Black Sands

by

LEWIS S. PRATER
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IDAHO BUREAU OF MINES AND GEOLOGY
MOSCOW, IDAHO
FOREWORD

In the past ten years the economic potential of the "black sand" deposits of Idaho has changed drastically. No longer are these sands economically interesting solely for their gold content. Many useful minerals, bearing uranium, thorium, titanium, columbium, tantalum and the rare earth metals, are concentrated in central Idaho placers. In consequence of this changed economic picture, the Idaho Bureau of Mines and Geology is actively investigating the geology, metallurgy, and economic potential of these deposits. As part of this program Information Circular No. 1, defining and describing "black sands" in general, has been written by Lewis S. Prater, Metallurgist and Assistant Director of the Bureau.

E. F. Cock
Director
Idaho Bureau of Mines and Geology
Figure 1. This picture illustrates the manner in which the coarse gravel discarded by the stacker on a modern dredge is leveled. It should be noted that leveling operations are carried on immediately behind the dredge which is shown in the background (upper left). Although some fairly large boulders are visible in the picture the surface of the leveled ground is flat.

Figure 2. This picture is of essentially the same area as Figure 1, after the topsoil has been spread over the leveled tailings. Except for the opening stages of the dredging operation, the topsoil is replaced on a continuous basis; the topsoil which is removed ahead of the dredge is spread immediately over the leveled tailings behind the dredge. The ground in the above picture will be reseeded to grass.

Both of these pictures were taken in Bear Valley, Valley County where two dredges are recovering strategic columbium and tantalum-bearing minerals. The Bear Valley deposits contain the largest known reserves of columbium and tantalum in the United States as well as hundreds of tons of uranium. The first dredge started operating here in 1955 and the second one in 1956. They are now producing well over 90 percent of the columbium and tantalum obtained from domestic sources.
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INTRODUCTION

Mineral deposits composed of loosely consolidated gravel or similar rock debris which can be mined by processes such as dredging or hydraulicking are called placer deposits. The heavy minerals that collect in the sluice boxes or other concentrating devices used in placer mining are commonly referred to as "black sands." Similar sands may also be concentrated by natural agencies such as running water or wave action along beaches; in some instances river bars or beach sands, but particularly beach sands, may consist almost entirely of black sand. Regardless of whether they are the result of natural processes or of man's initiative, black sands are the product of rock weathering and decomposition, followed by gravity concentration. Consequently the minerals present in any black sand are in general resistant to the processes of weathering, both chemical and mechanical, and they also have high specific gravity. Beyond these common features, the minerals bear little resemblance to one another except that in most instances those composing the bulk of the sand are either black or very dark brown in color—hence the origin of the term black sand.

The purpose of this report is to summarize some general information on black sands without listing or describing specific deposits. The properties of the minerals most commonly found in black sands will be described and the possible uses and economic significance of those having commercial value will be outlined.

PLACER DEPOSITS AND ORIGIN OF BLACK SAND

Placer deposits may be classified in various ways but they are commonly divided into two main groups: residual deposits and transported deposits. In the residual deposits the minerals have been more or less liberated from one another by weathering but the deposit as a whole is in approximately the same position as the original rock from which it was formed. Such deposits have little or no commercial value except in extremely rare instances. This is because there has been no opportunity for the valuable constituents of the deposit to become concentrated. They are present in about the same quantity as in the original rock where they were formed in sparse amounts as accessory minerals.

In the transported placer deposits the rock debris has been moved some distance from its original location and then been redeposited. Running water is the most common means by which this is accomplished. The chemically unstable minerals are either dissolved or altered to clay, which is easily washed away; the lighter minerals such as quartz, which are chemically stable, are transported a greater distance than the heavy black sand.
Also as the gravel is carried along, a natural stratification occurs, the heavy minerals gradually working their way down through the lighter material until they eventually reach bedrock. Consequently black sands in a gravel deposit are commonly near the bottom of the deposit, because of the natural concentration that has taken place. Transported placer deposits may be worked and reworked by natural agencies any number of times, each step usually resulting in some enrichment of the black sand content.

The minerals found in a placer deposit depend upon the type of rock from which the deposit was derived. The black sand content is generally a mixture of various minerals but may consist almost entirely of one or two minerals. One would not likely find all of the minerals that will be described later in any one single deposit, however.

Placer mining is the most ancient form of mining and has been conducted from the time of earliest recorded history to the present. Most of the placer mining done in the past has been for the recovery of gold, although dredging operations for other minerals such as cassiterite have been conducted in various parts of the world for a number of years. More recently, the growing demand for minerals such as rutile, ilmenite, zircon, monazite, columbite, tantalite and the various "radioactive blacks" has made possible their economic recovery from many placer deposits. At one time or another all of these minerals were considered nuisances by the placer miner because they clogged the riffles of his sluice box or otherwise complicated the recovery of his gold values.

**BLACK SAND MINERALS**

It would be impossible in a report of this length to list and describe all of the minerals that may be found in a deposit containing black sand. Such a list would include virtually all of the heavier minerals that are resistant to weathering. Table I lists only the minerals that are the common constituents of most black sands plus a few additional ones that are never present in large amounts but are found in many of the black sands of Idaho.

**MAGNETITE** (magnetic iron oxide) is probably the most common of the black sand minerals, some being found in almost every placer deposit. It is quite soluble in an acid environment, however, and in some placer deposits may be almost completely removed by extended leaching in slightly acidic ground water; such a condition is suspected whenever little or no magnetite is found. The end result of such leaching is actually a natural enrichment of the more valuable minerals in the sand because magnetite, although a valuable mineral when found in large bodies, is seldom of economic significance in black sand.

The most common crystal form exhibited by magnetite is the octahedron, but in a sand the grains are commonly rounded and few crystal faces are recognizable. Magnetite is very strongly magnetic and can be completely removed from a black sand mixture with an ordinary horseshoe magnet. This test is generally sufficient for its identification.
<table>
<thead>
<tr>
<th>Mineral</th>
<th>Chemical Composition</th>
<th>Specific Gravity</th>
<th>Hardness</th>
<th>Luster</th>
<th>Color</th>
<th>Color of Streak</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetite</td>
<td>Fe$_3$O$_4$</td>
<td>5.2</td>
<td>5.5 to 6.5</td>
<td>Metallic</td>
<td>Iron black</td>
<td>Black</td>
<td>Strongly magnetic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>to rather dull</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hematite</td>
<td>Fe$_2$O$_3$</td>
<td>4.9 to 5.3</td>
<td>5.5 to 6.5</td>
<td>Metallic</td>
<td>Generally iron black</td>
<td>Red</td>
<td>Nonmagnetic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>to rather dull</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ilmenite</td>
<td>FeO·TiO$_2$</td>
<td>4.5 to 5.0</td>
<td>5 to 6</td>
<td>Submetallic</td>
<td>Iron-black</td>
<td>Black to brownish red</td>
<td>Weakly magnetic</td>
</tr>
<tr>
<td>Rutile</td>
<td>TiO$_2$</td>
<td>4.2</td>
<td>6.0 to 6.5</td>
<td>Adamantine</td>
<td>Varies - usually dark reddish-brown</td>
<td>Pale brown</td>
<td></td>
</tr>
<tr>
<td>Monazite</td>
<td>Rare earth phosphate with thorium</td>
<td>4.9 to 5.3</td>
<td>5.0 to 5.5</td>
<td>Resinous</td>
<td>Honey yellow to clove brown</td>
<td>Uncolored</td>
<td>Radioactive due to thorium</td>
</tr>
<tr>
<td>Zircon</td>
<td>ZrSiO$_4$</td>
<td>4.7</td>
<td>7.5</td>
<td>Vitreous to adamantine</td>
<td>Colorless to pale yellow</td>
<td>Uncolored</td>
<td>Fluoresces a brilliant orange under ultraviolet light</td>
</tr>
<tr>
<td>Garnet</td>
<td>Variable silicate</td>
<td>3.1 to 4.3</td>
<td>6.5 to 7.5</td>
<td>Vitreous to resinous</td>
<td>Varies - usually red to reddish brown</td>
<td>Uncolored</td>
<td>Usually found in rounded equi-dimensional grains</td>
</tr>
<tr>
<td>Gold</td>
<td>Usually alloyed with silver</td>
<td>15.6 to 19.3</td>
<td>2.5 to 3.0</td>
<td>Metallic</td>
<td>Gold yellow</td>
<td>Gold yellow</td>
<td>Nuggets to thin leaves. Very ductile and malleable.</td>
</tr>
<tr>
<td>Platinum</td>
<td>Usually alloyed with other platinum group metals</td>
<td>14.0 to 19.0</td>
<td>4.0 to 4.5</td>
<td>Metallic</td>
<td>Whitish steel-gray</td>
<td>Whitish steel-gray</td>
<td></td>
</tr>
<tr>
<td>Columbite</td>
<td>(Fe,Mn)(Cr,Fe)$_2$O$_6$</td>
<td>5.3 to 7.3</td>
<td>6</td>
<td>Sub-metallic</td>
<td>Iron-black to brownish black</td>
<td>Dark red to black</td>
<td></td>
</tr>
<tr>
<td>Tantalite</td>
<td></td>
<td></td>
<td></td>
<td>to Sub-resinous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral</td>
<td>Chemical Composition</td>
<td>Specific Gravity</td>
<td>Hardness</td>
<td>Luster</td>
<td>Color</td>
<td>Color of Streak</td>
<td>Remarks</td>
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<td>------------------------------------------------</td>
</tr>
<tr>
<td>Lukenite</td>
<td>Rare earth columbite &amp; titanate with uranium</td>
<td>4.7 to 6.0</td>
<td>5.5</td>
<td>Vitreous when fresh</td>
<td>Black to brownish black</td>
<td>Dark to reddish brown</td>
<td>Uranium content may vary but euxenite is usually quite radioactive</td>
</tr>
<tr>
<td>Samarskite</td>
<td>Complex columbium tantalum oxide with uranium</td>
<td>5.6 to 5.8</td>
<td>5.0</td>
<td>Vitreous to resinous</td>
<td>Black to brownish black</td>
<td>Dark to reddish brown</td>
<td>Radioactive like euxenite</td>
</tr>
<tr>
<td>Brannerite</td>
<td>Uranium-titanium oxide</td>
<td>4.5 to 5.4</td>
<td>4.5</td>
<td>Brilliant when fresh</td>
<td>Black</td>
<td>Dark greenish brown</td>
<td></td>
</tr>
<tr>
<td>Wolframite</td>
<td>(Fe,Mn)WO₄</td>
<td>7.0 to 7.5</td>
<td>5.0</td>
<td>Submetallic</td>
<td>Brownish black</td>
<td>Nearly black</td>
<td></td>
</tr>
<tr>
<td>Scheelite</td>
<td>Ca₂WO₄</td>
<td>5.9 to 6.1</td>
<td>4.5</td>
<td>Vitreous to adamantine</td>
<td>White to light brown</td>
<td>Uncolored</td>
<td>Fluoresces bluish to yellowish white</td>
</tr>
<tr>
<td>Chromite</td>
<td>FeO·Cr₂O₃</td>
<td>4.1 to 4.9</td>
<td>5.5</td>
<td>Metallic to submetallic</td>
<td>Iron-black</td>
<td>Brown</td>
<td>Gives green borax bead test for chromium</td>
</tr>
<tr>
<td>Cassiterite</td>
<td>SnO₂</td>
<td>6.8 to 7.1</td>
<td>6</td>
<td>Adamantine</td>
<td>Usually brown or black</td>
<td>Uncolored to light brown</td>
<td></td>
</tr>
<tr>
<td>Corundum</td>
<td>Al₂O₃</td>
<td>3.9 to 4.1</td>
<td>9</td>
<td>Adamantine to Vitreous</td>
<td>Varies</td>
<td>Uncolored</td>
<td>Characterized by extreme hardness and infusibility</td>
</tr>
<tr>
<td>Cinnabar</td>
<td>HgS</td>
<td>8.0 to 8.2</td>
<td>2.0</td>
<td>Adamantine to metallic and dull</td>
<td>Cochineal-red</td>
<td>Scarlet</td>
<td></td>
</tr>
</tbody>
</table>
HEMATITE (ferric iron oxide) is another iron-bearing mineral sometimes found in black sand but seldom in quantities comparable to magnetite. It generally has a black color similar to magnetite; the specular variety is an exception, having a micaeous structure, a gray color and a brilliant metallic luster. Specular hematite is mechanically brittle, however, and consequently it is not an important constituent in most black sands. All varieties of hematite are nonmagnetic to a horseshoe magnet and they all have a distinctive cherry-red streak when scratched on unglazed porcelain or when the mineral is pulverized. Hematite can be distinguished from magnetite by these properties.

Although a black sand may consist almost entirely of magnetite and hematite, it would have no present value as an iron ore. There is probably no placer deposit in Idaho that could ever supply iron in sufficient quantity to support a steel industry but if such a market were established near at hand, the black sands could contribute significantly to it. At present an occasional limited market is found for these minerals for some specialized uses. One possibility of using these iron oxides that has presented itself quite recently is in heavy aggregate for concrete required for shielding nuclear reactors.

ILMENITE (iron and titanium oxide) is a very common constituent of black sand, particularly in Idaho. Its general appearance is also similar to magnetite. It has a black to dark brown streak which is not particularly distinctive, making it more difficult to positively identify ilmenite in the field than either magnetite or hematite. Ilmenite is weakly magnetic, but this property varies considerably, depending largely on the iron-titanium ratio. It is readily attracted to a strong electromagnet but in most cases only weakly attracted to a permanent magnet—except perhaps the Alnico type. A laboratory test for titanium is the surest method of identifying ilmenite, but for Idaho sands it is reasonably safe to assume that any black mineral constituting a large fraction of a black sand, which by elimination has been found to be neither magnetite or hematite, is probably ilmenite.

RUTILE (titanium oxide) is found in some black sands but is of minor importance in Idaho.

Rutile and ilmenite are the principal ore minerals of titanium. To date, rutile has been the principal source material for the production of titanium metal, and ilmenite has been used mainly for the manufacture of paint pigment. Because of the relative abundance of ilmenite and the scarcity of rutile, however, considerable research has been directed toward developing some process whereby ilmenite can be utilized as a raw material for metal production and there is good reason to believe that before long some ilmenite will be consumed by the metal industry.

A small amount of ilmenite from Idaho has been sold under individual contract for processing into paint pigment and for miscellaneous non-titanium uses, but no firm market has been developed yet. Prospective producers must realize that the specifications with reference to titanium content that are established by the various buyers must be met. The minimum that is acceptable will vary somewhat but it is doubtful if any
sand containing less than 4.5 percent titanium dioxide is salable. Present (October, 1957) price quotations for ilmenite and rutile are:

Ilmenite: 59.5% TiO₂, f.o.b. Atlantic seaboard - $26.25 @ $30.00 per gross ton.

Rutile: minimum 94% TiO₂ - $125.00 @ $135.00 per short ton.

MONAZITE (rare earth phosphate containing varying amounts of thorium) has been recovered from Idaho black sands on a commercial basis, although at the time of this writing only as a byproduct. The characteristic properties by which monazite can generally be identified are its honey-yellow color and its radioactivity. The radioactivity is due principally to thorium although most samples of monazite contain traces of uranium.

The demand for monazite has fluctuated between wide limits, causing corresponding ups and downs in production. Although monazite is principally a rare earth compound, the value of the mineral has depended to a great extent upon its thorium content. Prior to the introduction of the electric light the principal market for monazite was as a source of the thoria required in the manufacture of mantles for incandescent gasoline lamps. This market still exists but obviously on a reduced scale. In recent years, much speculation has centered around the possibility of using thorium as a source of nuclear energy, but recent statements from the A. E. C. (Shaw, 1957) indicate that it will be some time yet before any firm market is developed for raw materials containing thorium. Considerable research is being conducted on the possible use of thorium in reactors, however, and the long range outlook is much more favorable.

The various rare earths that are contained in monazite are more readily available from other sources and consequently it does not seem likely that monazite will be able to compete in this field unless there is also a market for the thorium.

ZIRCON is a minor but persistent constituent in most of the black sands of Idaho. It is generally present as very small crystals that are commonly colorless, but may be tinted brownish yellow. Since zircon is quite hard, the external shape of the crystal is often retained even in transported sand. This shape is generally a four-sided prism which may have pyramidal ends. The crystals are small, however, and it is usually necessary to use a hand lens to determine their shape. The most characteristic property of zircon is its golden yellow to orange fluorescence under ultraviolet light.

Zircon is the ore mineral from which metallic zirconium is recovered. Because of the relative abundance of zircon from other sources, however, it has not yet been possible to find a market for the zircon which has been recovered from Idaho sands. Metallic zirconium is used widely in the design of nuclear reactors because of its low neutron absorption and its corrosion resistance—two properties that are particularly desirable for this type of application.

Garnet occurs in varying amounts in most of the placer deposits of Idaho, generally as rounded grains having a light red or pink color, but some varieties of garnet may be dark brown to almost black. Recognition of
the color is usually sufficient to identify garnet although there may be some doubt in the field identification of the darker-colored varieties. The latter are commonly more transparent on thin edges than the other dark-colored minerals in black sand and are much more fusible. This property can be checked if a blowpipe is available.

The principal use for garnet is in the manufacture of abrasives. Many of the garnet grains found in placer deposits are either too small or lack the sharp edges that are necessary for abrasive use; consequently only a minor amount of the garnet which has been produced from Idaho black sands has been marketed.

Metallic GOLD is, of course, a common constituent of black sand and in the early days of placer mining in Idaho it was the only economic mineral. Its appearance and behavior in the gold pan are well known to anyone who has ever done any prospecting.

It is very easy to overestimate the amount of gold in a pan; this is probably the most common error made by the beginning prospector. The gold in the Snake River of Idaho is present in extremely small particles and is often referred to as "flour gold." It is difficult to recover, at least by gravity concentration, and it takes a great many "colors" to equal a dollar. For example, in a sampling made by Hite (1933) it was estimated that 5,250 particles of Snake River gold would be equal to one cent, assuming a fineness of 943 for the natural gold and a price of 35 dollars per ounce for pure gold.

MICA and PYRITE are two valueless minerals that are sometimes mistaken for gold by persons not familiar with their respective behaviors. Mica breaks into thin leaves that tend to glisten under water, giving the illusion of a metallic luster. The specific gravity of mica is much lower than that of most of the black sand minerals and therefore most of the mica in a sample can usually be removed by washing or classification. When the flakes lie flat on the bottom of a gold pan, however, they are difficult to eliminate and they tend to "tall out" in the same manner as gold.

Pyrite (fool's gold) is mistaken for gold because of its yellow color. It can be readily distinguished from gold, however, because it is brittle and can be pulverized to a greenish black powder. In contrast, gold is the most malleable of all metals and it can be flattened into extremely thin sheets but not pulverized with a hammer.

PLATINUM is another native metal that is found in some placer deposits, although little or none has ever been recovered in Idaho. Several reported identifications are of doubtful accuracy, but any malleable, silvery white metal found in a placer concentrate should be investigated.

The several minerals containing columbium (niobium) and tantalum can be discussed to best advantage as a group. All of these minerals have complex chemical composition and virtually all of them contain minor amounts of various other elements. Those that contain uranium are commonly referred to as "radioactive blacks." Members of this group of minerals have been identified in the black sands from various placer deposits in Idaho. They are
present in minor quantities, but from an economic standpoint they are at the time of this writing the most important constituents in Idaho's black sands.

The minerals in this group are similar to one another in their general appearance and all of them are refractory to ordinary methods of field testing. For these reasons it is virtually impossible to identify the individual species in the field, although after continued experience with the minerals of a particular district one can sometimes learn to distinguish them by visual inspection.

COLUMBITE and TANTALITE are oxide compounds of columbium and tantalum with manganese and iron. The ratio of columbium to tantalum may vary from the nearly pure columbite to the nearly pure tantalite. Any ratio between the two extremes may exist; most varieties of the mineral contain both elements.

Prior to World War II these minerals had little value other than for specimen material, but within the last few years they have become of great economic importance. Although columbium and tantalum are both refractory metals and have similar properties the greater present demand seems to be for columbium. Its principal use is as an alloying element in steel. When added to stainless steel it prevents the embrittlement that otherwise occurs when these steels are subjected to service at elevated temperatures. Columbium is also an important component in many of the alloys that have been developed within the last few years to withstand extremely high temperatures such as those developed in jet engines. Metallic tantalum is used principally in applications requiring high corrosion resistance and for the manufacture of rectifiers and capacitors. Its use for capacitors is becoming increasingly important. Another application is in the repair of human bones when the metal support must be left in the body permanently.

ILMENORUTILE is principally an iron and titanium oxide that contains columbium and tantalum. The percentage of the latter two elements may vary quite widely. Ilmenorutile containing a relatively high percentage of columbium and tantalum is a marketable product but ilmenorutile that contains only traces of them is not. If the mineral containing only minor amounts is a major constituent of a black sand concentrate, the loss in columbium-tantalum values when this product is discarded may be serious (Shelton and Stickney, 1955).

BUXENITE, SAPARSKITE and FERGUSONITE contain varying amounts of uranium, rare earths, and other elements, in addition to columbium and tantalum. They are "radioactive black" minerals. A determination of the crystallographic properties and/or chemical analyses are required to distinguish between them but except for academic reasons the distinction is not too important. The minerals are of economic value for their uranium content as well as for columbium.

BRANNERITE is another "radioactive black" but the pure mineral does not contain columbium. It is a uranium and titanium oxide. Brannerite was first identified in some of the placer gravels from the Stanley Basin but has since been found in other deposits in the state. As yet it has not been recovered in economic quantities except perhaps for very minor amounts.
as a byproduct, but it may be considered a possible source of uranium from black sand.

There are many other heavy minerals that may be found in black sand concentrates. The tungsten minerals, both Scheelite and Wolframine, are examples. Both are sometimes identified in sands from Idaho, but rarely if ever is it possible to make an economic recovery. Scheelite in particular is quite brittle and fairly soft and consequently is usually disintegrated before it is transported very far. Chromite is an important constituent of many placer deposits, notably some of the beach sands, but no significant amount of it has ever been identified in any Idaho deposit. Cassiterite and Corundum have both been reported as minor constituents of Idaho placers, but seldom if ever in more than trace amounts. Because of its very high specific gravity, Cinnaabar is another mineral found in some placers, although it is very soft and quickly abraded if transported very far.

Many of the lighter minerals such as apatite, sphene, quartz, tourmaline and hornblende are not completely eliminated by the processes of gravity concentration and are therefore found as constituents of black sand concentrates.

**SAMPLING AND EVALUATION OF PLACERS**

Accurate sampling of a placer deposit to determine the values that it contains is one of the more difficult problems encountered by the operator. In the early days of placer mining, when gold was the only mineral recovered, the small operator seldom bothered to carry out any systematic sampling program. He was not in a position to do so and except for the satisfaction that he might have derived from knowing what lay ahead in the way of values, he had no reason to engage in a sampling program. He could more or less combine his mining and prospecting, following out the pay streaks as he went along; when they ran out he could move his operation to another location.

When a large scale operation, either for gold or other minerals, is planned, however, it is imperative that careful sampling precede the mining. To recover black sands on a commercial basis requires a large scale operation with correspondingly high capital investment and it is therefore necessary to know the yardage available and the average black sand content of the gravel before moving in to mine it.

There are many conditions that will define the value of a placer deposit being investigated for its black sand content. Janin (1918) lists several in discussing gold dredging and they are equally important for black sand placers. If any one of these conditions is extremely unfavorable, it can make exploitation of the deposit uneconomic and even the energy expended in preliminary sampling would be wasted. Some of these factors are:

1) Depth, character and quantity of ground to be worked.
2) Character and contour of the bedrock.
3) Surface contour and timber growth.
4) Water level and available supply.
5) Cost and availability of fuel and/or power.
6) Availability and cost of labor.

7) Transportation of supplies in and concentrates out. (Transporting concentrates was no problem to the gold miner. It is an important consideration for black sands).

8) Costs of lands, royalties, titles, etc.

9) Cost of complying with the restrictions imposed by dredging laws, e.g., levelling tailings, replacing and reseeding topsoil, water clarification, etc.

10) Climatic conditions

11) Feasibility of metallurgical treatment to separate the various minerals obtained in the black sand concentrate.

A complete discussion of sampling methods applicable to placer deposits is far beyond the scope of this report but a few general observations may be helpful. The first thing that should be emphasized is that it is virtually impossible to conduct a complete sampling campaign by hand methods using equipment such as gold pans, shovels, hand augers, etc., that may be owned by the average prospector. These tools may be utilized for preliminary qualitative testing of a deposit but that is about the limit of their usefulness. Hand augers cannot be used for sampling with any degree of success if there are any boulders in the gravel, and almost without exception the more valuable placer deposits do contain such material. Creek banks, steep sided gulches, old excavations, etc., where vertical cuts may be made are good places to sample in preliminary work. Seldom is it possible to obtain a good sample from a surface exposure.

Gravel in place weighs from 2600 to 3600 lbs. per cu. yd. depending upon the degree of compaction and cementation and also the type of rock debris. Gabbro and diorite boulders are heavier than quartz. For estimating tonnages, however, an average of 3000 to 3300 lbs. per cu. yd. may be assumed for gravel in place.

Another rough measurement that is helpful to the prospector is the size of the standard gold pan. Gold pans are made in various sizes but the one that is probably in most common use measures 15 1/4 inches in diameter across the top and is 2 3/8 inches deep. The volume of this pan is 321 cubic inches (Peake, 1941). Allowing for 20 percent expansion of the gravel, one pan is equivalent to 267 cubic inches of gravel in place or 176 pans equal one cubic yard. If the pan is heaped 1 1/2 inches in the center there will be about 133 pans to the yard. Since a small error in estimating the volume per pan is multiplied many times in computing a yard of material, this method of measuring yardage for calculating values is obviously subject to serious error. In experienced hands, however, the gold pan is useful in making preliminary estimates.

The techniques of sampling placer deposits have been fairly well established by the gold miners (Gardner and Johanson, 1934, Janin 1918) and fortunately these procedures can, with some modification, be adapted to sampling black sand. The two most common sampling methods are: (1) shaft
sinking and (2) churn drilling. The relative merits of the two methods are somewhat controversial but drilling techniques have been improved to the point where that is by far the most popular method. The Keystone or similar cable type drill is the almost universally accepted type of equipment used.

Shaft sinking is much slower and more costly than drilling and these two factors are usually the determining ones. On the other hand a shaft affords an opportunity to obtain data on the physical characteristics of the gravel which are not obtainable from a drill hole and also produces a larger and consequently more accurate sample. A shaft may be sunk with a minimum of equipment and less capital outlay than required for a drilling rig if the persons doing the job are willing to perform the laborious work involved. In modern prospecting, however, shaft samples are usually taken only after preliminary drilling has been done and are used as a check on drill holes of doubtful accuracy or marginal value.

There is no substitute for experience in operating a sampling drill. The experienced driller is well aware of the pitfalls such as the difficulty of recovering values in coarse gravel and of measuring volumes in wet and soft ground. He is careful to keep the drill shoe driven ahead of the bit except in instances where this is impossible and to recognize and make allowances for any unusual situations that may develop. Drill sampling has become a rather specialized operation and even many of the larger companies find it advantageous to contrast the work to a firm specializing in it. Certainly this should be the procedure to be followed by the individual who has neither the necessary capital to obtain a drill nor the experience required to successfully operate it.

In prospecting a placer deposit for black sand, the sample is obtained in essentially the same manner as for gold, but to properly evaluate the sample requires more elaborate treatment. The drill crew still usually includes the panner but it is impossible for him to make the final determination of values in the field, particularly if more than one mineral is involved in the economic picture and these minerals have similar appearances. Panning can give valuable information in logging the hole but it is usually advisable to send the samples to a suitably equipped laboratory for final testing. These samples may consist of everything recovered from the hole or it may be more convenient to do some of the preliminary work, such as scalping out oversize in the field. These are things to be determined by the engineer in charge and his decisions are based on experience and the factors involved in each particular case.

**METALLURGICAL TREATMENT**

The recovery of black sands involves more detailed mineral dressing procedures than the recovery of placer gold. Due mainly to the simplicity of operation, riffles of various types were probably the most common device used for trapping the gold values in dredging operations in the past. Rifflles retain only a small portion of the black sand and it is therefore necessary to replace them with some other gravity concentrating device when these minerals are to be saved.

Jiggs of the Pan-American type were introduced originally on dredges to supplement or replace riffles for recovering gold. They have proven to be
quite satisfactory for recovering black sand also, and have been the choice of virtually all of the operators in the field. They may be arranged on the boat in whatever manner is most convenient, but, if possible, provision should be made for a rougher and one cleaning stage.

The jig concentrate is a mixture of several heavy minerals and is not a marketable product. Developing the flowsheet by which these minerals may be separated into products meeting market specifications will, in most instances, require a considerable amount of testing work. Dry separation by electrostatic and electromagnetic methods has been the key to success in the commercial operations that have been developed to date. To complete the separation may require various supplementary operations such as wet or air tabling. Obviously there is not enough room on a dredge to install this equipment. The capital investment and the cost of operating a separate sand plant may be considerable.

Metallurgical treatment of the sand is an integral part of the operation and an understanding of the factors involved here is just as important to the success of the endeavor as the prospecting and mining phases.

OUTLOOK

Any discussion at this time of the economic future of black sands in placer deposits is largely speculation. To date their commercial exploitation has been based upon some strong demand for one particular mineral. Any mining venture that is recovering several minerals but which has a market for only one of them is obviously operating at a disadvantage. The entire cost of the operation must be borne by that one mineral and generally storage facilities must be provided for the other minerals being recovered in the hope that markets may be found for them at some later date. More important, should the market for the economic mineral suddenly disappear, the company has no choice but to close down the operation.

Currently the dredging operations in Idaho that are recovering black sands are being conducted solely for columbium and tantalum. The uranium, rare earths, and other elements contained in the several columbium-tantalum-bearing minerals are being recovered, but only because they must be removed in the chemical purification steps. No market exists for the other minerals that are being collected on the dredges as black sand concentrate, except possibly for an occasional carload sold for some specialized use.

The United States consumes about 85 percent of the columbium and tantalum produced in the world (U.S.B.M. Bull. 556, 1956) and prior to the last two years virtually all of it has been imported. Due principally to their accelerated consumption during wartime the available supply of columbium and tantalum has been too small to meet the demand during much of the time since 1940. Both metals were under strict government control during both World War II and the Korean War. There was a period in 1943 when the supply was so short that concentrates were being imported by air.

The first commercial production of columbium and tantalum from Idaho placers was in 1955 and now the state is contributing well over 90 percent of our domestic production. Imports are still substantial but the strategic value of Idaho’s columbium and tantalum production is certainly one of
national importance. Government contracts currently in effect call for the purchase of 1,050,000 lb. of 90 percent pentoxides (Baber, Fulkerson and Peterson, 1957). It is impossible to predict what may happen when this contract is completed but it is hoped that a situation similar to the one which closed the monazite dredges in 1955 will not be repeated.

The industry would be on a much firmer foundation and operations could be expected to be on a more continuous basis if markets could be developed for several of the minerals. Temporary weakness in one market would not necessarily close down the operation if buyers were still available for some of the other minerals.

There are many factors that will have a bearing on the development of markets for the minerals that currently have no value. The principal uses for each of the minerals found in black sands have been mentioned in the discussion of each mineral and of course, these will have a bearing on any analysis of the economic picture. Research may develop new uses. It would seem, however, that the full utilization of the minerals composing the bulk of the black sands is contingent upon the development of industries that consume these minerals in this area. They are mainly low price commodities that cannot stand the high cost of transportation to consuming centers in the east or midwest.

The total tonnage of black sand minerals available in Idaho placer deposits is not known but certainly it is considerable. Some of the deposits have been prospected quite thoroughly while others have received very little attention. Dredging appears to be the only practicable method by which these sands can be recovered and consequently only those deposits that can be mined by this method should be considered to have economic potential at least at this time. It is the author's opinion, however, that developing markets will be a greater problem than finding reserves for some time yet.
BIBLIOGRAPHY

The reference list that follows is provided for those who desire additional information on the subject of black sands. Only the more pertinent references, and particularly those that have been issued recently, are included. Some of the publications that are listed carry excellent bibliographies.


Hammond, P. R., 1946, Technology and uses of monazite sand: Mining Technology, V. 10, No. 4, July 1946.

Hite, T. H., 1933, Special features of fine gold from Snake River, Idaho: Econ. Geology, V. XXVIII No. 7.


The following reports pertain to the work done by the U. S. Bureau of Mines for the A. E. C. on monazite and other radioactive placers in Idaho. They are available from the office of Technical Services, Department of Commerce, Washington 25, D. C. at nominal cost.


