,571,208 tonnes grading 2.16 grams/tonne gold, 70.91 grams/tonne silver, 1.9% copper, 0.68% lead and 6.11% zinc. Total mineable reserves as of

January 1, 1991 were 9,975,000 tonnes grading 2.1 grams/tonne, 32 grams/tonne silver, 1.8% copper, 0.3% lead and 3.7% zinc.

Form of Deposits. These are variably deformed lenticular bodies which occur in groups at particular stratigraphic levels. Westmin's larger deposits include the Lynx, Myra and the H-W. Two new zones, the GAP and BATTLE were discovered north of HW in 1991.

The deposits are spatially associated with felsic volcanic rocks (intermediate to silicic tuff and volcanic breccia) within an otherwise basalt-dominated sequence. The deposits are lenses of massive pyrite, sphalerite, chalcopyrite, galena and barite, stratigraphically underpinned by alteration zones represented by pyritic, sericitic schist. Associated strata include volcanic greywacke, interbedded argillite and chert (black-grey-green), with an upward trend from non-hematitic chert to hematitic chert in the mine sequence.

Precious metal content. The precious metal content listed above enhances the economic viability of this deposit type. The gold present in the ore and the surrounding auriferous pyrite zones is also a potential source for placer gold deposits.

Regional Geological Setting. The key geological attribute of these deposits for exploration and resource assessment is their stratigraphic setting. The mine sequence is located in the oldest rocks on Vancouver Island - the Late Silurian (410 million years) Myra Formation, which is exposed in structural highs and is about 1800 metres thick. The mine sequence is overlain by about 460 metres of Early Mississippian (350 million years) greywacke and argillite intruded by diabase sills, succeeded by the Buttle Lake Formation: 150-450 metres of crinoidal limestone of Middle Pennsylvanian and Early Permian age (290-260 million years). These rocks constitute the Sicker Group, which is unconformably overlain by the Karmutsen Formation pillow basalts. The Sicker Group, with its marked lithologic variety and marked lateral facies changes is in contrast to the uniform, kilometres-thick pillow basalts of the mantling Karmutsen Formation. Detailed mapping and stratigraphic revisions by Massey and Friday (1989) have reinforced this contrast.

Potential for volcanogenic massive sulphide deposits in the study area depends strongly on our knowledge of regional stratigraphy. Until very recently the above stratigraphic data would have constrained the potential for this deposit type to low in most of the Queen Charlotte Islands region, because the Karmutsen Formation had been the

oldest rock unit mapped at surface. This deposit type had not even been considered by Schmitt et al. (1987).

The low assessment is now upgraded because of the discovery of Permian (Hesthammer et al., 1991) and Paleozoic or lower Mesozoic (Indrelid and Hesthammer, 1991) rocks in the Englefield Bay area (northwestern Moresby Island, outside of the study area) that resemble the Sicker Group. Wilton and Pfuetzenreuter (1991) also have reported drilling by Doromin Resources at the Cimadoro massive sulphide prospect on Deena Creek, northern Moresby Island. Nine short drill holes tested surface lenses of sheared lead-zinc-silver sulphide minerals with minor gold, copper, and locally high barium in cherts, argillites and limestones which appear to underlie the Karmutsen Formation. Wilton and Pfuetzenreuter (1991) interpret the new prospect as sedimentary-exhalative (sedex) in origin. This is yet another new exploration possibility for the Queen Charlotte Islands.

We would now rate the Englefield Bay area as high (2) in potential for Westmin-type volcanogenic, and sedex massive sulphide deposits. The new implications for volcanic- and intrusion-hosted gold in veins and shear zones are discussed earlier in this Open File. These ratings are likely to change, depending on further mapping, prospecting and work on litho geochemistry in the Queen Charlotte Islands.

Domains within the study area that include large amounts of Karmutsen Formation and have not yet been completely remapped under the Frontier Geoscience Program (Haggart, 1992a) are here considered to have moderate potential (4) for volcanogenic massive sulphides of the Westmin type or sedex deposits. These include the western part of BU and parts of LO. Mineral potential within the BU and LO domains would be higher on terrestrial lands than on marine lands because areas of deepest erosion, toward the west and adjacent to plutons which have caused uplift, would be most prospective for the older strata.

Virtually all of LY and SH have been remapped, and no older strata have been recognized (Sanborn-Barrie, 1992; Souther, 1992); these and other domains remain rated as low (6). Other than the Karmutsen basalts, younger volcanic rocks in these domains are Tertiary in age, commonly subaerial (ibid.), and are more likely to be associated with Cinola-type gold than with Westmin-type copper-zinc-precious-metal deposits.

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APPENDIX I. Metallic and non-metallic mineral occurrences of South Moresby Island proposed marine park adjacent on-land areas. List is ordered by domain and by minfile number; occurrences are located by Minfile number on Figure 2; abbreviations explained on last page.

DOM /type /mag	Name (s) /Status	NTS / Minfile	Commo-dities	Geologic Setting (Structure, Host & Associated Intrusions)	Mineralogy (trans/opaque)	Details of Deposits/ Occurrences + Comments	Sources Cited
BU /mag	Johnson N1 / S	103B-6W /16	Ni-Cu	gbb dyke + dort stock BIPS intrude Kunga lst + arg	gbb dissemin po-cp-br (pn?)	5.5 m outcrop with ~ 1% Ni, 1% Cu	MINFILE
CU /sed	Cumshewa Lst / S	103G-4W /07	lime-stone	Kunga lst -same as SK-LO/59, RS/38,61	ca	lower two members rep lst res of Queen C. Is.	MINFILE
CU /epi	Marino, Bella Moly / S	103G-4E /08 /28	Sb-Au	Yakoun ands , agg, dac, rhy tuff, epiclast, basic dykes	/ st-py-as	dissem in volcanics 6.1 m @ 5% sb, 5 g/t Au 6m @ 1.5 g/t Au	MINFILE
CU /epi	Cumshewa, Homestake / S	103G-4E /09	Au-Ag-Pb-Sb-	Yakoun ands , agg, dac, rhy tuff, epiclast, basic dyke	qz-ca/ au-ga-si-py-st-	vein 1.3x73 m vertical 040' brx qv. 3m @ 6.9 g/t Au + 144 g/t Ag	MINFILE
CU-RS /skn	Iron Duke / S	103B-13E /01	Fe-mt	Karmutsen vol + Kunga lst intruded by BIPS dort+gnod	ca-ga-qz-cl-ep-ka-two-tr / mt-py-cp	wedge-like mass, digit margins, at vol-1st cont, cut by 3 sinist faults, 500,000 t @ 46% Fe (mt)	MINFILE
LO /epi	Yakulahas / S	103B-5E /15	Mo-Cu	Karmutsen vol (ampb gnss) cut by qz dort SCPs	qz/ mo-cp-py	in irreg qv cutting ampb adjacent qz dort	MINFILE
LO /vrc	Louscoone / S	103B-3W /48	Cu	Karmutsen vol	/ cu-ct-tt	disseminated in basalt	MINFILE
LO /skn	Rose / S	103B-3E /65	Au-Cu-Mo	Kunga lst+arg + Karmutsen vol intr dort + qz dort of SCPs major N-NW fault part of LIFZ	qz-cl-ga-calcsi / py-cp-mo-po	ddh: 45m @ 0.3g/t; 3m @ 0.9 g/t Au in hfs argill, sparse sulph qv in dort	MINFILE
LY /epi	Hawkes Nest/ S	103B-13W /04	Au-Zn-Cu	Shattered chloritic Karmutsen basalts separated by LIFZ from BIPS pluton to west	qz-ca-ep, / sl-cp-po	propyl alter'n; sulph dissem in bas + dort dykes (grab 0.2 g/t Au)	MINFILE
LY /oil	Ramsay Isl / S	103B-11W /05	Bitumen	Masset volcanic agglomerate Ramsay+Agglomerate+Tar islands	bitumen	in fissures within agglomerate	MINFILE
LY /hyd	Hotspring Isl / S	103B-11W /14	NaSO ₄ -hotspring	Masset agg + porph plug & Longarm slt + gwk	chloride, sulphate	several fissures within agg ~.06 m ³ /min @ 72°C	MINFILE
LY /sed	Kunga Isl/ S	103B-13E /60	lime-stone	Kunga lst -same as SK-LO/59, RS/38,61	ca	lower two members rep lst res of Queen C. Is.	MINFILE

LY-SH /vic	Last Chance / P	103B-12W /03	Cu-Ag- Au	Karmutsen vol + Kunga lst +	qz-ep-cl / cp-cc-cu-bn	dissem, fract + vesicle- horizons; 3.3m @ 0.55 % Cu + 0.08 g/t Ag	MINFILE
LY-SH /vic	Swede, Brandy, "D" / P	103B-12W /09	Cu-Ag- Pt	Karmutsen vol + Kunga lst + faults (LIFZ) + dykes of dac, dort + ands (SCPS)	cl-ep-qz / cp-bn-py-po- (au-pd-ga-pt)	diss, blebs, veinlets in amyg bas; 100m @ 0.5-2 % Cu; max 3.5% Cu+20g/tAg	MINFILE
LY-SH /vic	McEchran Cove/ S	103B-12W /58	Cu	Karmutsen amygdaloidal basalt	/ cp	chalcopryrite dissem in amygdaloidal basalt	MINFILE
LY-SH /epi	Lockport Locke/ S	103B-12W /66	Au	Kunga lst + Karmutsen vol major N, NNW, NNE faults	qz-cl-jasper / as-py	diss in limy arg and in fract + qv; 1.5m @ 9.2g/t 0.25m @ 25.8 g/t	MINFILE
LY-TA /epi	Crescent	103B-13W /62	Au-Ag- Mo-Zn	Gabbroic rocks of BIPS intr * Yakoun vol + sed + Kunga lst Block faults 038' cut BIPS	ca-qz-cl/ py- po-as-mo-sil-mt	Au mainly w small qv in Massett py- rhy+gbb; 76 cm @ 4.7 g/t Au; grabs to 66g/t Au, 35 g/t Ag	MINFILE
LY-TA /epi	Collinear Creek/ S	103B-12W /68	Au	Karmutsen vol + Kunga lst + Yakoun vol/seds + Massett vol 038' block fault	qz / py-po	2-4 cm 055' qz vn. 8 m sample along vn assayed 25.4 g/t Au (no dilut)	MINFILE
RS /sed	Gillatt, Lime/ PP	103F-1E /38	lime- stone	Kunga lst - same as SK-LO/59, LY/60, RS 61	ca	lower two members are lst res of Queen C. Is.	MINFILE
RS /sed	Limestone Isl/ S	103B-13E /61	lime- stone	Kunga lst vol - same as SK-LO/59, LY/60, RS 38	ca	lower two members are lst res of Queen C. Is.	MINFILE
SH /skn	Apex, Star Alpine / P	103B-12W /08	Fe-Cu- Ag	Kunga lst + Karmutsen vol + intr by SCPS (fs porph dyke)	ga-ep-ca / mt-cp-py-po	at base lst roof pendant 180,000 t @ 34% Fe, 0.9% Cu, 24.6 g/t Ag	MINFILE
SH /plac	Shuttle Isl/ PP	103B-12E /10	Au	Unconsolidated seds on Karmu- tsen vol -beach setting	Au	in beach gravels from Au-qv in bas; 2468g Au	MINFILE
SH /epi	Ellen, Bud Aeroplane, Shuttle/PP	103B-12E /12	Au	Karmutsen gns, lst, tff, arg, brx qv	qz / Au	free Au in intersecting brx qv ~100m N-NE, 2.5 cm wide; 49t ore- 560g Au	MINFILE
SH /skn	Lobstalk, Marven/ S	103B-12E /13	Fe	Karmutsen vol + lst	skn / mt-py	pyritic mt replaces greenstone + minor lst	MINFILE
SH /epi	Highgrade / P	103B-12E /63	Au-Ag- Cu	Karmutsen Fm. massive+pillow gns (arg, tuff, chert); NW- faults + qv + brx + altered (argillic + propylitic)	qz-ca-ak-clay- sil-ep-cl-gr / Au-ak-sil-py- as	Au in py+as in qv & dis- sem. in gr arg; 4 zones, 0.5-8m, over 1.5 km; 1.7- 11.6g/t Au; .34-5.1g/t Ag	MINFILE

SH-LY /ep1	April / P	103B-12E /64	Au	Karmutsen + Massett rhy, tff, agg, ands flow + LIFZ faults	qz-ca- zeolite veins / py	lens in Massett rhy, 300 x 30-40 m; DDH inters 3-12 m @ 2-5 g/t Au	MINFILE
SK /skn	George Isl./P	103B-6E /02	Cu	Karmutsen vol + Kunga lst + amyg. ands + bas	qz-ga/ cp-mt- py-bo-tn-ct	cu in ga-rich lenses 3x300m + dissem in lst similar to vcr type	MINFILE
SK /ep1	Huxley Isl./ S	103B-6W /06	Cu-Zn- Au-Ag	Kunga blk + gry lst & andesite dyke	qz/ py-cp-sl (trace antim)	sulphide pods in silic lst adj dyke ~.8g/t Au	MINFILE
SK /ep1	Alder Gold/ S	103B-6W /07	Au	Kunga lst + Yakoun volc+sst cut by BIPS & andesite dyke	qz-ca/ Au-sl	best 10.9g/t Au over 15 cm in brx silic thn lst	MINFILE
SK /skn	Archie- Adit/ S	103B-6E /11	Fe-Cu-	Karmutsen vol + Kunga lst cut by BIPS felsic sills	ca-qz-ep-calc- silic/ mt-cp-py	pod of mt + selvage py+ mt+cp in lst near sill	MINFILE
SK /skn	Alder Island / S	103B-6W /17	Au-Cu- Mo-Ni- As-Sb	Karmutsen vol + Kunga lst + Yakoun vol + Longarm sst intruded by BIPS	px-ga-ac-zo- / po-cp-mo-mt- Ni-allemontite	metals in mylonite; soil geochemistry 5.5 g/t Au	EMPR pap 1989-3
SK /skn	Nick's Sh./ S	103B-6W /18	Cu-Mo- Ni	Kunga lst + arg intruded by qzms of BIPS	skn +hornfels / py-cp-po-mo	sulphides dissem in skn+hfs near QZMZ	MINFILE
SK /skn	Mac, Jones magnetite Burnaby/ P	103B-6W /19	Fe-mt	Karmutsen vol + Kunga lst cut by fine-gr mafic dykes+ sills + monz of BIPS	ga-skn / mt	concord mt replacement body at lst-gns contact 1,300,000 t @ 40-50% Fe	MINFILE
SK /skn	Poole, Jib / PP	103B-6W /20	Fe-mt- Cu-Ti	Karmutsen vol + Kunga lst intr by qzms of BIPS	ga-ep-ac-px-cl /mt-py-cp-po-sl	lower mt skn conf to volc\lst contact; upper lenses on sills; indic tot 7,438,220t @ 49% Fe	MINFILE
SK /skn	Skincuttle Island / S	103B-6E /21	Cu-Fe- mt	Kunga lst cut by sills of Karmutsen ands /basalt	qz/ cp-mt-py- tn-ct	ga-skn replaces volcs, cp+mt etc also diss in vns & veinlets in lst	MINFILE
SK /skn	East Copper Isl./P	103B-6W /22	Au-Ag- Cu	?Karmutsen vol + Kunga lst intr by and. sills + BIPS (mapped as Yakoun Fm)	gt-ep-hb-ca- qz / cp-bn-py- mt-tn-ma-ct	skn sill contacts + volcs; cp dissem in gt + in qz-veinlets	EMPR pap 1989-3; bull 54
SK /repl	Gigger, Sea King Bl Jay/ PP	103B-6W /23	Fe-Cu-	Kunga lst cut by "igneous dykes" of ?BIPS?	ca-hb / mt-cp-py	metre band of mt>>cp+py in lst; also grey dyke + stringers ca>mt-cp	MINFILE
SK /vein	Lucky 7, Dorathkalon Prod, Pipe/PP	103B-6E /24	Cu-Ag- Au	Kunga arg + lst	/cp-py-po- >> as-sl	2-3 m fissure vein of sulph; 38 t @ 1866 g Au, 6780 g Ag, 3781 kg Cu	MINFILE

SK /skn	Tip 1, Tip / S	103B-6E /25	Fe-Cu-Mt	Karmutsen vol + Kunga lst intr by BIPS	Ca-Qz-Ga skn / mt-cp-py	Irregular skn at lst-vol contact 46x15 m	MINFILE
SK /skn	Jessie, Jedway / PP	103B-6E /26	Fe-mt	Karmutsen vol + Kunga lst intruded by Jedway qz dort, porph dort, rhy dyke of BIPS	ga-ep-am-cl-se / mt	repl bands of mt separ. by skn, gns + dort porph, on flts; 4.26 x 10 ⁶ t @ 49% Fe, .78 % S, .09 % Ti + .035 % P ₂ O ₅	MINFILE
SK /skn	Adonis SweetPea / PP	103B-6E /27	Fe-mt-Cu	Karmutsen vol + Kunga lst intruded by sill-like dort & dort porphyry of BIPS	qz-ga-calc sil. / mt-py-cp	mt>>py+cp+skn replac lst-vol contact, also flts, ~10 ⁵ t @ 35% Fe	MINFILE
SK /skn	Lily Mine / PP	103B-6E /28	Au-Ag-Cu-Zn	Karmutsen vol+lst + Kunga lst intr by Jedway stock + dort sill of BIPS	ac-cl-gt-px / mt-po-cp-py-sil	veinlike masses within sheared+altered greenstone	EMPR pap 1989-3; MINFILE
SK /skn	Chrysanthemum, Rose / P	103B-6E /29	Au-Cu	Karmutsen vol+lst intr by Collison Bay dort stock of BIPS	gt-cl-ep-px / mt-po-cp-py	mt lenses dip gently; drill core assay 2.07 g/t Au over 1.5 m	EMPR pap 1989-3; MINFILE
SK /skn	Togo, AJ, Prince / S	103B-6E /30	Cu-Fe-mt	Karmutsen vol intruded at distance by Jedway stock BIPS	ga-ca-qz / mt-cp	mt replacement 18x3.6m in ga skn up to 3% Cu	MINFILE
SK /skn	Modoc (L83) / S	103B-6E /31	Cu-Fe-Au-Ag	Karmutsen vol intruded by Jedway stock BIPS	ca-skn / cp-mt-py	vein-like replacement 15x3.6m 1.4g/t Au, 13.7g/t Ag, 0.6% Cu	MINFILE
SK /skn	Reco (L82) / P	103B-6E /32	Cu-Fe-Au-Ag	Karmutsen vol intruded by Jedway stock BIPS	ga-skn / mt-py-cp	mt body 24 x 1.2-2.4m ~1.5 % Cu, 3.4 g/t Au, 24 g/t Ag	MINFILE
SK /skn	Blue Belle Dingo / S	103B-6E /33	Fe-mt	Karmutsen vol intruded by Jedway stock BIPS	ga-skn / mt	pipe-like lens of mt ~ 50% Fe	MINFILE
SK /skn	Nagnet, Fe Mtn / P	103B-6E /34	Fe-mt	Karmutsen vol intruded by Jedway stock BIPS	ga-ca-ep skn / mt-cp-py-sil	concord mt repl lens 110x55x6m ~400,000 t @ 60% Fe	MINFILE
SK /skn	Copper Queen / S	103B-6E /35	Au-Cu-Mo-Ni	Karmutsen vol + Kunga lst intr by Jedway stock (BIPS) & cut by grn py-and dykes	px-ga-ac-zo- / po-cp-mo-mt-	vol-lst-qz dort contact concord lenses mt>cp+py 7.6x12x3m no assays rep.	MINFILE
SK /skn	Moresby Island / S	103B-6E /36	Cu-Ag	Karmutsen vol+lst intr by Jedway qz dort stock of BIPS	gt-ep-ac / mt-cp	skn at contact of qz dort/vol; chip smpl Ag: 34 g/t; Cu 1.1 %	EMPR pap 1989-3; MINFILE

SK /skn	Eagle Tree/ S	103B-6E /37	Cu-Fe-Ag-Au	Karmutsen vol intruded by Jedway stock BIPS	skn / mt-cp-py	mass+diSS on sheared dort cont. 100x6m, 2.6%Cu, 3.5 g/t Au, 34.3 g/t Ag	MINFILE
SK /skn	Ida, Jim / S	103B-6E /38	Fe-mt	Karmutsen vol intruded by dort stock of BIPS *	ca-ga-skn / mt	dyke-like skn near dort contact 60x8 m	MINFILE
SK /skn	Morning, Lotus, Daykins, Maple,Cu, Roy's, Collison Bay/PP+P+S	103B-6E /39 /45, /47, /69, /70	Au-Cu Ag	Karmutsen vol+lst + Kunga lst intruded by Collison Bay dort stock of BIPS ? & Carpenter bay stocks of KPS? *39-43	gt-px-qz / mt-py-cp -po-as-bn	dyke-like sulphide bodies follow faults & intrusive contacts. Assays: 55m@-0.7g Au/t + 18.5g Ag/t + .37% Cu; 2.6 m@ 1.2g/t Au + 8.5 g/t Ag + 2.47% Cu	EMPR pap 1989-3; MINFILE
SK /skn	Plunger, Ivan / S	103B-6E /46	Fe-Cu	Karmutsen vol + Kunga lst cut by BIPS dort *	ga-skn / mt-cp-py	150x8m replacement of NW shear zone near dort	MINFILE
SK /cont	Sakai / S	103B-3E /49	Cu	Karmutsen vol + lst intruded by Carpenter Bay stock of KPS	ca + brx vol + seds / bn	450x50m diSS bn in ca-vol brx at lst-vol contact	MINFILE
SK /rep	Copper Coin/ S	103B-3E /50	Cu	Karmutsen vol + lst near Carpenter bay stock of KPS	/cp-py	60 cm cpy replacement at vol-sed contact	MINFILE
SK /skn	Swan, Flo/ S	103B-6W /52	Cu-Fe	Kunga lst & Longarm slt-gwk intr to E by monz of BIPS	skn / cp-mt	-60% Fe 40x30m repl vol; cpy in lst 9-22 x 3-5 m @ 1-4% Cu	MINFILE
SK /skn	Carpenter Bay / S	103B-6E /53	Fe-Cu	Karmutsen vol + Kunga lst + intr to W by dort of BIPS *	skn / mt-cp	lens 13.7x5.5m at vol-pluton contact	MINFILE
SK /skn	Hope / S	103B-6E /54	Cu-Fe (Au-Ag)	Karmutsen vol intruded by diorite pluton of BIPS *	ga-qz-skn /mt-cp-py-po-ll	mass skn 25x6m; 3m @ 2.7% cu + tr Au/Ag	MINFILE
SK /pph	Raspberry Cove/ S	103B-3E /55	Cu	Karmutsen vol intr by qzmz Langford Pt Pluton of KPS	/cp	veinlets in vol + qzmz up to 7% Cu across 60 cm	MINFILE
SK /epi	Carpenter / S	103B-3E /56	Au-Cu	Shear zone in Kunga lst intr by qzmz Langford Pt Plut KPS with extensive hornfels	qz-ca-clay / py-as-cp-po	in shears assoc w qz-ca veins & fels dykes; up to 0.42 & 0.72 g/t Au / 5 m	MINFILE
SK /epi	NFG / S	103B-6W /57	Fe	Kunga lst intr by BIPS monz	/mt	dissem in lst	MINFILE
SK /skn	Water Lily/ P	103B-6E /67	Fe-Cu	Karmutsen vol + Kunga lst nearby BIPS dort intrusion	ga-ca-skn / mt-cp-po-py	30x30m isl, ddh 44% Fe / 2.1 m; 3 m cp in ands	MINFILE

SK /skn	Archie Camp/ S	103B-6E /71	Cu	Karmutsen vol + Kunga lst intr by fels sills of BIPS	ep-calc-silic / cp-po-py	metals in mylonite; soil geochemistry	MINFILE
SK /ep1	Archie / S	103B-6E /72	Au	Karmutsen vol + Kunga lst+arg intr by fels sills of BIPS	qz-se / py-po	py + po diss in hfs + sil arg; Au in sul vnlt	MINFILE
SK-LO /skn	Treat Bay/ S	103B-3E /51	Fe-Cu	Karmutsen vol + Kunga lst + no known intrusions	/mt-cp-py-po-ma	irregular metasomatic body at lst-vol contact	MINFILE
SK-LO /sed	Kunghit Isl/ S	103B-3E /59	limestone	Kunga Group lst	ca	accessible lst resource of Queen Charlotte Isl.	MINFILE
TA /ep1	Early Bird / PP	103C-16E /01	Au-Ag-Cu	Karmutsen pillow bas & gns low grade regional chlorite pumpellyite metamorphism	qz-ca-cl-pu- / Au-py-cp	stringer qv in 60 m-wide fault zone 037./90; minor cl & sil walls; produced 171t, 8739g Au + 1244g Ag	MINFILE
TA /ep1	Haida Gold / PP	103C-16E /02	Au-Ag-Cu	Karmutsen massive gns contain E-striking S-dipping qv system	qz-ca-py-veins / py-cp	sil & cl walls of veins; ddh & adit indicate 2g/t over 0.9 m	MINFILE
TA /skn	Tasu / PP	103C-16E /03	Au-Cu-Ag-Zn	Karmutsen vol + Kunga lst intruded by SCPS (hb dort, qz dort, porph dort laccol)	ch-ep-ac-tr- / kf-at-gt-qz-ca /mt-py-po-cp-sl	4 stratiform mt bodies at lst-vol contacts, mt replaced by sulphides	EMPR pap 1989-3; MINFILE
TA /skn	Ajax, Garnet / S	103C-16E /04	Au-Ag-Cu-Zn-Mo-Pb-Fe	Karmutsen vol + Kunga lst intruded by SCPS (qz dort)	gt-ep-cl-qz- / am / mt-py-cp-sl-mo	skn & sulph at lst-vol contacts; py-cp-mo diss & in fract qz-dort	EMPR pap 1989-3; MINFILE
TA /skn	Old Tasu Townsite / S	103C-16E /05	Fe-Cu	Karmutsen vol + Kunga lst intruded by SCPS (qz dort)	gt-ep-cl-qz- / am / mt-py-cp-sl-mo	skn & sulph at lst-vol contacts; diss repl 90,000 t low grade	MINFILE
TA /ep1	QP / S	103C-16E /06	Cu-Ag-	Karmutsen gns and lesser Kunga lst + arg, minor qz-fp porp ?from BIPS to SE	qz-cl-gr / cp-bn-ma; 1.8% Cu, 3.4 g/t Ag	Cu in fault-bounded shale wedge surrounded by cl-ands. Cu in qv & fract.	MINFILE
TA /skn	SHG Magnum / S	103C-16E /07	Au	Karmutsen gns + Kunga lst, small dort dykes rel to qv & sil brx 800 x 800 m in lst	Au-py-po-as-mt / qz-tr-ep	skn near base of lst, tr at lst/vol contact; vein chips: to 0.155 g/t Au	MINFILE

APPENDIX I ABBREVIATIONS

DOM: Domains; see Table 3, Figures 1 and 2.

/type: TYPE OF DEPOSIT and Geologic Setting: ROCK TYPES and Details of Occurrences: ROCK TYPES.

agg	agglomerate	flt	fault, faults	mag	magmatic	rhy	rhyolite
ands	andesite	gnod	granodiorite	mbl	marble	SCPS	San Christoval
arg	argillite	grn	green	monz	monzonite	sil	Plutonic Suite
brx	breccia	gwk	greywacke	oil	hydrocarbons	sil	silica,
bas	basalt	gbb	gabbro	plac	placer	sil	silicified
BIPS	Burnaby Island	gns	greenstone	porp	porphyritic	skn	skarn
*	Intrusive Suite	hfs	hornfels	pycl	pyroclastic	slt	siltstone
cgl	conglomerate	KPS	Kano Plutonic Suite	qtzt	quartz arenite	sst	sandstone
dac	dacite	LIFZ	Louscoone Inlet	qv	quartz vein	vlcl	volcaniclastic
diss	disseminated	lst	Fault Zone	qzms	quartz monzonite	vol	volcanic
dort	diorite		limestone	repl	replacement	vrc	volcanic-red-
epi	epithermal,			res	resources		bed-copper

Name(s): from MINFILE

/Status: / S = showing (grab samples); / P = prospect (2- & 3-D size & grade); / PP = past producer.

Commodities and Mineralogy (trans/opaques)

ac	actinolite	ca	calcite	gl	galena	Pd	palladium	sl	sphalerite
Ag	silver	cb	carbonate	gr	graphite	pl	plagioclase	sp	sphene
ak	ankerite	cc	chalcocite	hb	hornblende	po	pyrrhotite	st	stibnite
am	amphibole	cl	chlorite	hm	hematite	ph	prehnite	Ti	titanium
ap	apatite	cp	chalcopyrite	il	ilmenite	ps	pyrolusite	tn	tennantite
as	arsenopyrite	ct	cuprite	kf	k-feldspr	Pt	platinum	tr	tremolite
As	arsenic	Cu	copper	ma	malachite	pu	pumpellyite	tt	tetrahedrite
at	anthophyllite	cv	covellite	mi	microcline	px	pyroxene	wo	wollastonite
Au	gold	do	dolomite	mn	manganese	py	pyrite	ze	zeolite
ax	axinite	ep	epidote	mo	molybdenite	qz	quartz	Zn	zinc
bi	biotite	er	erythrite	Mo	molybdenum	Sb	stibnite,	zo	zoisite
bm	bimuthinite	Fe	iron	mt	magnetite	se	antimony		
bn	bornite	fp	feldspar	Ni	nickel	sh	sericite		
br	bravoite	ga	garnet	Pb	lead		scheelite		

Sources Cited:

EMPR pap, bull: B.C. Ministry of Energy, Mines and Petroleum Resources paper, bulletin.

MINFILE: B.C. Ministry of Energy, Mines and Petroleum Resources: maps with printouts of mineral occurrences and deposits; run date: 1989/04/01. See also Jones (1989).

*: Plutonic suite from Anderson and Reichenbach (1991); differs from MINFILE data.