LEGISLATIVE FINANCE-HOUSE/SENATE FINANCE COMM. FILES 8879

HB 332 cont. 508

Goodnews Bay and the offshore vicinity to be included as critical habitat under HB332 also meet the criteria for "essential habitat" under the Cenaliulriit Coastal Management Program ("CCMP") as described at pages 16 and 17 of my May 8, 1989 letter. Moreover, the CCMP specifically describes the vicinity of Goodnews Bay and Platinum as "special areas" requiring "careful planning and management." See CCMP at p. 7-5. Among other things, the CCMP requires that:

> Essential offshore habitat will be managed as a fisheries conservation zone so as to maintain or enhance the state's sport, commercial , and subsistence fishery. Id. at 6-24.

That is precisely what HB 332 would require as a matter of state law. See A.S. 16.20.510 - .530. Moreover, HB 332 would close the proposed Goodnews Bay critical habitat to mineral entry, and thereby assure that the existing and growing sport, commercial and subsistence renewable resource economy will never again be jeopardized by offshore mining within state waters. For the reasons stated in my May 8, 1989 letter, Kuitsarak, Inc. can conceive of no circumstances under which offshore mining in the vicinity of Goodnews Bay would be compatible with the existing economy of the area. Moreover, the already established economy ought to be protected and supported as a matter of state law from future similar threats. HB 332 would further all of these goals.

Sincerely,

COPELAND, LANDYE, BENNETT and WOLF

David S. Case

cc: Kuitsarak, Inc.
Cenaliulriit
Lyman Hoffman (By Telefax)

DSC\1007\LReHB332.02:dsc

MIRL Report Number 61

FOURTH ANNUAL CONFERENCE ON ALASKAN PLACER MINING

March 30-31, 1982

Fine Arts Concert Hall

University of Alaska

Fairbanks, Alaska

School of Mineral Industry

and

Alaska Miners Association

An abridged format of papers, presentations and addresses given during the conference compiled and edited by:

Bruce W. Campbell
John J. DiMarchi
Ernest N. Wolff

PLATINUM MINING AT GOODNEWS BAY, ALASKA

Raymond A. Hanson
President, Hanson Properties

The Goodnews Bay Mine is located at Platinum, Alaska. It is 450 miles west and 150 miles south of Anchorage. It is also 150 miles directly south of Bethel. Summers are quite pleasant and winters are not too cold. The area receives only a few feet of snow, which is extensively drifted by the wind.

The discovery of platinum in the Goodnews Bay area was made in 1926 when Walter Smith, an Eskimo from a small village on Chaguan Bay led Henry Wuya and Charlie Thorsen to a place on Platinum Creek. Smith had earlier panned some of the heavy metal, which he termed "Black Gold". Thorsen, who was a prospector, persuaded Joe Jean, a French Canadian Trader at Mumtrak, Alaska, to send a sample of the metal to the College of Mines at Fairbanks for assay. the winter of 1927 a confirmation was received that the heavy gray metal was platinum.

Hand-mining operations began in the summer of 1927 in Clara Creek, Squirrel Creek, Fox Gulch and Platinum Creek. All of these streams are right-limit tributaries of the Salmon River and all cut the eastern flank of Red Mountain. Red Mountain, a rust colored ridge of rock, rises 2,000 feet from the Bering Sea.

From 1927 until 1933, hand-mining produced a scant 3,000 ounces of crude platinum (less than 500 ounces a year) with 8 to 10 individual miners involved in this project, it became clear that little profit or progress could be made in developing this deposit.

In 1933, an Anchorage prospector, Walter Culver, obtained leases and options on most of the mining claims in the area. In the fall of that year, Culver turned these claims and leases over to a group of successful pioneer goldminers headed by Andrew Olson. Olson, together with his partners, operated the Northland Development Company and Olson & Company in the Flat-Iditarod section of Interior Alaska.

By 1934, the Northland Development Company had shipped a dragline excavator, trestle sluice box, caterpillar tractor and other equipment and supplies into Goodnews Bay, thus setting up a complete and self-sufficient modern mining camp. The boat carrying this equipment arrived at Goodnews Bay on July 10th and the shipment was hauled twenty-five miles around the western flank of Red Mountain and up the Salmon River to Squirrel Creek, the mining campsite. Equipment was then assembled, buildings constructed and on August 11, 1934, mining operations began. Mining continued without interruption, except for seasonal shutdowns until the fall of 1975.

Early in 1935, the Goodnews Bay Mining Company, was incorporated in the territory of Alaska to consolidate the holdings of the predecessor company in the Goodnews area. The first two years of mining were limited to the dragline operations. Extensive exploration and drilling indicated a substantial yardage of deeper ground on the Salmon River, which provided the basis of a $600,000 loan for the purchase of a bucketline dredge. In 1937, a Yuba diesel electric dredge with 8 cubic foot buckets were purchased and transported to the Salmon River. The Yuba Dredge 129 started digging on November 10, 1937, perilously close to the freeze-up weather. A benign providence provided mild weather making it not only possible to complete the 30-day trial run, but as an added and most welcome bonus, allowed dredging to continue until December 22nd.

The total cubic yards dredged from 1938 to 1975 were 42,115,518. The total number of ounces dredged from 38 to 75 was 519,844,142. In the first year of operation, the mine produced approximately 2,575 troy ounces of crude platinum; increasing in 1935 to almost 8,000 ounces. The following two years showed a production decline, which was partially attributable to the preparation and erection of the dredge. 1938, the first full season of operation for both the dredge and the dragline, increased production to 37,000. In subsequent years, the operating methods did not change materially, although a number of mining problems were encountered and solved. Through the years, ingenious modifications and additions to the equipment have been introduced. The successful solution of mining and mechanical problems is largely contributed to the inventive minds of the two Olson brothers, Andrew and Edward.

One of the first tasks each season is the removal of ice from the dredge pond. The ice, which averages about 3 feet in thickness, is first cut into blocks with a power chain saw. These blocks are approximately 5 feet wide and 10 feet long and are hoisted from the pond by the dragline and piled on the shore. With an average dredge pond surface area of 2 to 2-1/2 acres, the weight of ice to be removed is formidable -- running from 8,000 to 10,000 tons.

The dragline operations utilized two Bucyrus-Erie machines with 1-1/4 yard bucket capacity, bulldozers and hydraulic water. Sometimes an elevated trestle was used for the sluice boxes and other times, the boxes were placed on bedrock. The dragline season was shorter than the dredge season, running from May 15 to October 15, involving the handling of about 200,000 cubic yards of gravel and bedrock. Dragline operations were discontinued in 1957 when the shallow gravels suitable for this method of mining were exhausted.

The Yuba Dredge was capable of digging 50 feet below pond water level and in 1961 an additional 10 feet was added to the digging ladder. The depth of the placer ground varies from 15 to 60 feet. The actual thickness of the pay gravel lying on a bedrock of altered dunite, serpentine and some extremely hard sed'mentary rock, ranges from 2 to 6 feet.

The Yuba Dredge originally weighed about 1,400 tons and now totals nearly 2,000 tons as a result of added equipment. The added weight required the addit'on of 4 more pontoons to the original 33 that constitute the steel hull.

The digging ladder of the original dredge carried a line of 94 buckets, each of 8 cubic foot capacity, running at a speed of 31 buckets a minute. Working 24 hours a day, the dredge has averaged a little over one million cubic yards each mining season.

A Bucyrus Erie walking dragline (200W) with a 6 cubic yard bucket was used in the later years to strip up to 40 feet of overburden so that the dredge could reach bedrock.

The mining season extends from about May 1st to November 15th each year. The first crew, however, starts work around the 1st of Ap il overhauling equipment and preparing for the season. The ground has little permafrost, although occasional lenses of frozen ground do occur. Transportation to the area is good. Air freight arrives almost daily, and Wien has three scheduled flights per week. Barge service is also available since the mine is located on the ocean.

Our company acquired this property in January of 1980 from the Goodnews Bay Mining Company. After refurbishing the dredge, the first operation season was completed in 1980. Once underway, the plan was to move the dredge from the bench where the former owners had it parked, down to the Salmon River Paystreak. The dredge operated until August of 1980 when it was shut down for the season. During the period between June and August, 1980, we dredged a total of 127,573 cubic yards. Digging mainly for flotation, the area dredged was not an area of indicated values for any platinum or gold. Some of the problems involved with the first season were almost a complete replacement of the water pipes on the dredge, electrical problems, a lower tumbler bearing change and the use of many untrained bucketline dredge personnel. We had the good fortune of having many of the former owners and workers act as consultants which somewhat eased our problems.

The 1981 season started in May with the dredge still proceeding off the bench toward the Salmon River. The season ran from May through October 8th, 1981, during which we dredged 322,396.166 cubic yards.

Our primary thrust is to remine the tailings. There are many examples of gold dredges running through old tailings and recovering as much the second and third time as the first. We hope to produce atleast half as much as the previous owners.

Fine platinum, we believe, is easier to recover than fine gold. Platinum is not malleable like gold. Fine grains of platinum retain their shape, unli   flat, flaky gold. I have placed fine platinum (-200 mesh) and fine gold together in a vial   ater. When the vial is turned over the platinum drops instantly to the bottom. The gold c   down like a leaf falling off a tree, by comparison. Although the platinum is 5% heavier than gold, its particle shape makes it easier to recover. Of course, this means that the first dredging may have recovered most of the platinum, but our testing is still favorable at this time.

The records kept by the previous owners are one of the property's most valuable assets. We can review these records and determine how much they recovered at any place on the property. They recorded all of their cable tool drilling and compared the drill results with their dredge recoveries. Every drill hole is related to the subsequent dredging and both are located on a map. They calculated and recorded the yardage dredged, area of bedrock mined, and screened and classified each recovery. The cleanup data is important because they recovered two-thirds of their metal from one-third of the ground. I do not want to spend the next 40 years going over the property again. We will cover the third of the ground where they had their best recoveries in about 15 years.

The overall values are not fantastic, totaling about $250 million at $500 an ounce. This value, divided by the 50 million yards of dredged tailings yields an average value of $5 per cubic yard. The best areas produced $20 to $30 per cubic yard. Our recoveries to date are approximating those of the original owners, in $2 per cubic yard ground.

The dredge has a capacity of 6,000 yards per day, averaging just over one million cubic yards per year. Material dumped by the dredge buckets into the main hopper feeds through a 7-1/2 foot diameter revolving trommel screen 36 feet long with perforations ranging from 3/8 to 5/8 inch in diameter. The trommel is powered by a 75 horsepower motor. Undersize material passing through the screen flows onto a bank of tables fitted with rubber covered wooden riffles, from which the major part of the platinum concentrates are recovered. Overflow from the tables goes through a series of Yuba jigs, the concentrates from which are collected on expanded metal and coconut matting in cleanup sluices. Oversize material from the trommel screen discharges on to a 140 foot long stacker belt at the stern end of the dredge.

The on board recovery system includes a closed loop that recycles the tails from the finishing jig back across the first rough jig. The system is however, quite labor intensive to clean up because half or more of the metal remains in the sluices ahead of the jigs. About a ton of material, mostly rock, is removed from the sluices with each cleanup, and must be worked down in the shore lab.

Dredge concentrates, consisting of crude platinum and some gold with considerable quantities of black sands of magnetite, chromite, ilmenite, chromiferous spinel, etc. are processed further in a cleanup house on shore where they are passed over a 4 x 8 foot Wifley table. Further concentration is affected after drying by screening and magnetic separation. Finally, air is blown through the concentrates as they drop from a vibrating hopper, the heavier platinum metals falling through the air into a sectionalized box, while the lighter impurities are blown away into different sections. This method successfully yields a 90% concentrate. Concentrates from our last season were processed by elutriation tubes of our own design. The elutriation yields a much cleaner concentrate in far less time than blowing and hand plucking the platinum.

When we upgraded the dredge, high pressure pumps were added inside the trommel substantially increasing the amount of water. A retaining ring keeps the clay balls in the trommel longer. Lifters are also present in the trommel. However, there is still a significant amount of clay leaving the trommel and going out the stacker. It may take major design changes to break up the clay.

Breaking up clay balls is perhaps the biggest problem on the property. Many of the recoverable values are trapped in the clays. In the upper bench the values are almost entirely in the top clay. We will probably not dredge this area at all, but will develop some other type of machinery that can selectively mine only the top 10 or 15 feet of material rather than the entire 60 foot section. There is also a lot of clay in the upper channel. We are presently mining in the lower channel where there is less clay.

We have tested many of the tailings, and determined that the values are in the top 10-15 feet. This indicates that the platinum did in fact go out via the clay. The tailings look clean on the surface, but one finds quite a bit of clay and fine material when you dig into them. We hope there are significant values remaining in this material.

Some of our recent ideas have included putting in rubber screen plates instead of the steel punch plate. We have purchased some spirals to install in the concentration circuit, hopefully to reduce the labor of cleanup. We believe we can automate and upgrade the machinery to cut down on labor by a third. At present it takes half a day to clean up -- this is half a day that the dredge is down.

Energy is a major expense. Since there is a lot of wind, we are going to consider the possibilities of using wind power to generate electricity. There is a natural wind tunnel in the saddle between Red Mountain and the mountain next to it.

Instead of pumping muddy water out of the pond for the washing plant, we would like to pipe in fresh water. Water could be piped in under pressure with about one mile of steel pipe. This would also save us the cost of the three or four 100 h.p. pumps now in use. We would not recover the cost of the pipe in fuel savings, but we believe we could significantly improve our recovery by washing with clean water.

General Geology

Both bedded and intrusive rocks are present in the area. Outcrops are rare. The bedrock in creek bottoms is the best source of geological information.

The Sedimentary Rocks have been highly indurated. These rocks are gray to light tan and yellow to greenish in color. They are dense, very fine grained, hard rocks with some epidote. They are thought to be mainly siliceous argillites and some quartzites. The strike and dip of these bedded rocks vary considerably. Highly altered and weathered tuffs are located at the north end of the east upper bench. These thin bedded strata are tan to brownish black in color, broken and quite soft. The dredge could dig 6 feet of this strata before it became too hard to dig.

Intrusive Rock. An ultrabasic mass of dunite forms the Red Mountain Ridge west of the Salmon River. The dunite weathers to a yellowish brown in color with small black crystals of magnetite and chromite exposed on the surface. The weathered zone varies, but is generally about 1/4 to 1/2 inch thick. The unweathered dunite is very fine grained and is black in color. The dunite appears to have been cracked and shattered at some time in the past, for these fine lines are now rehealed. Pyroxenite filled fractures cut the dunite.

Perknite is found to the east of Red Mountain dunite. Hornblendite with coarse black crystals of hornblende is found on upper Squirrel Creek.

Peridotite. Dark colored, medium grained, equigranular, with some mica is found in Fox Gulch and on Dowry Creek.

A one foot dike of dark, equigranular, fine grained diorite can be found cutting the meta sediments and the bleached serpentine zone at the head of Fox Gulch. There is only one place where the perknite border rocks can be seen in contact with the main dunite mass of Red Mountain. This contact is at the end of the upper placer workings in Fox Gulch. Here a major fault striking north 70^{o} east separates black dunite from the bleached light green serpentine zone, 110 feet in width, that contains blackish clots of magnetic rock that is considered to be a breccia. Coarse and medium grained peridotite is found southeast of the light green serpentine zone. On Dry Gulch a black pyroxenite is found in contact with metasediment breccia.

On Squirrel Creek, the perknite rocks appear to be an island surrounded on all sides by meta sediments. On Dowry Creek, medium grained equigranular, unaltered peridotite is found surrounded by highly faulted, serpentinized black dunite.

On the crest of the hill above McCann Creek, 1/2 to 3 inch wide pyroxenite filled fractures cut the dunite.

Two complete chemical analyses of the dunite of Red Mountain were made by E.T. Erickson of the U.S. Geological Survey: one (A) of a composite sample of fresh unaltered dunite with a representative content of marginal perknitic rocks and one (B) of the oxidized shell that forms a veneer on these ultrabasic rocks.

Ultrabasic Rocks, Chemical Analysis in weight percent

	(A)	(B)
$Si\ O_2$	39.20	28.54
Al_2O_3	1.50	.78
Fe_2O_3	3.10	5.29
Mg O	37.79	42.29
Ca O	5.66	.34
Na_2O	N.D.	N.D.
K_2O	N.D..	N.C.
H_2O +	5.81	5.53
TiO_2	.05	.14
Cr_2O_3	.27	.13
MmO	.01	.01
NiO	.077	.053
CuO	.007	.004

The presence of chromite (Cr_2O_3) shown by the chemical analysis is significant, as the placers contain platinum nuggets that are intergrown with or have adhering chromite. Chromite constitutes a small but significant part of the accessory minerals recovered with the platinum metals. In an analysis of pebbles of chromite recovered from these placer concentrates made by E.T. Erickson, the tenor in platinum metals was found to be 0.05 troy ounces per ton of chromite. An interesting characteristic of the Goodnews Platinum deposit is the wide variation in the percentage of iridium. Clara Creek, which is the northernmost of the creeks cutting Red Mountain, yielded a crude that contained 4% iridium. The iridium percentage increases progressively in each creek to the south, reaching a high of 33% in Fox Gulch, the southernmost of the creeks cutting the mineralized section of Red Mountain. The Salmon River deposit, which is a mixture of mineral from its north right limit tributaries, has averaged an iridium content of 10% over the years.

Platinum is 50 times as rare as gold. All the platinum mined in the world would fit into a 13 foot cube. There are 50 million cubic yards of tailings at Goodnews Bay, from which 1 1/4 cubic yards of platinum have been extracted in 40 years of mining. At the time we purchased the property, platinum was selling for $800 an ounce. Since then it has gone up to $1,100 and down to $300 an ounce. We converted all of our cost data to a price of $500 an ounce, even though platinum is now worth $350.

We received a little bad news recently. Our watchman called and said that the dredge was sinking. What he meant was that it was already on the bottom of the pond. Fortunately the pond is not too deep. We hope to be able to pump enough water out of the pond to get to the pontoons. We will then pump out the pontoons and refloat the dredge. If we are unable to lower the pond level it will be a big job for underwater divers. There are now five or six feet of ice on the pond and three or four feet of ice inside the dredge. We may be delayed a month this year.

Engelhard and Johnson-Mathey purchased last season's platinum. Engelhard's new office in Anchorage will be a big help to us as they buy gold and all precious metals.

Q How much did you recover?

A The last two years we have been digging to obtain flotation. We have mined only one corner of a known pay area. We recovered about $2 per cubic yard, which is roughly what the Goodnews Bay Company produced. We also recovered approximately the same graduation of platinum from fine to coarse in size. This is encouraging, but we do not pretend that we will also have the same recovery in an area where the previous owners produced $20 to $30 of platinum per cubic yard.

We sold about $200,000 of platinum, which is not much considering that we spent about a million and a half getting it. We are not very skilled yet. We are also desperately in need of experienced winchmen. We have built and trained an excellent crew that is good at everything except winching.

Q How do you break up the clay?

A Inside the trommel are high pressure pumps and water jets. There are also retainers and lifters, but it's really hard to break up one of those clay balls once it's formed. It reminds me of plowing on the farm, when a crust formed on the soil we'd harrow to break it up. If we just went out there with a tillage tool the crust ripped into clods. We could then harrow it ten times over and never get rid of the clods. I think the same things apply here. The best way to solve the clay ball problem is to not make one. I haven't figured out how to do that yet, but it's the end I'm going to work on.

Q How will you utilize the spirals?

A They are part of the effort to reduce the labor involved in cleanup. If we can we're going to put them in a circuit in such a way as to clean the concentrate a lot better before we take it ashore. Exactly how we're going to do that, I don't know. I'm going to ask Tom Feree while I'm here and he's going to give me all the answers, I'm sure.

Q Do you use your trommel to physically break up the clay?

A Well, I think it's physical, but I also think that there's got to be some help chemically. The magnitude of the problem is determining how much water is needed to dissolve the amount of fine clay present. There is a physical limitation. Even if solved mechanically, the ability to dissolve more clay, or to settle out the clay in the pond, might be enhanced chemically, producing cleaner water to work with.

Q Is the greenstone bedrock hard on your machinery?

A No, most of the tailings are less than a foot in diameter. Scraping bedrock is, of course, hard on it. Where the bedrock is deteriorated, we dig into it as far as we can, between two to five feet. This is where the values are. That's the only time it's very hard on the equipment. In the upper channel, which was there 10,000 years ago, before the glaciation of the area, the bedrock is more deeply decomposed. It is yellowish material that looks like clay. The values may be from the weathered bedrock and all mixed up with the clay. Some clay balls assay up to $1,000 a cubic yard. On the other hand the next 100 clay balls may have nothing in them.

Q Have you tried methods that cut down the amount of water needed to break up the clay, such as a scrubber or trommel arrangement with fewer holes? This might save some washing water.

A We haven't tried that, but it might be a good approach. Major changes like that are not easy to accomplish in an existing machine.

Q Have you tried retaining the clay longer?

A There is a retaining ring in the trommel and we could add more. This approach would work best, if the washing section were larger and revolved at an r.p.m. suitable for scrubbing and if the screen was a separate trommel that revolved at the right speed for screening. I think that's a good idea that would work much better than what we presently have, and it would be much more energy efficient. Using high pressure pumps is not an energy efficient way to break up the clay. If we could also retain, rather permanently, a few of the rocks in the scrubbing section it would help. I think that's a good idea and I thank you.

Q What about physically breaking the clay?

A We've thought about it, but haven't really figured out how we could make that clay into a slurry. The former owners tried a special sort of impact device, appropriately called a 'mudhog'. It worked like a traditional hammer mill but the anvil parts were continuously moving large bars mounted on a chain revolving very slowly to prevent it from plugging up, no matter how much mud went through it. The hammers beat up the clay balls. Of course, the rocks went through also, and it turned out to have a high maintenance cost. But, I guess it worked quite well. I thought more about mashing those clay balls with something like the old wri ‑er washing machine. If we had some huge rollers that we could run everything through, the rocks would pass through without harming the machine, but the clay balls would be squeezed into flat pancakes which would break up in the trommel. The worst thing about the clay is that it often comes out of the bucket line in a ball the size of the bucket. If you start out with a ball, it's pretty hard to not have a ball come out the back end.

Q Joe Vogler: Have you considered using a revolving cutter wheel like that developed by the Germans?

A Yes, that goes back to my story about the farmer. The best way to not have a clod is to not make one. If we could dig clay so that it was cut in to little shavings it would be a help. I don't think little balls will grow into big balls. I make that kind of machinery, by the way, so I certainly have thought of it. That kind of machinery would also work well above water level where clay occurs. I'm not sure I believe the story that a clay ball rolling through the trommel and the sluice boxes is picking up the values. I think that, if we find a clay ball with values in it, the values were always inside of it. Perhaps we could not recover the clay shavings from deep underwater. But there e suction dredges being made now that have a little wheel on them, very much like a German wheel, that pick up the material and dump it in to the suction of the dredge. That might also be an answer.

THE FOLLOWING DOCUMENT HAS NOT BEEN FILMED BUT IS AVAILABLE IN THE ORIGINAL FILE

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.

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[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

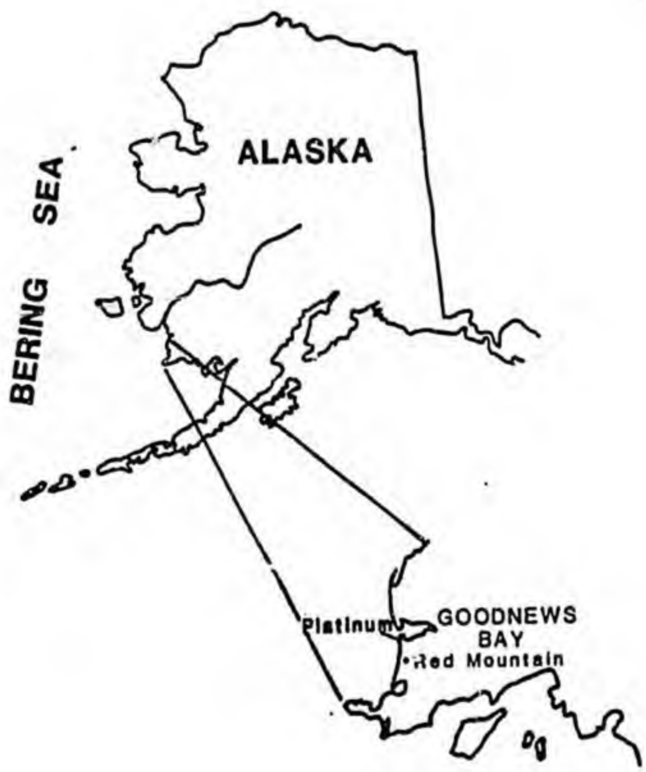

FIGURE 1. - Index map showing project area in southwest Alaska.

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

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[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

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[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]).

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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

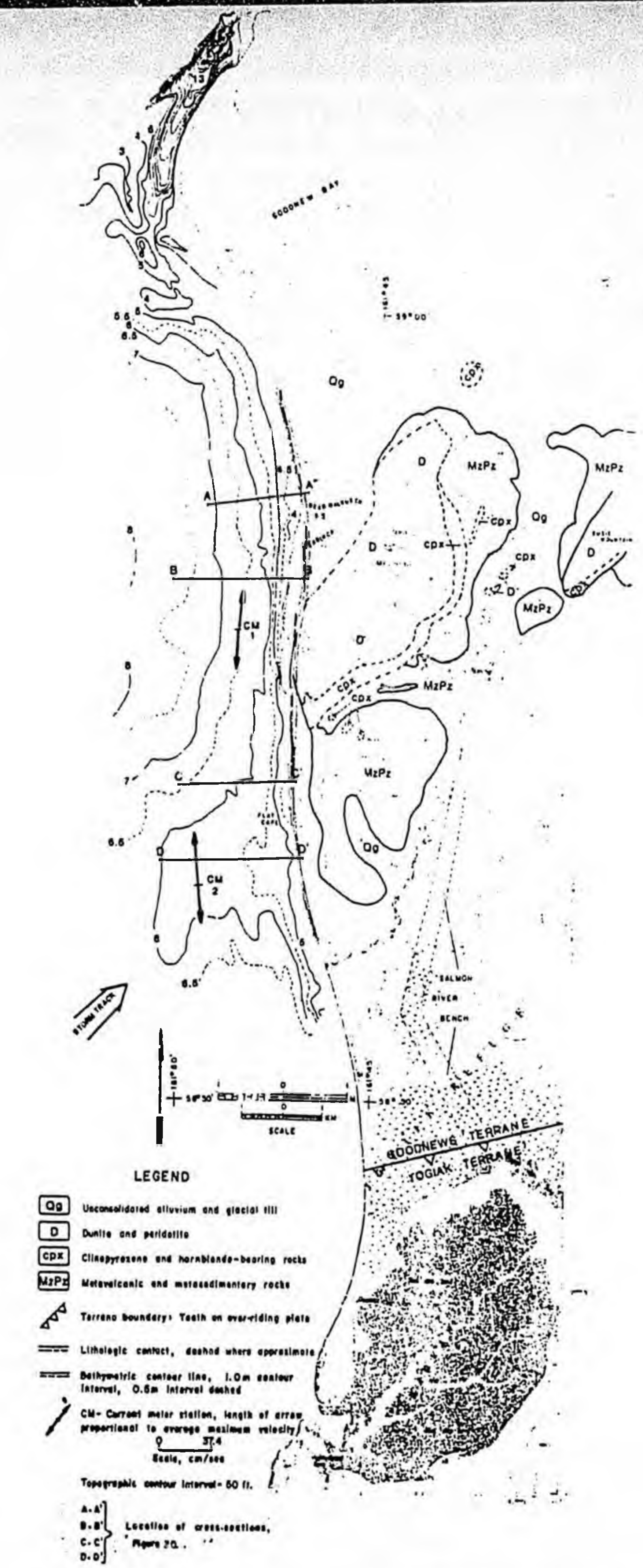

FIGURE 2 - Offshore bathymetry and current meter stations with onshore topography and regional geology

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.

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[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]

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[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

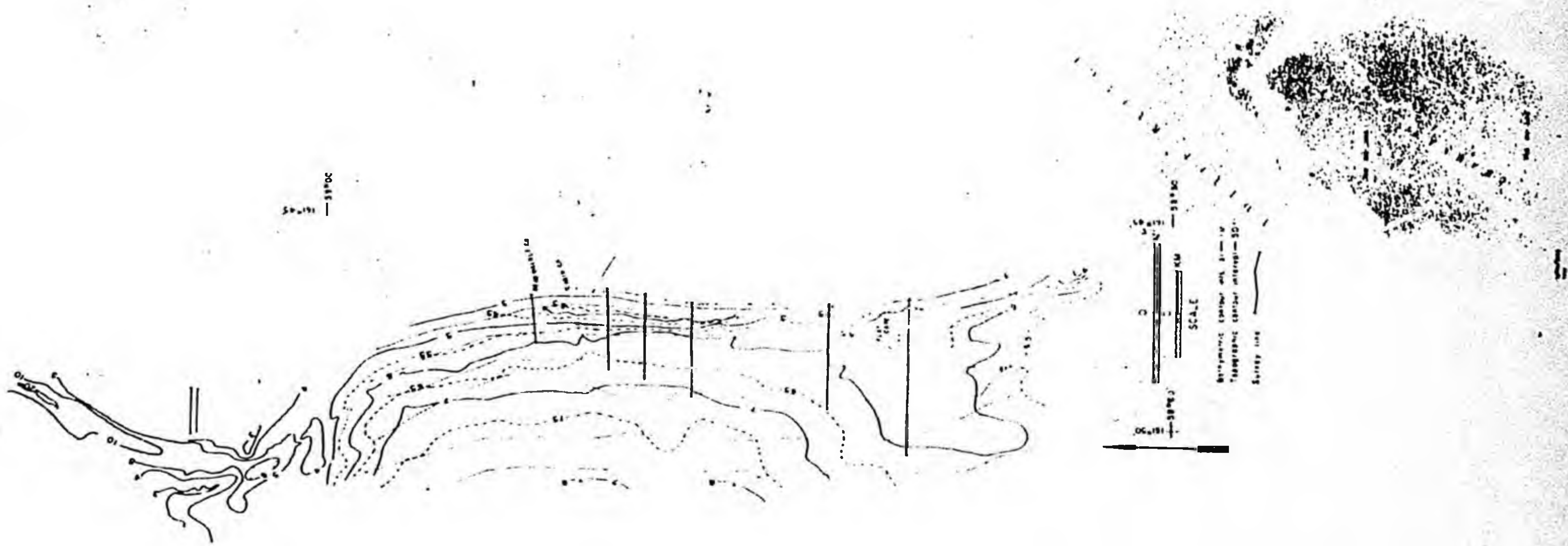

FIGURE 3. - Map showing location of offshore survey lines.

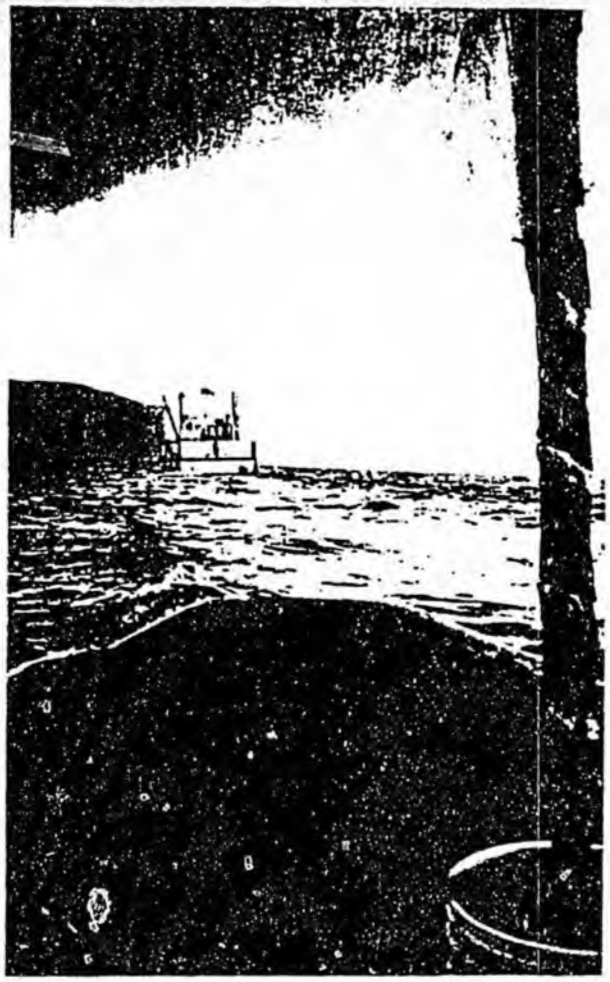

FIGURE 4. - Total magnetic field sensor unit on staff being towed in nonmagnetic raft on trackline parallel to shore. Red Mountain can be seen in distance.

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

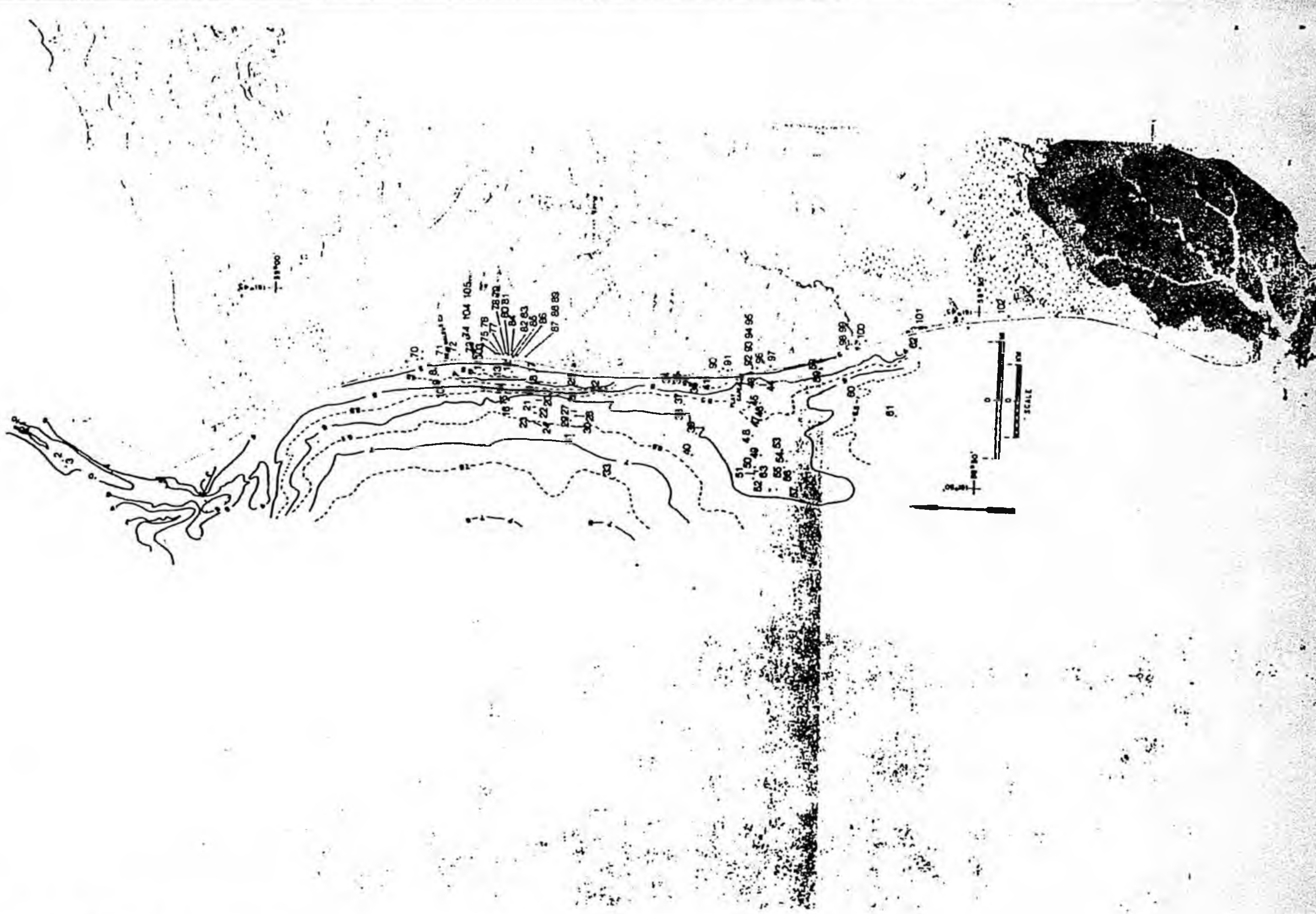

FIGURE 5. - Sample location map.

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

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

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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 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 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

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

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

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.

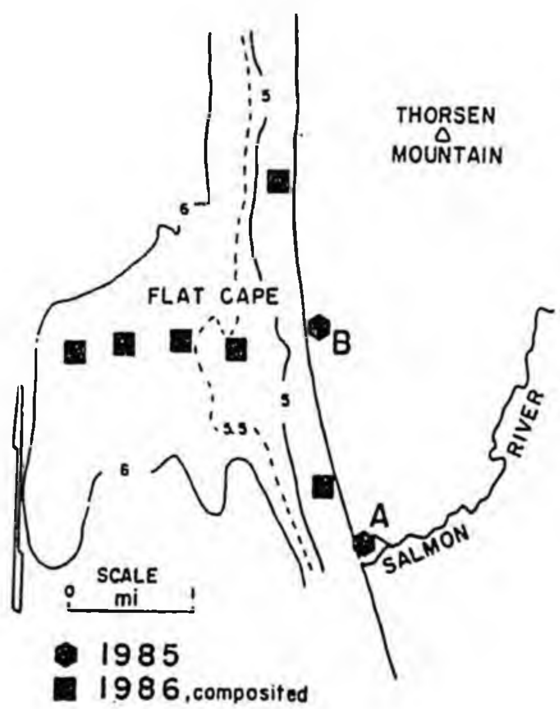


FIGURE 7. - Beneficiation sample location map.

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 ± 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

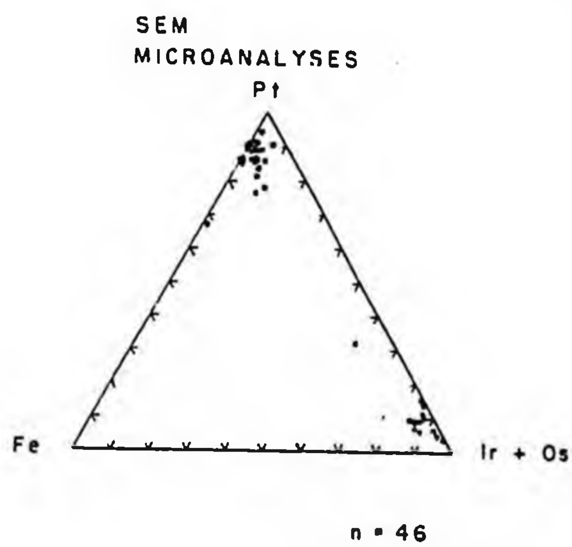


FIGURE 10. - Fe-(Ir+Os)-Pt ternary diagram of 46 SEM microanalyses on PGM grains.

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	-	-	Isoferro-
		-			-	-	-	-		-	-	platinum.
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	-	-	-	-	-	-	-	Osmir-
		-		-	-		-	-		-		idium.
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	Sperry-
		-		-	-		-	-		-		lite.
97-I	62	-	-	-	-	-	-	-	3	-	35	Do.
81-A	10	-	83	-	-	-	-	-	7	-	-	Platinir-
		-		-	-		-	-		-		idium.
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.

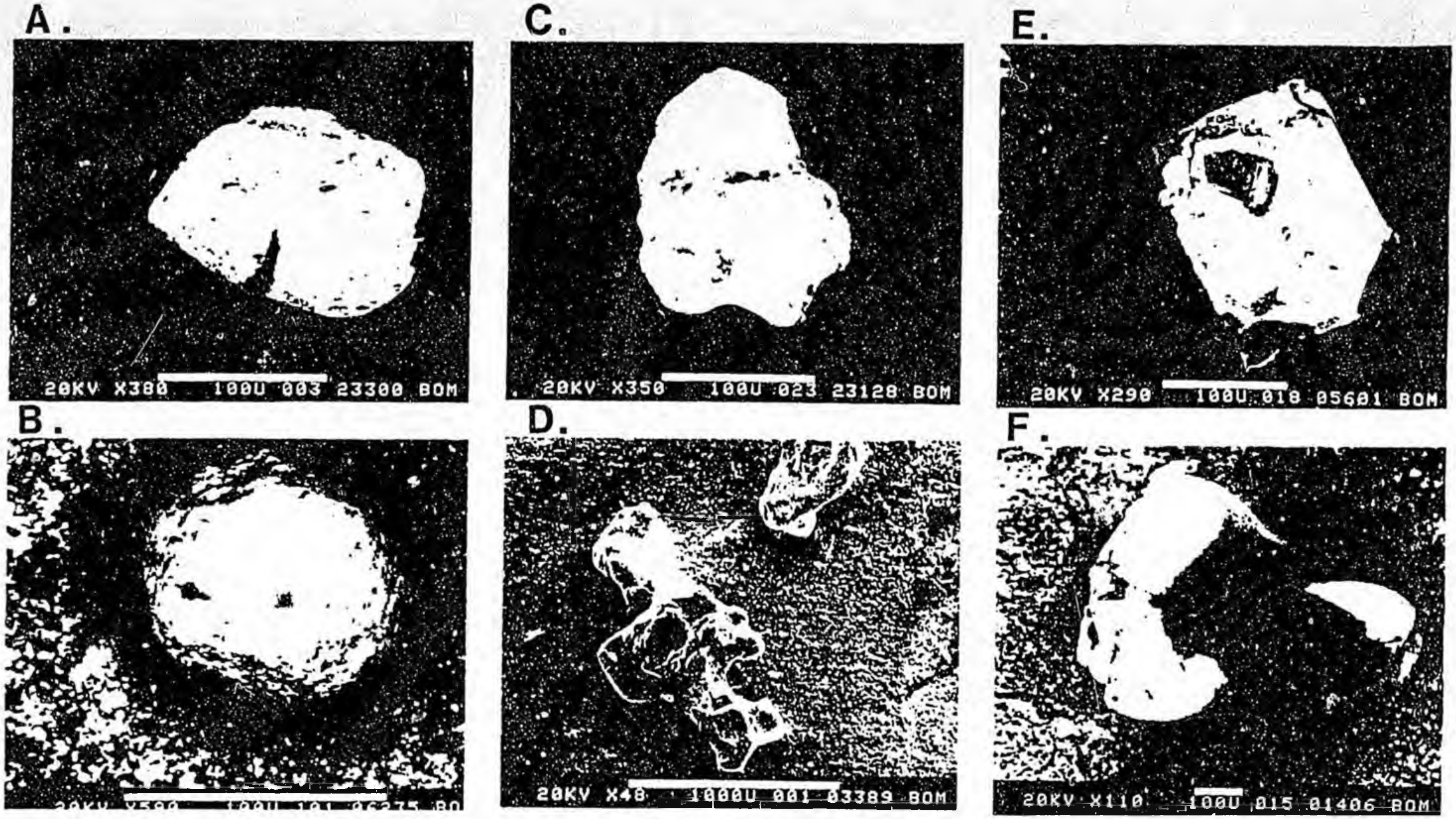


FIGURE 11 A-F. - SEM backscatter images of types of PGM grains found in marine sediment samples. Note scale on each image given in microns. A) Well-rounded osmiridium with interlocked pyroxene from sample 53. B) Typical rounded isoferroplatinum grain, sample no. 97. C) Faceted osmiridium grain, note 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.

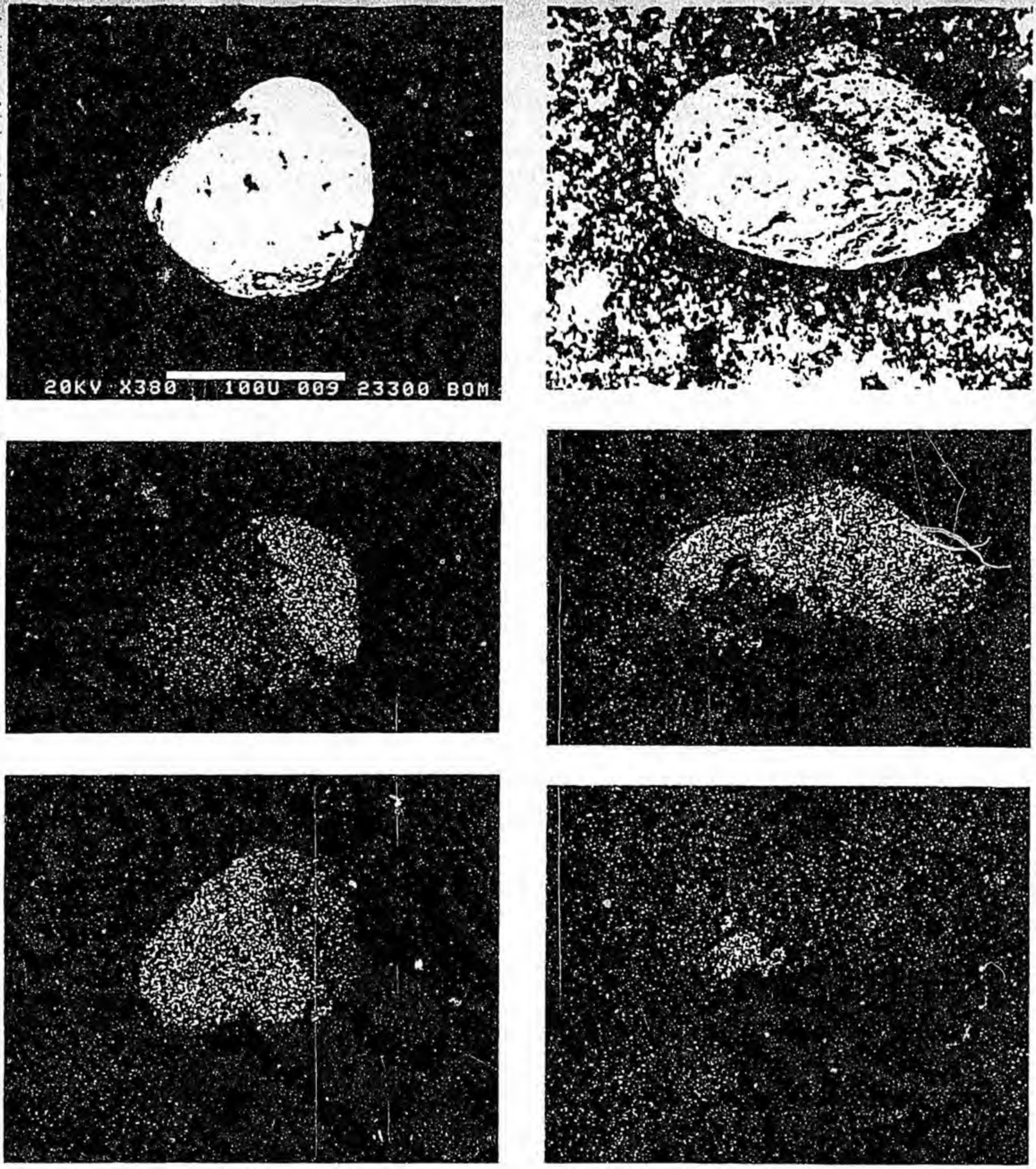


FIGURE 12. - PGM grains with interlocked alloy compositions. Note scale bar in upper-left SEM backscatter image is 100 microns. The grain on the left (sample no. 53) comprises osmiridium and isoferroplatinum. X-ray may in mid-left is iridium, lower left is platinum. Grain on the right is sperrylite from 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.

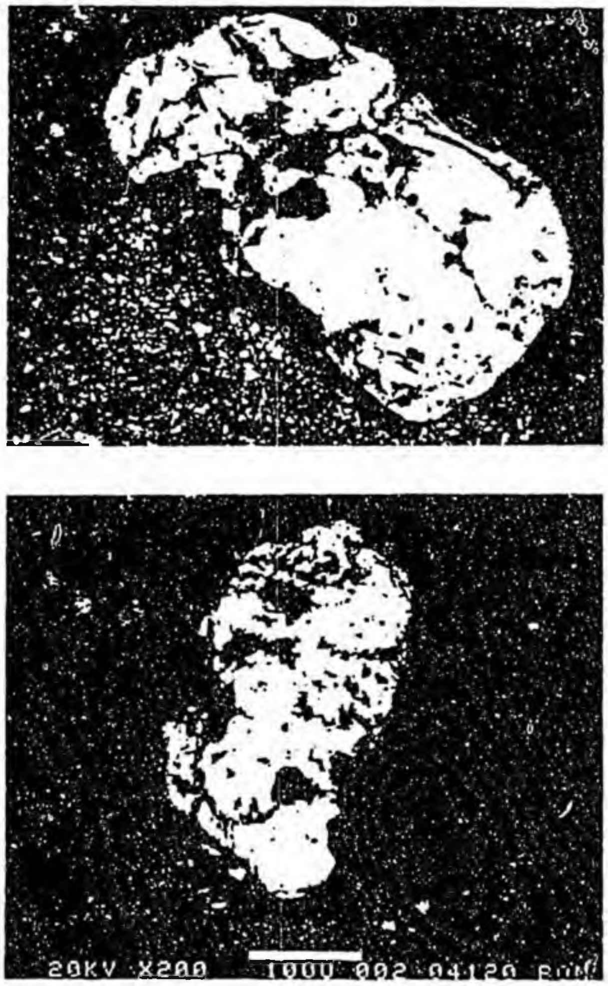


FIGURE 14. - SEM backscatter images of typical rounded amoeboid gold grains from sample no. 49 offshore of Flat Cape. Note scale bar is 100 microns.

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

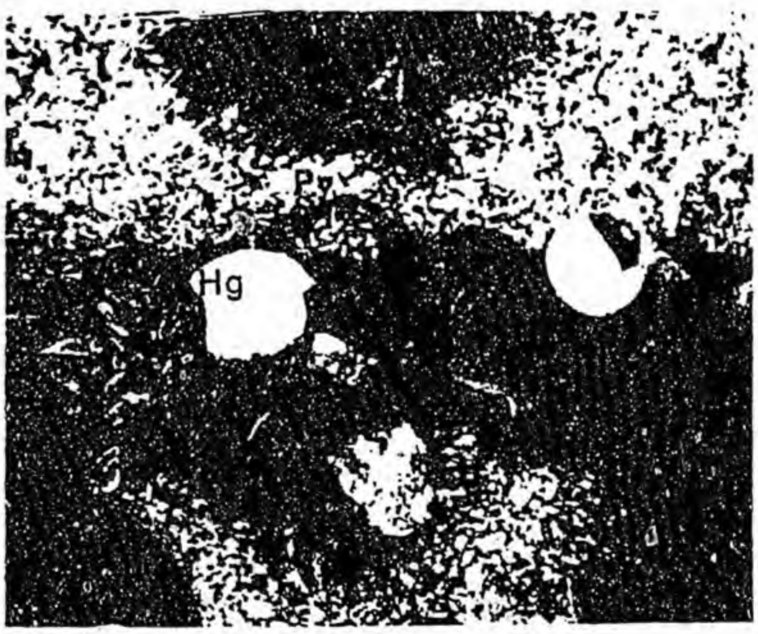


FIGURE 15. - SEM backscatter image of accessory heavy minerals including globule mercury (Hg) and pyritized microorganism (Py). From sample no. 48 taken offshore of Flat Cape. Note image is approximately 1000 microns across.

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	9.74936		.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: 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
+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.

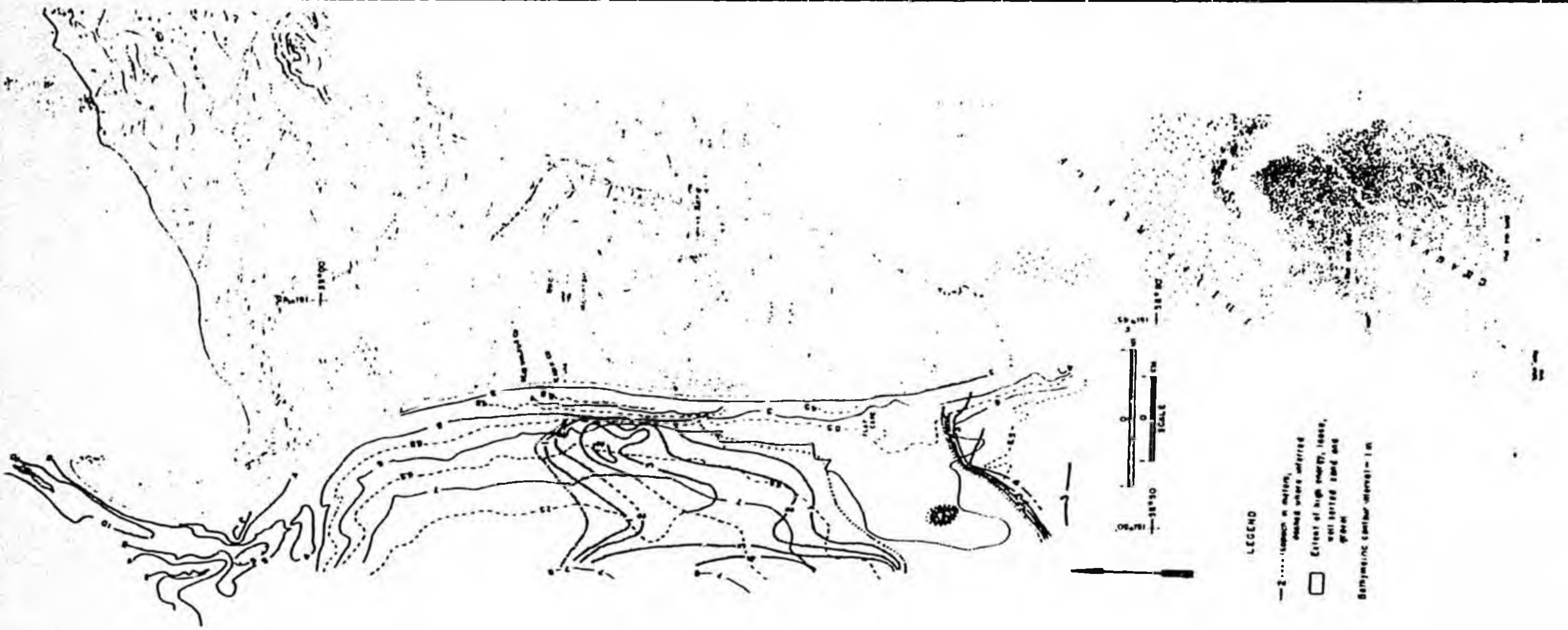


FIGURE 16. - Low frequency acoustic isopac map showing extent of high-energy sediment reflector.

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.

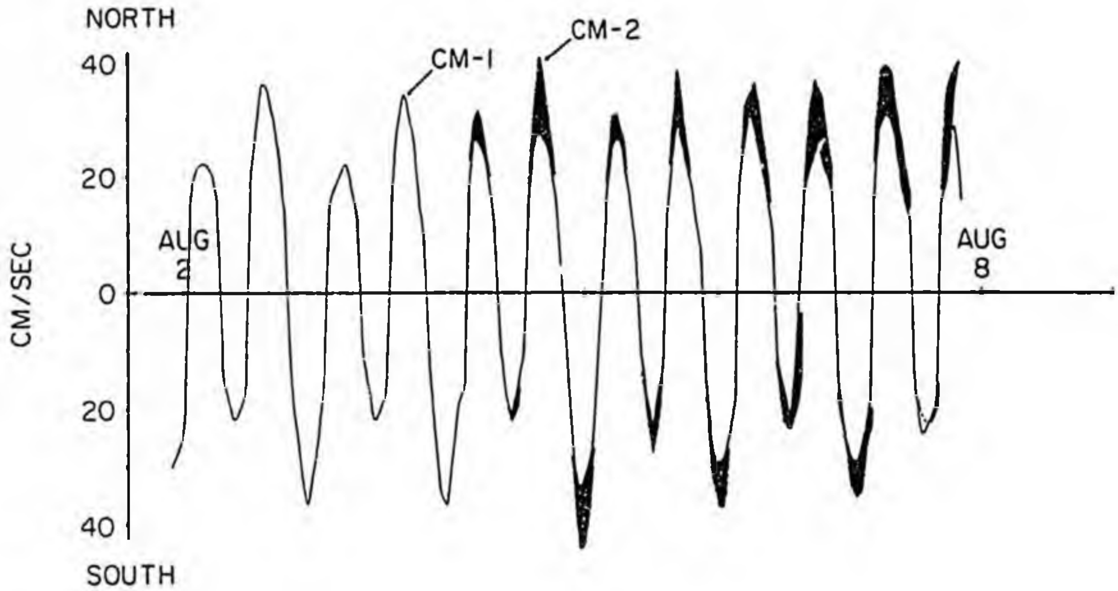


FIGURE 17. - North and south directed current velocity data collected at current meter stations from Aug. 2 to 8, 1985.

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.

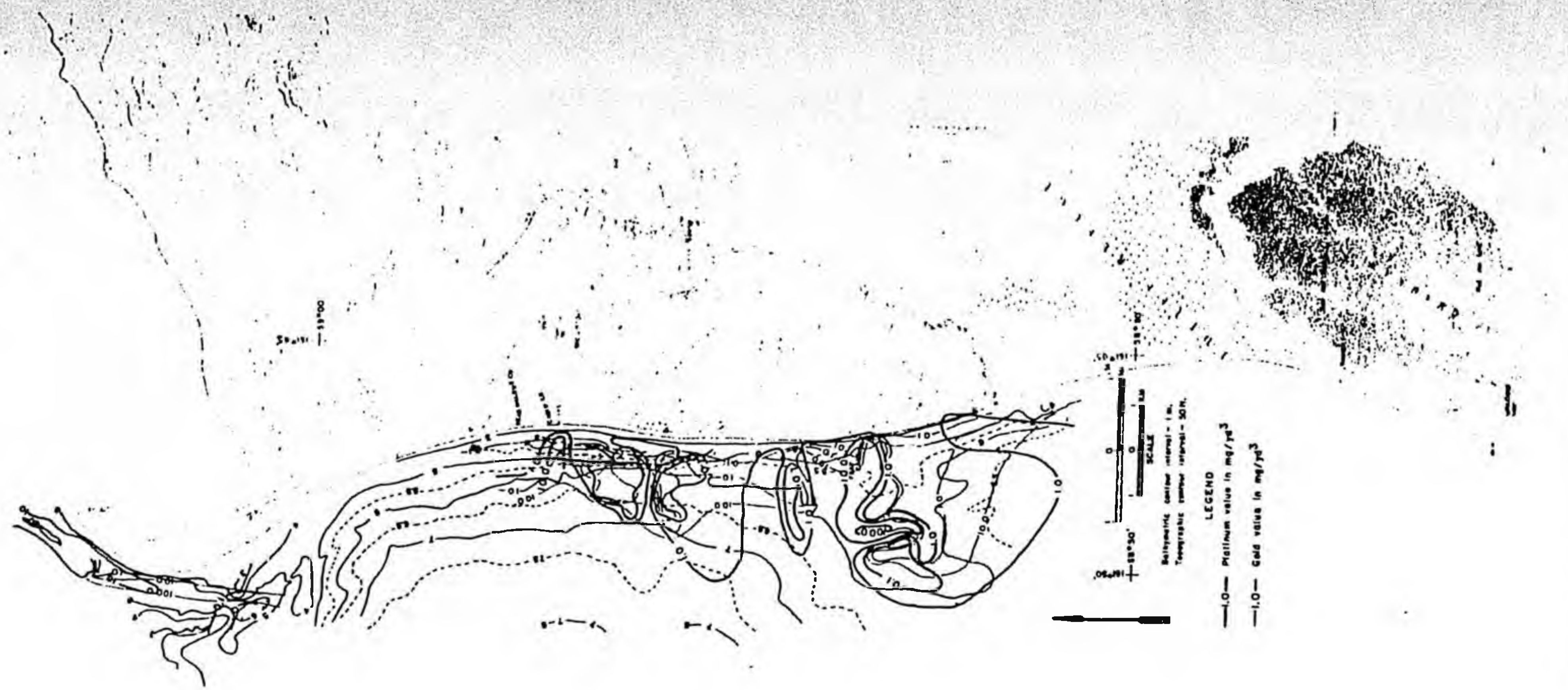


FIGURE 18. - Contoured values of Pt and Au sample analysis.

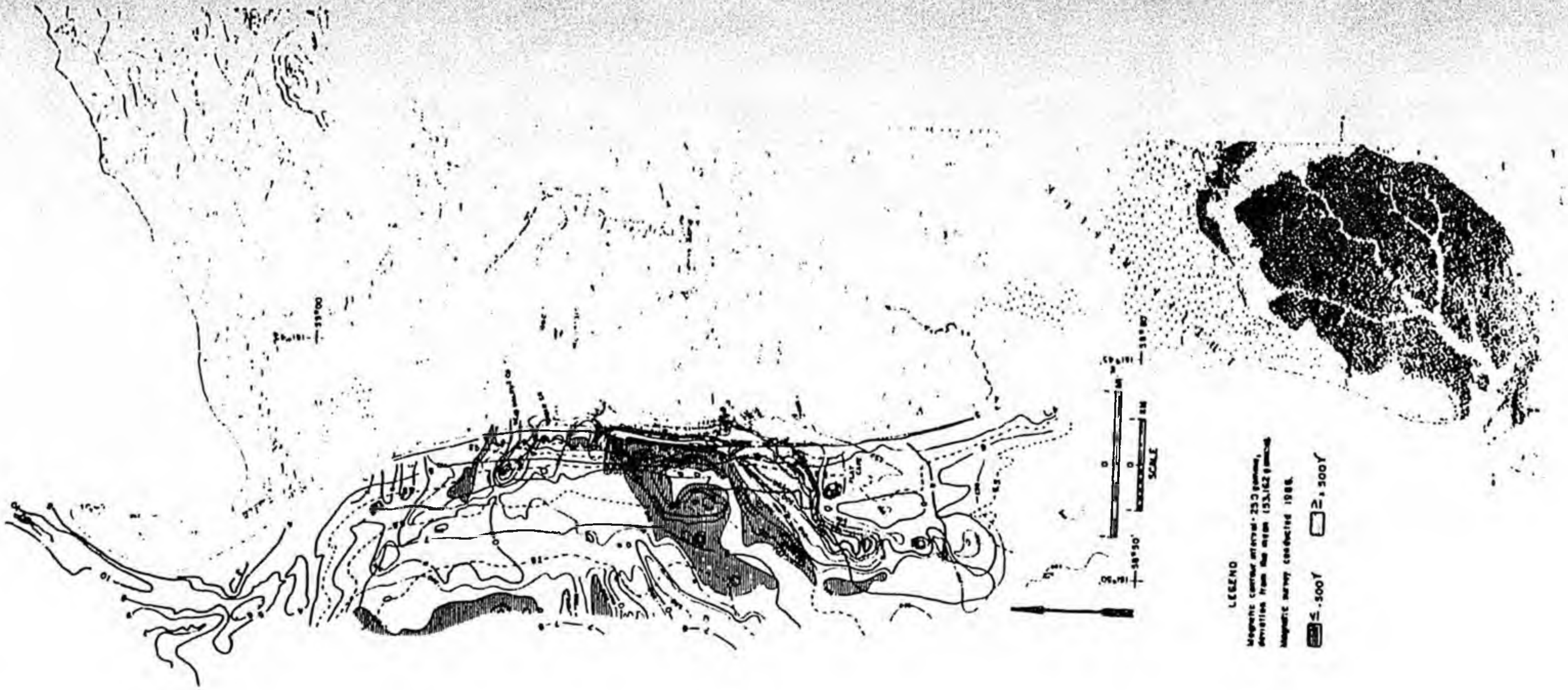
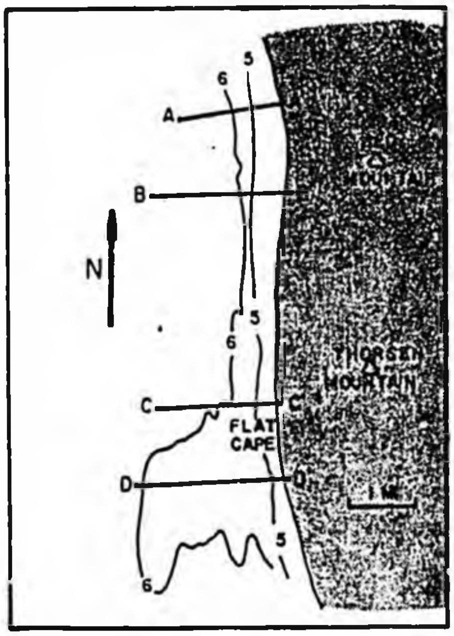


FIGURE 19. - Contoured magnetic data.

LEGEND

- Black sand accumulation
- Modern beach sand and gravel
- High energy sediment, well-sorted, transport toward shore
- Ice-rafted boulders from Red Mountain
- Lag deposits, reworked, mixed till, bedrock, alluvium, and drift
- Paleo alluvial channel deposits
- Glacial till, outwash, clay beds, lake sediments
- Pre-glacial surface, undivided
- Ultramafic — bedrock and rubble (+—+)
- MzPzu — undivided, metavolcanic and rubble (+—+)



Location of cross-sections.

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.

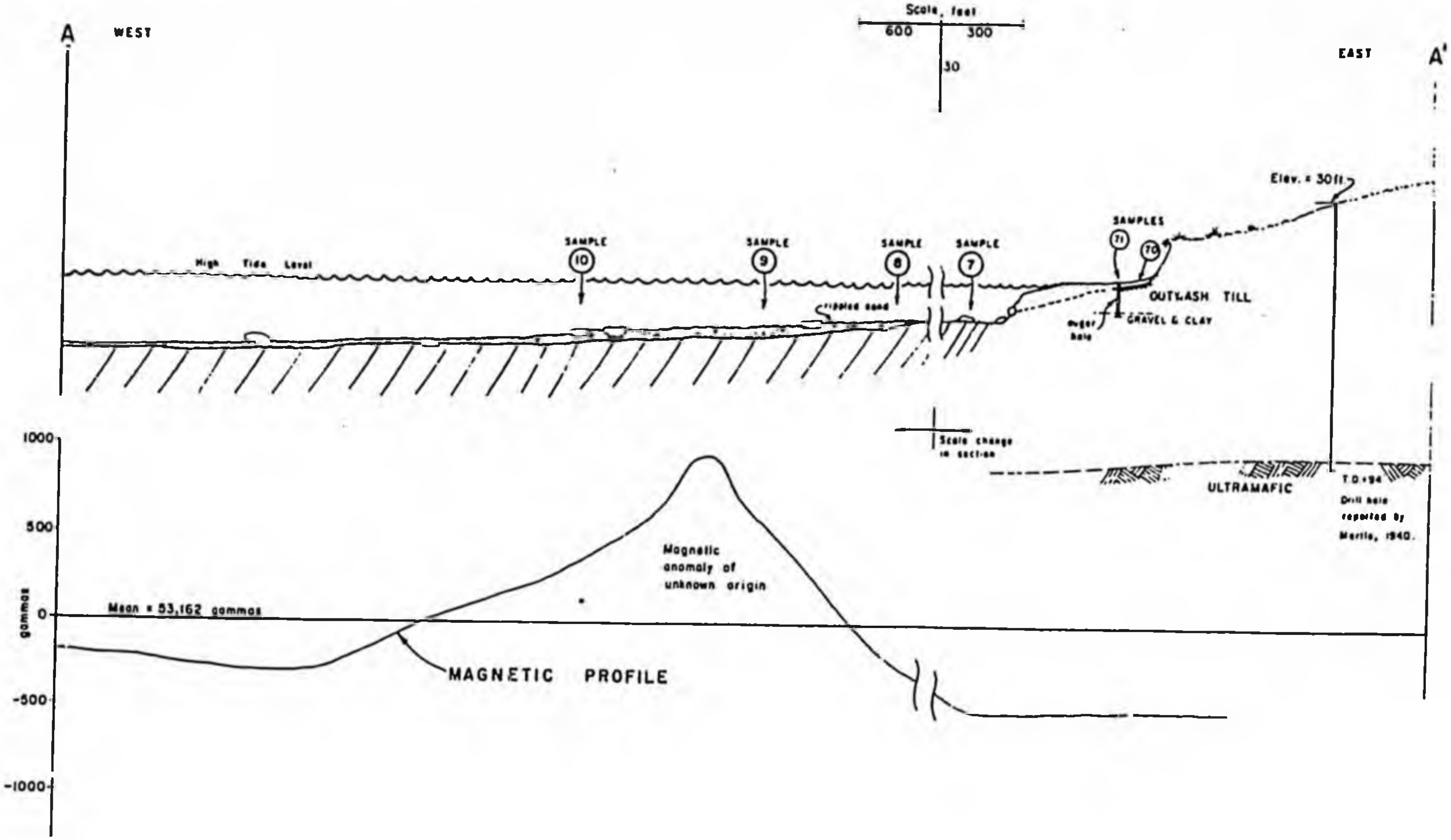


FIGURE 20-A. - Geologic and magnetic cross-sections A - A,' of seafloor offshore Dead Walrus Creek.

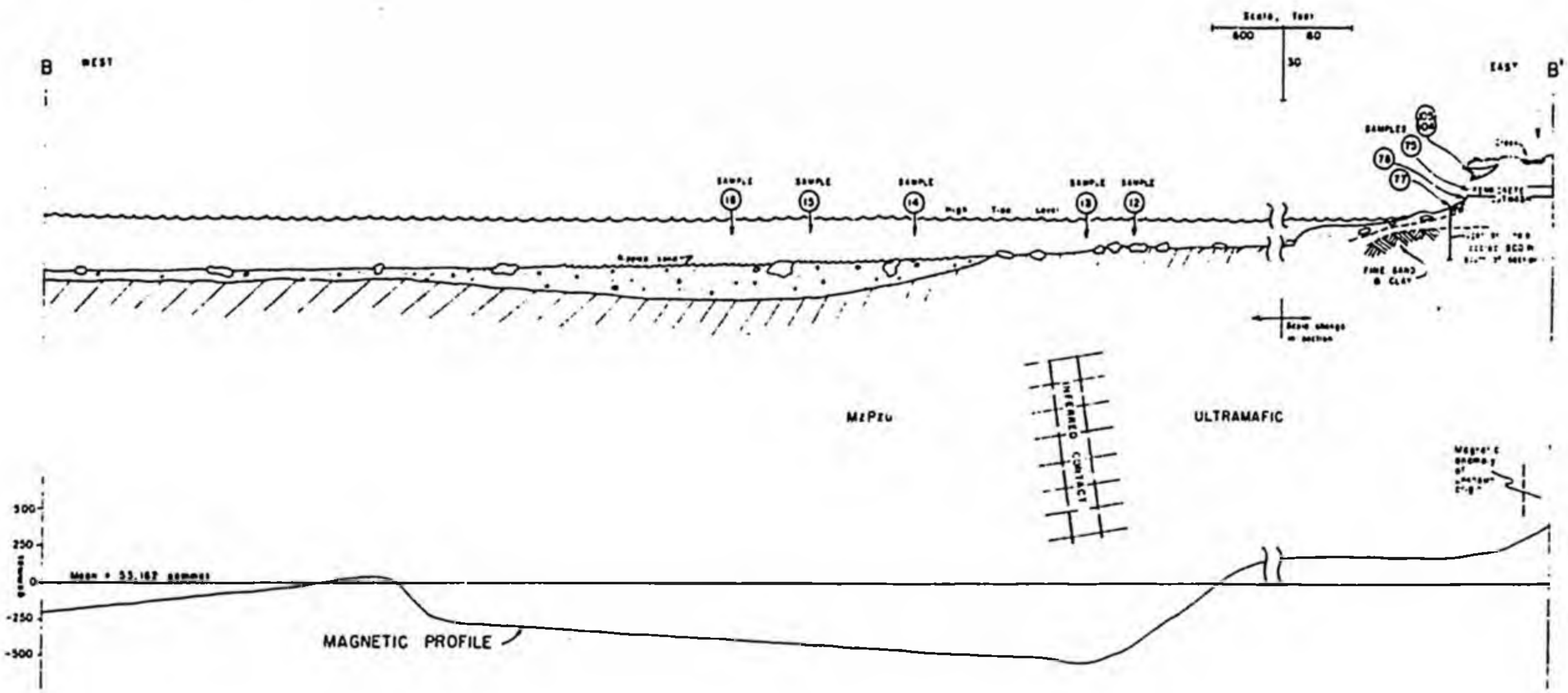


FIGURE 20-B. - Geologic and magnetic cross-sections B - B,' of seafloor south of Cabin Creek.

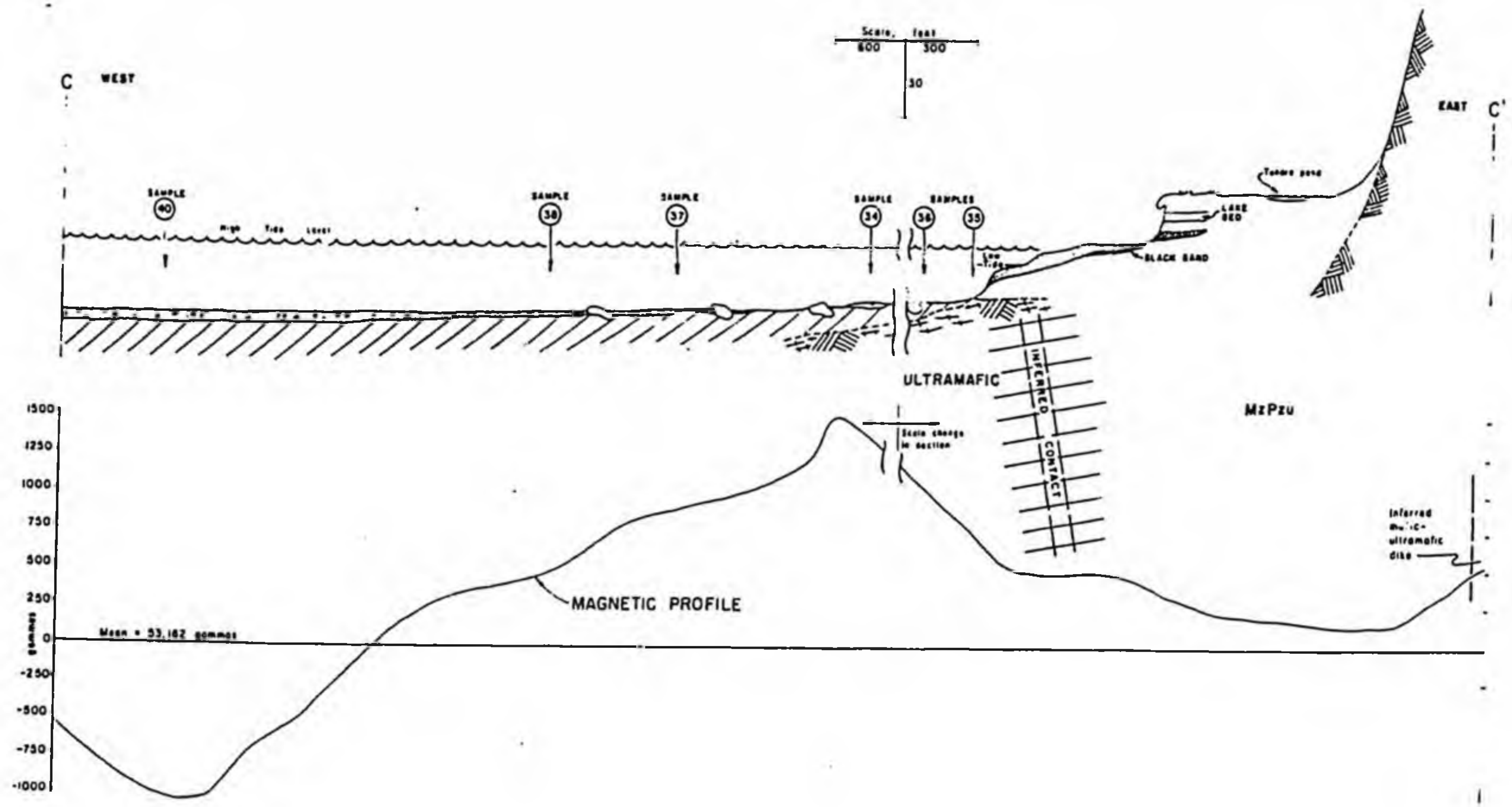


FIGURE 20-C. - Geologic and magnetic cross-sections C - C,' of seafloor offshore Thorsen Mountain.

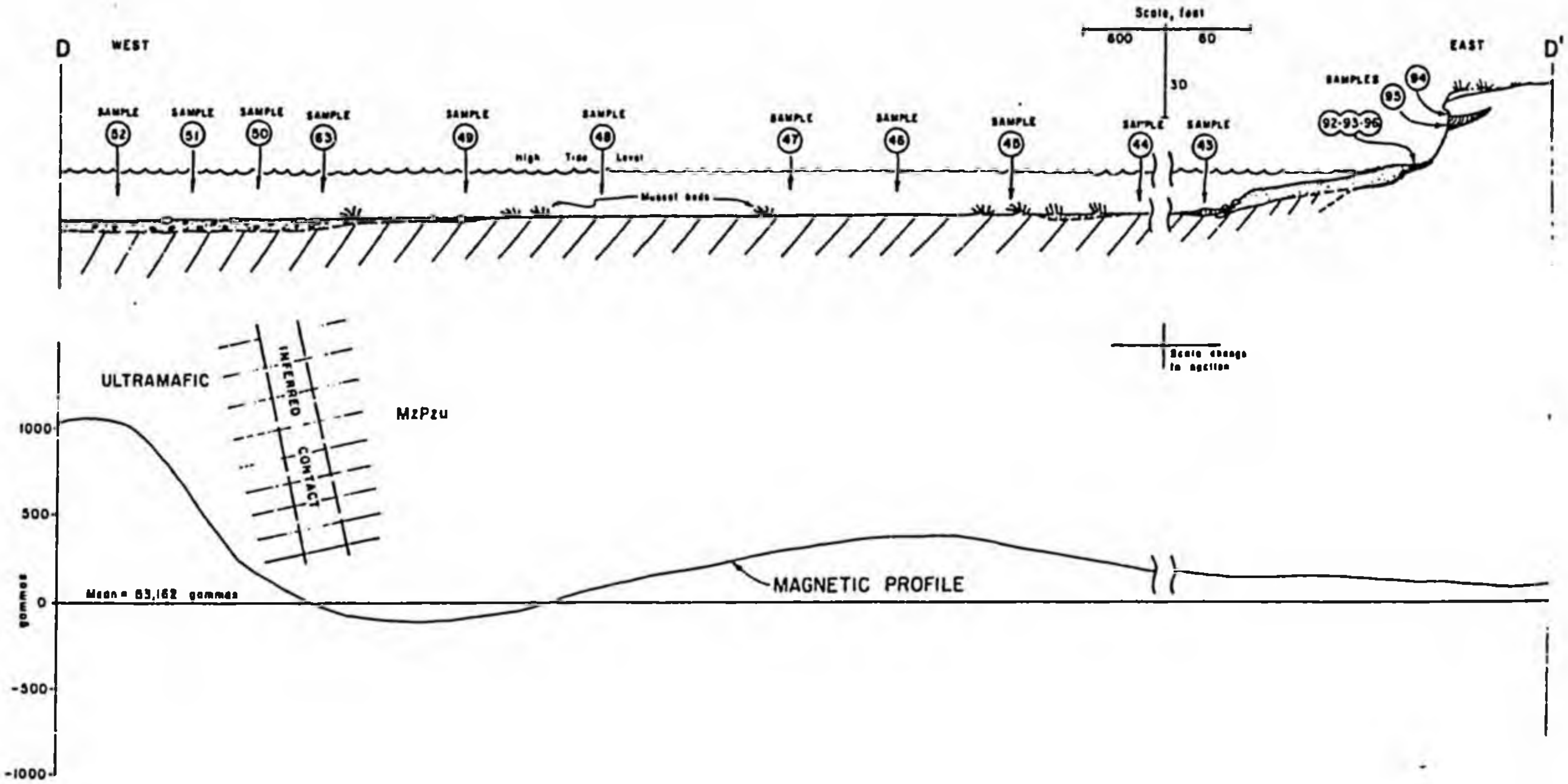


FIGURE 20-D. - Geologic and magnetic cross-sections D - D,' of seafloor offshore Flat Cape.

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 pained 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

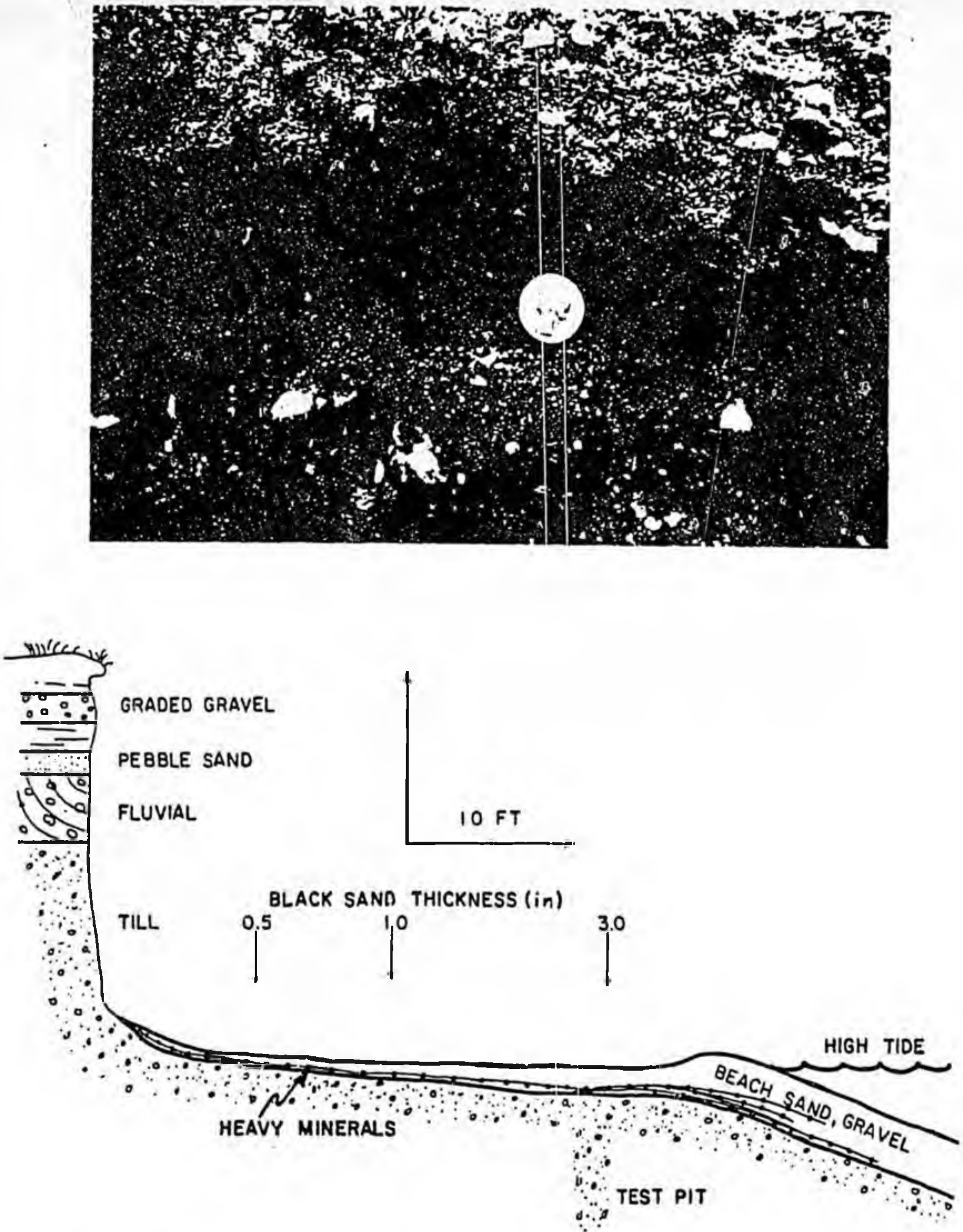


FIGURE 21. - 3-in-thick layer of heavy minerals, accumulated in June, 1985, on glacial till underlying up to 2 ft of beach gravel above the swash zone near Flat Cape. Cross-section shows site of beneficiation sample B.

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

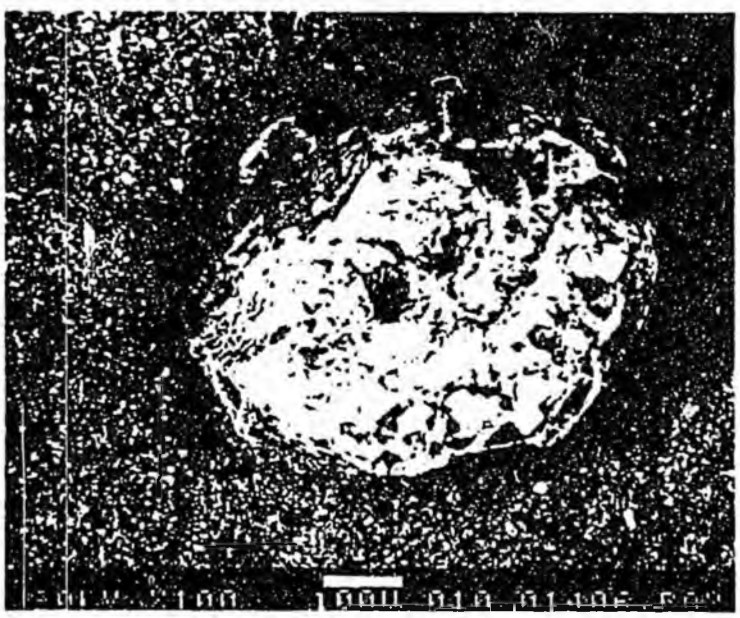


FIGURE 23-A. - Rounded sperrylite grain about 0.5 mm in diameter from test pit site sample no. 88. Note scale bar is 100 microns.

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.

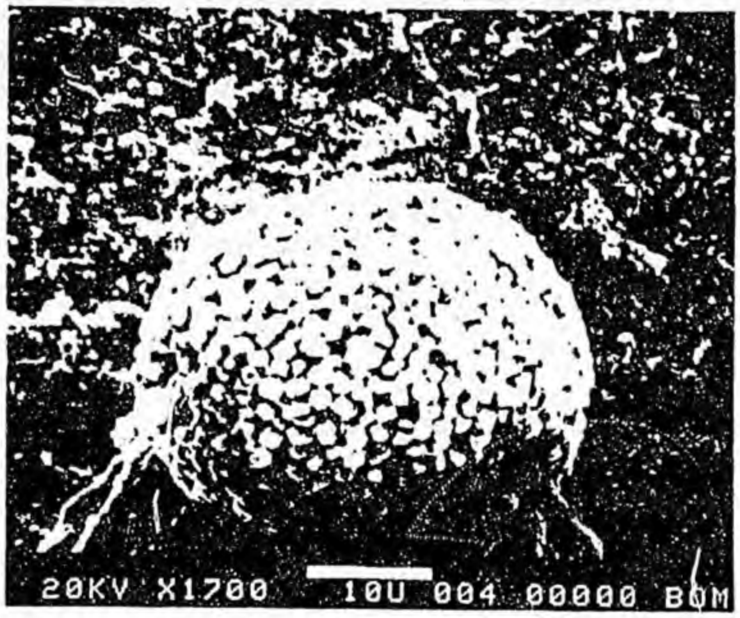


FIGURE 24. - Pyrite relacement and crystalline growth on diatom from sample no. 48, about 2 mi off Flat Cape. Scale bar is 10 micron.

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.

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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/yd[3] [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 [5/]	24.0	3.34	4.31
23	23037	39.1	10.8	468.5	20.0	31.0	.88	T	1,251.20 [5/]	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 graval. 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 ovarlying 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/yd^3 [1] Pt	mg/yd^3 [1] Ir [2]	mg/yd^3 [1] 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	47.30	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 graval from 1 ft hole.
31	Clayey, sandy, cobbly gravel with boulders to 3-ft-diameter. Sample collected from edge of bouldar. Visable Au and Pt spacks.
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	Sampla of sandy gravel from toe of dropoff. 1 Pt speck. Van Vaen 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 spacts 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	Sampla 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	Sampla 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[3]	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	2.35	.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/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.

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 augor 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 beech 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 D - 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/yd^3 [1] Pt	mg/yd^3 [1] Ir [2]	mg/yd^3 [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	11.60
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 baach. Pan concentrate had 10 Au- and 6 Pt-coarsa grains, and over 100 fine colors.
92	Channel sample from 2-ft hola 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 sampla 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 baach and includas 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 represants 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 spacks 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-intarval of well-rounded, well-sorted, paleo-alluvial gravels in bluff. Pan concentrate contained 3 to 4 spacks of Pt.
105	3-ft channel sample of loose gravel, possibly from paleo-channel trough. Contained a few spacks 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/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 Martie (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.

THE FOLLOWING DOCUMENT HAS NOT BEEN FILMED BUT IS AVAILABLE IN THE ORIGINAL FILE

A REVIEW OF FAVORABLE OFFSHORE AND COASTAL DEPOSITIONAL SITES FOR PLATINUM-GROUP METALS IN THE GOODNEWS BAY MINING DISTRICT, ALASKA

By Brian R. Zelenka
Alaska Field Operations Center, Anchorage, Alaska

*** Open File Report 11-88

UNITED STATES DEPARTMENT OF THE INTERIOR

Donald P. Hodel, Secretary

BUREAU OF MINES

T S Ary, Director

CONTENTS

ILLUSTRATIONS

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter
cm/yr	centimeter per year
g/m^3	gram per cubic meter
gr	gram
kg	kilogram
km	kilometer
m	meter
m^3	cubic meter
ppb	part per billion
ppm	part per million
pct	percent
sp gr	specific gravity
um	micron
yd^3	cubic yard
yr	year

A REVIEW OF FAVORABLE OFFSHORE AND COASTAL DEPOSITIONAL SITES FOR PLATINUM-GROUP METALS IN THE GOODNEWS BAY MINING DISTRICT, ALASKA

By Brian R. Zelenka[1/]

ABSTRACT

The Bureau of Mines (Bureau) reviewed all available information regarding geologic and depositional processes contributing to potential coastal and offshore platinum group metal (PGM) placer deposits around the Goodnews Bay Mining District. The Bureau found that favorable environments for PGM along with gold and chromite enrichment include: (1) buried paleofluvial channels; (2) recent paleofluvial channels with little marine sediment overburden, (3) beach deposits, particularly in the upper swash zone and near back beach environments; (4) paleostrand lines; (5) shoal lag deposits inside the mouths of Goodnews and Chagvan bays; and (6) bases of far offshore tidal ridges which may represent reworked glacial deposits.

Limited geologic and compositional (assay) data prevent determination of deposit size and grade of PGM mineralization for each deposit class. Future geologic sampling requirements for demonstration of identifiable offshore and beach PGM-bearing placers are discussed. Beach and offshore sampling programs conducted by the Bureau in 1986 will contribute additional information providing verification of specific deposit classes.

INTRODUCTION

The Bureau is currently investigating known and potential nearshore and offshore placer deposits in Alaska. The offshore region adjacent to the Goodnews Bay Mining District is recognized as having a high potential for PGM, gold, and chromium placers. Reliable quantitative analyses of beach and offshore sands around the Goodnews Bay Mining District are limited and the potential for economically extracting marine placers remains largely unknown. This study was undertaken as an attempt to compile available literature and evaluate the offshore and coastal placer potential near the Goodnews Bay Mining District. Specific depositional environments with possible economic concentrations of PGM, gold, and chromium are hypothesized.

Fluvial PGM placers were discovered in a small region south of Goodnews Bay, southwestern Alaska, during 1926 (23-25)[2/]. From 1927 to 1934, the placers were worked by small-scale hand mining methods. Dragline excavators were employed in 1935, and in 1937 the Goodnews Bay Mining Company built a bucket-line dredge which was seasonally used until 1975. The dredge has been used intermittently since then.

1/Mining Engineer, Alaska Field Operations Center (AFOC), Anchorage, Alaska (deceased).

2/ Underlined numbers in parentheses refer to items in the list of references at the end of this report.

Although PGM extraction has been restricted to gravels in the creeks which drain Red Mountain, the ultramafic source for the PGM (25, 35,), numerous researchers have reported trace to possibly economic concentrations of platinum in beach and offshore sands around Goodnews Bay, Chagvan Bay, and the adjacent coastal waters of Kuskokwim Bay (5, 7, 11, 28, 42). The presence of PGM-bearing sediments offshore was verified by the Bureau in 1985.

Significant concentrations of chromite, with lesser amounts of gold, are locally associated with the PGM placers and may represent economically recoverable co-products or by-products of PGM production. During the summer of 1986, the Bureau's Mineral Land Assessment (MLA) section and the Critical and Strategic Minerals sampling program continued to systematically collect bulk samples for PGM and heavy mineral analysis in the offshore and intertidal regions between Goodnews and Chagvan Bay.

This paper, which integrates the work of previous researchers, summarizes those characteristics which together suggest favorable marine placer environments in the Goodnews Bay Mining District. These include: (1) coastal and offshore geology; (2) Holocene geomorphology and its relationship to placer depositional environments; (3) Quaternary geology; (4) primary PGM sources; (5) secondary depositional environments; (6) PGM transport models; and (7) the results of marine sediment analyses. Depositional environments with possible PGM resources are identified using available data. Analysis of samples collected by the Bureau in 1985 and 1986 is incomplete, nor have assay data suggesting specific PGM placers in various offshore depositional environments been completely evaluated. However, limited compositional data from beach samples collected during 1986 by the Bureau's MLA program is presented.

ACKNOWLEDGMENTS

Peter Barnes, Geologist for the U.S. Geological Survey, is gratefully acknowledged for providing invaluable unpublished data from his offshore investigations in 1969 of the Goodnews Bay district. The author also wishes to acknowledge his colleagues at the Bureau of Mines, Alaska Field Operations Center, who provided both data and interpretive reviews.

STRATEGIC IMPORTANCE

Approximately 92% of the PGM consumed by the United States is imported from South Africa and the U.S.S.R., and is therefore considered strategic and critical for the U.S. (10, 27)). Platinum is used for two principal functions; (1) as a catalyst in automotive, petroleum refining, and other industries, and (2) as a corrosion-resistant material for industries such as chemical, electrical, and dental-medical (21). The Goodnews Bay Mining District is the only district in the U.S. which has produced PGM as a primary commodity. Significant resources and limited reserves of this commodity exist in the Salmon River valley, adjacent tributaries, and nearby coastal zones in the Goodnews Bay Mining District; however, the reserve base has been only partially evaluated (13, 29).

LOCATION

The Goodnews Bay Mining District is located north of Bristol Bay in southwestern Alaska (fig. 1). The district encompasses approximately 1.1 million acres, and is bounded by the Indian River on the north, Cape Newenham on the south, and Ungluayagat Mountain to the east (fig. 2, 31). This study investigates the nearshore and offshore region between the north spit at Goodnews Bay and the southern side of Chagvan Bay along the Bering Sea coast.

PRODUCTION AND RESERVE BASE

Total production of PGM from the entire Goodnews Bay District between 1927-81 is approximately 20,031 kg (2). The bucket-line dredge at Goodnews Bay, operated by the Goodnews Bay Mining Company from 1937-75, produced at least 16,949 kg of PGM (13). Presently, the platinum dredge, owned by the R. A. Hanson Company, is being operated on a limited basis, hence current PGM production from Goodnews Bay is negligible (12).

Measured recoverable reserves for PGM contained onshore in fluvial placers near Goodnews Bay are in excess of 9,330 kg (12). Hypothetical resources of subeconomic grade include 40,430 kg recoverable from lode occurrences at Red Mountain, 15,550 kg from beach deposits, and 155,500 kg from offshore placers according to Page and others (29). The U.S. Geological Survey (USGS) estimate of 171,050 kg of PGM for coastal placers should be recognized as an estimate of order of magnitude precision only (29), because they rely heavily on analyses of a limited number of grab samples (5, 11). Data obtained by the Bureau during 1986 suggests that a significantly smaller resource base is present on the beaches and probably offshore.

REGIONAL GEOLOGY

The geology of the Goodnews Bay Mining District has been studied by numerous investigators. The most significant contributions are discussed below. Reed (32, 33), in 1931 and 1933, described the early placer mining at Goodnews Bay and the ultramafic rocks comprising Red Mountain. In 1940, Mertie (23) reported on the regional geology and the character of the placers which included detailed petrographic investigations of the PGM. Mertie (24-25) went on, in 1969 and 1976, to summarize the mining history and composition of the PGM placers and also described the regional geology, Quaternary depositional environment, and economic significance. The heavy mineral potential of beach deposits along the coast of Bristol Bay was first reported by Berryhill (5) in 1963. Porter (30) described the Quaternary glacial history of the Chagvan Bay area in 1967. A comprehensive investigation of the Goodnews Bay District was released in 1978 by the USGS as part of the Alaska Mineral Resource Appraisal Project (AMRAP) (11, 16, 18-19). Bond (7) and Ulrich (42) reported on the distribution and processes involving the formation of beach placers in the Goodnews Bay district in 1982 and 1984 respectively. Wakeland (37), Welkie (40), and Walish (39) investigated the sedimentological processes active in Goodnews Bay, Chagvan Bay, and in nearshore environments in 1973, 1976, and 1977 respectively. The most recent

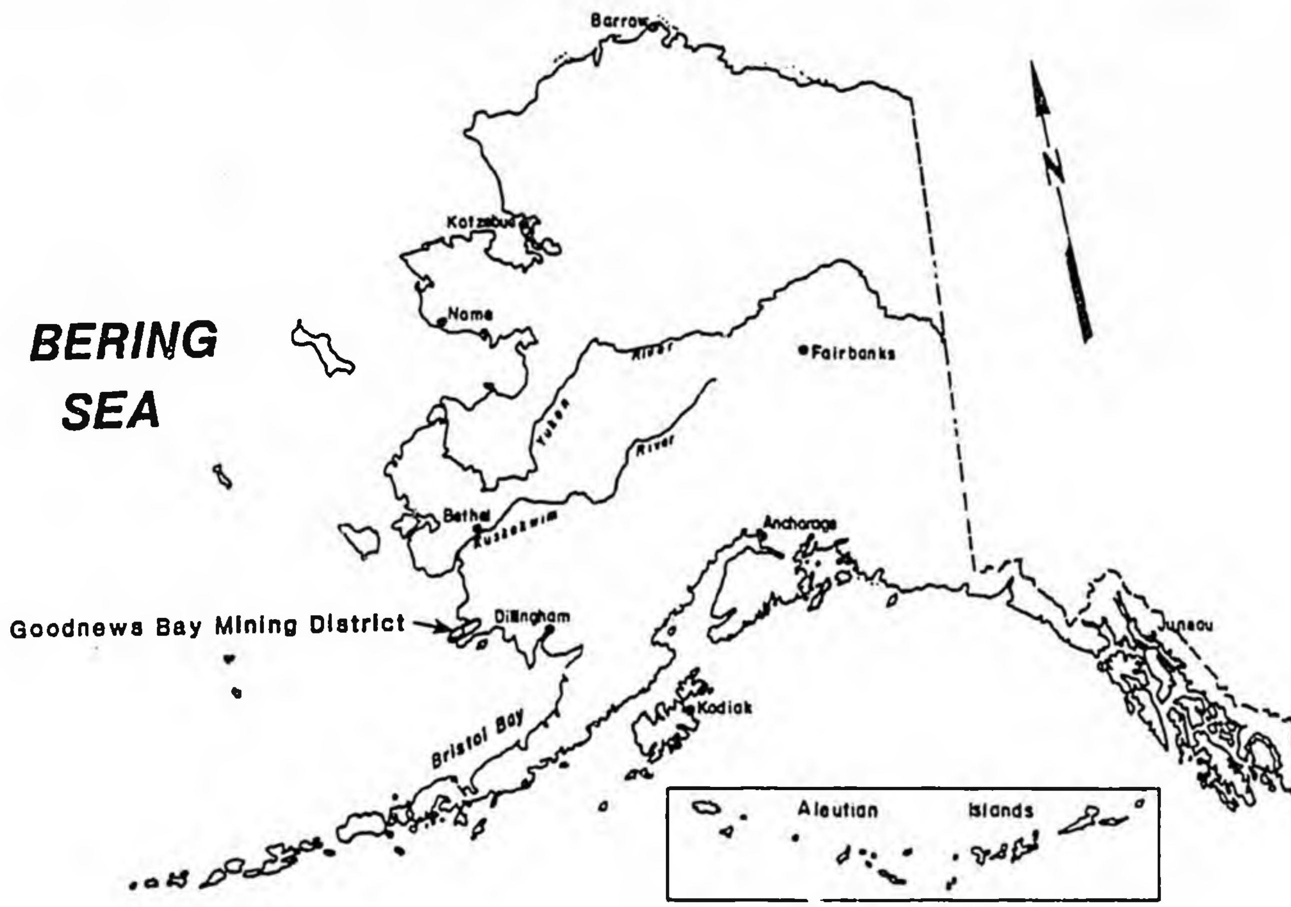

FIGURE 1. Location map of the Goodnews Bay Mining District, Alaska.

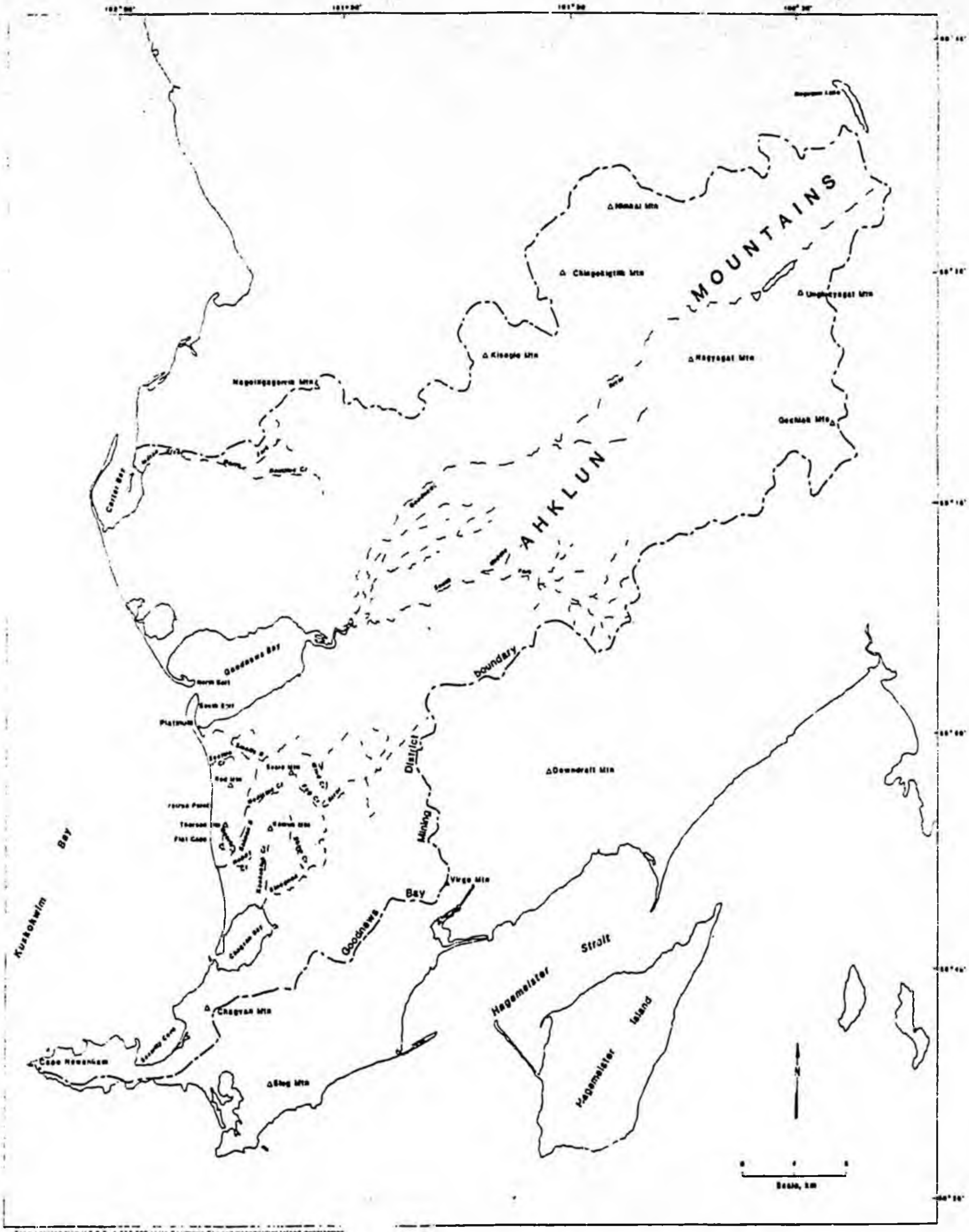

Figure 2. - Detailed Location Map showing boundaries of the Goodnews Bay Mining District and main topographic features

geologic map of the Goodnews Bay area was compiled by Hoare and Coonrad (19) for the Goodnews-Hagemeister Island quadrangles region in 1978. The tectonic setting of southwestern Alaska was recently investigated by Box (8-9), in 1982 and 1985, for the USGS. Southworth and Foley (36), and Southworth (35) published detailed descriptions of the ultramafic source rocks for PGM mineralization at Red Mountain. In 1982 and 1984, Box (8-9) subdivided the Goodnews Bay district into terranes which are overlain by unconsolidated glaciofluvial Quaternary deposits.

The tectonic setting of the Goodnews Bay complex is best described using the tectonostratigraphic terrane framework developed by Jones and others (20) and Box (8). The Goodnews Bay region consists of the Goodnews and Togiak Terranes. The following discussion is adapted from Box (8-9).

TOGIAK TERRANE

The Togiak Terrane consists of Mesozoic volcanic and volcaniclastic sedimentary rocks which may be subdivided into the Hagemeister and Kulukak subterranes (fig. 3). The Hagemeister subterrane is a northeast striking belt which includes Chagvan Bay and Chagvan Mountain. The Hagemeister subterrane is comprised of Upper Triassic through Lower Cretaceous mafic igneous rocks, shallow marine volcaniclastic sedimentary rocks, and intercalated cherts. The subterrane may be further divided into three units with unconformable contacts.

The Kulukak subterrane consists of Jurassic volcaniclastic turbidites, and is exposed as a northeast trending belt south of the Goodnews Bay District (fig. 3). A northeast striking linear fault separates the Hagemeister and Platinum subterranes from the Nukluk subterrane to the northwest.

GOODNEWS TERRANE

The Goodnews terrane is subdivided into the lithologically distinct Nukluk, Platinum, and Cape Peirce subterranes (fig. 3). The Nukluk subterrane strikes northeast with its western margin extending from Goodnews Bay to Carter Bay (fig. 3). The Nukluk subterrane consists of Triassic limestone and volcaniclastic sedimentary rocks, radiolarian cherts, and polymictic clastic rocks in a matrix-poor melange package. Locally, the subterrane is overprinted by greenschist to blueschist facies metamorphism along the northwestern margin. The Nukluk subterrane is separated from the Platinum and Hagemeister subterranes by a northeast trending linear fault. The Platinum subterrane is exposed around Goodnews Bay and the Upper Goodnews River, and consists of an unfoliated package of basalts, limestones, and volcanic conglomerates of Permian age. The Cape Peirce subterrane outcrops between Goodnews Bay and Chagvan Bay, around Security Cove, and on the northern shore of Hagemeister Strait (fig. 3). The Cape Peirce subterrane consists of foliated greenschist to blueschist facies metamorphic rocks of late Triassic or early Jurassic age, which have been thrust over the Platinum subterrane to the northwest. The Cape Peirce subterrane is exposed through a window under a low-angle fault overlain by the Hagemeister subterrane.

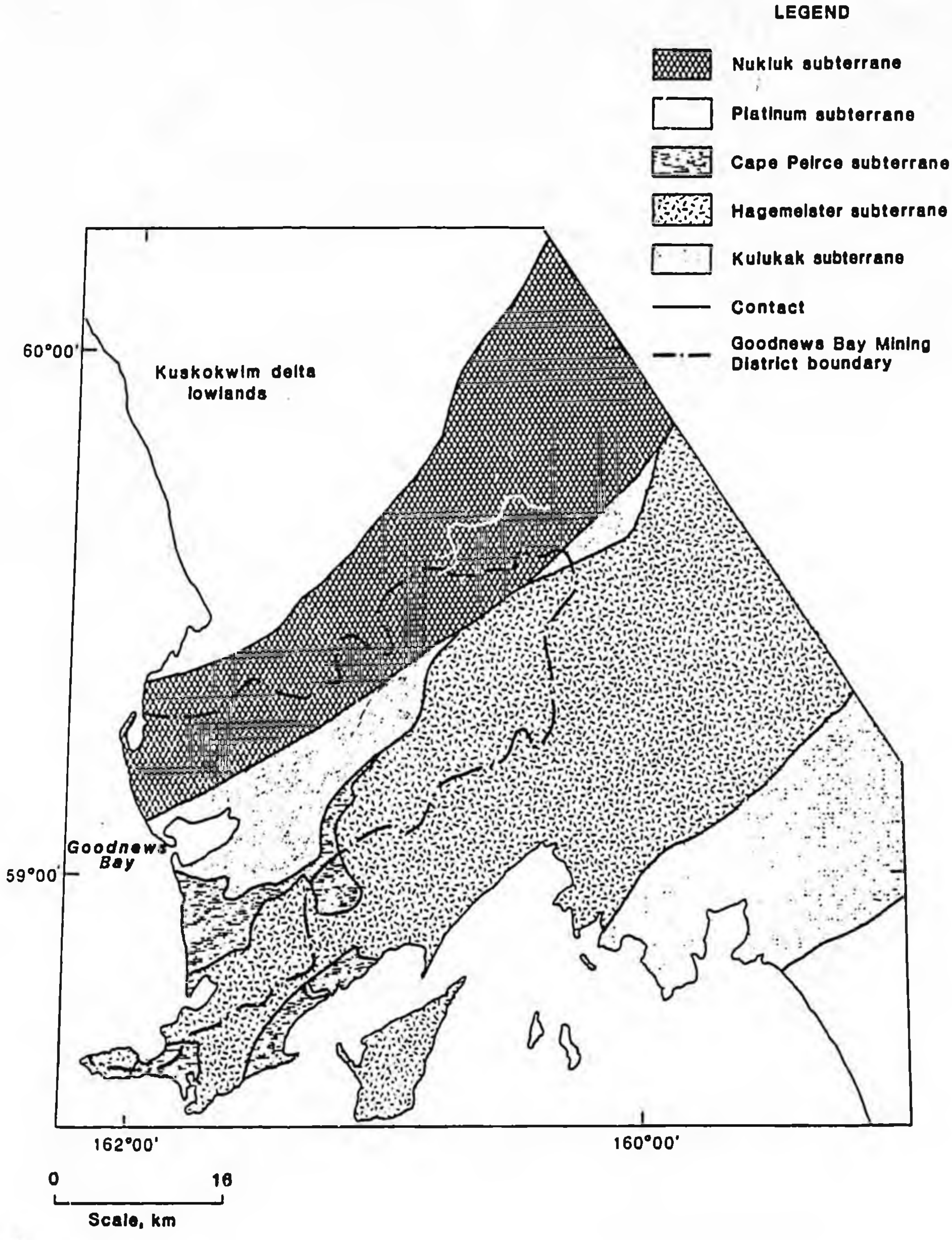

FIGURE 3. Teconostratigraphic terrane map of the Goodnews Bay Mining District

ULTRAMAFIC ROCKS

Red Mountain and Suzie Mountain are two exposures of ultramafic rock within the Goodnews Bay Mining District and probably represent the same complex (35, 36). The ultramafic intrusives consist of dunite, pyroxenite, hornblendite, and gabbro which form a discontinuous belt of sill-like bodies which intruded the Cape Peirce subterrane during Late Cretaceous to Early Tertiary time (35). These intrusives represent the source of PGM, chromite, and minor gold (25, 35). Hoare and Coonrad (19) report potassium-argon ages of 176.4 ± 5.3 and 186.9 ± 5.6 million years for secondary amphibole located along the Red Mountain contact zone.

QUATERNARY GEOLOGY AND DEPOSITS

Unconsolidated Quaternary deposits in the Goodnews Bay Mining District are derived from glacial, fluvial, and marine origins. A discussion of each is presented below.

GLACIAL HISTORY AND DEPOSITS

Porter's (30) description of the glacial history of the Chagvan area may be applied to the Goodnews Bay area. Mertie (25) summarized many of Porter's conclusions and provided additional interpretations based on his observations of the placer mining operations.

Glaciers originating in the Ahklun Mountains, northeast of the Goodnews Bay Mining District, spread over the coastal lowlands at least four times as broad piedmont lobes. From oldest to youngest, the four ice sheets have been named Kemuk, Clara Creek, Chagvan, and Unaluk, which correspond to the Nebraskan, Kansan, Illinoian, and Wisconsinian Glaciations, respectively (25). The Kemuk drift sheet is deeply buried beneath younger drift and is indicated only from a single drill hole located half a mile north of Happy Creek. The sediments are characterized as strongly weathered and oxidized and directly overlie weathered bedrock. The Kemuk Glaciation did not erode bedrock at lower elevations in the Salmon River Valley, as evidenced by preservation of the bench placer on the east wall of the valley which was buried by the earliest ice advance. This early advance may have covered the entire upland as suggested by the distribution of placer gold presumably carried in by ice sheets from source rocks to the east.

The Clara Creek (Kansan) Glaciation was the most extensive of the four ice advances and produced massive morainal material which has been remobilized by erosion and mass-wasting. The preglacial course (bench placer) of the Salmon River was probably abandoned during the Kemuk or Clara Creek Glaciation because the younger, valley-bottom placer was truncated by ice advancing into the lower Salmon Valley from Chagvan Bay during the third glaciation.

The third ice advance, represented by the Chagvan (Illinoian) Glaciation, has been radiocarbon dated to have occurred at least 45,000 years before present (30, p. 13). The deeper (Clara Creek) bench placer was not eroded by this ice advance. This glaciation did, however, destroy PGM placers that presumably existed on the northeastern side of Red Mountain, as evidenced by erratic boulders