Place Minerals on the U.S. Continental Shelves-Opportunity for Development
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Abstract

A high potential exists for discovering placer minerals on the Alaskan continental shelf. The eastern Bering Sea shelf may have the greatest potential for locating gold placers. The shelf areas offshore of Nome and Goodnews Bay, Alaska, deserve special emphasis in the search for offshore gold placers. East of Cape Prince of Wales and off St. Lawrence Island there is also potential for heavy mineral placers. Offshore Seward Peninsula appears to have high potential for tin.

The Washington and Oregon Outer Continental Shelf (OCS) offers opportunities for mineral exploration. A full suite of heavy minerals occurs along these coasts. Occurrences of gold placers and platinum with other heavy mineral sands have been found along the Washington coast from Cape Flattery to the Columbia River, Oregon. Crescent City, California, has potential for offshore platinum and gold.

Kyanite and sillimanite are the dominant heavy minerals on the eastern Gulf of Mexico shelf. The amphibole-pyroxene group are dominant in the western Gulf of Mexico shelf.

Heavy mineral placers are abundant and widespread on the Atlantic OCS. Areas offshore of Florida, South Carolina, and Virginia have potential for containing economically viable heavy mineral placers. Heavy mineral sands are titanium rich. Other minerals included in the suite are rutile, ilmenite, zircon, garnet, kyanite, sillimanite, and staurolite.

Resource estimates for offshore undiscovered placers range from tens of millions of ounces of gold in Alaska to millions of tons of heavy minerals off the Pacific coast. The Atlantic OCS may contain well over a million tons of titanium alone.

I. INTRODUCTION

Placers are mineral deposits formed by the weathering of parent rocks and mechanical concentration by the action of rivers, waves, and currents. Although placer deposits occur in rivers and lakes as well as in offshore marine environments, this discussion focuses primarily on the occurrence of placer deposits on the continental shelves of the United States.

A significant amount of metals are imported into the United States and some placer metals are important to the economy of the United States and critical to the defense industry. Examples of important heavy metals and minerals that can occur as placers include gold, platinum, cassiterite, chromite, ilmenite, rutile, zircon, and monazite.

The availability of several of these metals is dependent upon foreign suppliers. For example, the United States, which does not produce chrome ore, is heavily dependent upon imports from southern Africa. South Africa and the USSR are the two principal producers of platinum accounting for 90 percent of world output. Canada is the only major and significant producer of platinum (Murphy, 1980). Ilmenite and rutile ores are a source for titanium, which is commonly supplied to the United States by Australia and Canada. Prices for these metals in the United States can increase from reductions in world supplies, which can in turn direct attention to our continental shelves as the United States can increase from reductions in world supplies.

BACKGROUND

The occurrence and residence times of placer minerals on the shelf are influenced by the tectonic framework of the coastal region and the geomorphology and environmental setting in which the placers are deposited. In light of recent plate tectonic theory, the east coast of the United States is an example of a trailing edge coast. This type of coast faces a continental shelf that is relatively smooth and deepens gradually seaward. Placers on the shelf adjacent to a trailing edge coast are likely to have long residence times and contain a mature suite of minerals; except on glaciated shelves where immature suites of minerals are dominant.

The south coast of Alaska is an example of a collision coastal region. This type of coastal region is characterized by narrow continental shelves bordered by oceanic trenches and deep basins. The onshore areas are predominantly rugged with mountainous topography and are seismically active.

Placers on the shelf adjacent to a collision coastal region are likely to be numerous and well sorted owing to high energy transportation and concentration processes.

A third type of coast is a marginal coastal region that tends to develop along the shores of continental shelf and is typically bordered by a wide continental shelf and shallow shelf with an irregular shoreline. Coastal plains are common and active in width. Delta forming coastal plains are common along continental shelf areas and have potential for containing placer deposits.

The Pacific shelf area can be subdivided into three regions which reflect differences in wave action, coastal morphology, and oceanic depth. A narrow continental borderland exists in southern California north to Point Conception. This continental borderland is characterized by a simple slope and ridge submarine topography with depths significantly less than those of the deep ocean. Further north, the shelves are narrow or even absent along the continental shelf from Point Conception to Monterey Bay. Near San Francisco, the shelf again widens and maintains its width off Oregon and Washington and becomes more complex (Shepard, 1973). The topography of the continental shelf off Washington is fairly smooth and deepens gradually seaward to the edge of the continental shelf.

The Pacific coast is influenced by subduction zones to the north and south resulting in mountain building, earthquakes, faulting; and the symptans of a seismically active region. In several cases, submarine canyons extend beyond river mouths to oceanic depths.

Gulf of Mexico Shelf

The Gulf of Mexico (GOM) continental shelf and slope is a vast region encompassing nearly 697,000 km² (233,000 sq mi) as compared with about 1,862 km² (1,157 sq mi) for the entire western U.S. Atlantic Shelf. Water circulation in the GOM is primarily gyral in nature. From east to west, the Gulf of Mexico shelf can be subdivided into five regions based on major sediment type and morphology: (1) the Florida Limestone Plateau; (2) the Big Bend of Florida-Alabama-Mississippi; (3) the Mississippi Delta Shelf; (4) the West Texas-Northern Mexico Shelf; and (5) the Campeche-Yucatan Limestone Plateau (Gorsline and Swift, 1977).

Atlantic Shelf

The Atlantic shelf varies in width from less than 10 km (6.2 mi) off Miami, Florida, to more than 150 km (93.2 mi) off New York. Considerable differences in climate, meteorological events (e.g., storms), and the physical characteristics of the shelf results in the east coast experiencing a wide range of oceanographic conditions. Several of these include a mean southerly drift over the continental shelf, and southern Atlantic shelf and lower mean wave height and shorter wave periods relative to the west coast.

Seismic reflection studies have shown a thick sequence of sediments, presumably Mesozoic and Cainozoic Coastal Plain material, off the northeastern coast of the United States (Brazeau and Drake, 1975). The shelf off the southeastern coast combines areas rich in terrigenous clastics separated by areas lacking detrital material and dominated by biogenic deposits (Gorsline and Swift, 1977). The effects of glaciation are apparent throughout New England, the Gulf of Maine, New York, and Long Island. These effects extend to the shelf offshore on the northeastern continental shelf in the form of till-like deposits of gravel, sand, and silt found on parts of the shelf of the Gulf of Maine and Georges Bank shelf (Ross, 1970).

RESOURCES

Gold and Platinum - Alaska Region:

The continental shelf of the eastern Bering Sea adjacent to northern Alaska may have the highest potential for gold placers anywhere in the United States. Onshore placer deposits are estimated to be nearly a third of the placer gold produced in Alaska. The shelf area offshore of Nome and Goodnews Bay is of particular interest, despite special emphasis for offshore gold placers (Shepard, 1977). Submerged shorelines and stream channels may be prime localities for gold placers. One area of high interest begins about 15 km (9 miles) west of Nome and continues to Cape Nome.
nearshore sands and relict sands being the most likely repository on and estuary systems (e.g., Columbia River). Different sediment types on coast from Cape Flattery to the Columbia River (Phillips, 1979).

Beaches along the northern part of the Gulf of Alaska have been mined for nearly a century. Offshore exploration, however, has not proceeded with any real interest. Weather and lack of supporting facilities have been limiting factors to exploration. A reconnaissance study by Reisentz and Pfaffler (1976) revealed concentrations of gold in the beach sediments of the Copper River Delta. The shelf area of the Gulf of Alaska, bordered by beaches containing placers, may have economic potential. Trace amounts of gold are commonly found in lag deposits that unconformably overlie marine clastic rocks characterized by glacial detritus (Yakataga Formation). The Yakataga Formation underlies much of the shelf and is the most likely source of placer gold found on the beach at Middleton Island. This implies some onshore transport of placer gold in this region.

Gold and Platinum - Atlantic and Gulf of Mexico Shelves:

There are no known occurrences of gold or platinum placers on the continental shelves of the Atlantic and Gulf of Mexico Regions.

Gold and Platinum - Atlantic Region:

Occurrences of gold flaxes and platinum, in association with other mineral sands (e.g., black sands), have been found along the Washington coast from Cape Flattery to the Columbia River (Phillips, 1979).

Placer deposits of gold and platinum are likely to occur, in association with other heavy mineral deposits, offshore of present rivers and estuary systems (e.g., Columbia River). Different sediments on the Washington shelf occur in bands parallel to the coast with nearshore sand deposits being the most likely regions for placers. The nearshore sands extend out to an approximate water depth of 90 m (295 ft) (Yates and others, 1967) and extend seaward of Cape Blanco. Further on, placer deposits have been found at greater depths, particularly seaward of Cape Blanco (Phillips, 1979). Additional work is required to determine the economic potential of gold and platinum deposits offshore on the Washington shelf.

The coast of Oregon has experienced limited mining activity for gold and platinum placers since the turn of the century. Beaches and elevated terraces from Coos Bay south to the California border have received attention. Platinum group minerals have been located in beach sediments from the mouth of the Columbia River south to Crescent City, California. Offshore placer deposits, although not delineated at present, may exist within a nearshore sand facies that parallels the Oregon coastline and extends to depths of over 100 m (622 ft). Favorable locations on the shelf may also include the southern coast, the area at the mouth of the Columbia River (Phillips, 1979), and estuarine river systems, where stream patterns migrate through known gold or platinum bearing rocks.

Gold mining along the northern California coast was initiated in the mid-1800's. Beaches and elevated terraces were preferred sites of mining activity. Gold has been identified in offshore sediments near Crescent City, California, and in southern California occurring off river mouths (Phillips, 1979). The offshore gold accumulations may be lag deposits resulting from erosion of Cenozoic deposits during postglacial rise in sea level. Platinum has also been reported to occur in beach sediments near Crescent City as well as further south on Oregon Coast (Phillips, 1979).

The Monterey Bay area has also been identified as a site for some platinum. Geomorphologically guided offshore reconnaissance sampling of sediments needs to be conducted to determine gold and platinum occurrences on the Monterey and coastal California shelves.

Tin - Alaska Region:

Tin, in association with gold placers and other heavy minerals, has been found on a shelf which extends from Cape Prince of Wales along the northwest portion of Seward Peninsula (Tagg, 1979). Since western Seward Peninsula is a significant resource area for tin, the offshore area appears to possess a favorable potential for tin placers.

Tin - Pacific/Gulf of Mexico/Atlantic Regions:

Occurrence of tin as placer deposits on the continental shelf is relatively unknown in the Pacific, Gulf of Mexico, and Atlantic offshore regions. Further sediment sampling is necessary in these offshore regions to determine potential for tin placers.

Heavy Minerals - Alaska Region:

Even though gold is of prominent interest, in terms of offshore mining, genuine interest in an array of heavy minerals (e.g., lead, silver, tin, and tungsten) has persisted, particularly in promising localities. Approximately 50 km (27 miles) east of Cape Prince of Wales heavy mineral placers have been reported and some production of lead, silver, tin, and tungsten has taken place (Tagg, 1979). Attention should also be directed toward the offshore area off the western end of St. Lawrence Island.

Tin is reasonable to conclude that offshore areas in Alaska that possess a fairly high potential for harboring gold placers may also possess tin heavy minerals. For example, offshore Nome and Daniels Creek at Bluff; offshore of the western part of St. Lawrence Island, near Unga and Popof Islands west of Kodiak Island, Kamshak Bay, Shelikof Strait, and most of southeast Alaska (Copper, platinum, antimony, and zinc, usually associated with gold (Tagg, 1979). The likelihood of finding heavy-mineral placers with lag deposits offshore of the Copper River Delta (Reisentz and Pfaffler, 1976). Intensive glaciation in concert with widespread metalliferous outcrops and proximity of the Gulf of Alaska enhance the potential for discovering offshore heavy-mineral placers, given appropriate concentration mechanisms.

Heavy Minerals - Pacific Region:

A full suite of heavy minerals occur along the coast of Washington in a discontinuous manner. They are found as detrital placers within beach and estuarine sediments and include: platinum group, apatite, xenotime, zircon, sphene, rutile, leucoxene, monazite, ilmenite and chromite (Phillips, 1979). As noted earlier, the Washington shelf sediments are differentiated into major types: nearshore sand, outer shelf silt-mud, and relict sands. This differentiation reflects on physical as well as biological processes operative in the area. Lowstands of sea level, winnowing effect, and bioturbation have, collectively and at different times, been responsible for distributing and concentrating heavy minerals on the shelf.

Favorable locations for heavy mineral placers occur in submerged beaches on the Washington shelf in the area south of the Nis River at depths of 10 and 19 m (33 and 62 ft); off Grays Harbor at depths of 10 to 16 m (33 to 52 ft); and off Port Angeles at depths of 10 to 16 m (33 to 52 ft) (Yenancham, 1977); and seaward of Willapa Bay at depths of 20 to 30 m (66 to 98 feet). The largest concentration of heavy minerals on the Washington and Oregon shelf occur seaward of the mouth of the Columbia River (Phillips, 1979). Byrne and Panshin (1966) reported greater than 30 percent heavy-mineral concentrations in sediments on the south side of the mouth of the Columbia River. These concentrations extend out to depths of 100 m (328 ft). Opalite minerals range between 6 percent and 16 percent concentration. Bredg spot sills from the Columbia River may account for high concentrations levels to the south (Figure 2).

Available information suggests reworking and concentration of older deposits containing heavy minerals by physical processes and bioturbation. Heavy minerals at shallow depths (< 40 m) may be acted upon and concentrated primarily by physical processes (Phillips, 1979).

The suite of heavy minerals found along the Oregon coast is similar to that found along Washington State, namely platinum group, apatite, zircon, sphene, rutile, monazite, and others. Generally, offshore deposits tend to occur seaward or adjacent to river systems. To the north, heavy minerals occur seaward of the Nehalem River and extend to depths of 65 m (213 ft).

Heavy mineral placers have also been reported off the Sitka Sound in depths of 55-65 m and the Umpqua River at 130-185 m (426-617 ft) in depth. As mentioned earlier, heavy-mineral placers with occurrences on the Oregon Coast have been uncovered at the mouth of Cape Perpetua. Further out on the shelf, heavy minerals of high concentration (43 percent) are located near the shelf break adjacent to the Quinault Submarine Canyon. Concentrations of placer deposits off the mouth of the Roque River at 80-90 m (262-295 ft) also show potential for recovery. In most cases, occurrences of heavy-mineral placers coincide with low stands of sea level.
Heavy-mineral placers along the California coast appear to be more limited than those along the Atlantic and Gulf coasts. This is probably a function of a lack of research in the region. With the exception of offshore Crescent City, only minor occurrences of heavy-mineral placers have been reported. Zoisite and hornblende concentrations may have economic value, although heavy mineral data is available only for part of the northern California shelf. Heavy-mineral occurrence appears to be similar (platinum group, apatite, zircon, ilmenite, rutile, monazite and others) to the Washington and Oregon shelf with the addition of barite, glauconite, and phosphorite. The California shelf is fairly narrow and is incised by many submarine canyons. Detrital material may not remain for any duration on this part of the shelf because the canyons act as conduits for the transport of sediment to oceanic depths.

**Heavy Minerals - Gulf of Mexico Region**

Kyanite and sillimanite, along with garnet, rutile, zircon, monazite and ilmenite, are found on the continental shelf around the mouth of the Kachemak River on the Gulf of Alaska (Nossaman, and others, 1968). In the western part of the Gulf of Mexico, the amphibole-pyroxene group are a dominant. Mississippi River derived sediments, recent beach sands, and older reworked sediments off Louisiana contain heavy minerals; ilmenite and zircon are common. Ilmenite may be a major contributor of calcium carbonate, in the form of course shell material, for cement manufacturing.

**Heavy Minerals - Atlantic Region**

As discussed earlier, the continental shelf along the eastern United States varies topographically and texturally along its extent. The shelf has been repeatedly emerged and submerged over the recent geologic past. As a consequence of glaciation, the shelf topography along the mid-Atlantic states is much smoother than the glaciated shelf bottom to the north, however, ridges and swells are common in all parts of the shelf. Heavy-mineral placers are and have been mined onshore from ancient beach sands along the coasts of New Jersey, Georgia, and Florida. An example includes Trask Ridge near Jacksonville, Florida (Maine and others, 1979). Coastal placer deposits in New Jersey have also been a source of placer minerals, particularly ilmenite and zircon.

On the basis of existing information, it is difficult to evaluate the potential for offshore placers along the Atlantic shelf. Offshore sand have typical shown only about 1-4 percent total heavy-mineral concentration. However, the vast extent of these sands and abundance of titanium rich phases from loose sands suggest a fairly large resource of titanite (i.e., rutile, ilmenite and monazite) and other minerals. Other heavy minerals in the suite include monazite, xenotime, anorthosite group, zircon, garnet, kyanite, sillimanite, staurolite and others. Sand samples from the New England continental shelf have been analyzed and therefore the suite is apt to be immature (i.e., amphibole group and garnet abundant). Whereas the shelf area to the south has more mature heavy-mineral suites (i.e., interest has focused primarily on Gross, personal communication).

In a recently completed study of 71 grab samples from marine sediment deposits in Virginia, South Carolina, and northeastern Florida (A, B, and C, Figure 3), Comparisons of offshore heavy-mineral concentrations were made with results from previous onshore studies and onshore mining operations (Table 1). Offshore Virginia suites show larger concentrations of heavy minerals than offshore areas to the south and only slightly less than the richest onshore control area in South Carolina. In addition, though significant concentrations of heavy minerals are present offshore Virginia, no economic deposits are found onshore (Gross and Escowitz, 1983). Estimates of economic potential are not known owing to the lack of vertical control for the offshore area.

From the examination of 92 grab samples, Drucker (1983) identified 6 zones of heavy-mineral concentration within the inner New York Bight area as having economic potential. It was estimated that zircon accounted for the bulk of heavy minerals in zones 1, 2, and 3, and ilmenite was concentrated in zones 1, 4, and 6.

**RESOURCE ESTIMATES**

**Alaska Region**

Alaska has produced approximately 30 million ounces of gold (Nossaman, and others, 1968) largely from deposits in or near the coastal region. However, placer deposits may account for a minor portion of this production. The region around Nome yielded about 5 million ounces, mainly from ancient and modern beaches.

The continental shelves of the Bering and Chukchi Seas possess, in part, a background concentration of gold in the order of 0.02-0.08 ppm in particles 10-20 microns in size. Gold particles of a coarser size may exist on the inner parts of the shelves. The magnitude of gold mineral resources may be in the range of millions of ounces. The Gulf of Alaska may have the same potential for placer deposits as the Bering and Chukchi Seas, possibly amounting to tens of millions of ounces in undiscovered resources.

Past production of platinum from placer deposits in the Salmon River, Seward Peninsula, and at Lituya Bay in southeast Alaska has been estimated to be well over a half million ounces. Potential offshore resources of platinum may be in the order of tens or hundreds of thousands of ounces (Nossaman and others, 1968).

Heavy-mineral placers with high concentrations of magnetite and ilmenite may exist off southeastern Alaska near Kuskwan where an alluvial deposit of several hundred million tons may have a magnetite content of 10 percent (Berg, Eberlein, and Mackevert, 1964). It is conceivable that these placer deposits may have may contain billions of tons of placer gold. Placement of placer tin has been mined on the western part of Seward Peninsula. The offshore potential for placer tin ranges from thousands to tens of thousands of tons (Nossaman, and others, 1968).

**Pacific Region**

Placer gold concentrations along the Washington shelf range from 0.01 to 0.004 ounces per ton of sediment. These estimates are based on only a few samples. The potential of the region is difficult to evaluate because there are no known or postulated occurrences of offshore placer gold, platinum, or tin on the Atlantic and Gulf of Mexico continental shelves, and it is not possible to estimate any placer deposit or value at this time. Other heavy mineral placers have been located on the Atlantic and Gulf shelves and are discussed in terms of potential availability. Estimates of resource potential for offshore placer gold, platinum, and tin are presented in Table 2. Although offshore gold and tin potential on the east and west coasts is low, offshore tin potential in the Pacific is low, offshore gold potential in the Pacific is high.

**References Cited**


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Figure 1 Bering Sea

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Figure 2 Northern California and Oregon Coast

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Figure 3 Study areas in Virginia, South Carolina, and northeastern Florida (after Grosz, 1983).
### Table 1: Comparison of the range and mean of heavy-mineral percentages of onshore with offshore samples.

<table>
<thead>
<tr>
<th>State</th>
<th>Number of Samples</th>
<th>Percent of SG &gt;2.85</th>
<th>Mean</th>
<th>High</th>
<th>Mean, Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia</td>
<td>80</td>
<td>0.01</td>
<td>0.65</td>
<td>11.40</td>
<td>30</td>
</tr>
<tr>
<td>ONSHORE</td>
<td>South Carolina</td>
<td>58</td>
<td>0.20</td>
<td>3.32</td>
<td>26.60</td>
</tr>
<tr>
<td>Florida</td>
<td>60</td>
<td>0.02</td>
<td>0.75</td>
<td>10.01</td>
<td>68</td>
</tr>
<tr>
<td>Virginia</td>
<td>44</td>
<td>0.02</td>
<td>3.12</td>
<td>11.16</td>
<td>34</td>
</tr>
<tr>
<td>OFFSHORE</td>
<td>South Carolina</td>
<td>10</td>
<td>0.08</td>
<td>1.13</td>
<td>4.60</td>
</tr>
<tr>
<td>Florida</td>
<td>17</td>
<td>0.13</td>
<td>0.94</td>
<td>2.40</td>
<td>10</td>
</tr>
</tbody>
</table>

1. ECH is defined as the sum of percent, in SG >2.85, concentration of ilmenite, leucoxene, rutile, zircon, sillimanite, and monazite.

### Table 2: Potential resources of heavy minerals on the Atlantic and Gulf shelves (between state limits and the 200 meter contour; millions of short tons).

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Atlantic</th>
<th>Gulf</th>
<th>Atlantic</th>
<th>Gulf</th>
<th>Atlantic</th>
<th>Gulf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monazite</td>
<td>0.9</td>
<td>no data</td>
<td>0.1</td>
<td>3.7</td>
<td>1</td>
<td>not estimated</td>
</tr>
<tr>
<td>Ilemite</td>
<td>34</td>
<td>-</td>
<td>109</td>
<td>90</td>
<td>1000</td>
<td>-</td>
</tr>
<tr>
<td>Rutile</td>
<td>1.9</td>
<td>-</td>
<td>1.4</td>
<td>12</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>Zircon</td>
<td>10</td>
<td>-</td>
<td>13.6</td>
<td>14</td>
<td>140</td>
<td>-</td>
</tr>
<tr>
<td>Kyanite and sillimanite</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>35</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>Staurolite</td>
<td>7</td>
<td>-</td>
<td>13.6</td>
<td>15</td>
<td>140</td>
<td>-</td>
</tr>
<tr>
<td>Garnet</td>
<td>no data</td>
<td>-</td>
<td>no data</td>
<td>no data</td>
<td>no data</td>
<td>-</td>
</tr>
</tbody>
</table>

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