PLACER PLATINUM-GROUP METALS OFFSHORE OF THE GOODNEWS BAY ULTRAMAFIC COMPLEX, SOUTHWEST ALASKA

by James C. Barker and Kathryn Lamal

with a section on mineralogy by C.L. Mardock

with a section on beneficiation by W.C. Hirt

**OFR 53-88

UNITED STATES DEPARTMENT OF THE INTERIOR

Donald P. Hodel, Secretary

BUREAU OF MINES

T S Ary, Director

CONTENTS

CONTENTS--Continued

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°C	degree Celsius
cm	centimeter
ft	feet
g	gram
in	inch
kg	kilogram
kHz	kilohertz
km	kilometer
lat	latitude
lb	pound
lb/yd^3	pounds per cubic yard
long	longitude
m	meters
mg	milligrams
mg/yd^3	milligrams per cubic yard
mi	miles
min	minute
mm	millileter
mph	miles per hour
oz	ounce
pct	percent
ppm	parts per million
psi	pounds per in^2
sp gr	specific gravity
sec	second
t	ton
t oz	troy ounce
um	micron, micrometer
yr	year

PLACER PLATINUM-GROUP METALS OFFSHORE OF THE GOODNEWS BAY ULTRAMAFIC COMPLEX, SOUTHWEST ALASKA

By James C. Barker[1] and Kathryn Lamal[2]

with a section on mineralogy by C. L. Mardock[3], and a section on beneficiation by W. C. Hirt[4]

ABSTRACT

In 1981 and 1985-1986, the Bureau of Mines conducted orientation studies of marine placer platinum-group metals (PGM). PGM are derived from the Goodnews Bay ultramafic complex and magnetic surveys show that the complex extends offshore at least four mi. The present seafloor was an emergent foreland as recently as 8000 years ago. High-energy ocean processes are transporting and depositing sediment such that PGM-bearing materials are reworked and later masked by barren littoral drift.

Exploration targets include 1) placers formed since present transgression began, and 2) ancient marine and drowned fluvial deposits. Additionally, there is evidence of PGM solution transport and accretion. At least minor values of PGM in Recent lag-type placers and possible submarine strands are concentrated along an offshore scarp incised through glacial deposits into the preglacial surface between Flat Cape and Red Mountain. Other Recent PGM-bearing features include Flat Cape shoal, Chagvan Bay, Salmon River delta, and modern beaches. Ancient placers include possible N-S fluvial systems 2 to 3 mi offshore, a nearshore scarp 50 ft below sea level, and strands adjacent to projected ultramafic bedrock slopes. The existance of ancient placers is dependent on depth of glacial erosion.

---

[1] Supervisory Physical Scientist, Alaska Field Operation Center, Fairbanks, AK.
[2] Geologist, Alaska Field Operation Center, Fairbanks, AK.
[3] Mineralogist, Albany Research Center, Albany, OR.
[4] Chemical Engineer, Salt Lake City Research Center, Salt Lake City, UT.

SEM studies show PGM are principally isoferroplatinum and osmiridium, with minor sperrylite, moncheite, and platiniridium. Gold is a co-product, and concentrates comprise chromite, ilmenite, and magnetite. Beneficiation tests successfully concentrated precious metals from natural blacksand accumulations, but failed to concentrate low-grade lag gravels.

INTRODUCTION

As part of an on-going assessment of strategic and critical minerals in Alaska, the Bureau of Mines investigated marine placer deposits near the village of Platinum in southwest Alaska (fig. 1). The village is named for the nearby Salmon River platinum mine and serves as the logistical center for the region. Platinum group metals (PGM) were first mined from placer deposits in the Salmon River drainage in 1926 when platinum grains were identified in creeks draining the Goodnews Bay ultramafic complex at Red Mountain 5 mi south of Platinum village. Over the subsequent years more than 650,000 t oz

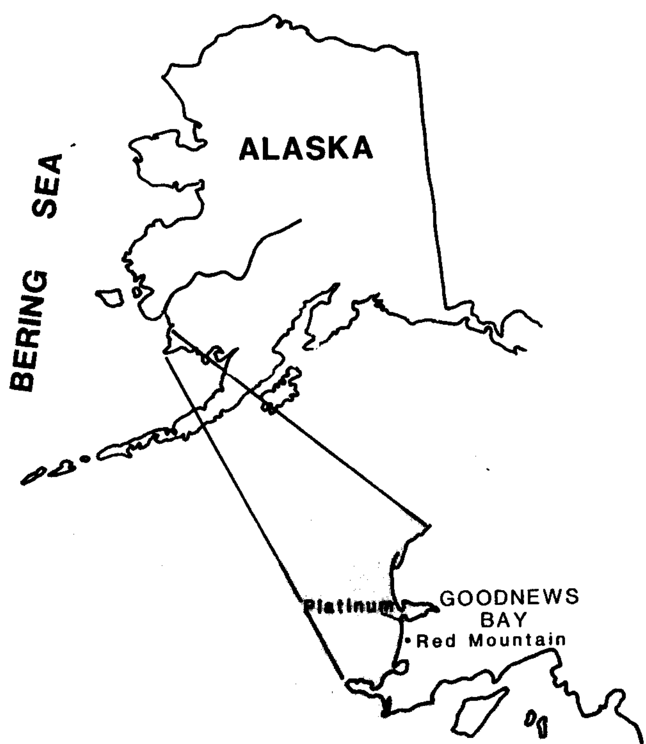


FIGURE 1. - Index map showing project area in southwest Alaska.

of PGM have been recovered by dragline and bucket-line dredge operations along the Salmon River (1-3).[5]

---

[5]Numbers in parentheses refer to items in the list of references at the end of this report.

It has long been suspected that placer PGM are concentrated in sediments in Goodnews Bay or offshore in the Bering Sea, west of Red Mountain. Page and others (4) cite identified PGM resources of 5 million t oz contained in offshore deposits near Red Mountain and vicinity: estimates based on limited field studies (5)[6] and on geologic inferrence to deposits elsewhere. At the time of this report, however, no viable deposits have been delineated. Foreland and offshore

---

[6]The U.S. Geol. Surv. performed reconnaissance level offshore studies in 1969. A report of their findings is being prepared concurrently with this report, and includes a more complete listing of references to the Goodnews Bay region (Barnes, Tagg, and Coonrad [in press]).

---

exploration by industry since the 1930s have been inconclusive, and most analytical data from these activities are not available (6). The most recent exploration took place in the early 1970s and there are reports that some drilling was undertaken. Exploration by Inlet Oil Corp. may have revealed recoverable concentrations of fine-grained platinum in sediments at a site offshore of Red Mountain (7), but no specific location is given and analytical tecniques at the time lacked the accuracy now available. Concurrently with the exploration by Inlet Oil, a series of academic studies under the auspices of Dr. J. R. Moore, University of Texas, Austin, focused on marine sediment transport, sedimentology, and trace element distribution in fine-grained sediments in the vicinity of Red Mountain (7-12). The results of those studies, particularly the sampling and magnetometer work by Bond (11) and Ulrich (12) provided direction for the 1981 starting point for investigations by the Bureau of Mines.

Part of the Bureau's program in Alaska, including the Exclusive Economic Zone (EEZ), is to appraise sub-economic and unconventional mineral resources, particularly those containing strategic and critical commodities, and to encourage their exploration and development by industry. Bureau investigations of chromium and PGM in the vicinity of Platinum, Alaska, are divided into two parts. The first was a study of the lode PGM in the Goodnews Bay ultramafic complex which is the source rock for placer PGM in the area (2-3); the report describes geologic investigations and includes assay results of approximately 1,000 churn drill holes by the Goodnews Bay Mining Co. in the Salmon River valley. The second part, which is the subject of this report, is an orientation-type reconnaissance of marine placer exploration targets and tests of various assessment techniques. The area investigated in this study includes the foreland, beach, and seafloor as far as four miles offshore. The offshore investigation included a magnetometer survey, low frequency acoustic profiling, bathymetric and geologic mapping, heavy mineral sampling, and mineralogical and beneficiation studies.

It is not the objective of the Bureau to make the actual discoveries of ore deposits but rather to investigate known occurences. Neither of the two parts of the Bureau's work were intended to, nor funded at a level needed to delineate a deposit or tonnage reserve. This was an orientation study only. It was also not possible to provide full areal coverage of the prospective favorable geologic units at this level of investigation. Although occurrences of PGM and gold were documented during the course of these orientation investigations, no discoveries of mineable or even sub-economic deposits were found.

ACKNOWLEDGMENTS

Several individuals provided helpful advice and support during the course of this investigation. Dr. J. Robert Moore, Professor, University of Texas, Austin, was a continuous source of assistance and encouragement since 1979. Helpful discussion, data, and manuscript review were provided by Mr. Steve Bond, former graduate student at the University of Texas, Austin. Manuscript review was also performed by Dr. Warren Coonrad, Geologist, U.S. Geological Survey. Technical advice, computer programing, and field assistance were given by Dr. Sathy Naidu, Professor, and his assistants John Smithisler and Dave Foster, Institute of Marine Science (IMS), University of Alaska, Fairbanks. During 1985 field studies, IMS and the Bureau jointly participated in cooperation with the French ocean institute, IFREMER (Institut Francais de Recherche pour l'Exploition de la Mer), which provided the vessel K-Way. Work in 1986 was partially supported by the Bureau's Salt Lake City Research Laboratory, Ocean Minerals Group.

Messrs. Dennis Southworth and Jeff Foley, authors of the companion report describing the Bureau's onshore work, contributed most helpful advice and field assistance toward understanding the offshore resource potential.

METHODS

Field studies were conducted during portions of the 1981 and 1985-1986 seasons, and were variously based onshore from the camp of the Goodnews Bay Mining Co., from facilities at the village of Platinum, and from a tent camp located above the beach in a semi-sheltered ravine south of Cabin Creek (fig. 2). Access along the shoreline for sampling, auger drilling, and geological mapping was gained by 4-wheel ATVs.

Limited work offshore was undertaken using motorized inflatable rafts that were launched, weather permitting, through the surf at the tent camp site. Seafloor mapping and underwater observation were done with use of SCUBA equipment.

Most offshore surveys were conducted from shallow draft vessels that provided living quarters as well as work area. In 1985, the French research vessel K-Way was used, and in 1986, the Fat Emma was contracted out of Dillingham, AK. It should be noted for the benefit of future investigations in the area, that support vessels must have shallow draft, preferrably no more than four feet, and be suitable for work during periods of prolonged foul weather. The lee of the South Spit of Goodnews Bay offers excellent anchorage and access to telephone and supplies at the village. Sheltered anchorage is also available

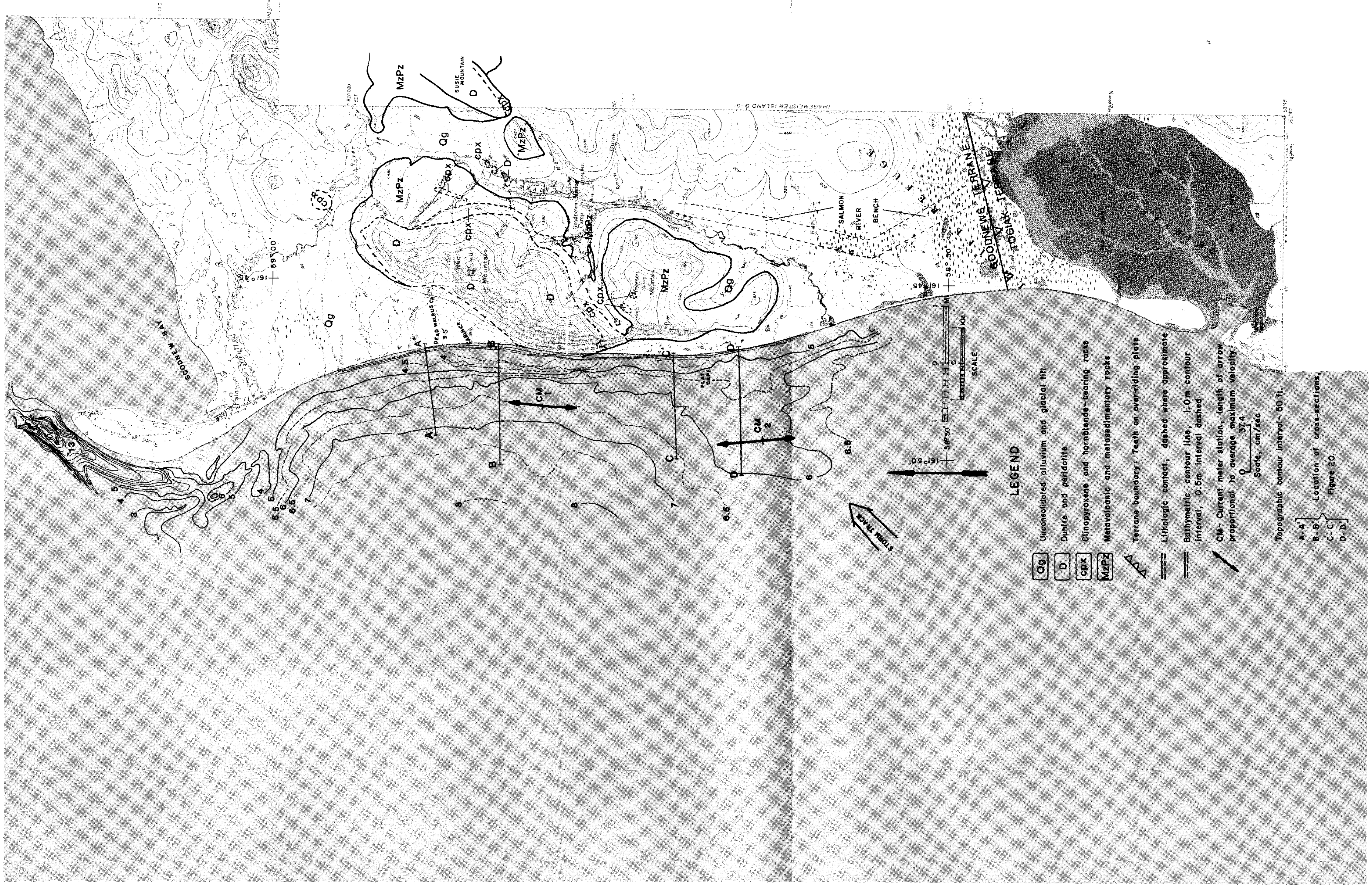


FIGURE 2. - Offshore bathymetry and current meter stations with onshore topography and regional geology.

along the south side of Chagvan Bay, however the entrance into the bay is difficult to negotiate. Personnel working offshore must constantly be aware of the strong longshore currents that affect navigation, positioning, and underwater activities, and the incidence of sudden storms.

NAVIGATION

All sample sites and data recordings were located by latitude and longitude using Loran-C navigation (King Marine 8001 Loran-C Receiver)[7] with multi-position waypoint memory and instantaneous position printout (King Marine 1060) capacity. Positions were located to the nearest 0.01 minute. During geophysical survey transects, the general course was held by predetermined waypoints and verified by radar. Positioning was recorded simultaneously with data collection. Position and geophysical data were later correlated by computer.

---

[7]Use of trade and manufacturer names in this report does not constitute endorsement by the Bureau of Mines.

BATHYMETRY

Previously available bathymetry, except for the entrance to Goodnews Bay, was limited to widely (approximately 1,000 ft) spaced soundings most of which were located further offshore than the area under investigation. For this project, bathymetric data was compiled for the area between the entrance of Goodnews Bay and the mouth of the Salmon River and extended offshore for about 3 to 4 mi (6.5 km; fig. 2). Soundings were profiled along survey lines with a chart recording depth finder (King Marine 1060) and a location was fixed every 20 sec according to the above description. Tidal variation corrections were simultaneously recorded at a pre-established tide gauge station located on the seafloor at current meter station CM-1. The gauge (Aandera WLR-5) had a pressure range of 0 to 400 psi with a resolution of 0.001 % at full scale. Tide gauge readings were automatically recorded every 15 min for five days while surveys were being conducted, and the stored data computerized with the depth soundings to correct to mean low tide. A maximum tide range of 8.43 ft (2.57 m) was recorded. Data were plotted by computer and manually contoured using 1.64 ft (0.5 m) contour intervals.

CURRENT METER STATIONS

Current meter data were collected at two stations, both of which were several miles from Red Mountain (fig. 2). The stations were located to determine the differential in longshore currents between those that flow across the top of the Flat Cape shoal and those across a deeper, presumably depositional area 3.9 mi (6.32 km) to the north. Data were collected only for the period of August 1-7, 1985, and are presented on figure 2 as vectors representing the average northerly and southerly components. The approximately opposite directed vectors reflect the periodic reversal of longshore currents due to the reversing tidal current. The magnitude and differential velocity between the stations were calculated and are discussed and compared in the Interpretation section.

Current meters (Aandera RCM-4) were anchored approximately 3 ft (1 m) off of the seafloor and have a specified accuracy of $\pm 5^{\circ}$ at velocities of 2 to 39 in (5 to 100 cm)/sec. Readings were taken every 15 min and stored internally on magnetic tape.

MAGNETICS

An offshore total field magnetometer survey was conducted to determine the extent, if any, of the Goodnews Bay ultramafic complex under the seafloor. Due to the magnetic signature of the magnetite-bearing ultramafic complex, areas underlain by these rocks can generally be distinquished from areas underlain by nonmagnetic country rock.

The magnetic survey includes offshore transects and several onshore lines (fig. 3) that tie the survey to the known outcrop of the ultramafic complex (fig. 2). The offshore survey was conducted along lines parallel to the coast and spaced about 0.25 mi (405 m) apart. Magnetic data points were simultaneously located by latitude and longitude as previously described. To avoid magnetic interference from the vessel, the sensor unit (EDA Omnimag PPM 350) was mounted on a 4-ft (1.3-m)- vertical staff and towed 150 ft (46 m) behind in a nonmagnetic inflatable raft (fig. 4). A correction for this 150-ft-distance was made prior to plotting the data. The survey was conducted at a speed of about 2 to 3 knots (2.3 to 3.5 mph). The onshore data were collected with the same instrument mounted on a 10-ft (3.3-m)-vertical staff and positions were located on existing 1:63,360 scale topographic maps by hip chain and compass measurement from known map points. During all data collection, a self-recording base station (EDA Omnimag PPM 400) was established onshore to monitor diurnal magnetic variation which did not exceed 10 gamma during the survey. Both the field and base station data were recorded automatically and a field computer (EDA DCU 400 thermal printer) was used to correlate the two sensors and provide printouts of the corrected data. The corrected data for each line was then profiled.[8]

---

[8]Corrected magnetic field data and profiles are available upon request from U.S. Bu Mines, 206 O'Neill Bldg., Fairbanks, AK 99775.

Following the survey, magnetic and location data were computerized and gradients of 250 gamma above and below the determined mean value (53,162 gamma) of the entire data set were determined. The data set was plotted by computer and manually contoured at these gradients. Results are discussed in the Interpretation section.

LOW-FREQUENCY ACOUSTICS

Simultaneous with the collection of the magnetometer data, seafloor profiling was done with a transceiver using a low frequency transducer operating at 7 kHz (Raytheon RTT-1000A). The objective was to ascertain the extent of loose, high-energy sand and fine gravel

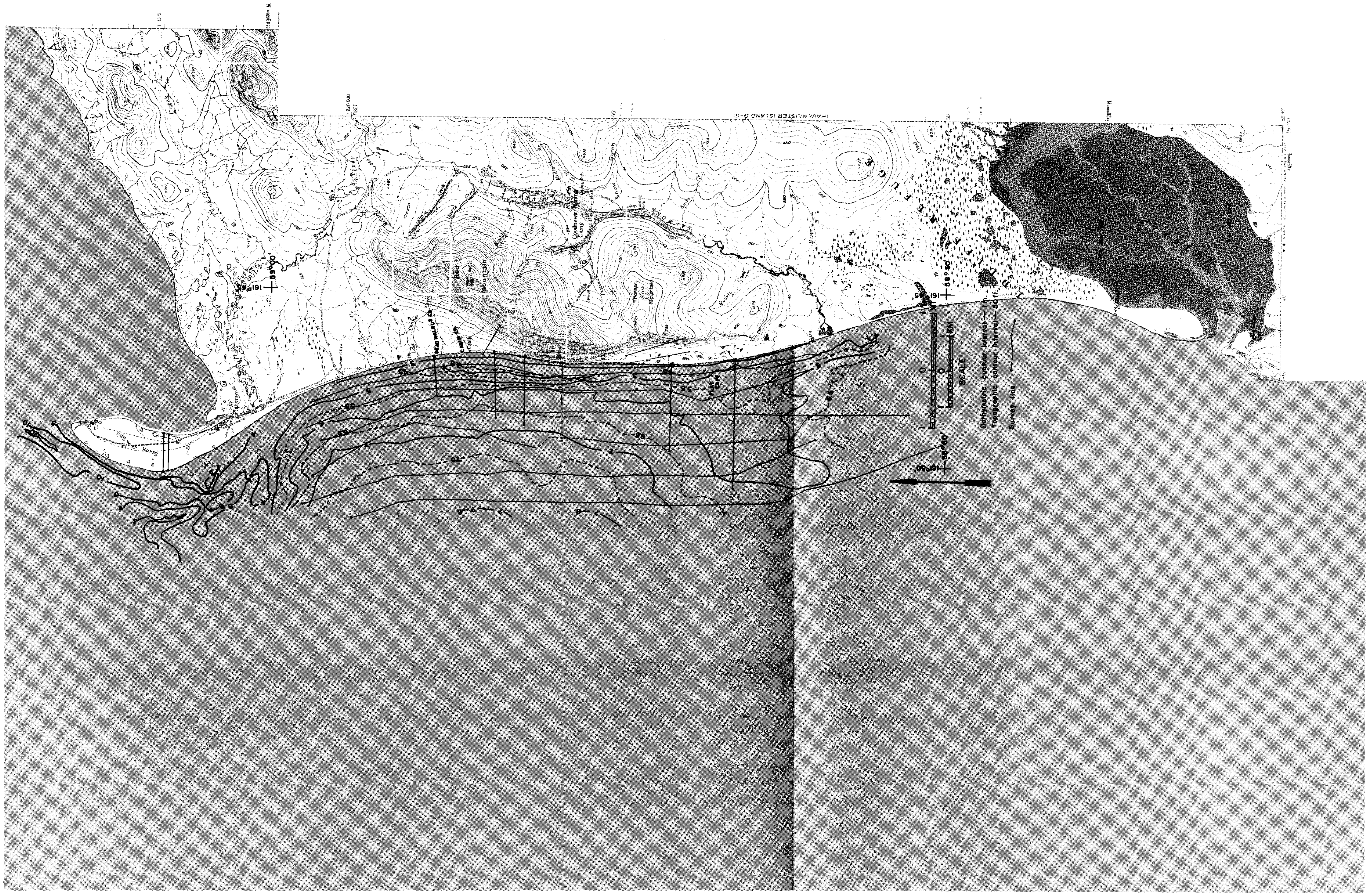


FIGURE 3. - Map showing location of offshore survey lines.

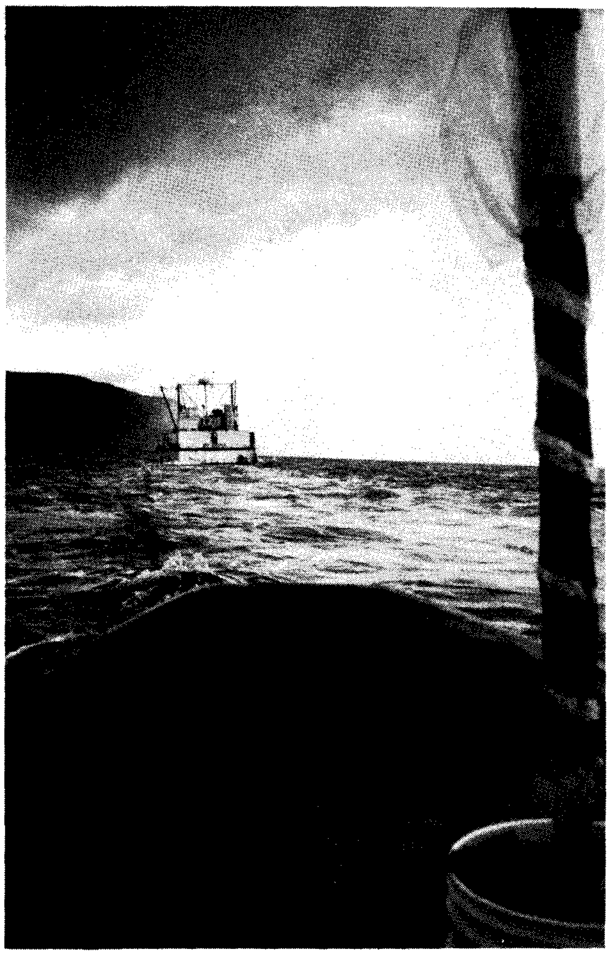


FIGURE 4. - Total magnetic field sensor unit on staff being towed in nonmagnetic raft on trackline parallel to shore. Red Mountain can be seen in distance.

deposits. Data were collected on chart strips and visually interpreted. Occurrences of multiple reflectors were spot checked by visual examination of the seafloor by divers. Isopachs of sediment depth to the second reflector were constructed from the data and plotted at contour intervals of 3.28 ft (1 m) (see discussion in Interpretation section).

MAPPING, SAMPLING, AND AUGER DRILLING

Unconsolidated sediments forming the coastal bluffs, beaches, and seafloor were sampled (fig. 5) and mapped. Sediments were classified according to their origin, lithology, and mode of transport. Aerial photography used to assist interpretation and included high-altitude

FIGURE 5. - Sample location map.

false-color photos flown in July, 1980.[9] Geologic cross-sections were prepared where sufficient information was available. Sampling was not

[9]Available from Alaska Photo Lab, Univ. of AK, Geophysical Inst.

confined to only areas or features estimated to contain PGM, but also included barren geologic features pertinent to the interpretation of the study area.

Several procedures were used to collect samples. Onshore, sediments were directly shoveled into buckets from the selected feature and weighed. Attempts to collect offshore samples using standard grab sample devices (Van Veen and Shipex samplers) had limited success due to (1) the limited amount of sediment obtained from each drop and (2) the problem of pebbles invariably jamming the devices partially open, resulting in loss of fine sediment while the device was being hoisted from the bottom. Sample values noted in appendix A as having been collected with Van Veen or Shipex samplers, should be considered as minimum values. Most seafloor samples were collected by shoveling into buckets while using SCUBA. Seafloor features and depth from which the samples were collected were also noted during the course of sampling.

Shallow auger drilling was performed at several beach sites (fig. x6). A portable auger, using 1.75-in (4.4 cm)-diameter auger flights, and powered with a chainsaw engine, was used. The auger stem required a tripod to remove it from the drill hole to recover the cuttings. Due to the clay content of the sediments, the holes generally

FIGURE 6. - Auger drillsite located on magnetic anomaly about 0.7 mi south of Cabin Creek (sample no. 77). West slope of Red Mountain is in right background, Bering Sea to left.

remained open so that drilling could be resumed. Holes were drilled to depths of 4 to 18 ft (1.3 to 5.5 m) and samples were collected from several intervals.

SAMPLE PROCESSING AND ANALYTICAL PROCEDURES

Samples generally consisted of 50 to 200 lbs (23 to 90 kg) of material prior to screening in the field. Site descriptions and other details are listed in appendixes A and B. Samples were screened at 20-mesh and the oversize fraction was examined, described, and split for sample archival. The undersize fraction was tabled to recover the heavy mineral fraction and table tailings were further processed by flotation using a precious metal, xanthate collector. Splits of the minus 20-mesh tailings were also retained for archival. The heavy mineral table concentrate was panned by hand to attempt recovery of native PGM and gold in a final pan concentrate of 0.066 lb (30 g) or less. Pan concentrates were examined under a binocular microscope and selected grains were removed for mineralogical characterization. Grains thus removed were later recombined prior to fire-assay analysis unless otherwise indicated.

Concentrates from the flotation cell and the pan concentrates were weighed and preconcentrated by fire-assay (1 assay-ton unit) using a nickel sulfide collector before platinum and gold analysis by direct coupled plasma (DCP).[10] In this manner, the entire recoverable platinum and gold concentrate from the original sediment sample was

---

[10]Analyses by Nuclear Activation Services, Inc., Ann Arbor, MI.

---

analyzed and the results reported in milligrams of metal present, provided no losses occurred during sample reduction. The foregoing procedure attempts to minimize the wide variance inherent to sampling material with random, particulate, high-value metal grains.

All particulate PGM and gold could not be completely recovered by panning and some remained in the residual heavy mineral fraction. Therefore, a 0.066-lb (30-g)-split of the heavy mineral fraction was analyzed for platinum by fire-assay followed by atomic absorption procedure, and for gold by direct irradiation on a fire-assay bead.[11] For samples in which platinum and gold were detected, these

---

[11]Analyses by Bondar-Clegg, Inc., Lakewood, CO.

---

values were included in the cumulative final assay value of the original sample site by dividing the analytical value (in ppm) by one million and multiplying by the weight (in milligrams) of the heavy mineral fraction recovered by tabling.

Placer deposits near Red Mountain, if present in the marine environment, may additionally contain by-product amounts of chromite, ilmenite, and magnetite. Analyses by X-ray fluorescence techniques for Cr, Ti, and Fe were performed and reported as weight percent of the heavy mineral fraction.

Volumetric weight tests of wet sediment were made in the field. Subsequently it was determined that a yd^3 of typical seafloor sediment weighs approximately 3,700 lbs (1,680 kg). This weight was used to determine the estimated assay value per yd^3 by dividing 3,700 lb by the weight of the original sample and multiplying the result by the cumulative assay total of recovered metal weights (presented in milligrams/yd^3 for platinum and gold in appendixes A and B).

MINERALOGICAL PROCEDURES

Concentrates from 16 sample sites were examined by binocular microscope for color, reflectivity, hardness, structure, inclusions, size, and alteration products. Grains were selected for further study and mounted on stubs. These specimens were coated with carbon in a vacuum evaporator, and examined in an AMA 1000 with a Kevex 8005 energy dispersive X-ray (EDX) spectrometry system, equipped with a scanning electron microscope (SEM), and run at 20 kv working voltage to facilitate excitation of PGM. Examinations were done in the backscatter mode to simplify contrast between mineral phases by utilizing brightness, which is a function of atomic weight. The attainable resolution is less than 100 angstrom and Polaroid photographs were made to record the images.

Semiquantitative analyses of elements above atomic number 10 were done by EDX spectrometry. Because the grains were whole and presented a rounded surface for analysis, a certain amount of analytical error is introduced due to angular discrepancy and working distance variations. An attempt was made to analyze large enough (or numerous enough) spots to neutralize this error. Also, X-ray scans display shadowed areas as a result of the grain shape. It is also difficult in the EDX system to totally discriminate between some overlapping PGM signals and between platinum and gold. However, careful standard-based, gaussian deconvolutions were done on each grain analyzed; and the error was kept within 2 % reliability. Furthermore, during analysis of high platinum alloys, the platinum peak apparently overlaps into the gold peak zone enough to exceed the software's ability to delineate emission lines. A gold content of 2- to 5-weight-pct was consistently recorded during analyses of isoferroplatinum, but was discounted as probable analytical error.

BENEFICIATION TESTING

Three bulk samples were tested for gold and platinum recovery using gravity and flotation procedures. Samples were collected as previously discussed; note sample C is a composite from six sites over the Flat Cape shoal (fig. 7). Field screening was done at 8-mesh to remove cobbles and gravel and the undersize fraction was shipped in plastic drums to the laboratory. Care was taken to include all of the slimes with the undersize for processing.

In the laboratory, samples A and B were split into bulk and representative samples and each of these four samples was wet screened at 28-mesh. The plus 28- and minus 28-mesh fractions were run over the laboratory shaking table (Deister Super Duty Diagonal Deck Concentrating Table) to produce black sand concentrates (mostly chromite and magnetite) and tailings composed mostly of silicates (quartz, albite, diopside).

The table concentrates were panned to produce platinum and gold concentrates. One table concentrate was also amalgamated. Table tailings and concentrates (if present in sufficient amounts) were also processed through a 10,000 g Galigher flotation machine to recover fine native metals which escaped gravity concentration. The flotation reagents used were 0.029 to 0.133 lb/st each of potassium amyl xanthate and Aerofloat 208 as collectors and 0.0015 to 0.0066 lb/st Aerofroth 65 and 0.0045 to 0.0198 lb/st MIBC as frothers.

In the case of the plus 28-mesh of sample A, a hand magnet and a laboratory magnetic sparator were used to attempt to produce high-grade iron and chromium concentrates from the table concentrate.

Sample C was first screened at 10-mesh and then separated into a heavy-mineral and a light-mineral fraction using a Humphrey spiral. Each fraction was then wet screened at 28- and 150-mesh using a Sweco shaking screen.

The plus 150-mesh fractions were treated on shaking tables in a rougher-cleaner circuit to produce heavy mineral concentrates, the higher grade cuts of which were hand panned to a final concentrate. Gravity tailings from the 28- by 150-mesh fraction and the minus 150-mesh slimes were similarly treated as above in laboratory-scale flotation cells (Denver and Agitair). The 10- by 28-mesh fraction was not treated by flotation because it could not be adequately suspended (agitated) in the float cells.

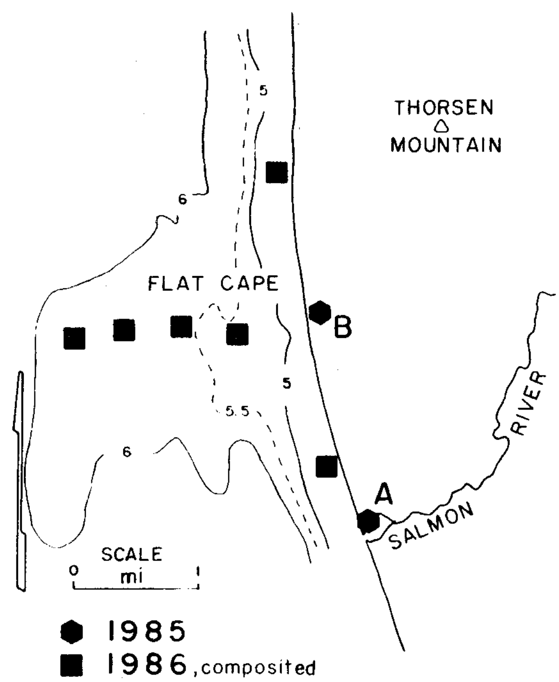


FIGURE 7. - Beneficiation sample location map.

GEOLOGY

GEOLOGICAL SETTING

Country rock in the vicinity of Goodnews Bay consists of Paleozoic and Mesozoic volcanic and sedimentary rocks which have been intruded by ultramafic rocks. Jones and others (14) divided the area into two tectonostratigraphic terranes; the Togiak terrane and the Goodnews terrane (fig.2). These terranes were divided into component subterranes by Box (15-16). The Togiak terrane is a structurally complex assemblage of volcanic and volcaniclastic rocks intercalated with chert, and ranges in age from Late Triassic through Early Cretaceous. The Goodnews terrane which includes the MzPz unit of Hoare and Coonrad (17), consists of pillow basalt, chert, limestone, blueschist, and greywacke, and ultramafic rocks. These rocks range in age from early Paleozoic to Early Cretaceous.

The Goodnews terrane is interpreted by Box (16) to have been structurally emplaced against and beneath the northwestern edge of the Togiak terrane during Mesozoic crustal shortening along an active southeast dipping subduction zone. After consequent accretion, the Goodnews terrane was intruded by ultramafic rocks called the Goodnews Bay ultramafic complex. Box (16) suggests the present configuration of the terranes is the result of Late Cretaceous right-lateral faulting along northeast trending faults including the Iditarod-Nixon Fork, and the Susalatna lineaments (16).

GOODNEWS BAY ULTRAMAFIC COMPLEX

Rocks of the Goodnews Bay ultramafic complex are exposed at Red and Susie Mountains. In addition, small bodies of intrusive rocks are found in the valleys of the Smalls and Salmon Rivers (2-3). There is an intrusive contact zone and country rock has been amphibolized up to 200 ft from the ultramafic contact.

The ultramafic rocks of the Goodnews complex are divided into mappable units based on their relative content of olivine, clinopyroxene, magnetite, and horneblende (3). Dunite, which is partially serpentinized, comprises more than 80 % of the ultramafic body. Ulrich (12) suggests two generations of serpentinization; the first related to late-stage hydrothermal activity, and the second related to near-surface H_2O-CO_2-olivine reactions. Wehrlite has been mapped discontinuously adjacent to the dunite core. Outwards from the dunite, olivine content decreases and magnetite and hornblende increase. As a result, lithology gradually changes from clinopyroxenite to hornblende clinopyroxenite to hornblendite. This concentric zonation is similar to complexes in southeast Alaska, British Columbia, and the Urals in the U.S.S.R. Where it can be mapped, there is an intrusive contact zone.

Minor amounts of Fe-Cu- and Fe-Ni-sulfide minerals were found along the southern margin of the Goodnews Bay ultramafic complex. In addition, accessory grains and rare pods of chromite are disseminated through out the dunite, and magnetite is a minor constituent. PGM display a chemical affinity for chromite and magnetite (6, 12, 18-19), and microscopic PGM mineral grains were observed in several cases during petrographic studies (12-13).

The ultramafic rocks occur in elongate northeast-trending lobes (2). Interpretation of gravity and magnetic data suggests that the Smalls and Salmon Rivers exposures, and the Red and Susie Mountain masses, are parts of the same larger convoluted ultramafic sill-like mass which is repeatedly exposed by one or more N-S folds or faults, and elsewhere covered by a thin veneer of country rock and surficial sediment (2-3).

LATE TERTIARY - PLEISTOCENE GEOLOGY

The area offshore from Red Mountain has experienced a complex history of sea transgression and regression cycles that have periodically inundated an extensive, low relief, coastal plain extending at least tens of miles to the west. Earlier strand lines were further west than the present coastline, and are now drowned. According to Hopkins (20), much of the region of the Bering Sea was above sea level throughout most of the middle and late Tertiary. Sometime during the Late Pliocene or the Early Pleistocene, the Bering-Chukchi Platform was lowered with respect to sea level and inundated, thereby drowning preexisting alluvial valleys. Subsequently, scarp platforms were locally cut into the bedrock that now lies below present sea level. Aerial photography suggests as ancient wave-cut scarp along the base of the ridge east of Flat Cape that is now covered by till deposits. Further suggestion of a buried scarp is indicated by results of drilling on the foreland in 1938 (6) which showed bedrock to be relatively flat and 40 to 50 ft (12 to 15 m) below sea level at the very base of the steep bedrock slope near lat 58° 55.' The inferred scarp can be projected south-southeast toward the confluence of Happy Creek and Salmon River.

During the Pleistocene, sea regressions coincided with glacial advances, intermittently exposing the broad coastal plain. Corresponding interglacial rises in sea level, however, do not appear to have attained the present-day level. There is no known evidence of marine deposits in or above the glacial and glaciofluvial accumulations onshore or in the coastal bluffs near Red Mountain. The entire offshore area of this investigation was a foreland prior to transgression of the sea that began with conclusion of the last glacial epoch and has continued through approximately the last 10,000 yr. Transgression is still actively occurring as evidenced by continuing encroachment of the surf against the bluffs. As much as one half meter of shoreline retreat per year is cited (21) and is evident in the field.

GLACIATION

The area around Red Mountain was glaciated by at least four glacial advances, ranging back in age from 8,910 $\pm$ 110 yr to greater than 45,000 yr, possibly even late Tertiary in age (21). Although the main portion of the Salmon River valley escaped glaciation, major WSW-trending glaciers advanced along the ancestral Goodnews River and along the Unaluk and Kinegnak Rivers into Chagvan Bay (21). Glacial till and glaciofluvial outwash sediment from the younger glacial events, Unaluk and Chagvan advances, are well exposed in bluffs both north and south of Red Mountain. Till deposits are characteristically fine-grained and there are few cobbles and boulders which are usually associated with high-energy, high-gradient glaciation.

It is unclear how far glaciation may have extended southward along the western, seaward side of Red Mountain and to what extent the ice disrupted the preglacial surface. Porter (21) and Mertie (1) both suggested ice encroached upon the western flank of Red Mountain. Mertie (1) suggested that glacial scouring removed placers that had most likely formed on the west and northwest sides of Red Mountain. Several small cirques are preserved on the northern end of the Red Mountain ridge crest, and Mertie (1) reported finding glacial erratics as high as 825 ft (250 m), apparently the result of a large lobe of glacial ice that widened over the area now occupied by Goodnews Bay. There is evidence of lateral moraine features oriented ENE on the foreland above the mouth of Last Chance Creek that would align with ice contact at the northern tip of the ridge, suggesting that ice movement diverged away from the central western mass of the mountain (fig. 8).

Although glaciers have advanced to the margin of Red Mountain, the principal course and focus of erosional energy of major ice movements was aligned WSW with the axis of present Goodnews Bay. The western slope and offshore area from Red Mountain are oblique to this direction of thrust and therefore would not be as directly affected. Other than glacial erratics on the northern-most end of the Red Mountain ridge, no additional erratics or till deposits were noted in contact with the western slope of the mountain. Sediment in bluff exposures from the last glacial advance (Unaluk drift) include ancient mudflat deposits,

FIGURE 8. - Photogragh of the north end of Red Mountain ridge. Note the elongate pond and vegetation line marking the lateral moraine from the most recent (Unaluk) Goodnews Bay glacier. Goodnews Bay is in the extreme left background of the picture and the Bering Sea in the foreground.

lake beds, and bedded till typical of marginal meltwater reworking, as well as alluvial channels (fig. 9) and cross-channel features such as those observed near Cabin Creek and at Flat Cape.

The extent of glacial scouring, near, or on the west side of Red Mountain, is an important factor regarding the preservation of preglacial PGM placers. Summarizing available information, only marginal glacial erosion with low energy ice-gouging is indicated and the principal ice contact is limited to the northern tip of the mountain mass. In comparison, south of Red Mountain, glacial scouring has not destroyed the ancient Salmon River placer bench which is up to 0.5-mi (800-m)-wide and now, 200-ft (60-m)-deep as it approaches the north side of Chagvan Bay (fig. 2, 2). Glacial ice, in this area overrode the preglacial platiniferious gravels. The glacier, nevertheless, may have truncated the more recent and shallower channel of the present Salmon River as suggested by Mertie (18), although the terminous of the paystreak may otherwise be due to an ancient sea scarp. Only a few traces of platinum were found in drill holes downstream of Claim 15 Below near the mouth of Happy Creek (2).

PHYSIOGRAPHY

The report area lies along a coastal region of subdued tundra-covered topography typical of southwest Alaska (figs. 2 and 8). The prominent 1,887-ft (575-m)-high Red Mountain is an exception to the moderate relief. The mountain mass and adjoining ridges separate the Salmon River Valley from the shallow Bering Sea. There is an abrupt and anomalous change in gradient along the steep western face of Red Mountain which sets off the sloping uplands from the virtually flat

FIGURE 9. - Paleochannel alluvial deposit with numerous dunite cobbles. Channel cuts outwash till of the Unaluk Glaciation near Flat Cape.

seafloor. Expansive, shallow, lagoonal-type water bodies of Goodnews and Chagvan Bays lie north and south of Red Mountain. Both bays are protected from frequent storms by well-formed sand spits several miles long. The prevailing south and southwest weather pattern, characterized by cool temperatures and frequent storms, are caused by low-pressure systems common over the Aleutian Islands.

CLIMATE

The climate in coastal southwestern Alaska is usually cool, wet, and windy from April through September. During the fall and winter months, storms are especially frequent; sea ice forms by late December but is intermittently broken up by sea currents, storms, and tides. Generally, sea ice is unsafe for travel except in the sheltered bays or for occasional short periods of unusually cold weather in late winter. Seawater temperature off of Red Mountain varied from 3.9°C in late May to a range of 12.5 to 13.6°C for early August. The mean ambient annual temperature is 0.6°C and annual precipitation is about 45 in (114 cm) with heaviest rainfall in late summer. Because of the relatively warm maritime influence, permafrost is rarely encountered, limited to relic lenses surviving from the last glacial period. The effective working season for the dredge operation on the Salmon River generally spanned late April to mid-December.

COASTAL PROCESSES

Seaward, the Bering Sea is a shallow, high-energy marine environment with a flat, featureless bottom interrupted by scattered ice-rafted boulders. The narrow channel into Goodnews Bay, scoured by tidal currents with observed velocities up to 10 mph (15 km/hr), is 70 ft (21 m) deep. Elsewhere, within four miles of the coast, water depths at mean high tide do not exceed 35 ft (11 m) and vary up to 10 ft (3 m) with tidal fluctuations. Nearshore sediments consist of compacted and shingled, rounded chert and quartz-rich gravel with a clayey, silty matrix. Highly-mobile, rippled sand and well-sorted, fine gravel locally overlie the shingled gravel, and increase in thickness as distance increases offshore.

The youngest sediments in the near coastal area have a distal, or seaward source. Littoral currents, driven by prevailing southwest winds and frequent storms, accompany a strong swell surge that rakes the seafloor for at least several miles from shore. The observed presence of rippled sand and fine gravel oriented perpendicular to the offshore swell direction indicates sediment transport toward the shore from further out to sea. On the basis of an average wavelength of incident waves of 120 ft (36 m) and a calculated surge depth of 60 ft (18 m), Welkie (7) also suggested a net movement of sediment toward shore occurs from as far out as 6 to 10 mi (10 to 16 km).

Wind generated, southwest, littoral current and accompanying drift, particularly during storms, approaches the shoreline between Goodnews Bay and Chagvan Bay, bifurcates along a subdued shoal off Flat Cape, and parallels the coastline both to the north and south (fig. 2). Currents flow faster over the Flat Cape shoal than the surrounding seafloor and support thick growths of mussel beds that thrive in the flowing water. The strong longshore currents transport sediment to a northward-trending spit at the mouth of Goodnews Bay, and to the south toward a southward-trending spit at the mouth of Chagvan Bay. Measurements made during fair-weather summer conditions indicate combined littoral and tidal currents within one meter of the bottom and 1 to 2 mi (1.5 to 3 km) of shore, exceed 40 cm/sec (2.2 mph). It was observed that during storms the waters outside the surf zone are very turbid due to suspended sediment in longshore transport.

ANALYTICAL RESULTS

Analytical results for platinum, iridium, and gold in seafloor and onshore samples are listed in appendixes A and B. The values presented (in mg/yd^3) for iridium are calculated on the basis of Ir:Pt = 0.13, as determined from dredge cleanup data given by Mertie (1, 18). Weight percent analyses of chromium, iron, and titanium are similarly listed in appendixes.

MINERALOGICAL CHARACTERIZATION

by C. L. Mardock

The offshore mineral concentrates studied during this project include PGM minerals that fall into two major classificatons, isoferroplatinum and osmiridium; and three minor classifications, sperrylite, moncheite (?), and platiniridium (fig. 10). Also examined were native gold and other heavy mineral accessories. Over 100 PGM- and gold-bearing grains, collected from sixteen sites, were examined by SEM; 74 of which were quantitatively analyzed by energy dispersive

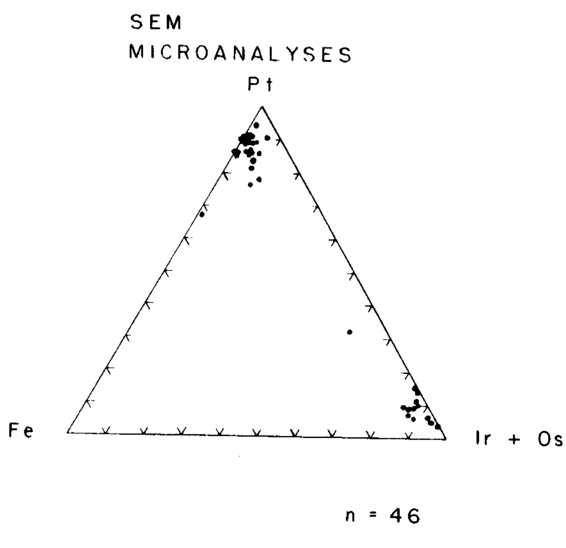


FIGURE 10. - Fe-(Ir+Os)-Pt ternary diagram of 46 SEM microanalyses on PGM grains.

X-ray spectrometry (EDX). Results of the EDX analyses are listed in table 1.

PGM MINERALOGY

The most common PGM-bearing mineral found in this study is isoferroplatinum $(Pt,Pd)_3(Fe,Cu)$ as defined by Fleischer (22). The isoferroplatinum grains contain 68- to 90-weight-pct Pt, with the majority containing approximately 90 % Pt, and the iron content is generally 10 %. The grains are not strongly attracted to a hand magnet, except when they are locked with magnetite. Locked grains are common in samples from onshore deposits and the magnetic concentrates from the Salmon River operation have traditionally been crushed, milled, and concentrated in order to recover the contained PGM. Apparently locked grains are less common in the PGM offshore as few of the grains examined in this study were similarly locked.

Isoferroplatinum with less than 90 % Pt generally contains from 1- to 5-weight-pct each of Ir, Os, and/or Rh. No appreciable palladium (<1.0%) was detected in any of the concentrates. Palladium is more soluble than the other PGM, especialy in a saline environment, and is subject to leaching. A previous electron microprobe study (23) of 13 Salmon River placer samples showed the Pt-Fe compositions of the principal platinum alloy to be very similar to those determined in this study, indicating no apparent Pt-Fe variation between onshore and offshore.

Isoferroplatinum grains are generally amoeboid in outline, quite pitted (fig. 11 A-B), with numerous cavities, and are layered or terraced (fig. 11 D-E). The size of the grains range from 50 to 500 um with a third dimension that is generally flattened. Grains are commonly liberated, however some also occur locked with osmiridium (fig. 12). In one sample, isoferroplatinum is present as a covering or growth on a grain of sperrylite. Isoferroplatinum was also observed locked with pyroxene or with small inclusions of chromite and magnetite. Previous studies (1-2, 6, 12, 23) have found that isoferroplatinum is commonly locked with either chromite or magnetite in the Salmon River placers.

The second most abundant PGM mineral in offshore samples is osmiridium (Ir,Os) as defined by Fleischer (22). It contains 58- to 80-weight-pct Ir, 6- to 30-weight-pct Os, and variable percentages of Pt, Ru, and Fe, each not exceeding 15 %. Chemically comparable osmiridium was also reported from onshore placers (23-24).

Osmiridium is commonly intergrown in a pseudoeutectic fabric with isoferroplatinum (fig. 12). Osmiridium is brighter than other PGM minerals and has silver-hued, high reflectance surfaces untarnished by alteration processes. Grains generally exhibit some abraided cubic crystal faces, but lack the amoeboid, layered, terraced or flattened characteristics of the isoferroplatinum. Furthermore, grains are smaller than isoferroplatinum grains, averaging 50 to 100 um in diameter. Figure 11A (sample no. 53) shows an osmiridium grain with interlocked pyroxene.

Sperrylite ($PtAs_2$) was identified in a few of the PGM-bearing grains. Figure 12B shows a well-rounded sperrylite grain interlocked with moncheite (?) $[Pt,Pd)(Te,Bi)_2]$. Sperrylite is a common mineral in the Salmon River concentrates and is associated with isoferroplatinum and Rh-bearing minerals (23).

TABLE 1 A. - EDX analyses of PGM placer grains in weight percent.

Sample #	Pt	Pd	Ir	Os	Ru	Rh	Au	Ag	Fe	Hg	As	Mineral Type
81-B	89	-	4	-	-	-	-	-	7	-	-	Isoferroplatinum.
88-A	84	-	-	-	-	2	-	-	13	-	1	Do.
13-A	85	-	1	-	-	-	-	-	14	-	-	Do.
13-B	90	-	1	-	-	-	-	-	9	-	-	Do.
13-C	91	-	1	-	-	-	-	-	8	-	-	Do.
89-D	68	-	-	-	-	-	-	-	32	-	-	Do.
89-E	87	-	-	-	-	-	-	-	13	-	-	Do.
89-F	87	-	4	-	-	-	-	-	9	-	-	Do.
96-B	86	-	3	1	-	-	-	-	10	-	-	Do.
96-C	87	-	3	-	-	-	-	-	10	-	-	Do.
96-D	90	-	-	-	-	-	-	-	10	-	-	Do.
96-E	91	-	-	-	-	-	-	-	9	-	-	Do.
96-F	91	-	-	-	-	-	-	-	9	-	-	Do.
96-G	87	-	-	-	-	-	-	-	13	-	-	Do.
96-H	87	-	1	1	-	-	-	-	11	-	-	Do.
96-I	85	-	5	1	-	-	-	-	9	-	-	Do.
97-A	88	-	2	2	-	-	-	-	7	-	1	Do.
97-E	89	-	-	1	-	-	-	-	9	-	1	Do.
97-F	90	-	-	1	-	-	-	-	9	-	-	Do.
97-G	85	-	-	-	-	5	-	-	10	-	-	Do.
97-H	86	-	-	1	-	4	-	-	9	-	-	Do.
52-B	77	-	8	-	-	-	-	-	15	-	-	Do.
100-D	91	-	-	-	-	-	-	-	9	-	-	Do.
100-E	90	-	-	-	-	-	-	-	10	-	-	Do.
53-A	87	-	3	1	-	-	-	-	9	-	-	Do.
53-F	89	-	1	-	-	-	-	-	10	-	-	Do.
53-G	89	-	-	2	-	-	-	-	8	-	-	Do.
53-H	86	-	5	2	-	-	-	-	7	-	-	Do.
89-A	6	-	63	31	-	-	-	-	-	-	-	Osmiridium.
89-B	11	-	69	18	-	-	-	-	2	-	-	Do.
89-C	9	-	67	22	-	-	-	-	2	-	-	Do.
48-A	6	-	73	11	4	-	-	-	6	-	-	Do.
48-B	5	-	80	11	2	-	-	-	2	-	-	Do.
48-C	4	-	85	10	-	-	-	-	1	-	-	Do.
100-A	15	-	76	9	-	-	-	-	-	-	-	Do.
100-B	7	-	79	8	-	-	-	-	6	-	-	Do.
100-C	9	-	79	7	-	-	-	-	5	-	-	Do.
53-B	15	-	79	6	-	-	-	-	-	-	-	Do.
53-D	9	-	67	18	-	-	-	-	6	-	-	Do.
88-B	65	-	9	-	-	6	-	-	9	-	11	Sperrylite.
97-I	62	-	-	-	-	-	-	-	3	-	35	Do.
81-A	10	-	83	-	-	-	-	-	7	-	-	Platiniridium.
81-C	32	-	58	-	-	-	-	-	10	-	-	Do.

See notes at end of table.

TABLE 1 B. - EDX analyses of gold placer grains in weight percent.

Sample #	Pt	Pd	Ir	Os	Ru	Rh	Au	Ag	Fe	Hg	As	Mineral Type
81-D	-	-	-	-	-	-	85	15	-	-	-	Gold
23-A	-	-	-	-	-	-	92	8	-	-	-	Do.
23-B	-	-	-	-	-	-	85	15	-	-	-	Do.
96-A	2	-	3	1	-	-	85	2	-	7	-	Do.
96-J	-	-	-	-	-	-	96	4	-	-	-	Do.
97-B	-	-	-	-	-	-	98	2	-	-	-	Do.
97-C	-	-	-	-	-	-	95	-	3	-	2	Do.
97-D	-	-	-	1	-	-	91	-	8	-	-	Do.
52-A	-	-	-	-	-	-	93	7	-	-	-	Do.
49-A	-	-	-	-	-	-	91	9	-	-	-	Do.
49-B	-	-	-	-	-	-	91	9	-	-	-	Do.
49-C	-	-	-	-	-	-	96	4	-	-	-	Do.
100-F	-	-	-	-	-	-	99	1	-	-	-	Do.
100-G	-	-	1	-	-	-	98	-	1	-	-	Do.
53-C	-	-	2	-	-	-	94	4	-	-	-	Do.
53-E	-	-	1	2	-	-	95	2	-	-	-	Do.
53-I	-	-	-	-	-	-	88	9	3	-	-	Do.
62-A	-	-	-	-	-	-	89	11	-	-	-	Do.
62-B	-	-	-	-	-	-	92	8	-	-	-	Do.
6-A	-	-	-	-	-	-	90	11	-	-	-	Do.
6-B	-	-	-	-	-	-	99	1	-	-	-	Do.
6-C	-	-	-	-	-	-	84	16	-	-	-	Do.
6-D	-	-	-	-	-	-	91	9	-	-	-	Do.
6-E	-	-	-	-	-	-	96	4	-	-	-	Do.
6-F	-	-	-	-	-	-	92	8	-	-	-	Do.
2-A	-	-	-	-	-	-	84	16	-	-	-	Do.
64-A	-	-	2	1	-	-	97	-	-	-	-	Do.
64-B	-	-	-	-	-	-	95	3	2	-	-	Do.
64-C	-	-	2	2	-	-	89	7	-	-	-	Do.
64-D	-	-	1	1	-	-	98	-	-	-	-	Do.
64-E	-	-	-	1	-	-	92	5	2	-	-	Do.

Notes: Numbers refer to sample location, fig. 5. The letters following the numerical identifier refer to serialization during examination.
- Not detected.

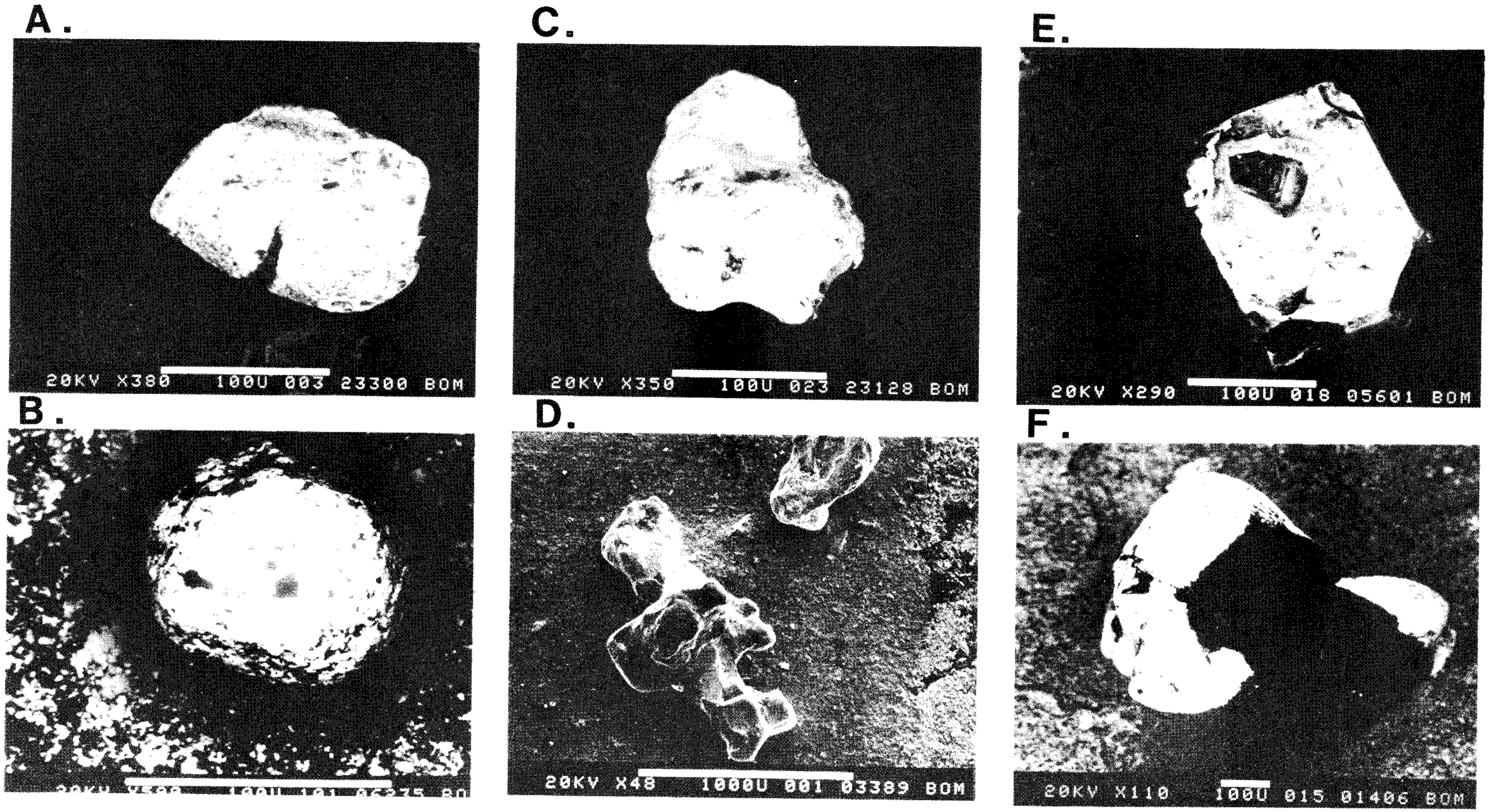


FIGURE 11 A-F. - SEM backscatter images of types of PGM grains found in marine sediment samples. Note scale on each image given in microns. A) Well-rounded osmiridium with interlocked pyroxene from sample 53. B) Typical rounded isoferroplatinum grain, sample no. 97. C) Faceted osmiridium grain, note high brightness, from sample 100. D) Lower, darker, and largest grain is highly sculptured isoferroplatinum, whereas the two grains above are platiniridium, sample no. 81. E) Crystalline isoferroplatinum from sample no. 45. F) Crystalline isoferroplatinum from sample no. 88.

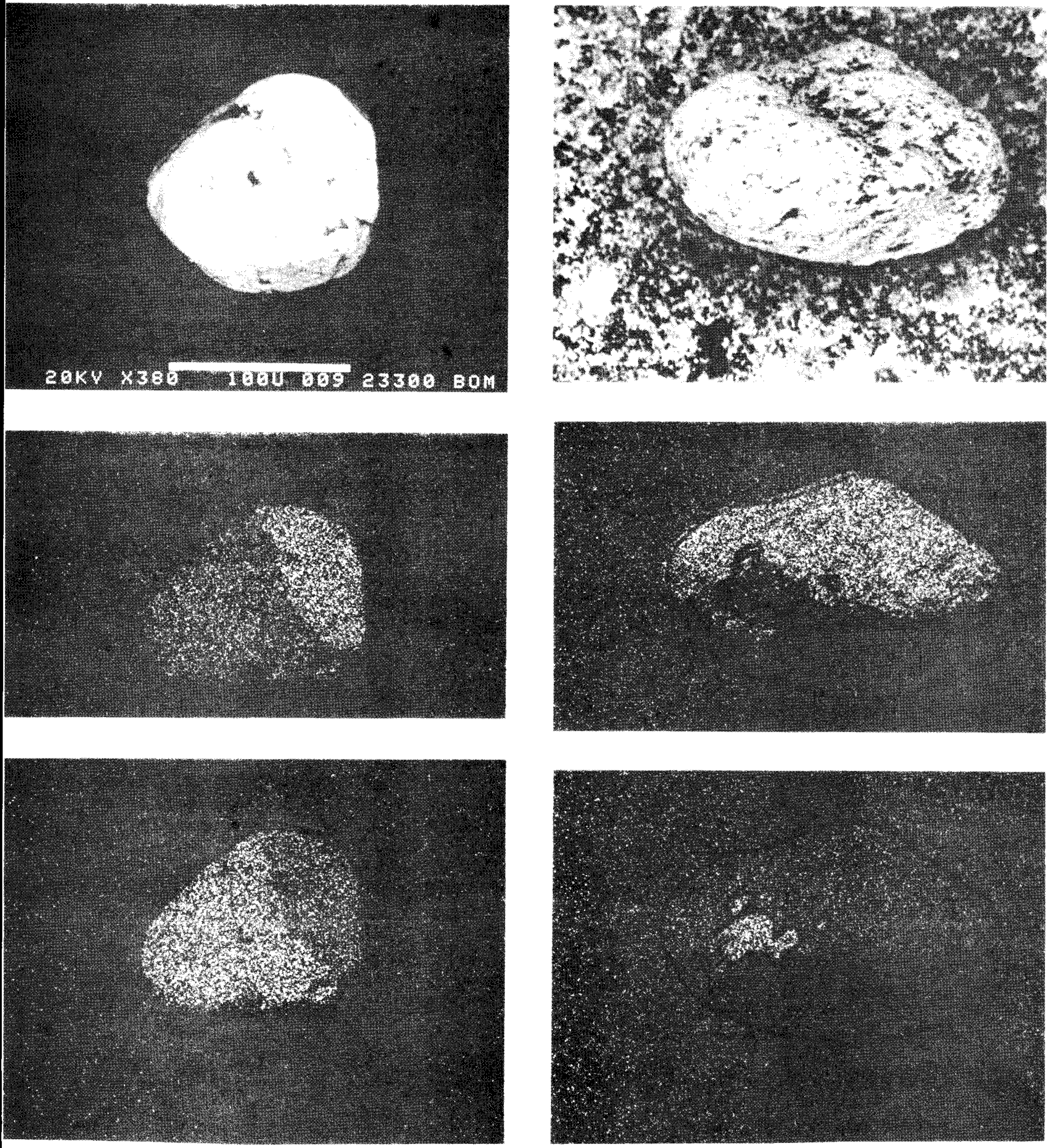


FIGURE 12. - PGM grains with interlocked alloy compositions. Note scale bar in upper-left SEM backscatter image is 100 microns. The grain on the left (sample no. 53) comprises osmiridium and isoferroplatinum. X-ray may in mid-left is iridium, lower left is platinum. Grain on the right is sperrylite from sample no. 97. Mid-right X-ray map is arsenic. There is a large inclusion of moncheite (?) as indicated by the lower-right X-ray map for tellurium. Alloy-bimodal zoned compunds.

Two platiniridium (Ir,Pt) grains were found in concentrate from sample no. 81 (fig. 11D, upper 2 grains). Their compositions are $Ir_{84}Pt_{10}Fe_6$ and $Ir_{58}Pt_{32}Fe_{10}$. The grains are large and moderately rounded, approaching 500 um in diameter, and have faint outlines that indicate layering. As seen in figure 11D, they appear brighter than the larger adjoining isoferroplatinum grain. Rosenblum and others (23), have also reported bladed crystals of an unnamed Ir-Fe mineral in magnetic concentrates from Salmon River.

GOLD MINERALOGY

Gold grains were present in concentrates from all but four sites. Generally, gold comprises an appreciably higher percent of the precious metal concentrate offshore than the 2 to 3 % reported for the Salmon River placer (1).

Gold is generally coarser than the PGM mineral grains and commonly ranges between 300 and 500 um in diameter; several grains up to 3 mm were noted (sample no. 23). Some grains exhibit a marked layered structure as shown in figure 13; grains show both undercut and overhang layering, and exhibit a honeycomb structure apparently caused by preferential leaching. All of the observed layers are about 5-um-thick, and each layer lies flat without undulation.

The outer form of many gold grains is amoeboid, much like that of the isoferroplatinum (fig. 14). The surfaces are pitted with honeycomb and fracture cavities that may represent voids left after inclusions of other minerals have been mechanically or chemically removed. Gold content at the surface lacks most common alloy metals (e.g., iron, copper) and samples range from 84- to 99-weight-pct Au with a corresponding balance of silver values to total 100 %. In several grains, iridium and osmium were additionally detected by EDX analyses in amounts up to 2 weight pct each. Gold has been reported to contain iridium and platinum in solid solution (24) and palladium, platinum, and rhodium concentrations in gold have been documented (25), however there is no reference to the occurrence of osmium.

ACCESSORY HEAVY MINERALS

Accessory minerals in heavy mineral concentrates primarily include magnetite, ilmenite, chromite, and pyroxene (enstatite?), with lessor amounts of olivine, zircon, barite, monazite, arsenopyrite, pyrite, pyritized microfossils, hematite, garnet, leucoxene, cinnabar, and native mercury (fig. 15). Mertie (1) additionally identified rutile, tremolite, epidote, spinel, sphene, diamond, tourmaline, topaz, and corundum in Salmon River concentrates.

Magnetite is the most common accessory mineral. Grains are uniform in size and average 80- to 100-um diameter. The grains are generally subhedral, moderately rounded, and often exhibit vestigial octahedral crystal faces. Surfaces analyzed by EDX contained approximately 93 weight pct iron oxide and a few percent each of chromium and titanium oxides. The occurrence of chromium, as well as PGM in Red Mountain magnetite is documented onshore (1, 12, 23, 26).

Chromite comprises up to 20 % of the offshore concentrates. PGM, as inclusions in chromite, have been reported from Red Mountain (1-2, 12-13), however, as with magnetite, similar inclusions of PGM are suspected but were not observed in the offshore chromite grains tested. Chromite is subhedral, exhibits incipient octahedral crystal faces, and incorporates sufficient iron to be more accurately termed chromian magnetite.

Traces of both cinnabar and native mercury occur in a few of the samples; discrete cinnabar grains and globules of mercury are shown in figure 15. In addition to these Hg-bearing minerals, a single grain of Au-Ag-Ir-Os-Pt-amalgam was identified (sample no. 48).

BENEFICIATION RESULTS

by W. C. Hirt

Three samples for beneficiation testing were collected (fig. 7). The first two were from natural black sand accumulations; sample A was from

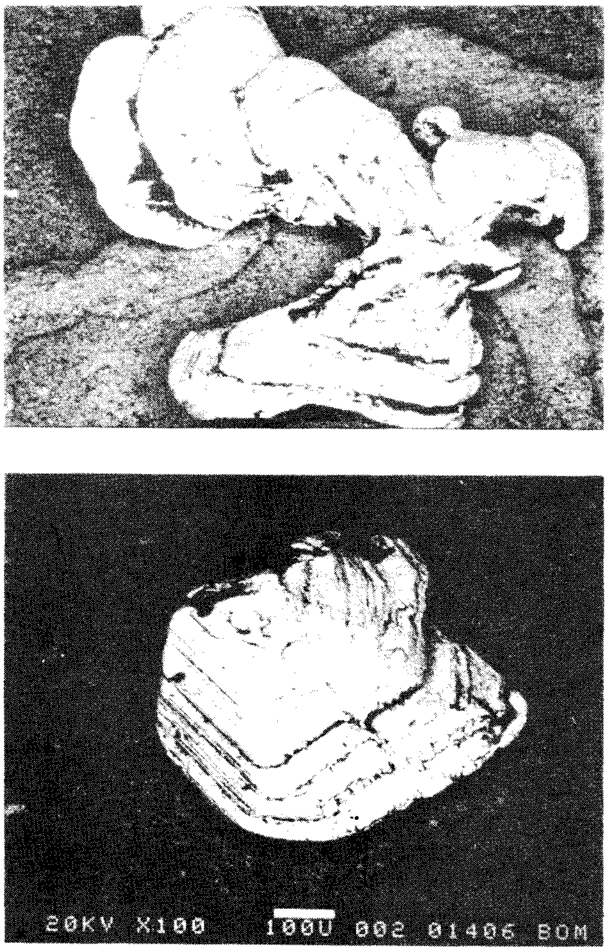


FIGURE 13. - SEM backscatter images showing layering in gold grains from sample no. 6 offshore of Platinum villege. Note scale bar is 100 microns.

black sand layers on ferricreted gravel at the mouth of the Salmon River, and sample B was an 18-in-wide channel sample of the black sand layer between the swash zone and the bluff at Flat Cape. Sample C is a composite of material shoveled from the upper 16 in (40 cm) of the seafloor sediment at six locations over the Flat Cape shoal. Table 2 summarizes sample weights, assays, and recoveries.

For the black sand beach samples (tables 3 and 4), the best platinum and gold recoveries were in the minus 28-mesh fraction gravity concentrates from sample B (representative), which contained 95.45 % of the Pt and 82.32 % of the Au. Notably there was a 7.85 % recovery of fine-grained gold from the minus 28-mesh fraction by flotation. Additionally, a middlings heavy mineral product that assayed 16.7 % Cr_2O_3 had 75 % recovery for chromium; this was the highest grade Cr_2O_3 product produced in this work.

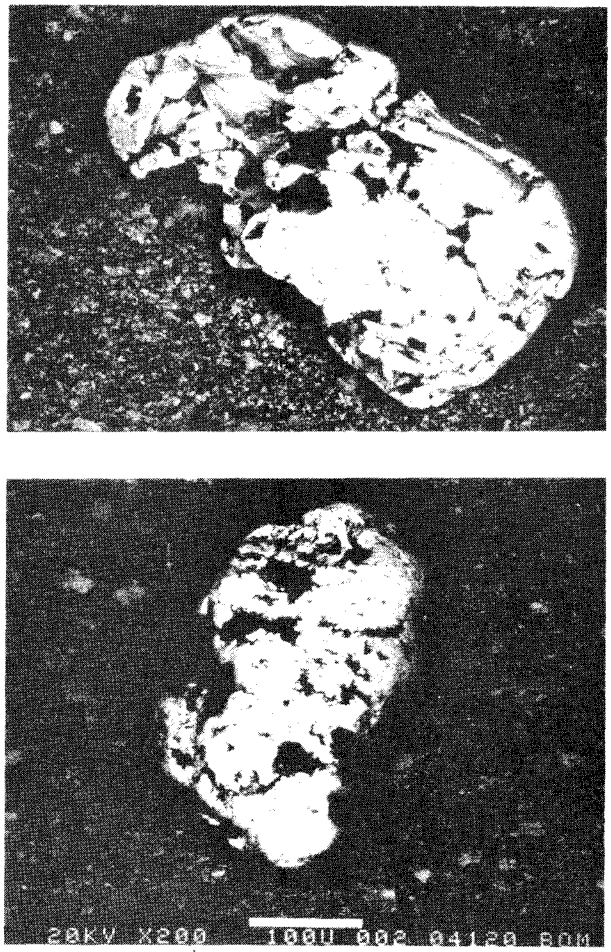


FIGURE 14. - SEM backscatter images of typical rounded amoeboid gold grains from sample no. 49 offshore of Flat Cape. Note scale bar is 100 microns.

More attention was given to sample C (table 5) due to the larger resource potential it represented and the posssible occurrence of ultra-fine platinum grains suggested by previous studies (7, 12). The highest grade products from laboratory separation work ranged from only 0.105 to 0.9 t oz Au/t and 0.01 to 0.03 t oz Pt/t. Metal recoveries were negligible suggesting most of the platinum and gold were interlocked with other minerals and thus failed to concentrate.

INTERPRETATION

LITTORAL CURRENTS AND SEDIMENT TRANSPORT

Bathymeteric mapping, low frequency acoustics (fig. 16), and visual observations, reveal a smoothed seafloor where sediment is accumulating in depressions and around obstacles such as ice-rafted boulders. On a broader scale, mobile sand and fine gravel derived from non-local lithologies and transported from further offshore, are accumulating with carbonaceous muds both north and south of Flat Cape. Bedrock is relatively shallow along this portion of the coast and outcrop is exposed at or near sea level at the base of Red Mountain. At sample site 35 ultramafic bedrock rubble was observed in 15 ft (5 m) of water at the base of the dropoff beyond the surf zone. Bedrock surface dips to greater depths both north and south of this area. Previous exploratory churn drilling has shown that the bedrock surface slopes to more than 100 ft (30 m) below sea level north of Red Mountain (6) and to 200 ft (60 m) south of the Salmon River (2, 21). The thickness of

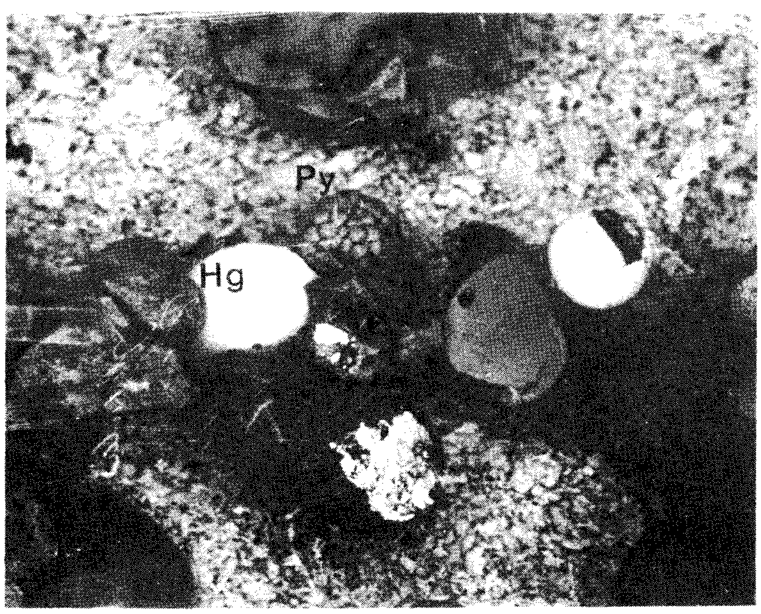


FIGURE 15. - SEM backscatter image of accessory heavy minerals including globule mercury (Hg) and pyritized microorganism (Py). From sample no. 48 taken offshore of Flat Cape. Note image is approximately 1000 microns across.

TABLE 2. - Summary of weights, assays, and percent recovery for beneficiation test samples.

Sample Number	Wt-lb raw	Wt-lb lab (-8m)	Assays, t oz/st: Head Pt	Head Au	Concentrate Pt	Concentrate Au	Recovery% Pt	Recovery% Au
A (Total)	300							
A (representative)		53.0	<0.001	<0.0008	5.253	0.834	42.0	16.3
					(pan con from table con from -28-mesh)			
					.056	3.27	.25	16.0
					(flo con from table con from -28-mesh)			
A (bulk)		149.4	<.001	.003	1.392	19.83	1.7	23.6
					(pan con fron non-mag-table con from +28-mesh)			
					.058	9.085	.13	20.0
					(amalgam from high-grade table con from -28-mesh)			
					13.93	.146	14.34	.15
					(pan con from high-grade table con from -28-mesh)			
					1.44	12.5	3.2	27.6
					(flo con from cleaner table con from -28-mesh)			
B (Total)	302							
B (representative)		39.7	.017	.049	.639	44.18	.06	6.7
					(pan con from table con from +28-mesh)			
					494.2	269.5	95.45	82.32
					(pan con from high-grade table con from -28-mesh)			
					.881	36.4	.12	7.85
					(flo con from table con from -28-mesh)			
B (bulk)		45.2	.032	.043	33.69	10.73	2.19	.82
					(pan con from high-grade table con from +28-mesh)			
					8.34	2.86	9.36	3.80
					(pan con from table con from +28-mesh)			
					50.97	45.36	75.64	79.70
					(pan con from high grade table con from -28-mesh)			
					2.594	.68	5.82	1.81
					(pan con from table con from -28-mesh)			
					.578	36.7	.15	11.69
					(flo con from table con from -28-mesh)			
C	1,320	588	.00096	.00105	.03	0.9	.53	.29

TABLE 3. - Placer test product distribution of sample A.

Sample Mesh Size	Sample Product	Weight lbs	Weight % Dist	Au Actual Assay	Au Unit wt Au	Au Dist % of Au	Au Calc oz/ton	Pt Actual Assay	Pt ·Unit wt Pt	Pt Dist % of Pt	Pt Calc. oz/ton
Representative Sample A:											
+28	Pan con-table con	0.027	0.0515	0.028	0.3472	.78052		.497	6.1628	5.6632	
	Pan tail-table con	.25	.4714	.001	.1135	.25515		.002	.227	.2086	
	Flo con-table tail	.023	.0428	.028	.2884	.64833		.02	.206	.1893	
	Flo tail-table tail	16.3	30.7273	.001	5.9184	13.3048		.003	22.194	20.3947	
+28	TOTAL	16.6	31.29		6.6675	14.99	0.000885		28.7898	26.46	0.00382
-28	Pan con-table con	.019	.0361	.834	7.2558	16.31133		5.253	45.7011	41.9961	
	Pan tail-table con	3.326	6.2734	.001	1.5104	3.39544		.002	3.0208	2.7759	
	Flo con-table con	.010	.0204	3.27	16.023	36.02034		.056	.2744	.25215	
	Flo tail-table con	22.427	42.2901	.001	8.1456	18.31163		.002	20.364	18.71309	
	Flo con-table tail	.022	.042	.101	1.0201	2.29323		.101	1.0201	.9374	
	Flo tail-table tail	10.629	20.0446	.001	3.8608	8.67923		.002	9.652	8.8695	
-28	TOTAL	36.436	68.71		37.8157	85.01	0.002286		80.0324	73.54	.00438
SAMPLE TOTAL		53.031	100.0		44.4832	100.0	0.001848		108.8222	100.0	.00452
Bulk Sample A:											
+28	Pan con-non-mag-table con	.005	.004	19.83	53.541	23.63377		1.392	3.7584	1.6832	
	Pan tail-non-mag-table con	1.811	1.213	.001	.8226	.36311		.003	2.4678	1.1052	
	Mag sep con-table con	5.94	3.9768	.001	2.697	1.19049		.003	8.0910	3.6235	
	Pan con-non-mag (hand mag) frac of table con	.042	.0282	.044	.8404	.37096		.063	1.2033	.5389	
	Pan tail-non-mag (hand mag) frac of table con	.121	.0814	.048	2.6496	1.16957		.002	.1104	.0494	
	Hand mag con-table con	1.502	1.0056	.001	.682	.30104		.004	2.7280	1.2217	
	Flo con-table tail	.045	.0307	.021	.4368	.19281		.010	.2018	.0904	
	Flo tail-table tail	60.814	40.712	.001	22.088	9.74996		.002	55.2200	24.7299	
+28	TOTAL	70.285	47.05		83.7574	36.97	.00262		73.7807	33.04	.00231
-28	Amalgam-high-grade table con	(.011)		9.085	45.3469	20.01677		.058	.2895	.1297	
	Pan con-high-grade table con	.005	.0034	.146	.3358	.14823		13.93	32.039	14.3485	
	Pan tail-high-grade table con	.755	.5058	.018	6.174	2.72529		.081	27.783	12.4424	
	Flo con-table tail	.035	.0237	-	-	-		-	-	-	
	Flo tail-table tail	28.775	19.2634	.001	10.4512	4.61331		.001	13.064	5.8506	
	Flo con-cl table con	.011	.0074	12.5	62.5	27.5884		1.44	7.2	3.2245	
	Flo tail-cl table con	26.638	17.8331	.001	9.6752	4.27077		.004	48.376	21.6649	
	Flo con-cl table tail	.008	.0059	-	-	-		-	-	-	
	Flo tail-cl table tail	22.863	15.3057	.001	8.304	3.66551		.002	20.76	9.2972	
-28	TOTAL	79.093	52.95		142.7871	63.03	.00398		149.5115	66.96	.00416
SAMPLE TOTAL		149.378	100.0		226.5445	100.0	.00334		223.2922	100.0	.00329

- from. Cl cleaner. Con concentrate. Flo flotation. Tail tails.

TABLE 4. - Placer test product distribution of sample B.

Sample Mesh Size	Sample Product	Weight lbs	Weight % Dist	Au Actual Assay	Au Unit wt Au	Au Dist % of Au	Au Calc oz/ton	Pt Actual Assay	Pt ·Unit wt Pt	Pt Dist % of Pt	Pt Calc. oz/ton
Representative Sample B:											
+28	Pan con-table con	.003	0.0001	44.18	75.106	6.747		.639	1.086	.06169	
	Table con	1.673	4.2157	.001	.7596	.06824		.004	3.038	.17258	
	Flo con	.009	.0003	-	-	-		-	-	-	
	Flo tail	12.154	30.6241	.001	5.518	.49572		.001	5.518	.31346	
+28	TOTAL	13.84	34.87		81.384	7.31	.01295		9.642	.54773	0.00153
-28	Pan con-high-grade table con	.007	.0002	269.5	916.3	82.317		494.2	1,680.28	95.45	
	Pan tails-high-grade table con	.535	1.3492	.01	2.431	.21839		.14	34.034	1.93	
	Pan con-table con	.104	.2631	.01	.474	.04258		.18	8.532	.48468	
	Flo con-table con	.005	.0001	36.4	87.36	7.848		.881	2.114	.12009	
	Flo tail-table con	12.947	32.6220	.001	4.702	.4224		.001	5.878	.33391	
	Flo con-table tail	.018	.0005	1.91	16.044	1.441		.382	3.209	.18229	
	Flo tail-table tail	12.229	30.8128	.001	4.442	.3991		.003	16.656	.94618	
-28	TOTAL	25.847	65.13		1,031.753	92.69	.08792		1,750.703	99.44715	.14919
SAMPLE TOTAL		39.688	100.0		1,113.137	100.0	.06178		1,760.345	100.0	.0977
Bulk Sample B:											
+28	Pan con-high-grade table con	0.001	.0034	10.73	7.511	.82479		33.69	23.583	2.19	
	Pan tail-high-grade table con	.238	.5285	.01	1.085	.11915		.02	2.170	.20127	
	Pan con-table con	.026	.0589	2.86	34.606	3.80012		8.341	100.926	9.36	
	Pan tail-table con	1.185	2.6207	.004	2.152	.23631		.006	3.228	.29941	
	Flo con-table tail	.019	.0434	-	-	-		-	-	-	
	Flo tail-table tail	14.088	31.1556	.001	5.117	.56190		.002	12.792	1.18650	
+28	TOTAL	15.559	34.41		50.471	5.54	.00715		142.699	13.24	.0202
-28	Pan con-high-grade table con	.035	.0779	45.36	725.76	79.69648		50.97	815.520	75.64	
	Pan tail-high-grade table con	.192	.4248	.01	.872	.09576		.09	7.848	.72793	
-28	Pan con-table con	.053	.1179	.68	16.456	1.80705		2.594	62.775	5.82258	
	Flo con-table con	.006	.0141	36.7	106.43	11.68719		.578	1.676	.15545	
	Flo tail-table con	18.876	41.7454	.001	6.856	.75286		.005	42.850	3.97	
	Flo con-table tail	.005	.0132	-	-	-		-	-	-	
	Flo tail-table tail	10.488	23.1962	.001	3.810	.41838		.001	4.762	.44169	
-28	TOTAL	29.658	65.59		860.184	94.46	.06388		935.431	86.76	.06947
SAMPLE TOTAL		45.218	100.0		910.655	100.0	.04436		1,078.130	100.0	.05252

- from. Cl cleaner. Con concentrate. Flo flotation. Tail tails.

TABLE 5. - Placer test product distribution of sample C.

Sample Mesh Size	Sample Product	Weight		Au				Pt			
		lbs	% Dist	Actual Assay	Unit wt Au	Dist % of Au	Calc oz/ton	Actual Assay	Unit wt Pt	Dist % of Pt	Calc. oz/ton
+10	Pan[1]	101.4	17.24	.0008	.081	13.00	.0008	.001	0.10	17.69	.001
-10+28	Pan con[2]	0.02	.003	.209	.004	0.65	.209	.001	.00002	.00009	.001
	Tail cl[2]	0.14	.023	.002	.0003	.00005	.002	.001	.0001	.0002	.001
	Table tail[2]	0.97	.165	.0008	.0008	.128	.0008	.001	.0009	.159	.001
	Ro table tails[2]	256.8	43.67	.0008	.205	32.92	.0008	.001	.257	45.42	.001
-10+28	TOTAL	257.9	43.86		.210	33.70	.0008		.258	45.58	.001
-28+150	Pan con[2]	0.10	.017	.105	.011	1.78	.105	.03	.003	.530	.03
(HF)	Pan tail[2]	0.02	.003	.113	.0023	.369	.113	.001	.00002	.00004	.001
	con cl[2]	0.07	.012	.06	.0042	.674	.06	.001	.00007	.00012	.001
	Table tail cl	1.09	.185	.0008	.0009	.144	.0008	.001	.0011	.194	.001
-28+150	Pan con[2]	.002	.0003	.90	.0018	.289	.90	.01	.00002	.00004	.01
(LF)	Pan tail[2]	4.03	.685	.019	.0766	12.30	.019	.001	.004	.707	.001
-28+150	Flo con[3]	.40	.068		.011	1.78	.028		.0012	.212	.003
(Composite)	Flo tail[3]	192.8	32.79		.19	30.50	.001		.193	34.10	.001
-28+150	TOTAL	198.5	33.76		.298	47.84	.001		.202	35.75	.0011
-150	Flo con[3]	2.8	.476		.010	1.61	.004		.0025	.442	.0009
	Flo tail[3]	27.4	4.66		.024	3.85	.0009		.0028	.495	.0001
-150	TOTAL	30.2	5.14		0.034	5.46	.0011		.0053	.936	.0002
SAMPLE TOTAL		588.04	100.0		.623	100.0	.00105		.566	100.0	.00096

HF heavy fraction. LF light fraction. - from. Cl cleaner. Con concentrate. Flo flotation. Tail tails. Ro rougher.

1/ Only one split of full sample assayed after coning and quartering.
2/ Products of shaking table gravity separation.
3/ Products of flotation.

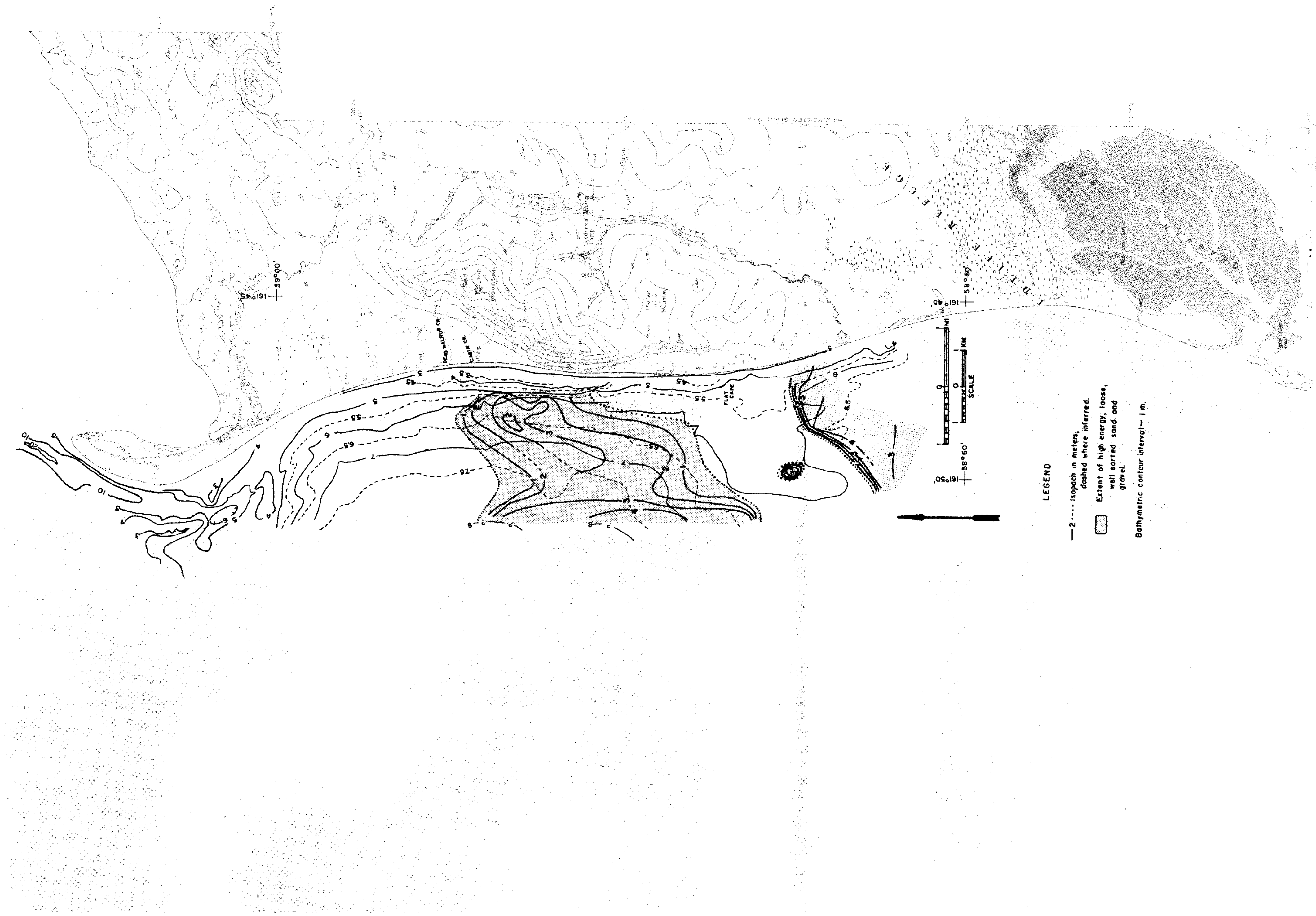


FIGURE 16. - Low frequency acoustic isopac map showing extent of high-energy sediment reflector.

littoral drift and lag deposits north and south of Flat Cape shoal is unknown and likely overlies glacial outwash or till that was below, and unaffected by the transgression.

Data collected from the two current meter stations indicate that currents regularly reverse with the change of tides and flow parallel to the shoreline in both directions. Longshore current has two principal components; the SW littoral current, and the tidal current. The northward current is strongest when the tide is rising and is about 10 % stronger than the southward, or ebb-tide current (table 6). Note that current meter station CM-2 records a persistently greater current velocity apparently due to the shallower depths across the Flat Cape shoal. Southwest storm winds accentuate the littoral current and will likely cause higher tides than normal and consequently even stonger northward currents north of Flat Cape. Velocity data for both stations are compiled in figure 17.

There is a pronounced 10- to 16-ft (3- to 5-m)-deep, well-shingled dropoff just outside of the surf zone where the ocean swells impact the coast (fig. 2). From Flat Cape to Goodnews Bay, most longshore sediment transport was to the north either in 1) a zone 200- to 500-ft (60- to 150-m)-wide immediately outside the 3- to 5-m dropoff, or 2) in the swash zone on the beach. In certain wave-surge combinations, finer grained material is eroded from the base of the dropoff by orbital surge, carried in suspension, and subsequently deposited on the beach. Previous investigators described the further transport of sediment along the beach and ultimate deposition in the low-energy zones at Goodnews and Chagvan Bays (11-12).

In summary, sediment from non-local, probably non-PGM-bearing areas, is being deposited on, and is in net one-way transport over, the pre-transgression land surface. Only where the wave-cut scarp is actively eroding into the preglacial surface along the base of an underwater dropoff, are locally-derived materials (including PGM) part of the littoral drift. This condition was observed at the base of the 3- to 5-m dropoff near lat 58°54' (sample no. 35, bedrock rubble exposed underwater) and extends at least intermittently north past Red Mountain to lat 58°56.5.' The locally-derived materials entrained in littoral transport are deposited either in a very narrow zone at the base of the dropoff or on the beach. As the coastline, including the offshore dropoff, continues to recede, a wave-cut platform is left which is rapidly mantled by mobile fine-grained, well-sorted sediment from offshore. The broad subdued shoal extending southwesterly off of Flat Cape is interpreted as being a wave-cut platform. The PGM values in samples from on top of the shoal (fig. 18) show that mixing of local sediments exposed there occurred as the scarp has advanced eastward to its present position.

MAGNETICS

The contoured magnetometer data in figure 19 indicates a southwest-trending feature strikes offshore about 3 mi (5 km) to the southwest of Red Mountain. The cross-structure, NW to SE dipole arrangement, is indicative of a structure with a southeasterly dip. Onshore, the Goodnews Bay ultramafic complex is interpreted on the basis of gravity and magnetic data and geologic mapping, as a convoluted sill-like body that also dips southeast and includes

TABLE 6.- Weighted average direction and maximum velocity from current meter stations. Station sites are shown in in figure 2.

Station	Rising tide direction	Ebb tide direction	Velocity[1/] (N:S)
CM 1	5°	183°	0.77:0.73
CM 2	353°	175°	1:0.84

[1/]Velocity is calculated as the average of the maximum velocities over the interval of time that data were collected; strongest average velocity equals 1.0.

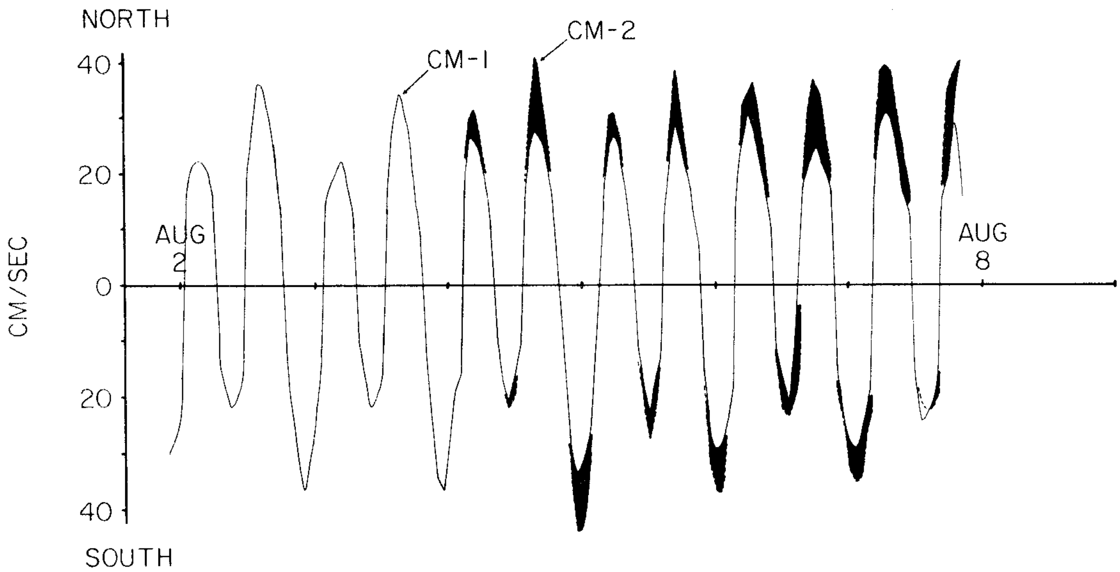


FIGURE 17. - North and south directed current velocity data collected at current meter stations from Aug. 2 to 8, 1985.

ultramafic rock at both Susie and Red Mountains (2-3, 27). The southwest trending dipole offshore of Red Mountain is interpreted, therefore, as an extension of the Goodnews Bay ultramafic complex.

Furthermore, the similar, but offset dipole in the west central part of the magnetometer survey is suggestive of either fault displacement, or an additional convoluted fold similar to that interpreted by Southworth and Foley (2) between Susie Mountain and Red Mountain. The offset is part of a 10-mi (16-km)-long linear feature representing a major lithology change or disruption in bedrock. In either case the structure of the ultramafic complex appears open to the west of the survey. The decreasing magnitude in total field readings along survey lines further from shore likely correlates to an increasing depth to bedrock.

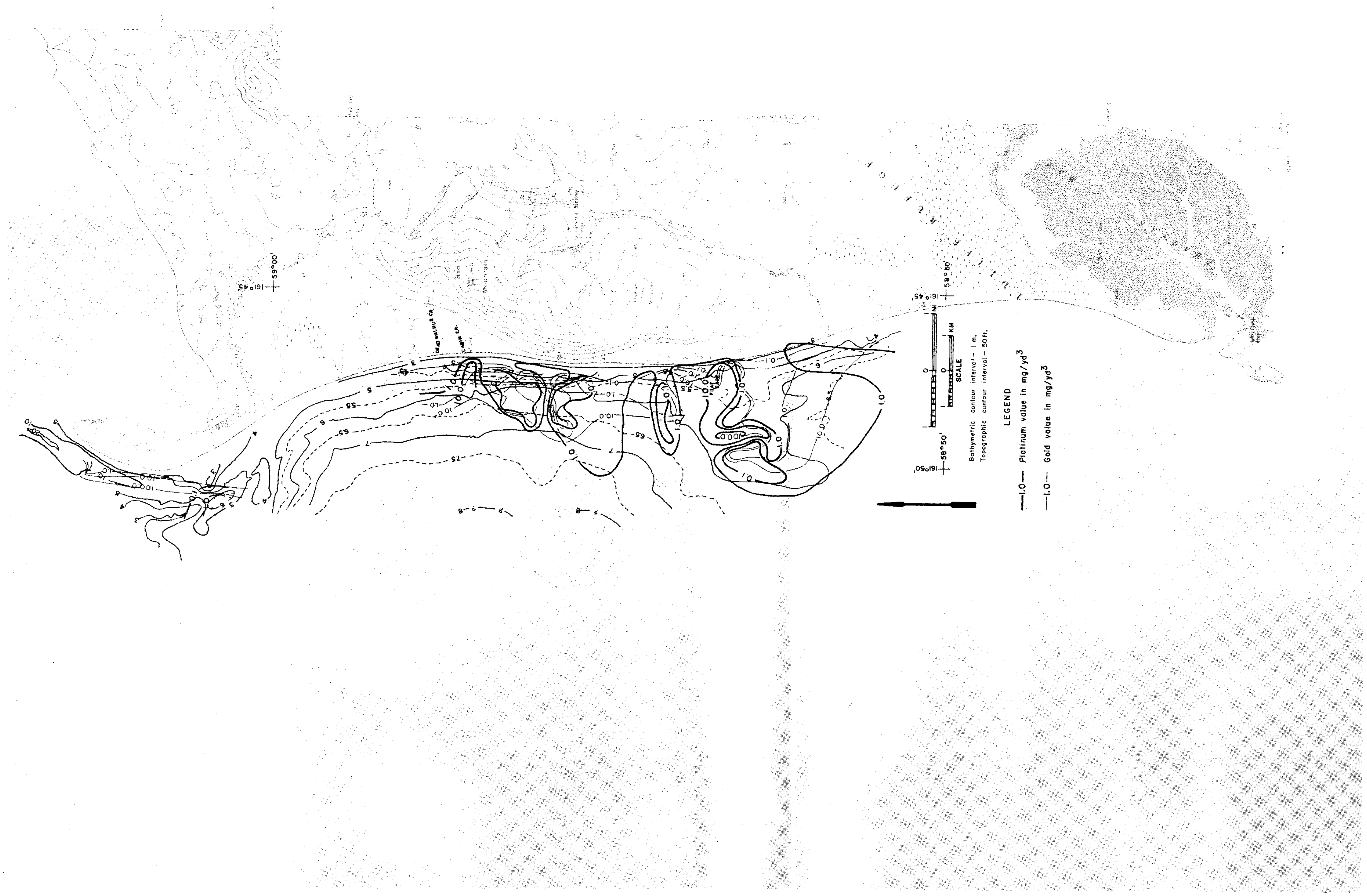


FIGURE 18. - Contoured values of Pt and Au sample analysis.

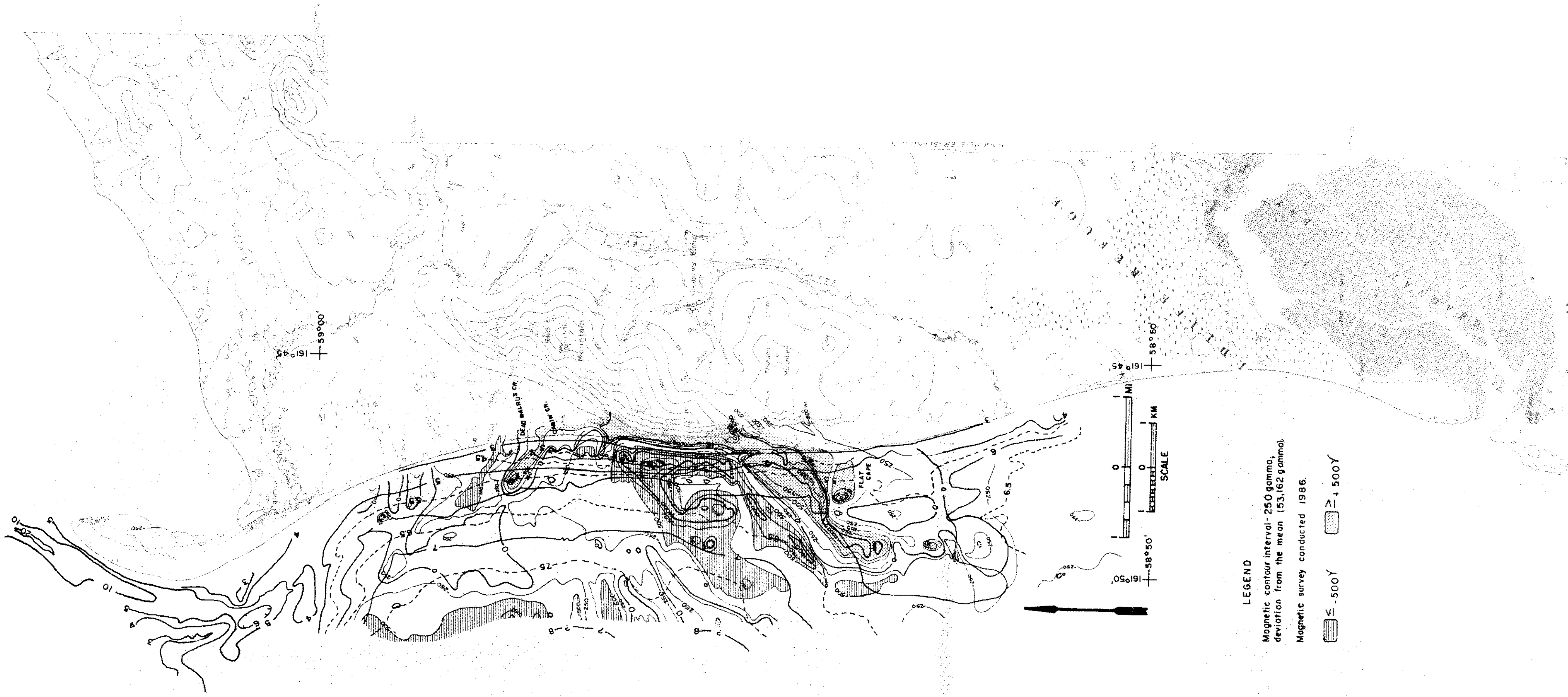


FIGURE 19. - Contoured magnetic data.

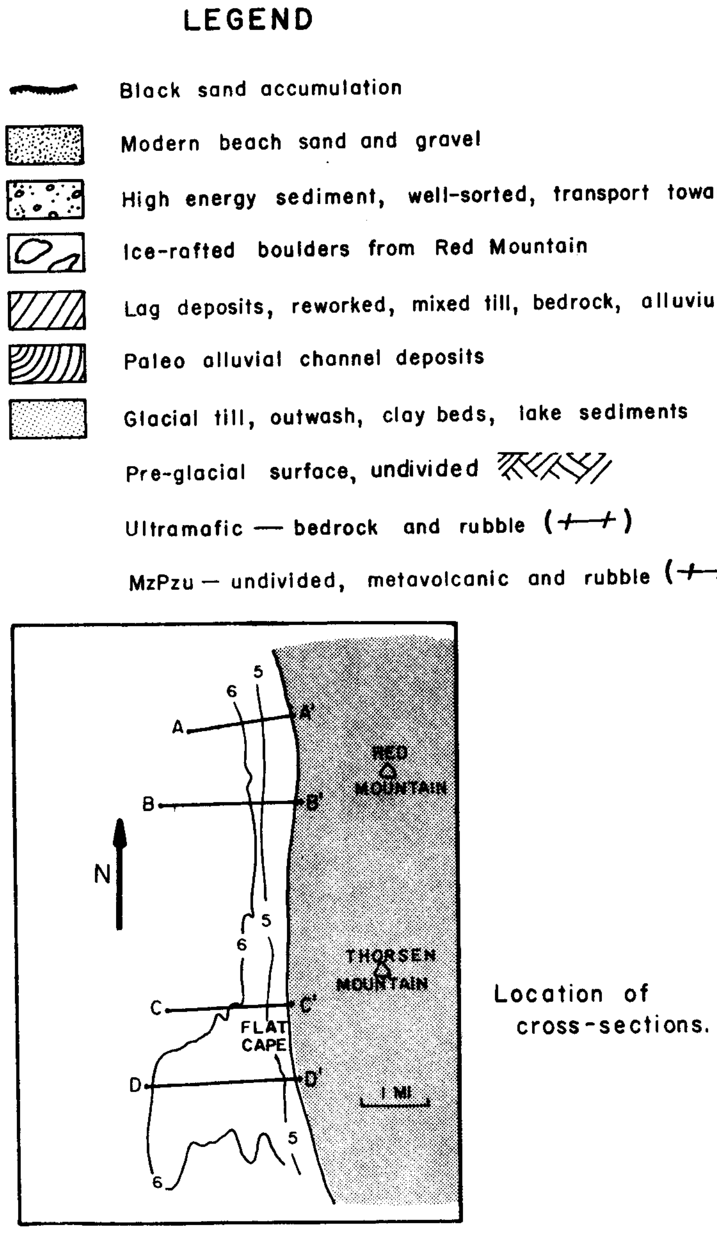


FIGURE 20. - Legend and location map of cross-sections 20-A-D of the coastline and seafloor near Red Mountain. .

The interpreted offshore extension of the ultramafic bedrock lies to the north of the northwestern margin of the Flat Cape shoal. The shoal likely is underlain by the same resistant metavolcanic rocks that form the hanging wall to the ultramafic complex onshore. These rocks are well-exposed at Thorsen Mountain immediatly south of Red Mountain, and also form the summit and SE flank of Susie Mountain.

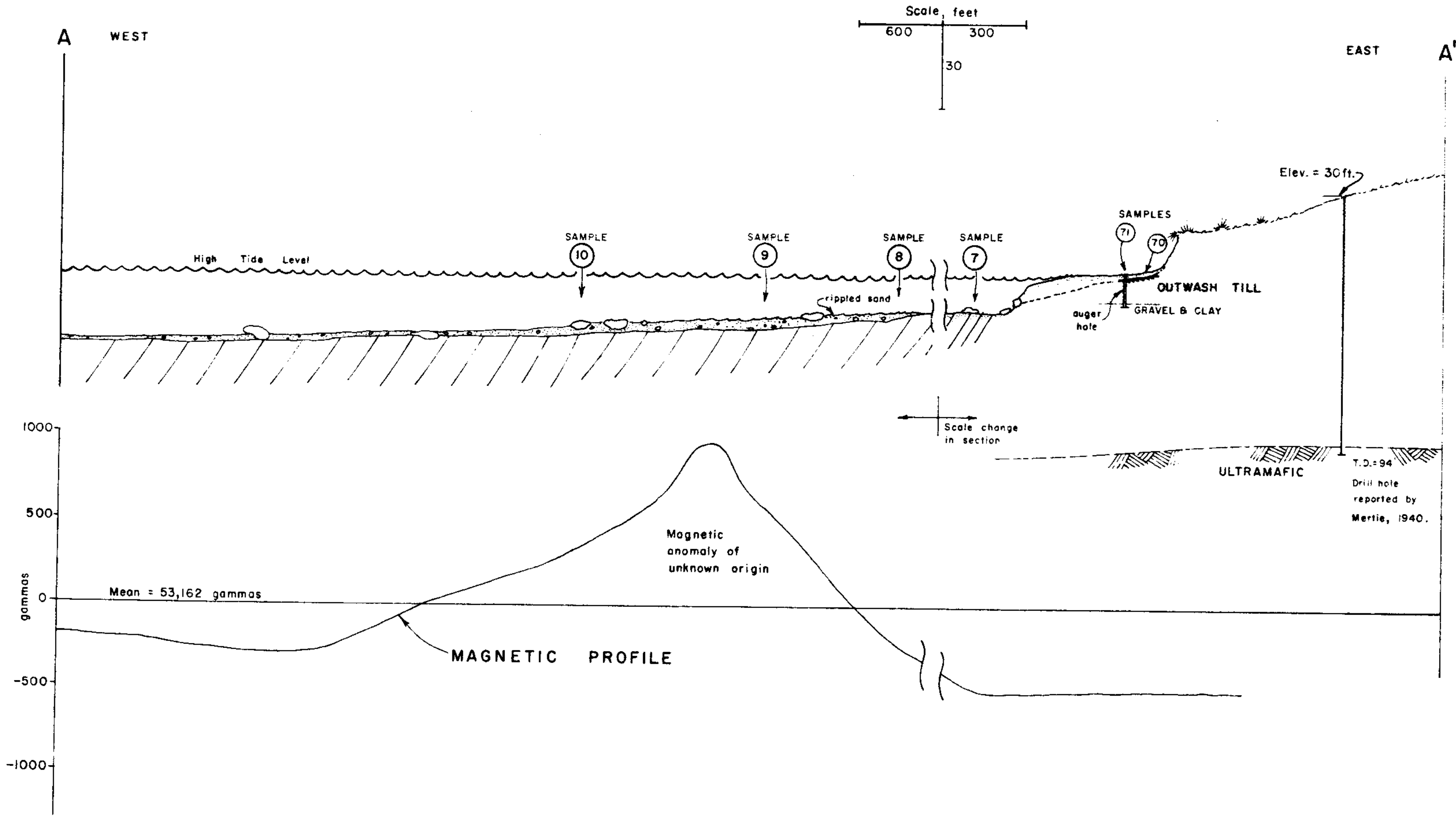


FIGURE 20-A. - Geologic and magnetic cross-sections A - A,' of seafloor offshore Dead Walrus Creek.

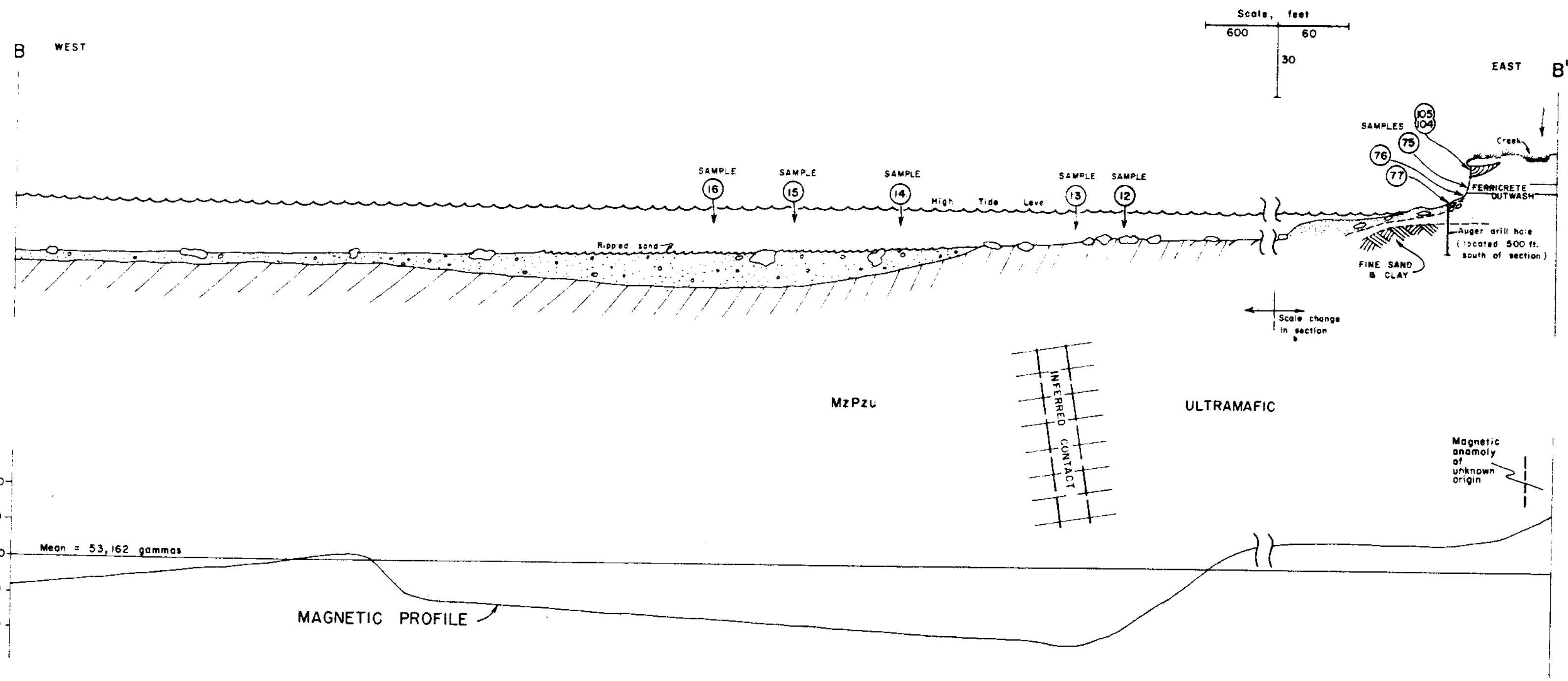


FIGURE 20-B. - Geologic and magnetic cross-sections B - B,' of seafloor south of Cabin Creek.

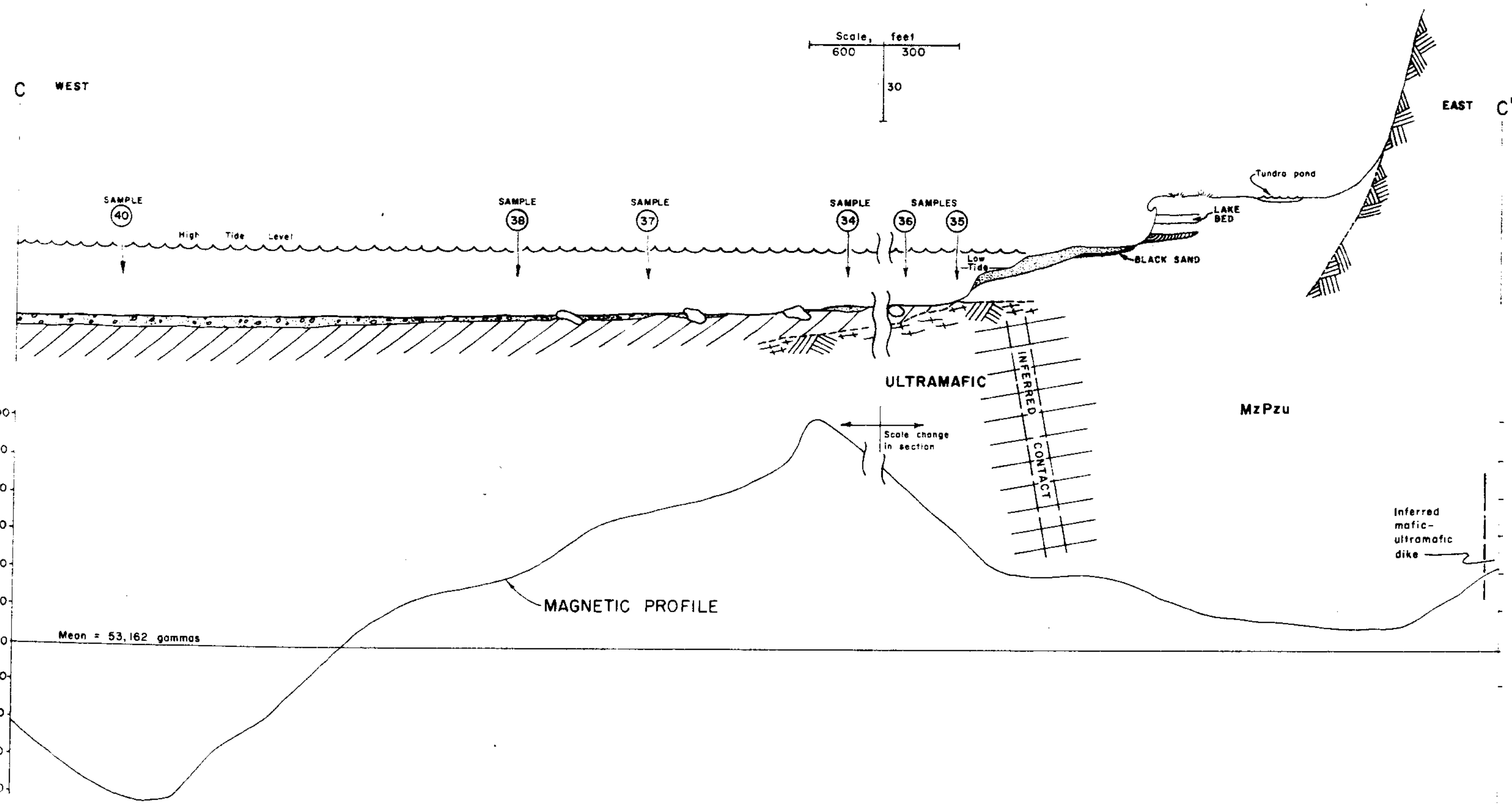


FIGURE 20-C. - Geologic and magnetic cross-sections C - C,' of seafloor offshore Thorsen Mountain.

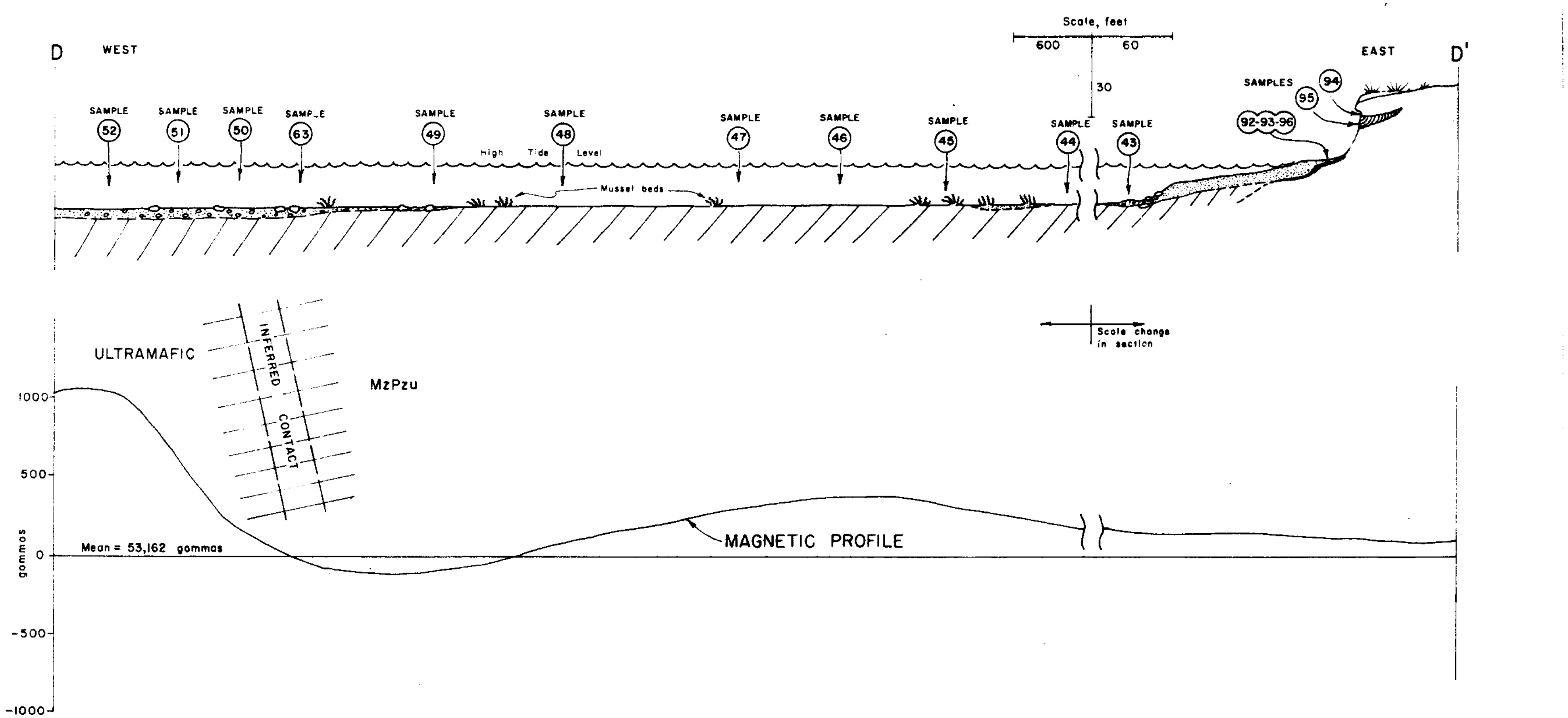


FIGURE 20-D. - Geologic and magnetic cross-sections D - D,' of seafloor offshore Flat Cape.

Several more localized features were examined in closer detail. A sinuous magnetic high in the vicinity of lat 58°57' and long 161°47' twice crosses the beach. More abundant, coarser-grained PGM, up to 3.0 mm, was found in samples from the sites within the southern lobe of the anomaly. Subsequent auger drilling to a depth of 18 ft (5.5 m; sample no. 77) encountered fine-grained, magnetite-rich olivine sand, and green clay. In 1982, Bond, and in 1984, Ulrich (11-12) also noted higher concentrations of PGM and higher amplitude ground magnetics at a beach site (referred to as Dead Walrus Creek) that coincides with the northern lobe of the feature. Additionally, within the northern lobe, Mertie (6) reported a mid-1930s drill location near the mouth of the first creek south of Last Chance Creek (presumably Dead Walrus Creek) that encountered ultramafic bedrock at a depth of 94 ft (30 m).

The sinuous anomaly and spatially associated PGM concentrations are suggestive of a magnetite-bearing channel or well-developed paleo-strandline, the later indicated by the fine-grained heavy minerals from the auger hole. It is likely that the wave-cut scarp at the base of the offshore dropoff is encroaching upon this buried feature and suppling the PGM to the northward littoral drift (sample nos. 11, 13) and local beach. The abruptly terminated ends of the feature may correspond to truncation resulting from one of the glacial episodes. Alternatively, due to the magnitude of the anomaly (fig. 19), this feature may represent near vertical dipping magnetic dike(s) or magnetic outer zones to the complex perhaps with PGM enrichment. In either case, it has locally been noted that PGM has an affinity for magnetite in the ultramafic complex.

Two magnetometer lines were placed E-W across the South Spit of Goodnews Bay (fig. 3). The magnetic gradient from west to east across the spit was relatively flat except for a pronounced 250 gamma rise approaching the eastern shore. Cause of the anomaly is unknown, however its location closely coincides with an aerial photo linear that marks the bluff scarp northward from the village cemetery (lat 58° 59,' long 161° 47.5') and continues north to trace the lower course of the Smalls River. Magnetite concentrations along an ancient wave-cut scarp, perhaps fault related, is a possible interpretation.

COASTAL GEOLOGY

Geologic mapping of sediments in relation to bedrock sources and littoral processes distinquished six map units overlying the preglacial surface comprizing ultramafic and metavolcanic bedrock and colluvium: (1) till of distal origin and associated glaciofluvial outwash, lake beds, peat bog, and clay deposits, (2) paleo-alluvial channel sediment of local derivation, (3) lag deposits left behind the receding coastline, (4) ultramafic boulder fields due to ice-rafting near Red Mountain, (5) mobile seafloor sediment from distant offshore sources, and (6) beach sand and gravel. Figures 20-A-D show these features and units in cross-section along four approximate E-W lines where sufficient information is available from field studies. Location of cross-sections is also shown on figure 2 for reference to regional geology. The geologic configuration of these cross-sections has developed as transgression of the sea progressed from west to east over the last several thousand years.

DISTRIBUTION OF PGM AND GOLD

Samples containing PGM are generally confined to a zone parallel to shore and across the top of the Flat Cape shoal (fig. 18). Analytical results show that seafloor sediments of unit 5 previously described, generally are barren of platinum, whereas lag gravels of unit 3 which have been mixed with sediment from till (unit 1) and from materials below the preglacial surface generally contain at least traces of platinum. Thus, as predictable from geologic observation, PGM is found on the surface of the seafloor only in high energy sediment transport zones and on the shoal where fast currents deter sediment accumulation of unit 5. Elsewhere, lag materials extend outward and offshore under unit 5. The exposure of PGM to ocean processes at the base of the dropoff is the apparent source of the fine-grained PGM that is seasonally entrained in the beach sediment of unit 6. Due to the rapid rate of transgression, the lag deposits that are presently exposed on the seafloor are immature and poorly developed which reflects in the relatively low metal grades.

The occurrence of gold (fig. 18), on the other hand, does not completely correlate with PGM, nor the exposed extent of the preglacial surface, suggesting gold enrichment is largely derived from the glacial till of unit 1 or its reworked equivalent. Some gold, however, occurs in most samples that also contain PGM thereby indicating the degree to which the two placer sources have been mixed. The data indicate the higher grade gold values are due to a sporadic occurrence of gold grains that tend to occur where the glacial sediments have been most reworked and redeposited, e.g., samples nos. 2-6 in the channel leading into Goodnews Bay. In contrast, beach and near-shore samples near the base of Red Mountain comprise material mostly derived from the preglacial surface (sample nos. 11,13,77-89); these contain PGM, but little or no gold.

Chromite, as indicated by chromium analyses (appendix A-B), shows an obvious correlation to PGM as would be expected. Chromite is considered a possible by-product commodity and is shown to be recoverable, however, the overall content of chromium, as well as titanium, in the offshore samples is no more than a few lb/yd^3. This lower tenor may be due in part to significant losses of lighter heavy minerals during sample processing. Similar to chromite, there is an apparent correlation of cinnabar to PGM in samples; most concentrates from the Flat Cape shoal contained traces of cinnabar and/or native mercury (Hg-minerals noted in sample nos. 18,46,48,49,51,53).

Because iridium values reported in this study are determined on the basis of the cited Ir:Pt content of onshore dredge concentrates, the assigned value of 0.13 times the analyzed platinum value in samples may be lower than the actual presence of iridium. There is a tendency for iridium content of PGM placers elsewhere to be greater in relation to platinum, particularly where PGM grains have undergone additional reworking in a saline environment (28). Examination of the concentrates by SEM suggested a higher abundance of Ir-alloys in samples collected during this study than would be accounted for with a ratio of 0.13.

DEPOSIT-TYPES AND RECOMMENDED EXPLORATION TARGETS

On-going littoral processes are forming heavy mineral concentrations, and at the same time are depositing sediment that may mask drowned alluvial or ancient marine placers. Exploration should focus on 1) recent transitional and marine placers and 2) ancient, pre-trangression deposits. In addition, there is inconclusive evidence of PGM placer enrichment related to low temperature solubility, solution transport, and alloy accretion.

Due to the relative short transgression period (+ 10,000 yr) in or near the study area, it is likely that the more significant targets predate this event.

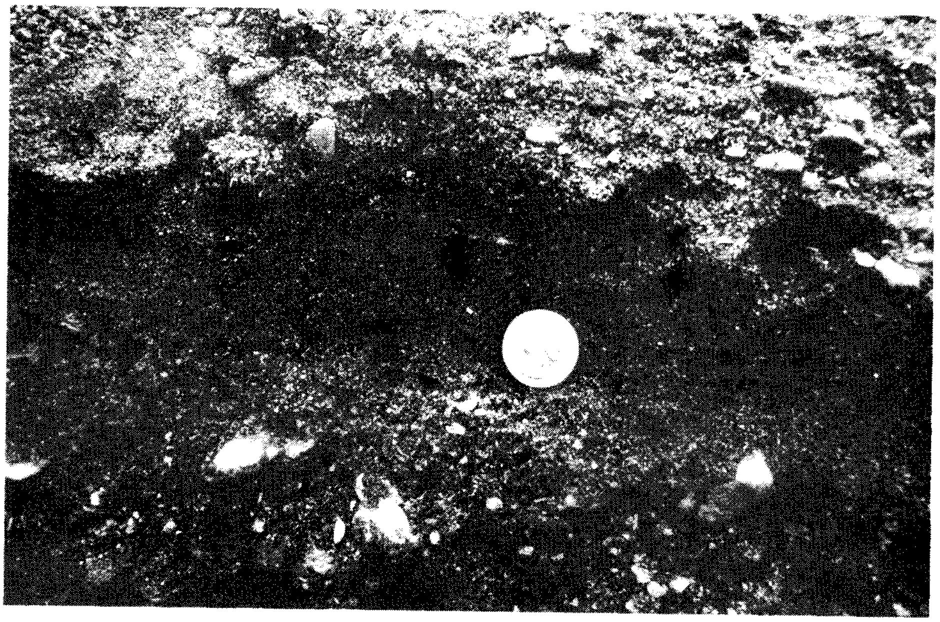
RECENT MARINE PLACERS

As the coastline recedes, lag deposits remain behind which host at least minor PGM values. These lag gravels contain preglacial locally derived sediment and PGM, and are exposed only in a narrow zone along the base of the offshore dropoff and on the Flat Cape shoal. Bottom samples contain PGM, but most values are far below the grade required for mining. Exploration should attempt to delineate stillstand strandlines within the rising sea level environment where more enriched strand deposits may have developed. The location of sample no. 49 may be an example of this.

Beach accumulations of PGM and gold were documented by Berryhill (29), Bond (11) and Ulrick (12). Assay grades from Bureau sampling (appendix B) demonstrate that fine-grained PGM and gold can be readily panned from black sand. From Seattle Creek to Chagvan Bay, seasonal deposits of black sand form a nearly continuous thin layer, typically 0.25- to 1.0-in-thick, overlying clay-rich till and under as much as several feet of washed beach gravel (fig. 21 site of beneficiation sample B). Such deposits may be present in the spring, but widely dispersed in the winter. Due to the highly immature nature of the rapidly receding beach, the resource potential is of little significance and may at times be stripped away by storm waves and consequently missing.

Black sand accumulations over semi-consolidated stratified ferricrete gravel till near the mouth of the Salmon River (fig. 22) are similar to beach heavy mineral accumulations, but are more widespread at this location. Sample A described in the Beneficiation section and sample nos. 98-99 were from this site. Full extent of this occurrence is unknown, however, shallow offshore drilling may resolve whether this occurrence is limited to the present beach area or is a wider deltaic feature extending offshore.

It has been suggested that fine-grained PGM entrained in sediment transport along the beach, may be accumulating in sediments of Goodnews and Chagvan Bays where beach transport terminates (7,9,11-12). Bottom samples (nos. 2-6) within the channel leading into Goodnews Bay contained minor gold values, probably concentrated from glacial sediments, but barely detectable platinum. PGM was, however, found along the beach offshore of Chagvan Bay (samples nos. 100-102, appendix B). Due to the closer proximity of Chagvan Bay to the projected ultramafic bedrock, the existence of modern and ancient PGM-bearing channels of the Salmon River leading toward Chagvan Bay, and the



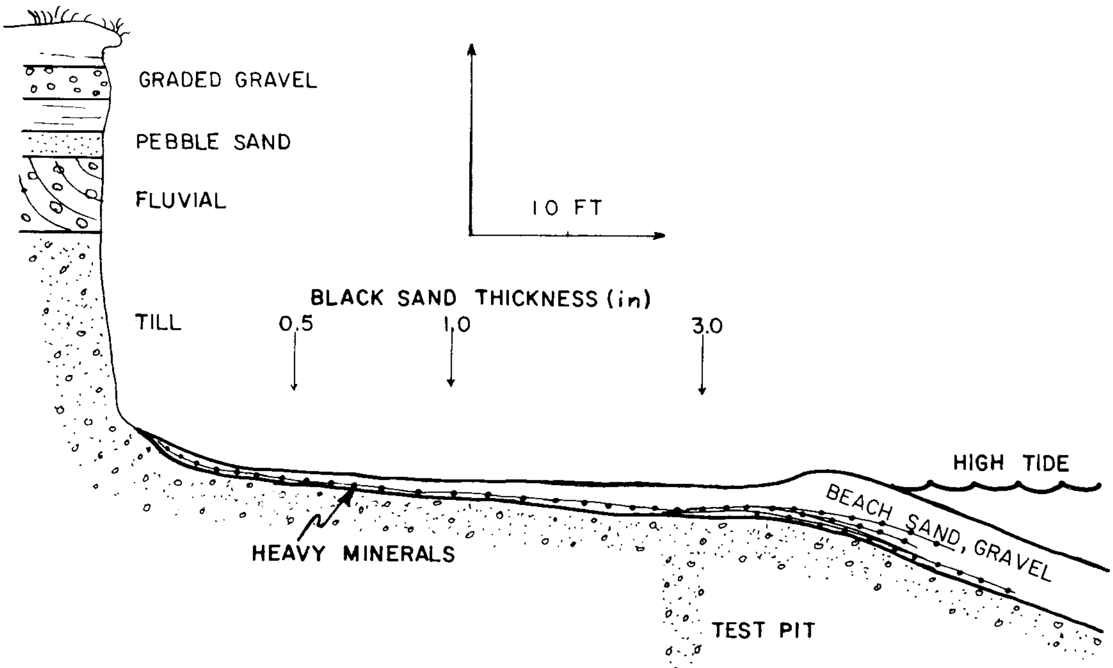


FIGURE 21. - 3-in-thick layer of heavy minerals, accumulated in June, 1985, on glacial till underlying up to 2 ft of beach gravel above the swash zone near Flat Cape. Cross-section shows site of beneficiation sample B.

possibility of offshore drowned channels trending that direction as well, it is likely that Chagvan Bay represents a more viable target for PGM concentrations in a low energy zone. PGM, if present in either bay, may, however, be too fine-grained to be recovered with gravity separation techniques.

FIGURE 22. - Ferricreted till strata near the mouth of the Salmon River creates a false bedrock surface on which heavy minerals with PGM and gold have accumulated. This site was found exposed following a storm in Aug, 1981.

ANCIENT MARINE AND DROWNED ALLUVIAL DEPOSIT-TYPES

At lower sea levels in the past, an extensive bedrock and alluvial plain extended well beyond the area of this study. The magnetometer survey indicates approximately as much ultramafic bedrock lies offshore as is known onshore, posing several potential deposit-types. Ancient placer deposits if present, will be buried by overburden of unknown thickness. Seismic surveys and drilling which was not a part of this project, will be required for further delineation.

Drowned alluvial channels likely exist beneath the offshore sediments. For example, a paleo-bench of the Salmon River has been explored from Medicine Creek to the margin of Chagvan Bay where it likely extends offshore (fig. 2). The gradient of the ancient channel is greater than the present channel and near Chagvan Bay it is overlain by up to 200 ft (61 m) of sediment (2). The magnetic interpretation of a N-S fault or fold offset of the ultramafic complex located about 2.5 miles offshore offers a plausable site for an ancient south to southwest-flowing alluvial channel. This direction would mimic the general trend of onshore valleys (e.g., Salmon and Kinegnak Rivers). Elsewhere, paleochannels are exposed in the bluffs at Flat Cape (sample no. 93, fig. 9) and south of Cabin Creek (sample nos. 103-104). These contain ultramafic detritus and traces of PGM. Other deeper channels may also exist below the bluffs, close to, or within the preglacial surface.

Ancient offshore strand lines from former transgression/regression cycles also represent favorable exploration targets. These include bedrock slopes along the northwestern margin of the projected ultramafic bedrock, and the southern margin of the Flat Cape shoal.

Closer to shore, strand deposits may correlate to an ancient wave-cut scarp. As previously described, near the base of the slope east of Flat Cape there is evidence of a buried and drowned, wave-cut scarp predating at least the last glacial advance. The scarp may additionally correlate to the deep incision at the base of Red Mountain, and the aerial photograph linear that extends northward from there to the bend in the South Spit. The occurrence of fine sand, clay, and magnetite associated with the sinuous magnetic anomaly north of Red Mountain, and the spatial association of PGM with this site is suggestive of deposition along a possible drowned scarp. South-southeast projection of the ancient scarp would coincide with the apparent terminous of the Salmon River paystreak between Claims 15 and 16 Below, near the confluence of Happy Creek. Exploration is recommended for potential PGM enrichment along the possible scarp, probably at depths of 50 ft (16 m) or less below sea level.

Unconventional Deposits

Examination by SEM of PGM grains found some to be quite crystalline with angular edges showing no abrasion (fig. 11E-F). As previously described, some grains are bimodal and comprised of several interlocked

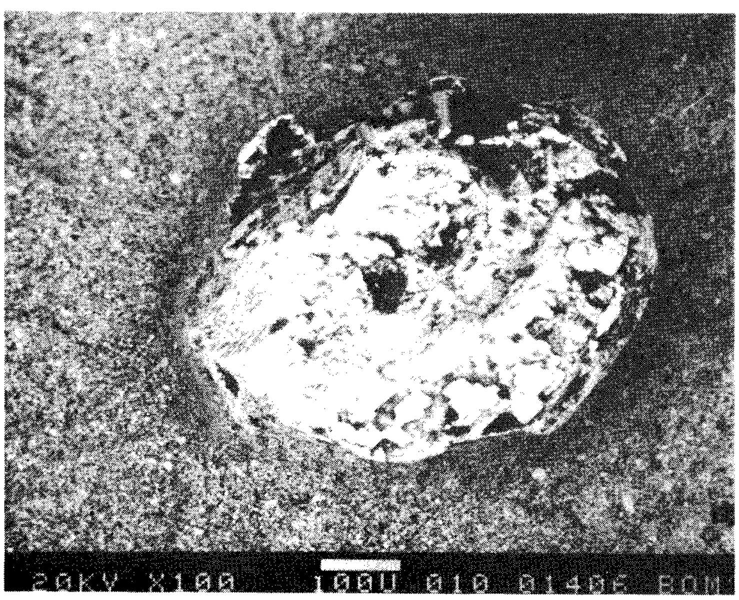


FIGURE 23-A. - Rounded sperrylite grain about 0.5 mm in diameter from test pit site sample no. 88. Note scale bar is 100 microns.

FIGURE 23-B. - Enlargement of lower center portion of sperrylite grain in above photograph. The platy crystalline growths (?) are composed of isoferroplatinum. Note scale bar is 100 microns.

alloy phases. In addition, plate-like growths (?) of Pt-Ir alloy were found as a rind on a sperrylite grain (figs. 23-A and -B). The coated sperrylite grain is evidence of possible accretion of isoferroplatinum at the expense of, or nucleated around sperrylite. The sperrylite grain is well-rounded but the euhedral isoferroplatinum crystals coating it are sharply delineated and appear not to have been abraided.

Evidence has been presented that platinum can be leached at low temperatures in an acidic, oxiding environment such as during serpentinization, then transported in migrating groundwater as soluble chloride complexes (28,30). Accretion of soluble platinum occurs where the platinum can nucleate in a more reducing environment.

A reducing environment is indicated within seafloor sediments. Crystalline pyrite was found in several samples of sediment overlying and along the northern flank of the Flat Cape shoal (e.g., sample no. 15). Bright white crystals of euhedral pyrite as loose grains up to 0.3 in (1 cm) across and as small dendritic branches were particularly abundant in the clayey matrix of the ultramafic bedrock rubble (sample no. 35). In several cases pyrite was also seen to have replaced microorganisms (figs. 15 and 24).

Layered gold shown in figure 13 may also have developed from precipitation of gold within a quiet depositional environment. The possibility of leaching, ground water convection into near shore sediments, and platinum accretion in localized PGM enriched placer zones, should be further studied.

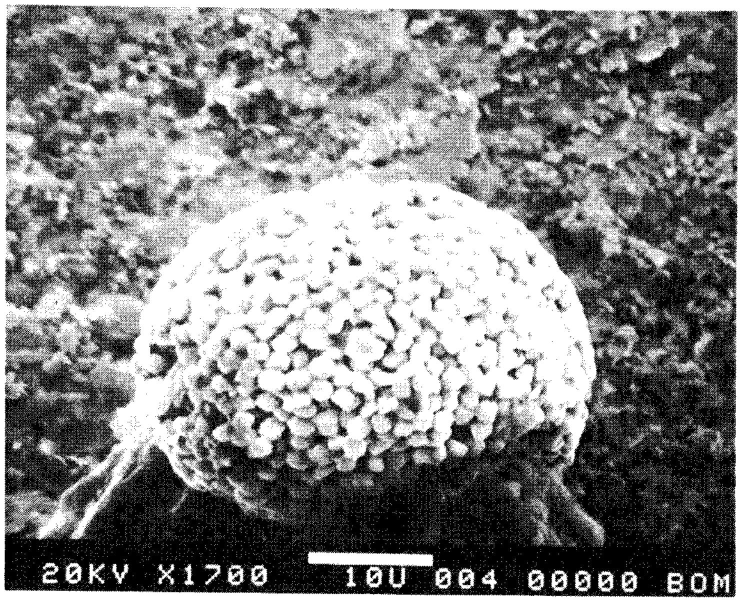


FIGURE 24. - Pyrite relacement and crystalline growth on diatom from sample no. 48, about 2 mi off Flat Cape. Scale bar is 10 micron.

CONCLUSIONS

It has long been suspected that placer PGM may occur in deposits offshore of the Goodnews Bay ultramafic complex. Although nearby onshore placers have produced 650,000 t oz PGM, no offshore deposits are known. There is, however, at least one report of PGM found in a seafloor drill hole west of Red Mountain.

The area offshore from Red Mountain has experienced a complex history of high-energy ocean processes with transgressive and regressive cycles that have periodically inundated an extensive coastal plain extending west at least tens of miles. On-going littoral processes are forming heavy mineral concentrations, and at the same time, depositing sediment that mask drowned alluvial or marine placers. Where the wave-cut scarp is actively eroding the preglacial surface, locally-derived materials (including PGM) are part of the littoral drift and resultant lag deposits. This condition was observed at the base of the 10- to 15-ft (3- to 5-m) below-sea-level dropoff scarp near lat 58°54' and extends at least intermittently north past Red Mountain to lat 58°56.5.' The locally-derived materials entrained in longshore transport are confined to a narrow zone at the base of the dropoff. As the coastline continues to recede, a wave-cut platform is left which is rapidly mantled by mobile, fine-grained, well-sorted sediment from offshore.

The extent of glacial scouring, near, or on the west side of Red Mountain, is an important factor regarding the preservation of PGM placers. A lobe of the Goodnews glacier was near the northwest face of Red Mountain, but appears to have been a relatively low-energy ice sheet with marginal erosional force. The principal ice contact is limited to the northern tip of the mountain mass. An ancient PGM-bearing channel of the Salmon River extending to and possibly below Chagvan Bay is known to have survived glaciation in the Chagvan Bay area.

Magnetometer data indicates approximately as much ultramafic bedrock lies offshore as is known onshore and the complex is open to the west, posing several potential deposit-types for exploration. Exploration targets should focus on 1) recent placers with particular emphasize on offshore lag deposits or strands at stillstand locations, and 2) ancient, pre-trangression deposits that include drowned fluvial channels and strands parallel to wave-cut scarps. There is photolinear, magnetometer, sampling, and drillhole indications of an ancient wave-cut scarp near but about 50 ft (15 m) below the present coastline. In addition, there is inconclusive evidence of PGM placer enrichment related to low temperature solubility, solution transport, and accretion.

The PGM and gold occurrences discussed in this report coupled with geophysical data and geologic observations suggest the offshore is favorable for placer PGM with associated gold and provides several promising exploration targets. Recovery of PGM and gold from low grade sediments, however, will require innovation beyond standard placer processing techniques.

REFERENCES

1. Mertie, J.B., Jr. Platinum Deposits in the Goodnews Bay District, Alaska. U.S. Geol. Surv. Prof. Paper 938, 1976, 42 pp.

2. Southworth, D.D. and J.Y. Foley. Lode Platinum-Group Metals Potential of the Goodnews Bay Ultramafic Complex, Alaska. U.S. BuMines OFR 51-86, 1986, 82 pp.

3. Southworth, D.D. Geology of the Goodnews Ultramafic Complex. M.S. Thesis, Univ. AK, Fairbanks, AK, 1986, 115pp.

4. Page, N.J., A.L. Clark, G.A. Desborough, and R.L. Parker. Platinum Group Metals. in U.S. Mineral Resources, U.S. Geol. Surv. Prof. Paper 820, 1973, pp. 537-545.

5. Coonrad, W.L., Hoare, J.M., Clark, A.L., Grybeck, Donald, and P.W. Barnes. Geochemical Distribution of Platinum and Gold in the Vicinity of Platinum, Goodnews and Hagemeister Island Quadrangles Region, Southwestern Alaska. U.S. Geol. Surv. OFR 78-9-S, 1978, scale 1:125,000, 1 sheet.

6. Mertie, J.B., Jr. The Goodnews Platinum Deposits. U.S. Geol. Surv. Bull. 918, 1940, 97 pp.

7. Welkie, C.J. Noble Metals Placer Formation; An Offshore Processing Conduit. M.S. Thesis, Univ. of WI, Madison, WI, 1976, 89 pp.

8. Wakeland, M.E. Surficial Sediments of Goodnews Bay, Alaska. M.S. Thesis, Univ. of WI, Madison, WI, 1973, 103 pp.

9. Owen, R.M. Sources and Deposition of Sediments in Chagvan Bay, Alaska. Ph.D. Thesis, Univ. WI, Madison, WI, 1975, 201 pp.

10. Walish, R.C. Mineralogical Compositions of Sediments, Goodnews Bay, Alaska. M.S. Thesis, Univ. of WI, Madison, WI, 1977, 71 pp.

11. Bond, S.C. Origin and Distribution of Platinum Enriched Heavy Mineral Accumulations in a Beach Placer Near Platinum, Alaska. M.A. Thesis, Univ. TX, Austin, TX, 1982, 63 pp.

12. Ulrich, S. Formation of a Platinum-Rich Beach Placer Deposit, Goodnews Bay, Alaska. M.A. Thesis, University of Texas, 1984, 179pp.

13. Bird, M.L. and A.L. Clark. Microprobe Study of Olivine-Chromitites of the Goodnews Bay Ultramafic Complex, Alaska and the Occurrence of Platinum. U.S. Geol. Surv., J. of Res., v. 4, no. 6, 1976, pp. 717-725.

14. Jones, D.L., Silberling, N.J., Berg, H.C., and George Plafker. Map Showing Tectonostratigraphic Terranes of Alaska, Columnar Sections, and Summary Descriptions of Terranes. U.S. Geol. Surv. OFR 81-792, 1981, scale 1:2,500,000.

15. Box, S.E. Tectonic Implications of a Geologic Transect Across Northern Bristol Bay, Alaska. AK Geol. Soc., Western AK Symposium Abstracts, 1982, pp. 52-53.

16. --------. Terrane Analysis of the Northern Bristol Bay Region, Southwestern Alaska. Sec. in The U.S. Geol. Surv. in Alaska: Accomplishments During 1984. U.S. Geol. Surv. Circ. 967, 1985, pp. 32-37.

17. Hoare, J.M., and Coonrad, W.L., Geologic Map of the Goodnews and Hagemeister Is. Quadrangles Region, southwestern Alaska. U.S. Geol. Surv. OFR 78-9-B, 1978, scale 1:250,000.

18. Mertie, J.B., Jr. Economic Geology of Platinum Metals. U.S. Geol. Surv. Prof. Paper 630, 1969, 120 pp.

19. Cabri, L.J. Platinum-Group Elements: Mineralogy, Geology, Recovery. Can. Inst. Min. and Met., Montreal, CAN, 1981, 270 pp.

20. Hopkins, D.M. Quaternary marine transgressions in Alaska, in, Hopkins, D.M., ed., The Bering Land Bridge. Stanford, Stanford University Press, 1967, pp. 47-90.

21. Porter, S.C. Glaciation of Chagvan Bay Area, Southwestern Alaska. Arctic, v. 20, no. 4, 1967, pp. 227-246.

22. Fleischer, M. Glossary of Mineral Species. Mineral Records, Tucson, AZ, 227 pp.

23. Rosenblum, S., Carlson R.R., Nishi, J.M., and W.C. Overstreet. Platinum-Group Elements in Magnetic Concentrates From the Goodnews Bay District, Alaska. U.S. Geol. Surv. Bull. 1660, 1988, 38 pp.

24. Wright, T.L. and Fleischer, M. Geochemistry of Platinum Metals. U.S. Geol. Surv. Bull. 1214-A, 1965, 24 pp.

25. Berdincourt, L.E., Hummel, H.H., and B.J. Skinner. Phases and Phase Relationships of Platinum-Group Elements. In Cabri, CAN. Inst. Min. Spec., v. 23, Chap. 3, 1981, pp. 19-46.

26. Overstreet, W.C., Lowering, T.G., Rosenblum, S. and G.W. Day. Minor Elements in Magnetic Concentrates from Alaska. U.S. Geol. Surv. GD-78-004, 1978, 596 pp.

27. Griscom, A. Aeromagnetic interpretation of the Goodnews and Hagemeister Island Quadrangles Region, Southwestern Alaska. U.S. Geol. Surv. OFR 78-9-C, 1978, scale 1:250,000.

28. Cousins, C.A. and E.D. Kinlock. Some Observations on Textures and Inclusions in Alluvial Platinoids. Econ. Geol. v. 71, 1976, pp. 1377-1398.

29. Berryhill, R.V. Reconnaissance of Beach Sands, Bristol Bay, Alaska. BuMines RI 6214, 1963, 48 pp.

30. Bowles, J.F.W. The Development of Platinum-Group minerals in Laterites. Econ. Geol. v. 81, 1986, pp. 1278-1285.

APPENDIX A - Sample analyses and descriptions for offshore sites

Map number	Sample number	Original sample kg	-20 mesh kg	Weight of heavy mineral-table g	Weight of pan conc-Pt concentrate g	Flotation conc g	mg/yd³ 1/ Pt	Ir 2/	Au	Weight pct in heavy mineral concentrate Fe	Ti	Cr
1	23318	21.2	3.0	NS	1.6	5.09	T	T	T	NA	NA	NA
2	23319	22.9	1.1	85.9	11.2	NS	T 4/	T	131.09 4/	4.9	0.71	0.09
3	23307	71.3	9.2	48.4	24.2	NS	T	T	1.02	6.2	.73	.18
4	23178	36.3	NS	187.4	104.1	NS	T	T	94.56	2.9	.23	.1
5	23317	45.1	6.5	NS	5.7	NS	N	N	28.67	NA	NA	NA
6	23310	34.5	19.6	88.6	26.5	5.14	5.75	.31	211.72	12.0	1.63	.87
7	23077	53.3	25.3	42.5	19.9	10.49	2.76	.36	.29	17.0	2.18	3.08
8	23074	39.0	33.1	93.0	28.3	2.54	.72	T	.55	25.0	3.82	4.09
9	23075	48.5	28.5	158.5	46.5	16.17	.82	.11	.55	27.0	4.25	3.66
10	23076	34.2	8.1	53.1	25.1	4.78	1.03	.18	.42	10.0	1.24	1.33
11	23311	36.8	29.0	456.4	37.3	NS	26.76	3.48	7.67	30.0	2.98	5.50
12	23302	6.8	2.3	NS	33.0	NS	.76	.10	.76	NA	NA	NA
13	23029	63.1	13.2	28.4	21.9	12.06	11.95	1.55	.14	34.0	2.95	9.62
14	23030	42.7	28.2	87.1	36.0	21.0	.13	T	.01	36.0	3.72	8.29
15	23034	50.8	12.8	115.0	19.5	21.0	.94	.11	3.92	19.0	1.86	4.33
16	23033	44.9	25.9	40.0	22.1	8.5	T	T	.29	28.0	5.20	4.11
17	23041	50.4	3.5	NS	16.9	15.2	1.13	.15	.12	NA	NA	NA
18	23040	64.5	26.7	479.1	32.0	22.9	.44	T	8.72	36.0	4.18	6.57
19	23039	61.7	32.6	247.1	52.6	15.0	.10	T	2.72	22.0	2.24	5.09
20	23038	54.9	14.5	100.8	26.8	20.7	.04	T	2.50	22.0	2.24	5.09
21	23035	54.9	5.3	67.9	16.7	3.0	.30	T	.20	15.0	1.38	3.14
22	23036	62.2	15.8	61.7	27.9	14.0	T	T	.90	24.0	3.34	4.31
23	23037	39.1	10.8	468.5	20.0	31.0	.88	T	1,251.20 4/	7.3	.52	.59

Map number	Description
1	Sub-rounded, sandy gravel. Predominantly chert, few UM. Van Veen grab.
2	Well-rounded gravel, minor sand. Au grain = 1.5 mg, Au attached to qz. 5 Pt specks. Cinnabar in pan concentrate. Shipex grab.
3	Sub-rounded to rounded, sandy gravel. 1 Pt speck, 1 Au speck in check pan. Van Veen grab.
4	0.5 ft loose, sorted gravel overlying clayey gravel from bottom of channel. Sample diluted when hole sloughed in.
5	Rounded, silty-clayey gravel with dark gray mud from toe of slope. 3 Au grains = 0.2 mg, 4 Pt specks. Chert, quartz, volcaniclastics comprise gravel. Van Veen grab.
6	Fine, sandy beach sand from deepest part of channel. Au grain = 2.4 mg. 3 Pt specks in check pan. Van Veen grab.
7	Sand and gravel overlying 0.5 ft coarse, sub-rounded, cobbly gravel, overlying compacted clayey, gravel. Sample from compacted gravel. Scattered UM boulders.
8	Sample taken from cobbly gravel overlain by 0.75 ft loose rippled sand.
9	0.9 ft brown, rippled sand overlying salt and pepper sand. Sample taken from salt and pepper sand. Scattered UM boulders.
10	0.5 ft gravely sand overlying compacted clay-rich gravel. Sample was taken at edge of and beneath large UM boulder, and from depth of 0 to 1.25 ft below seafloor.
11	Fine sand with beach pebbles from upper edge of dropoff. 6-10 Au specks. Van Veen grab.
12	Tightly compacted gravel with abundant UM boulders. Van Veen and Shipex grab.
13	Sample taken from 0.75-ft-deep hole in cobbly, silty, compacted gravel, with UM boulders up to 1 ft nearby.
14	Sample taken from 0.75-ft-deep hole in 0.25 ft of rippled sand overlying sandy, silty gravel, with cobbles up to 0.75 ft.
15	Sample taken from silty gravel with cobbles overlying veneer of rippled sand. 1 Au flake.
16	0.25 ft of rippled sand overlying sandy gravel. Sample taken from 0.8-ft-deep hole in sandy gravel.
17	Cobbly gravel. 2 Au specks.
18	Black, silty, sandy gravel.
19	Sample taken from sandy gravel overlain by rippled sand, scattered boulders nearby. A few Au and Pt specks.
20	Sandy gravel, sample depth of 1 ft .
21	Relatively loose, silty gravel, cobbles.
22	0.75 ft cobble bed overlying silty, clayey sediment. Sample from 1.5-ft-deep hole, which includes the clay-rich zone. 5 Au specks.
23	Sample from loose, silty, clayey gravel with numerous rounded boulders, a few to 4-ft-diameter. 28 mg of Au grains, Au is angular to sub angular, some attached to qz, some are flat scales. A few Pt specks also found.

See notes at end of table.

APPENDIX A - Sample analyses and descriptions for offshore sites--Continued

Map number	Sample number	Original sample kg	-20 mesh kg	Weight of heavy mineral-table g	Weight of pan conc-Pt concentrate g	Flotation conc g	mg/yd3 [1/] Pt	Ir [2/]	Au	Weight pct in heavy mineral concentrate Fe	Ti	Cr
24	23206	42.8	17.9	NS	24.9	NS	.04	T	1.56	NA	NA	NA
25	23055	37.2	6.3	84.7	20.4	NS	6.42	3.31	5.08	50.0	2.49	11.60
26	23053	52.7	11.2	68.7	35.8	8.00	.06	T	.69	10.0	1.28	1.18
27	23071	52.2		24.2	25.7	2.00	.17	T	.10	36.0	4.25	7.90
28	23073	52.2	26.3	0.0	34.0	30.70	.10	T	1.82	NA	NA	NA
29	23323	2.5	NS	0.0	9.1	NS	.15	.02	8.14	NA	NA	NA
30	23054	49.5	12.2	0.0	27.9	6.10	.08	T	.04	NA	NA	NA
31	23072	52.2	16.2	303.8	37.8	21.10	.71	.09	.64	8.0	.96	.79
32	23316	47.2	27.2	127.1	23.8	NS	.04	.01	.43	16.0	1.99	2.43
33	23305	51.3	7.7	0.0	27.9	NS	.33	.04	2.10	NA	NA	NA
34	23312	30.4	7.9	54.8	39.8	15.80	3.67	.48	2.16	38.0	4.41	6.29
35	23201	47.3	15.6	2,332.0	67.0	NS	.53	.07	>.34 [3/]	5.3	.60	.12
36	23202	49.9	32.9	3,208.0	61.4	NS	.13	.02	31.36	NA	NA	NA
37	23203	45.0	7.4	0.0.	45.8	NS	.56	.07	.78	NA	NA	NA
38	23313	95.3	4.6	35.0	32.6	4.92	.02	T	.34	30.0	5.10	3.64
39	23204	45.0	6.3	0.0	117.3	NS	.16	.02	21.46	NA	NA	NA
40	23205	42.8	5.0	330.3	NS	NS	.08	T	140.10	NA	NA	NA
41	23208	25.7	8.0	0.0	24.9	NS	1.75	.23	4.02	NA	NA	NA
42	23299	33.3	2.3	0.0	30.0	NS	20.00	2.60	47.00	NA	NA	NA
43	23296	30.0	22.4	124.8	54.7	NS	>2.18 [4/]	>.28 [4/]	4.06 [4/]	36.0	4.21	4.21
44	23297	32.0	3.2	0.0	11.8	NS	.46	T	.27	NA	NA	NA
45	23298	45.7	14.5	64.4	44.0	2.38	68.52	9.11	123.33	6.6	.77	.45
46	23126	56.8	35.4	84.4	.5	NS	1.0	.10	>29.30 [3/]	26.0	1.80	N
47	23125	56.8	49.9	73.7	4.6	NS	.44	T	>1.33 [3/]	24.0	1.90	>3.00
48	23124	56.8	40.0	111.6	.2	NS	.50	T	>2.66 [3/]	25.0	1.60	>3.00
49	23123	56.8	21.4	552.9	11.1	NS	141.26	18.36	>353.00 [3/]	38.0	>2.00	>3.00

Map number	Description
24	Sample taken from grey, clayey gravel covered by 0.6 ft of rippled sand. 3 Au specks.
25	Sample of silty, clayey gravel collected beside a 4-ft UM boulder.
26	Sample from 1 ft hole in compacted, clay-rich sediment. Mussle bed present. 12 Pt specks.
27	Sample of sandy gravel from 1- to 2-ft hole.
28	0.5 ft silty gravel overlying 0.6 ft loose pea gravel, overlying compacted, clayey gravel. Sample includes all three.
29	1 small Au flake in one pan. Van Veen grab.
30	Sample of silty gravel from 1 ft hole.
31	Clayey, sandy, cobbly gravel with boulders to 3-ft-diameter. Sample collected from edge of boulder. Visable Au and Pt specks.
32	Sample of rounded, loose sandy gravel, overlying a clay-layer not included in sample.
33	Sample of sandy gravel. 1 Pt speck in check pan. Van Veen grab.
34	Sample of sandy gravel from toe of dropoff. 1 Pt speck. Van Veen grab.
35	Sample of compacted clay-gravel, UM rubble, from toe of dropoff, from 1.5-ft hole. Abundant white metalic sulfide (pyrite). A few Pt and Au spects in final concentrate.
36	Sample from 0.75 ft hole in tightly compacted, sandy, rounded gravel with small, rounded UM boulders
37	Sample from 1.2-ft hole in compacted sandy gravel.
38	Sample of loose, fine-grained, well-sorted gravel. 1 Au speck in check pan. Van Veen grab.
39	Sample of loose, well-rounded, sandy gravel from 2-ft-deep hole.
40	Sample of loose, well-rounded, sandy gravel which is forming shallow bars.
41	Sample from gravelly clay, with boulders embedded, from toe of drop off. 2 or 3 Pt specks in check pan. Ferricrete on pebbles.
42	Sample from loose gravel, which is overlying sandy, clayey gravel. Sponges and starfish in vicinity. 1 Pt speck in pan. Van Veen grab.
43	Sample of loose, sandy, sub-rounded gravel. 1, 0.3 mm Au flake; 5, 0.1 to 0.2 mm Au flakes; 2, 0.05 mm Pt. Van Veen grab
44	Sample of sub-rounded, sub-angular gravel. Some small metallic grains. Van Veen grab.
45	Sample of subangular gravel, in mussel bed. 1, 0.02 mg Pt speck; 1, 0.03 mg Pt speck. Van Veen grab.
46	Sample from compacted cobbly gravel. Cinnabar in concentrate.
47	Sample from clayey, cobbly gravel.
48	Sample from subangular and subrounded gravel. Pt speck in oversize fraction.
49	Sample of loose, cobbly gravel overlying compacted clayey gravel, taken from 0.1- to 0.8-ft depth. Au and Pt specks, coarser Au grains to 0.5 to 10mm; Pt grains to 0.3 to 1.0mm.

See notes at end of table.

APPENDIX A - Sample analyses and descriptions for offshore sites--Continued

Map number	Sample number	Original sample kg	-20 mesh kg	Weight of heavy mineral-table g	Weight of pan conc-Pt concentrate g	Flotation conc g	mg/yd^3 [1] Pt	Ir [2]	Au	Weight pct in heavy mineral concentrate Fe	Ti	Cr
50	23121	56.7	10.5	742.0	51.50	3.63	.06	T	.24	7.2	0.87	0.58
51	23079	56.2	38.0	116.0	4.40	NS	.17	T	>14.30 [3]	30.0	>2.00	>3.00
52	23078	56.7	23.6	57.9	.77	NS	N	N	--- [3]	18.0	>2.00	1.41
53	23300	39.9	8.7	84.8	40.20	28.90	11.28	1.47	3.53	29.0	4.14	4.42
54	23301	39.5	6.9	18.3	11.40	14.12	.03	T	.61	15.0	2.78	0.86
55	23306	27.5	2.0	0.0	21.10	NS	.07	T	1.03	NA	NA	NA
56	23303	28.6	1.1	69.8	18.60	2.84	2.39	.31	.99	5.3	0.68	0.12
57	23304	20.7	2.5	27.6	17.40	13.21	.09	T	4.17	17.0	2.95	1.33
58	23173	45.0	6.1	0.0	61.23	NS	5.55	.72	.74	NA	NA	NA
59	23172	49.5		0.0	52.90	NS	1.08	.14	.35	NA	NA	NA
60	23308	19.1	13.6	11.8	20.70	7.24	.25	T	10.20	28.0	3.90	2.84
61	23200	47.3	12.4	0.0	63.55	NS	.25	T	95.14	NA	NA	NA
62	23309	37.0	20.0	137.0	28.10	NS	.32	T	43.41	18.0	2.23	1.86
63	23122	62.1	15.8	NS	34.00	NS	.51	T	1.30	NA	NA	NA

Map number	Description
50	Coarse, subangular, loose gravel overlying compacted clayey gravel.
51	Sample from top 0.6 ft of loose, coarse gravel overlying compacted cobbly gravel.
52	Sample from top 0.5 ft of loose, sub-rounded gravel overlying compacted cobbly gravel.
53	Sample of sandy, silty gravel with few fines. Au, Pt, and cinnabar in concentrate. Van Veen grab.
54	Sample of sandy gravel. Van Veen grab.
55	Sample of subangular gravel. Van Veen grab.
56	Sample of loose, sandy gravel. 2 small Pt specks in check pan. Shipex and Van Veen grab.
57	Sample of loose, sandy gravel. Small Pt specks in check pan. Van Veen grab.
58	Sample from 0.75-ft-deep hole in compact, cobbly gravel. Au and cinnabar in concentrate.
59	1.3-ft hole dug through 0.5 ft gravelly sand, then loose sandy gravel.
60	Sample of subangular and subrounded, sandy gravel. Van Veen grab.
61	Sample collected 0.5 ft down in loose, well-rounded gravel.
62	Sample of angular to subrounded, sandy gravel. 1 Pt in check pan. 1 Au grain = 0.5 mg. Van Veen grab.
63	Sample from 0.75 ft hole through loose cobbly gravel overlying compacted gravel.

qz quartz. b.s. black sand. UM ultramafic. T trace value. N not detected. NA not analyzed. NS no split prepared. kg kilogram. g gram. mg milligram.

[1]Conversion from mg/yd^3 to t oz/yd^3 is x 0.000032; mg/yd^3 used to simplify data presented in this table.

[2]Calculated iridium values based on reported Ir:Pt of 0.13 given by Mertie (1940).

[3]Spurious high Pt or Au value reported for analysis of heavy mineral concentrate, no final assay calculated due to high level of bias.

[4]Partial analysis, grains previously removed for mineralogical study.

APPENDIX B - Sample analyses and descriptions for onshore sites

Map number	Sample number	Original sample kg	-20 mesh kg	Weight of heavy mineral-table g	Weight of pan conc-Pt concentrate g	Flotation conc g	mg/yd^3[1/] Pt	Ir[2/]	Au	Weight pct in heavy mineral concentrate Fe	Ti	Cr
70	23011	4.5	NS	NS	20.30	1.50	151.70	20.20	25.20	NA	NA	NA
71	23106	18.2	NS	NS	27.10	NS	1.92	.26	T	NA	NA	NA
72	23015	1.0	NS	NS	4.17	NS	61.70	8.01	N	NA	NA	NA
73	23018	1.4	NS	NS	20.30	NS	1.33	0.17	10.53	NA	NA	NA
74	23043	18.2	5.9	0.0	16.00	NS	24.75	3.21	.37	NA	NA	NA
75	23004	5.0	NS	387.8	13.6	NS	13.35	1.74	8.89	NA	NA	NA
76	23006	20.0	3.1	320.1	20.0	NS	.59	T	.43	NA	NA	NA
77	23007	4.4	3.8	273.6	29.9	NS	96.20	12.90	7.80	NA	NA	NA
78	23010	3.6	NS	0.0	20.30	NS	1.16	.15	.05	NA	NA	NA
79	23032	29.2	7.2	106.7	40.10	10.04	>28.51[4/]	>3.70[4/]	1.75	34.0	1.50	14.90
80	23031	5.0	NS	231.7	NS	NS	5.36	.70	5.36	NA	NA	NA
81	23009	16.0	NS	122.0	25.20	NS	468.70	71.15	.02	21.0	1.16	6.00
82	23127	32.2	7.2	61.5	45.50	1.40	13.30	1.45	8.40	37.0	2.04	9.71
84	23086	5.0	NS	NS	22.30	NS	1.63	.21	N	NA	NA	NA
85	24444	39.0	NS	391.9	NS	NS	27.30	3.55	149.30	NA	NA	NA
86	24445	39.0	NS	866.4	NS	NS	12.84	1.67	2.57	NA	NA	NA
87	23027	32.2	7.2	61.5	68.20	1.40	57.09	7.42	4.61	37.0	2.04	9.71
88	23028	39.0	7.2	91.0	23.30	4.19	36.99	4.80	.05	18.0	.89	4.21
89	23042	29.1	6.5	516.6	40.51	5.39	252.64	32.84	1.23	23.0	1.15	5.67

Map number	Description
70	Sample of b.s. with visable Au and Pt.
71	Sample from 10-ft auger hole. 0- to 2-ft, beach wash; 2- to 9-ft glaciofluvial; 9+ ft gravelly clay.
72	Sample from 5-ft auger hole. Mostly beach sand and gravel.
73	Sample from 3-ft-deep auger hole on beach. 1- to .3-mm Au flake. Clasts of chert, UM, volcanics.
74	Pan concentrate of active channel. 0.3 mm Pt grain and 2 small Pt specks.
75	2-ft channel sample of well-rounded, Fe-oxide coated gravel of possible ancient fluvial deposit in beach bluff.
76	Channel sample of green-gray, sub-rounded to subangular, loose gravel, lower 3.5 ft exposed in bluff below sample 75.
77	Sample from 0- to 8-ft-interval of auger hole, consists of 1 ft loose pea gravel overlying green clayey sand. Abundant fine grained magnetite.
78	Sample collected from 6.5-ft auger hole in back beach.
79	Channel sample of a 2-ft-thick green clay/silt layer with subangular serpentinite clasts, overlying a ferricrete gravel unit. 4 coarse and 15 fine Pt grains found in concentrate.
80	Sample of clay and fine gravel from 1.5- to 8-ft-interval in auger hole on back beach.
81	Channel sample, top 1.5 ft of same auger hole as sample 80, contains minor b.s. Six Pt grains, measuring 0.4 to 1.5 mm, weighed 5.5 mg, combined.
82	Sample from 1.5- to 7.5-ft-interval of auger drill hole, consists of sandy gravel and clay. Ferricrete layer at 5.5 ft.
84	Sample of gravel from top of bluff. Concentrate contained 5 Pt specks.
85	Sample from 0- to 2.2-ft-interval of test hole, consists of ultramafic cobbles and boulders with a sandy matrix.
86	Sample from 1.75-ft-deep pit in beach sand with UM cobbles and boulders.
87	Sample 87, 88, 89 from 4-ft-deep pit in back beach. Sample 87 collected over 0- to 1-ft-interval of beach sand. Contained visable Au and Pt.
88	See no. 87. Sample from 1- to 2-ft-interval, consists of clay and sand.
89	See no. 87. Clay rich sample from 2- to 4-ft-interval.

See notes at end of table.

APPENDIX B - Sample analyses and descriptions for onshore sites--Continued

Map number	Sample number	Original sample kg	-20 mesh kg	Weight of heavy mineral-table g	Weight of pan conc-Pt concentrate g	Flotation conc g	mg/yd³ [1] Pt	mg/yd³ [1] Ir [2]	mg/yd³ [1] Au	Weight pct in heavy mineral concentrate Fe	Weight pct in heavy mineral concentrate Ti	Weight pct in heavy mineral concentrate Cr
90	23068	27.2	NS	659.2	NS	NS	78.69	10.23	19.77	33.0	.78	>3.00
91	23066	28.8	25.9	2,231.6	45.00	NS	31.22	4.06	251.21	46.0	2.62	11.80
92	23058	40.9	NS	apx 500	45.00	NS	34.95	4.65	39.90	37.0	.76	10.55
93	23056	4.5	NS	NS	54.36	NS	452.20	60.41	579.60	NA	NA	NA
94	23119	50.0	NS	0.0	33.30	NS	.81	.11	T	NA	NA	NA
95	23057	40.0	NS	0.0	25.40	NS	3.70	.50	1.30	NA	NA	NA
96	23060	27.9	8.8	5,469.0	NS	NS	---[3]	---[3]	---[3]	44.0	2.52	10.70
97	23069	17.3	17.0	1,542.7	NS	NS	>307.00[4]	>165.00[4]	>39.00[4]	48.0	2.56	11.60
98	19421	2.5	NS	2.5	NS	NS	2,948.30	383.00	346.90	NA	NA	NA
99	19422	5.5	NS	5.5	NS	NS	6,590.60	857.00	1,503.00	NA	NA	NA
100	23128	9.1	NS	47.0	37.40	NS	>18.50[4]	>3.40[4]	>5.42[4]	50.2	2.59	11.30
101	23129	6.8	NS	NS	49.30	NS	59.20	7.90	6.20	NA	NA	NA
102	23130	10.9	NS	NS	45.00	NS	74.00	9.80	154.00	NA	NA	NA
103	23012	.1	NS	NS	97.47	NS	3,074.80	399.72	12,128.30	NA	NA	NA
104	23197	27.0	NS	NS	82.50	NS	2.40	.32	.06	NA	NA	NA
105	23196	36.0	NS	NS	21.40	NS	T	T	T	NA	NA	NA

Map number	Description
90	1.2-ft channel sample across 3 layers of b.s. in beach gravel below swash.
91	Sample of b.s. from back beach. Pan concentrate had 10 Au- and 6 Pt-coarse grains, and over 100 fine colors.
92	Channel sample from 2-ft hole in back beach, includes narrow b.s. layer overlying till and under beach sand.
93	Sample from 0.33-ft-thick b.s. layer, which had 20 Pt- and 100-Au specks in check pan.
94	Channel sample of well-graded gravel and coarse gravel and sand, 8- to 12-ft fluvial interval.
95	Sample is lower zone of sample no. 94, consists of 2-ft-thick UM fluvial coarse gravel and sand.
96	Channel sample of .05- to .25-ft-thick b.s. layer. Sample is 0.5-ft-wide by 16-ft-long, in back beach and includes only the b.s. layer. Abundant visable PGM-Au.
97	Sample of b.s. layer underlying beach.
98	Sample of b.s. accumulation on ferricrete. Analysis represents minimum value as "riffles" on ferricrete could not be thoroughly cleaned.
99	Sample of b.s. accumulation, as in no. 98, but this sample included b.s. washed from ferricrete. .
100	Sample from b.s. layer below 1-ft of loose gravel. 20 Au and 15 Pt specks found. Grains removed for mineralogic study.
101	Sample from b.s. layer overlying coarser gravel, collected over 50-ft-interval along back beach.
102	Sample of high-grade b.s. up to 0.25-ft-thick, overlying well-compacted, clayey gravel. Fine Au and Pt recovered from check pan.
103	Sample from 2-ft hole consists of pebble, sand, and boulders.
104	Channel sample of 3-ft-interval of well-rounded, well-sorted, paleo-alluvial gravels in bluff. Pan concentrate contained 3 to 4 specks of Pt.
105	3-ft channel sample of loose gravel, possibly from paleo-channel trough. Contained a few specks of Pt.

qz quartz. b.s. black sand. UM ultramafic. T trace value. N not detected. NA not analyzed. NS no sample. kg kilogram. g gram. mg milligram.

[1] Conversion from mg/yd³ to t oz/yd³ is x 0.000032; mg/yd³ used to simplify data presented in this table.

[2] Calculated iridium values based on reported Ir:Pt of 0.13 given by Mertie (1940).

[3] Spurious high Pt or Au value reported for analysis of heavy mineral concentrate, no final assay calculated due to high level of bias.

[4] Partial analysis, grains previously removed for mineralogical study.