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GEOLOGY OF THE PORCUPINE STRAND BEACH PLACERS, EASTERN LABRADOR

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ABSTRACT

The Porcupine Strand, in eastern Labrador, consists of over 40 km of sandy beach, known to contain accumulations of heavy mineral sands (iron–titanium, garnet). The 1991 field program included a small, drill program carried out by Cominco Limited, channel sampling and geophysics, with emphasis placed on the North Strand. The best economic potential lies in the modern and raised beach sands, which developed during a time of relatively slow coastal emergence and low sediment supply. The reworking of a finite supply of sediment has produced a relatively high-grade placer deposit of limited extent.

INTRODUCTION

The placer potential of modern and raised beach sands of the Porcupine Strand, eastern Labrador, is presently being investigated by Cominco Limited, the Newfoundland Department of Mines and Energy and Centre For Cold Ocean Resources Engineering (C-CORE). The potential economic value of these placer occurrences lies principally in the iron and titanium (Fe–Ti) content of the magnetite, hematite and ilmenite. The purpose of this paper is to provide a review of the results from the 1991 field season and to advance a depositional model for placer development in the area.

The Porcupine Strand consists of over 40 km of sandy beach tracts separated by low-relief rock headlands (Figure 1). The most prominent headland is Cape Porcupine, which separates the North Strand from the South Strand. Beach slopes are generally low ($< 3°$) with the intertidal zone ranging from 50 to 100 m in width and the backshore, from 10 to 40 m in width (Plate 1). All beaches are cut into a broad coastal plain, which abuts a more rugged mountainous terrain to the west of the Strand. The coastal plain is deeply incised by the North River, the single major river in the area.

The placer potential of the Porcupine Strand beaches was first investigated by Emory-Moore and Meyer (1991). Based on 10 test pits, 50 to 100 cm in depth, an estimated 33,600 tonnes of Fe–Ti concentrate and 9,150 tonnes of garnet concentrate were delineated over 1 km of the beach; the overall thickness and lateral extent of the mineralized sand was not established.

Based on field observations, the South Strand beaches (both modern and raised) were noted to have far lower heavy mineral concentrations, and presumably less mineral potential. Thus, the following discussion is limited to placer occurrences on the North Strand.

STUDY AREA

Bedrock Geology

The study area falls within the northeastern portion of the Precambrian Grenville Province and is underlain by paragneiss, granitic orthogneiss, and granulite-facies gabbroic, monzonitic and granitic rocks (Gower, 1984). Immediately to the west and south of the Porcupine Strand there are numerous thick, folded gabbronorite–monzonite layered intrusions (Gower *et al.*, 1981). These have not been prospected but given their layered nature they almost certainly contain fractionated Fe–Ti oxides.

Quaternary Geology

During the Quaternary, glacial ice extended onto the continental shelf of Labrador, into present water depths of approximately 600 m (Josenhans *et al.*, 1986). The extent of late Wisconsinan ice is not well defined in the study area; some workers believe ice extended into the present offshore (Josenhans *et al.*, 1986) whereas others believe that the ice margin was close to the present coastal limits (Rogerson, 1977). It is generally agreed that ice flow was toward the coast,

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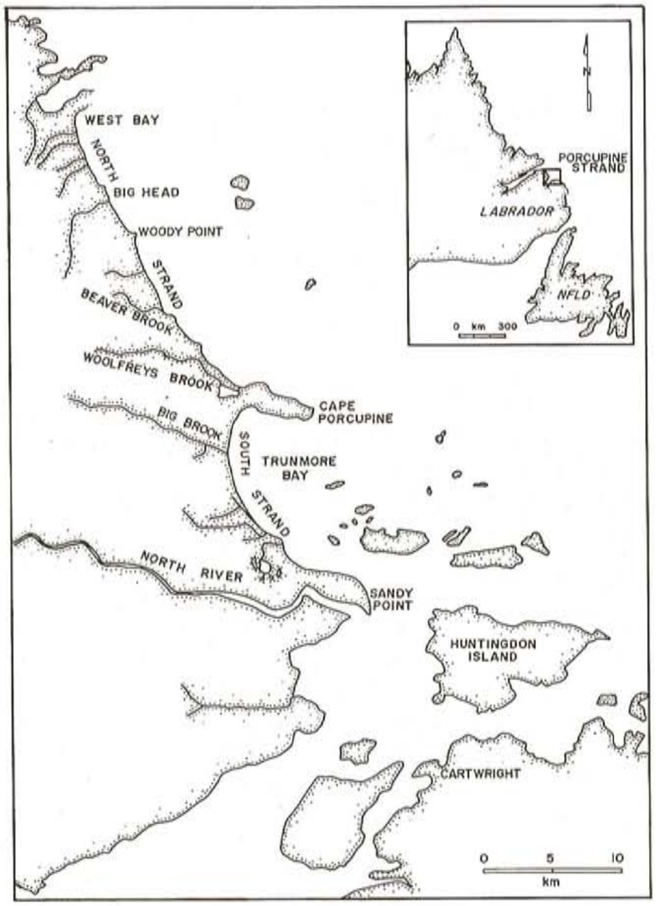

Figure 1. *Location map and place names, Porcupine Strand, eastern Labrador.*

Plate 1. *Aerial view of the North Strand beach (tract).*

spreading east from a divide that occupied the central part of the Labrador peninsula and that deglaciation commenced almost 12,000 years BP (Vincent, 1989).

Thick Quaternary sequences underlie the coastal lowlands of the study area (Figure 2). An extensive suite of valley and plain sandurs cover much of the lowlands and overlie a thick sequence of glaciomarine mud (Rogerson, 1977). Postglacial isostatic rebound in the study area resulted in a drop in relative sea level of over 60 m (Figure 3; Rogerson, 1977). Sea level dropped at a rate of approximately 1.2 to 2.4 m/100 years from 10,000 to 6,000 years BP. A minor transgression in sea level occurred after 5,600 years BP and has since been followed by a slow (0.18 m/100 years) continuous drop in sea level (Rogerson, 1977).

Oceanographic Regime

During the ice-free season, from June to November, the North Strand is fully exposed to the Labrador Sea where wave heights can exceed 9 m and over fifty percent of the time do exceed 1.5 m (Walker, 1984). Tides in the study area are semi-diurnal with tidal range of 1.2 to 3.0 m. Ebb and flood tidal velocity is 10 cm/sec (Canadian Hydrographic Service, 1988).

METHODS OF SAMPLING AND ANALYSIS

Forty-five holes were drilled in the modern beach complexes of the North Strand using a vibra-core drill. In all cases, drill penetration was limited to less than 2 m due to the presence of gravel and clay horizons and in some areas, frozen ground. A composite sample weighing from 1 to 5 kg was recovered from each drillhole.

Forty-seven channel samples were collected from trenches in the modern beach complexes of the Strand and, where possible, exposed sections of raised beach terraces. Near Beaver Brook (Figure 1) several beach profiles were measured and detailed sampling of each undertaken.

Twelve graduated sediment rods were driven into the beach at selected sites and will be used to monitor net sediment erosion and/or deposition. A loosely fitting washer was slipped over the rod and placed on the surface of the beach. At the end of the observation period, the distance from the washer to the original sand surface, as measured on the graduated rod, will provide a measure of net erosion. The distance from the washer to the final sand surface will indicate the amount of subsequent backfilling. Magnetic surveys of the modern beach and raised beach terraces were undertaken using an Omni magnetometer. A total of 49 transects were completed, 10 of which included repeated surveys using different sensor heights.

Geochemical analyses of the samples are being carried out by the Newfoundland Department of Mines and Energy using inductively coupled plasma spectroscopy. Detailed textural and mineralogical analysis of select samples will be undertaken as part of two undergraduate Honours theses at Memorial University.

COASTAL SEDIMENT SUITE

The coastal sediment suite of the North Strand is composed of three sediment types: glaciomarine muds, outwash sands and gravels, and mineralized beach sands. A brief description of each is provided below.

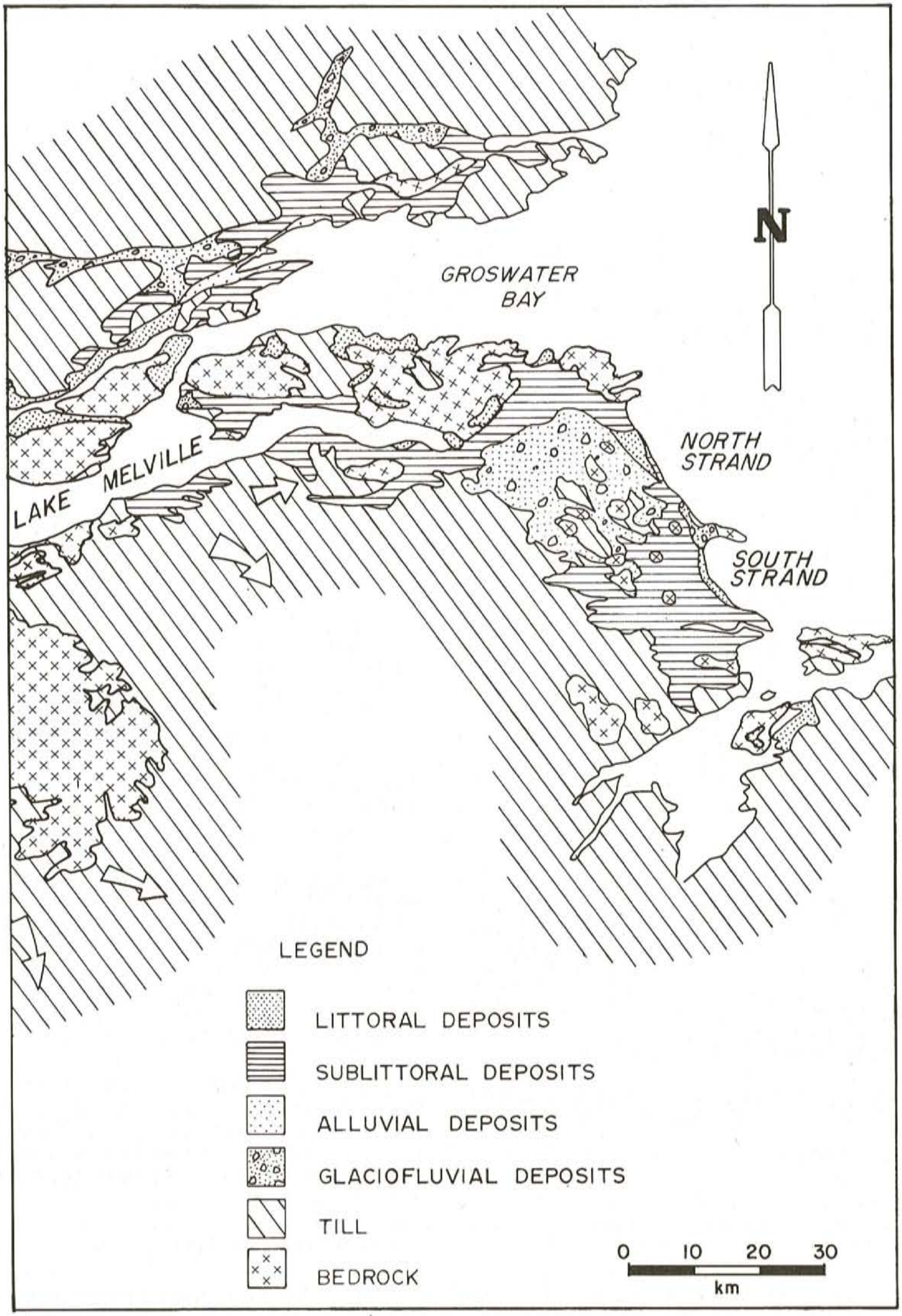

Figure 2. *Surficial geology (from Fulton, 1986).*

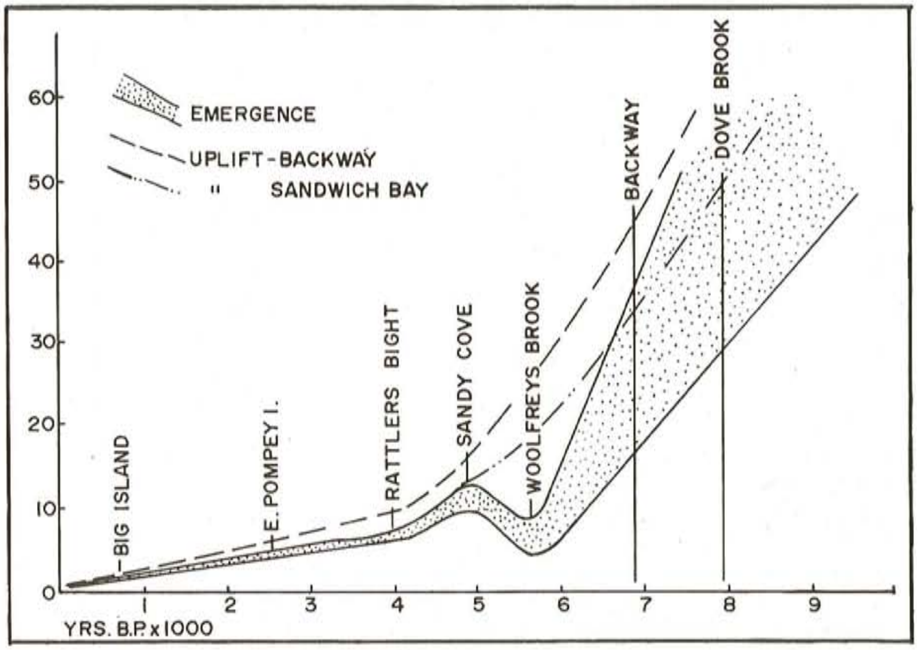

Figure 3. *Postglacial sea-level history (from Rogerson, 1977).*

Glaciomarine Mud

Thick sequences of glaciomarine mud underlie the coastal lowlands of the North Strand, and are well exposed in the modern coastal bluffs, (up to 30 m high). The modern beach and most low-elevation terraces are cut into the relatively resistant bluffs, (with the exception of Woody Point; Figure 4). Glaciomarine muds underlie the modern beach complex at depths of 1 to 2 m. The muds are composed of a silty clay having isolated dropstones, and are generally massive and prone to slumping. The glaciomarine muds were not examined in any detail as they hold no placer potential.

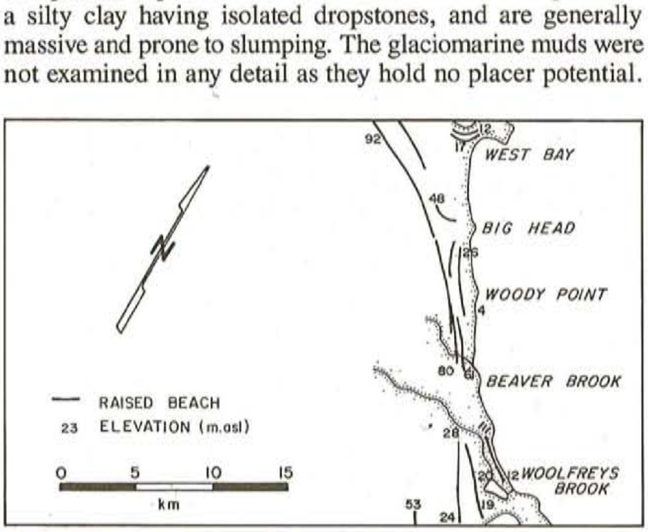

Figure 4. *Distribution of raised terraces (modified from Rogerson, 1977).*

Outwash Sands and Gravels

Outwash sands and gravels overlie the glaciomarine muds and form much of the surficial cover of the North Strand coastal lowlands. Terraces cut into outwash sands and gravels occur at various elevations, including 24 to 28, 48, 61, and 80 to 92 m; in some cases, the terraces can be traced for distances greater than 20 km (Rogerson, 1977; Figure 4). The sand and gravel unit is generally quite thin in coastal exposures (<3 m) except around Woody Point and Woolfreys Brook where it exhibits thicknesses of greater than 5 m.

The outwash sediments exposed in the coastal bluffs are generally composed of moderately sorted medium to coarse sands having interbedded gravels (Plate 2). Sedimentary structures include large and small trough and planar tabular crossbeds, isolated scour fills and low-angle inclined stratification. Outwash sediment is characterized by thin (< 3 mm) heavy mineral laminations, and in many places the sediment is cemented and heavily iron stained. Deflation lags occur on non-vegetated surface exposures.

At higher elevations the outwash sediment becomes coarser grained and less sorted (Rogerson, 1977). Some littoral reworking and redistribution of outwash sediment has occurred on the terrace surfaces.

Mineralized Beach Sands

Mineralized beach sands are found both in low-elevation terraces (<10 m) and on the modern beach complex. The most extensive exposure of mineralized terraces occurs at Woody Point where three terraces were identified (Figure 5). The uppermost terrace (4 m above high tide) abuts outwash sands and is approximately 1 km long and between 25 and 30 m wide. The terrace, at 1.8 m above the high tide level, extends for approximately 5 km and is about 5 to 10 m wide. In many areas, only traces of the lowermost terrace (<0.5 m above high tide) have been preserved.

Two, well-developed mineralized terraces occur immediately north of Beaver Brook (Figure 5). The upper terrace is cut into glaciomarine muds and is approximately 1 km long and 28 m wide. The lower terrace is partially

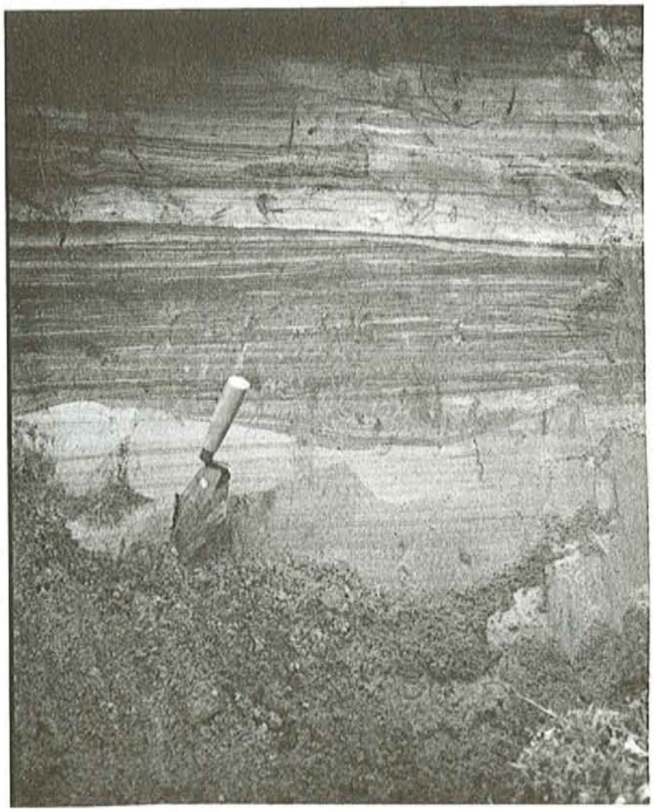

Plate 2. *Mineralized terrace sands.*

eroded. Low-elevation mineralized terraces (1 to 2 m above high tide level) also occur in some small brook outlets (Figure 5).

The terrace sands are generally composed of subhorizontal planar laminations—beds of light-coloured quartzofeldspathic minerals, alternating with dark-grey, well-sorted heavy mineral layers (Plate 2). The heavy mineral layers are typically 0.3 to 2.0 cm thick, although a 1-m-thick section of massive heavy mineral sands was encountered in a mineralized terrace, approximately 100 m north of Beaver Brook. Heavy mineral laminations/beds constitute from 30 to 80 percent of each terrace and have a slight decrease in occurrence with an increase in terrace elevation. The heavy mineral content in the laminations/beds ranges from 80 to 99 percent.

Mineralized sands occur within the supratidal zone of all modern beach tracts on the North Strand but are richest where mineralized terraces are present. Concentrations of heavy minerals are highest in the supratidal zone, at the base of eroding bluffs, and decrease substantially within the intertidal zone. The width of the supratidal zone varies from 10 to 40 m and the zone of mineralization appears to be less than 2 m thick.

The sedimentology of the modern beach sediments is similar to that of the raised terraces. Within the supratidal zone, subhorizontal planar bands of quartzofeldspathic minerals are interlaminated with well-sorted heavy mineral layers (Plate 3). Laminations are gently inclined and thin seaward, and crosscutting erosional surfaces are evident. Heavy mineral layers vary from 0.5 to 40 cm in thickness, and contain from 80 to 99 percent heavy minerals. At Beaver Brook, the heavy mineral assemblage consists of hematite,

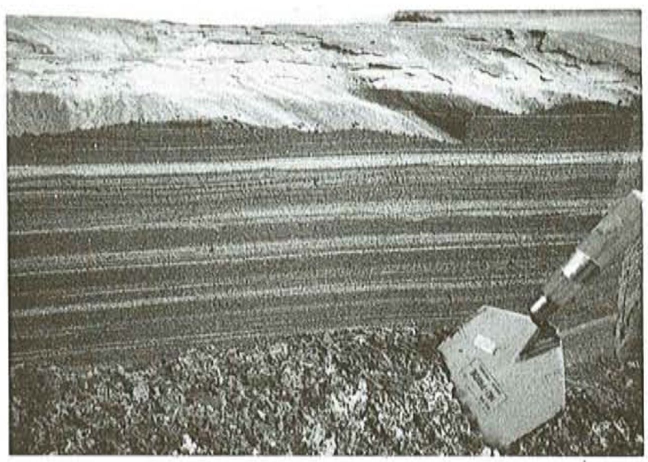

Plate 3. *Mineralized beach sands within the supratidal zone of the modern beach.*

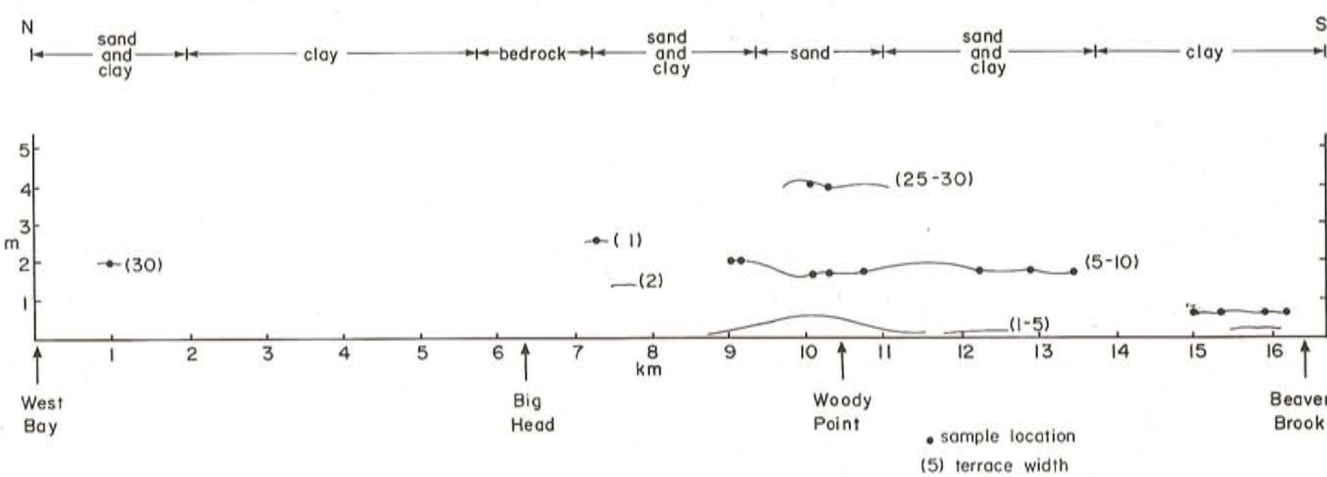

Figure 5. *Distribution of mineralized beach terraces on the North Strand.*

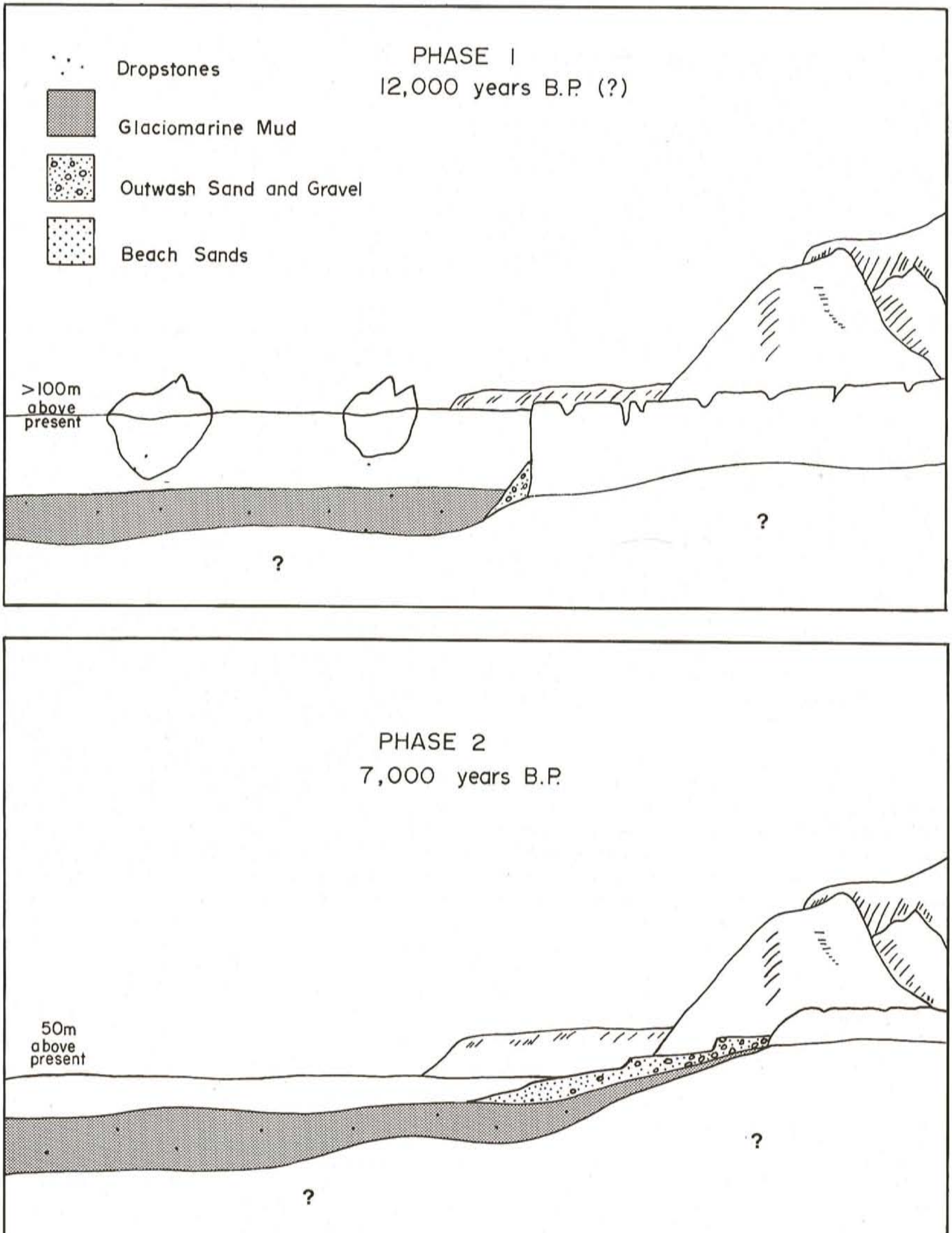

Figure 6. *Three-stage conceptual model depicting coastal evolution and placer formation.*

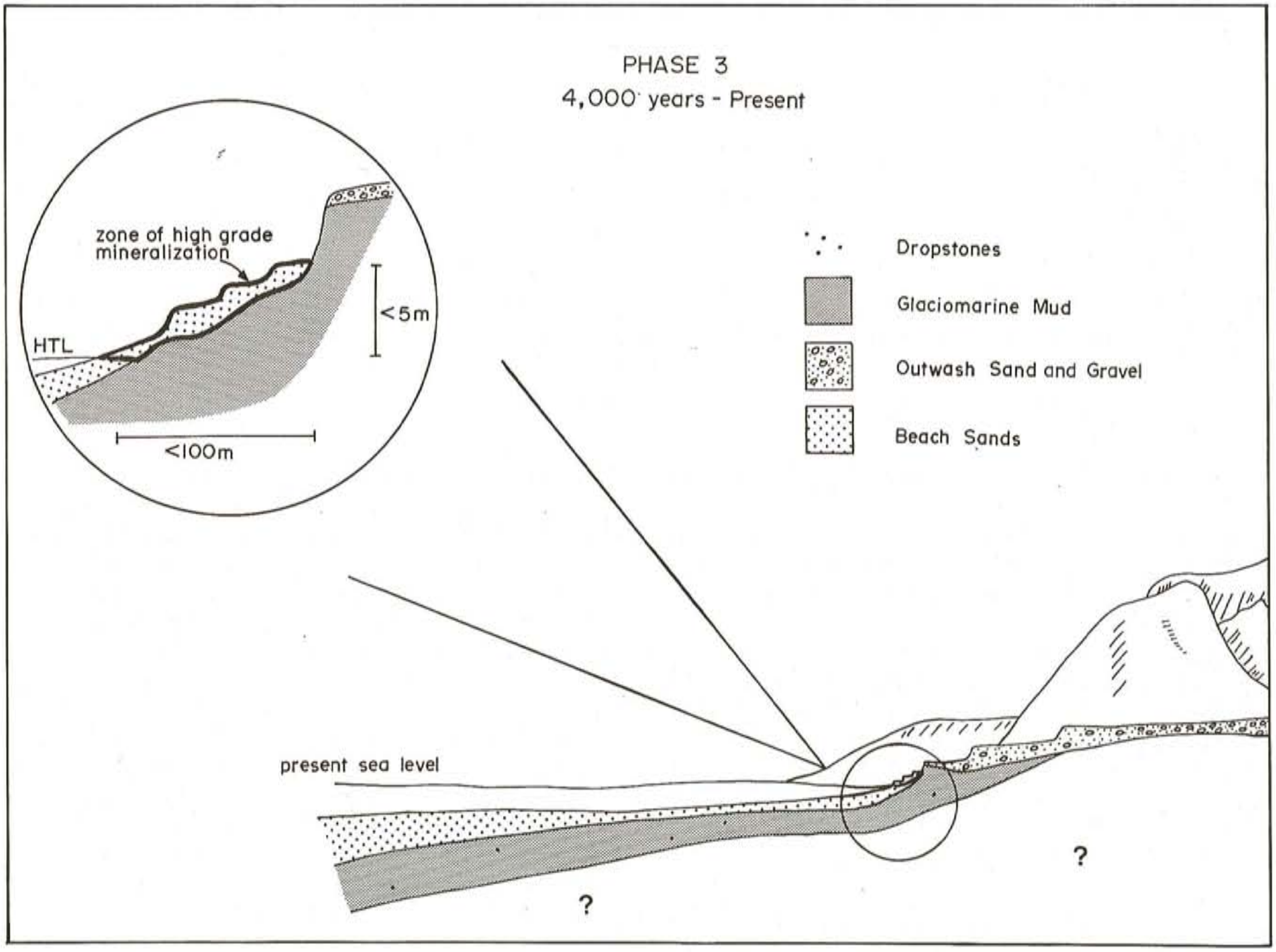

Figure 6. *(Continued).*

amphibole, garnet, magnetite and ilmenite (Mathieu and Boisclair, 1990), which are often found in mono-mineralic laminations. The overall TiO_2 content, determined from vertical channel samples through these sediments, ranges from 1.79 to 7.4 percent, with an average content of 4.6 percent, and total Fe content averages 30.4 percent.

The intertidal sediments exhibit well-defined mineral layering, with the heavy-mineral laminations comprising between 15 and 35 percent of the sampled sections. At Beaver Brook, the intertidal sediments are characterized by an average TiO_2 content of 0.79 percent and a total Fe content of 5.4 percent.

INTERPRETATION AND DISCUSSION

In an attempt to integrate the Quaternary geology of the North Strand, (as outlined by Rogerson, 1977) and the observed distribution of mineralized beach sands, a conceptual model depicting coastal evolution and placer formation is proposed (Figure 6).

Phase 1

At some time during the late Wisconsinan ice recession, (possibly around 12,000 BP; Rogerson, 1977) the ice margin remained stationary for an extended period of time near the present coastal limits. The marine limit was greater than 60 m above present sea level and a thick sequence of glaciomarine mud was deposited. The occurrence of dropstones in the glaciomarine muds suggests that icebergs were present, perhaps calving off the face of a tidewater glacier.

Phase 2

As ice began to recede, substantial volumes of sediment-laden meltwater issued from the front of the ice margin. Sands and gravels were deposited in a large outwash complex that prograded over the glaciomarine mud. The seaward margin of the outwash was deposited within a subaqueous deltaic environment, the stratigraphy of which is revealed in the modern coastal bluffs. During the constructional phases of outwash deposition, relative sea level was dropping at a very

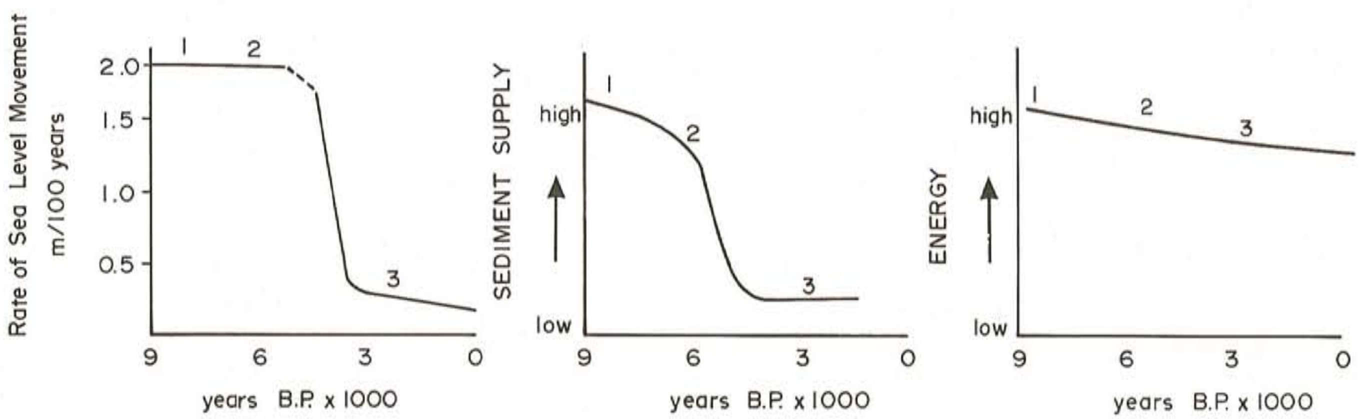

Figure 7. *Temporal variations in the rate of sea-level movement, sediment supply and marine energy.*

rapid rate (1.2 to 2.4 m/100 years). A series of terraces were cut into the outwash sediment during emergence, perhaps as a result of sea-level stillstands or temporary reductions in sediment supply.

The outwash sands and gravels are clearly an important secondary store of heavy minerals but do not hold significant placer potential. Reworking of the outwash sands and gravels on high-elevation terrace surfaces does not appear to have enhanced the mineral potential, possible because of the rapid emergence and the coarse-grained nature of the sediment.

Phase 3

A major change occurred in the depositional setting of the North Strand approximately 5,000 years BP. Ice retreated from the area and meltwater no longer contributed high-sediment loads, the rate of emergence had slowed dramatically (by a factor of 10), and the emergence of rocky headlands resulted in the division of the coastline into discrete beach tracts (e.g., Big Head, Figure 1). As a result of these changes, a period of backshore bluff-cutting and placer formation began.

Mineralized beach terraces were most extensively developed where the coastal bluffs were composed of outwash sand and gravel (e.g., Woody Point). Beaches bordered by clay bluffs (e.g., Beaver Brook) received sands via longshore transport and the resultant terraces, whereas in some areas heavily mineralized, are volumetrically small. Preservation of mineralized terrace sequences is greatest within small embayments at the mouths of brooks and in the lee of offshore islands (e.g., Woody Point).

In summary, the upper non-mineralized terraces formed under conditions of a high-sediment supply (principally through glacial melt), high energy and rapid emergence. The lower elevation mineralized terraces were formed during a period of slow emergence, high energy and limited sediment supply (Figure 7). Clearly, the high energy and the slow rate of emergence on the North Strand have favoured recent placer development but perhaps the low-sediment budget has precluded more widespread mineralization. In some of the large placer districts of the world (e.g., Australia), a sustained supply of sediment is provided through longshore transport of material derived from rivers and/or coastal erosion. During the formation of mineralized terraces on the North Strand, the primary source to the beach complexes was, and continues to be, the erosion of coastal bluffs. Most of the bluffs are, however, dominated by glaciomarine mud (with the exception of Woody Point) and hence the supply of sediment is quite low. Furthermore, the occurrence of rock headlands at several sites along the North Strand constrains longshore sediment transport and perhaps prevents sediment bypassing between beach tracts. A finite volume of beach sediment has thus been continually 'processed' and upgraded, producing very high-grade placers, but of a limited extent.

The 'processing' or dynamics of mineral sorting, which generates the mono-mineralic layering evident in the supratidal sediments of the North Strand, is of considerable interest. It would appear that under storm and high swell conditions, the backshore sediments are eroded and the heavy minerals are selectively sorted through the process of differential grain entrainment. This type of sorting phenomena has been previously examined, (Komar, 1989) but rarely is such a high level of mineral enrichment attained.

ECONOMIC POTENTIAL

Sand samples from testpits in the supratidal and intertidal zones were collected in 1990 from the Beaver Brook area, and sent to CANMET for mineral separation and identification. A composite sample from the supratidal zone has the following concentrations: 27.7 percent hematite, 24.9 percent quartz, 17.1 percent amphibole,, 16.7 percent feldspar, 8.8 percent garnet, 3.9 percent magnetite, and 2.0 percent ilmenite (Mathieu and Boisclair, 1990). However, geochemical analyses of the composite sample was found to have an average TiO_2 content of 4.6 percent, suggesting that the TiO_2 is not entirely found in the free ilmenite. A preliminary investigation of polished thin sections, being carried out at Memorial University, has shown that the TiO_2 is bound in free ilmenite and as ilmenite intergrowths in hematite grains, (R. Patey, personnal communication, 1991).

Placer deposits similar to those of the north Strand have been mined in New Zealand, Philippines, China and Japan (Elsieev, 1980). Iron–titanium placers also occur on the south shore of Quebec, in a geological environment very similar to the north Strand (MacKenzie, 1912). The principal use of titaniferous ores (hard-rock and heavy mineral sands) is in the manufacture of titanium dioxide, a non-toxic, powdered white pigment used in paint, paper, plastics, rubber, and other filler and extender applications (Harben and Bates, 1990). In the manufacture of titanium dioxide, high-grade titaniferous feedstock, usually natural or synthetic rutile, or high-TiO_2 slag is used. One of the world's largest producers of titanium slag is Q.I.T.- Fer et Titane Inc., whose plant at Sorel, Quebec, produces TiO_2 slag from ilmenite ore mined at Lac Allard, Quebec. Q.I.T. is also looking at importing low-alkali ilmenite beach sand from their deposit in Madagascar, for the production of low-alkali slag. There may be opportunities for other producers of competitively priced titaniferous sands with suitable chemistry (i.e., <0.5 percent MgO, and <0.1 percent CaO) (Bergeron, 1990).

SUMMARY

The placer potential of the Porcupine Strand, in eastern Labrador, is being investigated through channel sampling and very shallow drilling. The economic value of these placer occurrences lies in the Fe and Ti content, with garnet sand being a possible economic co-product. Although geochemical results from the 1991 program are not yet available, the greatest potential appears to be in the modern and raised beach sands, where concentrations of heavy minerals are up to 80 percent. Results from the 1990 sampling program indicate that the TiO_2 content ranges up to 7.4 percent.

The coastal evolution and placer formation of the Porcupine Strand has been controlled by the rate of sediment supply and rate of coastal emergence. Initially (12,000 to 5,000 years BP), there was a high volume of sediment supply and rapid rate of emergence, conditions that were not conducive to placer formation. At approximately 5,000 years BP, sediment supply was greatly reduced, and the rate of emergence slowed dramatically, allowing for increased sorting of sediment, and thus placer formation. However, it has been a relatively finite volume of sediment that is continually being reworked, and the resulting placers, although of high grade, may be of limited extent.

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