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Uranium and Thorium-Bearing Minerals in Placer Deposits in Idaho

by

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U. S. GEOLOGICAL SURVEY

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IDAHO BUREAU OF MINES AND GEOLOGY

Moscow, Idaho

FOREWORD

The paper here presented as Mineral Resources Report No. 7 of the Idaho Bureau of Mines and Geology is of great interest and importance to Idaho, for it deals with the economic geology of one of our big and relatively undeveloped mineral resources, the uranium- and thorium-bearing placer deposits of central Idaho.

The variety of useful minerals contained in these placer deposits presents a technological challenge to the mineral industry. Minerals bearing uranium, thorium, titanium, columbium, tantalum, and the rare earth metals are concentrated in the central Idaho placers. Their economic recovery depends upon the cooperative efforts of geologists, mining engineers and metallurgists.

This present paper is of fundamental importance to an understanding of the geologic processes which have resulted in the concentration of uranium- and thorium-bearing minerals in certain placer deposits. It first appeared in 1956 as pages 375-380 of U. S. Geological Survey Professional Paper 300 which is entitled Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955. Available at $6.00 from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., this volume is the most comprehensive and up-to-date source book on the geology of uranium and thorium. On the other hand, it is as large and unwieldy as its title; for this reason, the Mackin-Schmidt paper has been taken from it and reprinted as a service to the people of Idaho.

E. F. Cook
Director
Idaho Bureau of Mines and Geology

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URANIUM- AND THORIUM-BEARING MINERALS IN PLACER DEPOSITS IN IDAHO

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ABSTRACT

Uranium- and thorium-bearing placer deposits sufficiently large to be worked by dredges have been studied in the northern Rocky Mountains. In the Bear Valley area, Valley County, Idaho, the higher grade parts of the placer deposits commonly contain the following quantities of heavy minerals in pounds per cubic yard: euxenite 1.0; monazite 0.5; columbite 0.2; zircon 0.05; garnet 10; ilmenite 20; magnetite 5.0. In the Hailey area, Blaine County, Idaho, the higher grade parts of the placer deposits commonly contain the following minerals in pounds per cubic yard; uranothorite 0.5; zircon 0.5; sphene 1.0; garnet 0.1; magnetite 10. The principal uranium-bearing minerals, euxenite and uranothorite, seem to be mutually exclusive in these two areas. In the Cascade-Long Valley area, Valley County, Idaho, no more than traces of euxenite and uranothorite are found in the placer deposits being worked for monazite.

The radioactive placer minerals were derived from quartz monzonite phases of the Idaho batholith. The euxenite of the Bear Valley area, the uranothorite of the Hailey area, and the monazite of the Cascade area, occur as accessory minerals in the quartz monzonite. Segregations of these accessory minerals a few inches to a few tens of feet in diameter, containing as much as 0.05 pound of euxenite per ton in the Bear Valley area, 0.8 pound uranothorite per ton in the Hailey area, and 0.25 pound monazite per ton in the Cascade area, occur in parts of the quartz monzonite which are megascopically indistinguishable from surrounding rock having much lower content of radioactive minerals. The distribution of these segregations is erratic; there is no tendency for similar high concentration of the minerals to be in or near pegmatite dikes.

The grade of the placer deposits depends largely on the number and size of these segregations of the radioactive minerals in the quartz monzonite and on the physiographic history of the drainage basin.

INTRODUCTION

Placer deposits containing radioactive minerals were investigated in several parts of the Rocky Mountains of central Idaho by the United States Geological Survey during the summers of 1952-54 (Mackin and Schmidt, 1953; Reed, 1937). The principal radioactive placer minerals are monazite, euxenite, and thorite; valuable associated minerals are columbite and xenotime. This study was undertaken primarily to determine the origin of deposits drilled concurrently by the United States Bureau of Mines. Earlier reports on gold placers in central Idaho are cited by Reed (1937) and Capps (1940).

GENERAL GEOLOGY

The placer deposits lie within and around the borders of the Idaho batholith, a complex of granitic rock units ranging from diorite to granite and mostly Cretaceous in age (Ross, 1936; Anderson, 1952). The batholith and its wall rocks are overlain unconformably by several groups of volcanic rocks: early Tertiary Challis volcanic rocks in the eastern part (Ross, 1938), mid-Tertiary Columbia River basalt on the west and southwest (Kirkham and Johnson, 1929) and Snake River basalt of Pliocene to Recent age on the south (Stearns, Crandall and Stewart, 1938).

Three major topographic elements form the physiographic setting of the deposits. The first is a rolling upland surface, with a local relief of 2,000 feet (600 m), preserved in divide areas between broad open valleys that stand 5,000 to 6,000 feet (1,500 to 1,800 m) above sea level. This late mature surface is sharply trenched by young canyons of the major streams; the formation of canyons was begun by regional uplift in late Tertiary time (Fenneman, 1931, p. 185-196). The third element is the north-trending range, with crest lines from 8,000 to 10,000 feet (2,400 to 3,000 m), commonly asymmetric in cross section, and associated on one or both sides with deeply alluviated basins. There is reason to believe that ranges of this type were formed by block-fault movements that occurred from time to time during the Tertiary and continued into the Pleistocene. These three topographic elements may be sharply distinct or they may blend from place to place, depending on the extent of canyon headward erosion and the recency of block faulting.

Detail of relief in the higher parts of the region is due largely to the effects of alpine glaciation. Areas above 9,000 feet (2,800 m) are generally characterized by matterhorn topography. In the 7,000 to 9,000 (2,200 to 2,800 m) altitude zone, individual and coalescing cirques are cut in the flanks of rounded summits. Lower parts of the late mature upland were not glaciated during the late Pleistocene.

Moraines and outwash deposits on floors of some of the upland valleys indicate two late Pleistocene glacial stages. The younger of the two is represented by hummocky, boulder-strewn morainal ridges, clearly late Wisconsin. The deposits of the older stage are characterized by subdued morainal forms, and a degree of weathering suggesting an early Wisconsin age. A few widely scattered deposits of deeply decomposed till indicates a

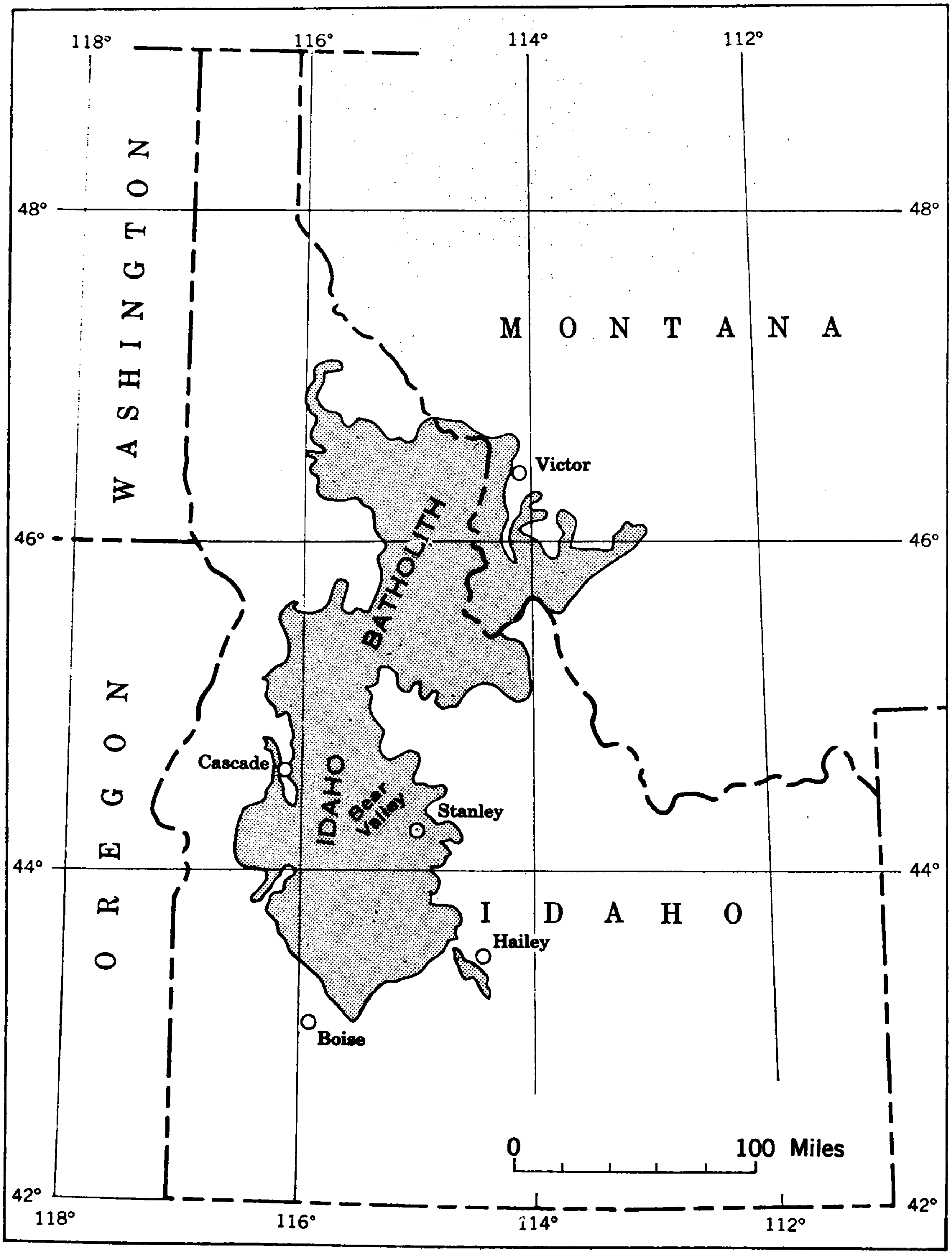

FIGURE 1.—Index map of Idaho.

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much greater extent of alpine glaciers during early Pleistocene time, but subsequent erosional modification of the region has been so complete that the effect of early Pleistocene glaciers on the geology of the placer deposits is negligible. For this reason, areas beyond the limits of early Wisconsin glaciers will be referred to as nonglaciated.

An essential requirement of a commercial placer deposit of the Idaho suites of radioactive minerals is a depth and extent of material capable of supporting a large-scale dredging operation over a period of years. Detailed investigations were therefore limited to thick alluvial fills, each of which is due to some local reversal of the normal process of stream downcutting. The principal causes of accumulation of the valley fills, and examples of each, are: (1) block faulting during Pleistocene time (monazite placers in the Cascade area); (2) late Pleistocene glacial derangement of drainage (euxenite-monazite placers of Big Meadow in the Bear Valley area); and (3) blocking of drainage lines by Pleistocene basalt flows (thorite placers in the Hailey area). (See fig. 1) A contributing cause of valley fill was an increase in the loads of streams due to accelerated downslope movement of the weathered mantle under periglacial conditions during Pleistocene glacial stages.

RADIOACTIVE MINERALS IN BEDROCK

Monazite is the most widespread radioactive mineral in the granitic rock of the Idaho batholith. Reconnaissance pan sampling of minor streams and of weathered granitic rock over most of the southern part of the batholith indicates that monazite is more often present than not, and that its gross distribution is not uniform. The distribution of the monazite placer deposits drilled by the U. S. Bureau of Mines at Cascade near the western border of the batholith, at Bear Valley in the interior, and at Victor and Stanley near the east border indicates the scatter of the richer bedrock source areas. (See fig. 1.)

In the drainage basins from which the monazite of the Cascade placers was derived the mineral occurs as an accessory in a porphyritic granitic rock in the quartz diorite to quartz monzonite compositional range. The distribution is exceedingly erratic in detail, ranging from almost zero to as much as 0.3 pound per cubic yard (0.18 kg per cu m, or 0.01 percent) within a few tens of feet in apparently uniform granitic rock. There is no evident spatial relation between the distribution of the monazite and pegmatite or aplite dikes or quartz veins. The common associated heavy accessories are magnetite, ilmenite, garnet, apatite, and zircon; there is no consistent relation in the abundance of any of these minerals with the abundance of monazite.

The gross yield of a given drainage basin, as indicated by stream panning, appears to be a function of the number and richness of the local segregations of monazite in the granitic rock--the term "segregation" being used with a descriptive rather than a genetic meaning. The gravel of small streams heading in rich source areas may contain as much as 10 pounds of monazite per cubic yard (6 kg per cu m). By the same gross standard of tenor of stream deposits, the belt of migmatitic gneiss into which the granitic rock grades along the western border of the batholith is very nearly barren of monazite. However, local quartz-feldspar pods in the gneiss contain as much as 0.5 pound per cubic yard (0.3 kg per cu m, or 0.02 percent). Massive monazite replacements in phosphatic marble in the migmatite zone along the eastern border of the batholith, described by Abbott (1954, p. 21-22), have not been seen in the area covered by this study.

Euxenite occurs in trace amounts in several localities widely scattered over the batholith. The only commercial placers now known in Bear Valley are supplied from a 6-square-mile (15 km) area of quartz diorite. The euxenite occurs as an accessory mineral in the granitic rock and in associated pegmatite dikes. The distribution in the granitic rock is spotty; pan samples of deeply weathered rock in a single exposure may range from a trace to 0.05 pound of euxenite per cubic yard (0.03 kg per cu m, or 0.002 percent), with the best ore sharply localized within an outcrop area of a few square feet. As with monazite, the yield of a given small drainage basin depends on the number and richness of the segregations. Associated heavy minerals commonly include monazite, magnetite, ilmenite, and zircon, and may include apatite, allanite, columbite, xenotime, and spinel. Well-washed gravel in favorably situated small streams may contain as much as 3 pounds of euxenite per cubic yard (2 kg. per cu m).

As far as is now known, thorite occurs in significant amounts only in an inlier of the Idaho batholith, an intrusive satellite in the vicinity of Hailey, Idaho. The thorite is an accessory mineral in quartz monzonite and has the same habit as the euxenite of Bear Valley; that is, it occurs in small segregations in rock not distinguishable megascopically from the surrounding rock. The segregations may contain as much as 1 pound of thorite per cubic yard (0.6 kg per cu m, or 0.04 percent), while the adjacent quartz monzonite averages 0.005 pound per cubic yard (0.003 kg per cu m, or 0.0002 percent). Common associated heavy accessories are magnetite, sphene, hornblende, and apatite. Less abundant accessories include ilmenite, garnet, zircon, allanite, anatase, and rutile. Gravel deposits of small streams draining the richest source area contain as much as 0.3 pound of thorite per cubic yard (0.2 kg per cu m).

The method of origin of the radioactive minerals is an open question. The field relations and relations observed in thin sections favor the view that they were formed at the same time as the enclosing rock rather than by later hydrothermal solutions. Monazite is associated with euxenite in the Bear Valley area, but the monazite-rich rock of the Cascade, Victor, and Stanley areas contains only trace amounts of euxenite or none at all. Euxenite and thorite have the same habits of occurrence as accessories in granitic rock, but there is no thorite in the euxenite-rich rock of the Bear Valley area, and no euxenite in the thorite-rich rock of the Hailey area. The thorite-rich rock of the Hailey area contains no monazite. Because of the favorable scatter of the areas studied in detail and the reconnaissance sampling done between the areas, any systematic distribution of the radioactive minerals within the batholith should be apparent. But the batholith is a composite mass, consisting in part of granitic rocks of metasomatic origin and in part of orthomagmatic intrusive rocks emplaced at different times. Much more extensive and detailed study of distribution of heavy-mineral suites in the batholith, particularly in relation to the boundaries between units of different rock type, origin, and age, is needed before any definite statement can be made of the origin and occurrence of the radioactive minerals.

EFFECT OF GLACIATION ON THE SUPPLY OF PLACER MINERALS

The effective concentration of heavy minerals in placer deposits requires: (1) disintegration of the source rock sufficient to free the heavy minerals; and (2) residual concentration of the heavy minerals by removal of the soluble and some of the light minerals by weathering and erosion in an accelerated movement of the thus enriched mantle to the streams (Jenkins, 1935). Primarily for these reasons, the distribution of late Pleistocene glaciers is thus a decisive factor in the localization and tenor of the Idaho placer deposits.

Gravel in the deposits of streams draining nonglacial areas commonly consists of vein quartz and various resistant dike-rock types; the granitic rock which makes up more than 99 percent of the drainage basin, is represented only by coarse sand. In the Bear Valley area, for example, alluvium deposited by minor streams entering Big Meadow from nonglaciated terrane during the early Wisconsin glacial stage averages 30 pounds of heavy-mineral concentrate per cubic yard (18 kg per cu m). This high concentration is believed to be due to the thorough weathering of the bedrock during middle Pleistocene time and a quickened downslope movement of the enriched mantle under periglacial climatic conditions during the early Wisconsin. Yet, outwash deposits formed by streams entering Big Meadow from early Wisconsin glaciers and the morainal deposits of these glaciers consist predominantly of subrounded fragments of granitic rock, and average only 20 pounds of heavy-mineral concentrate per cubic yard (12 kg per cu m); probably this concentration is lower than in the alluvium from the neighboring nonglacial area because some of the heavy minerals are still locked up in the granitic pebbles. Late Wisconsin moraines and outwash deposits from the same drainage basins average 10 pounds of heavy concentrates per cubic yard (6 kg per cu m). The difference between the amount of heavy-mineral concentrate in early and late Wisconsin deposits is probably due to the fact that a deep regolith, formed during a long period of pre-Wisconsin weathering, was available to the early Wisconsin glaciers, while erosion by the smaller late Wisconsin glaciers was confined within cirque basins that shortly before had been scoured in fresh bedrock by early Wisconsin ice.

Panning of large numbers of samples of deposits derived from nonglaciated drainage basins, early Wisconsin deposits, and late Wisconsin deposits, gives comparable average results in the other areas covered by this study. The ratio of the amount of total heavy-mineral concentrate in the three types of material is approximately 3 : 2 : 1.

EFFECT OF AGGRADATION ON THE TENOR OF THE PLACER DEPOSITS

Changes in stream velocity accompanying seasonal variations in discharge cause cycles of scouring and redeposition of the alluvial materials making up the channel floor, each time with a winnowing of the materials on the basis of particle size and, within any given size range, on the basis of specific gravity and shape (Mackin, 1948). Because the vigor of this process varies greatly from place to place in the channel, and because of sidewise shifting and changes in alinement of the channel, the deposit is an aggregate of lenses differing markedly in degree of sorting.

The lenses of gravel may contain as much as 100 times the amount of heavy-mineral concentrate as adjacent lenses of sand.

In streams that swing back and forth across valley floors for a long period of time with little change in grade, repeated reworkings of the valley-floor alluvial deposit tends to develop concentration of heavy minerals far higher than the average proportions of these minerals in the detritus annually delivered from the slopes of the drainage basin. In aggrading streams, on the other hand, this type of sorting is less effective because some part of the load handled each year is deposited in the accumulating fill where it is not subject to reworking. As the amount of material thus deposited in a given segment of the stream per year approaches the amount of material shed into that segment each year from the local valley sides or from the next up-valley segment, the winnowing action approaches zero. For this reason, other things being equal, the concentration of heavy minerals tends to be higher in deposits of graded streams than in deposits of aggrading streams, and in the latter, the concentration tends to be inversely proportionate to the rate of aggradation. In the Cascade area, for example, deposits of modern streams that are stable or slowly degrading are consistently higher in heavy-mineral concentrate than aggradational deposits in the same area formed during the Pleistocene time by similar streams.

DOWNVALLEY CHANGES IN COMPOSITION OF THE HEAVY-MINERAL SUITES

Changes in the total concentrate, and in the proportions of the different heavy minerals downstream from the source area are due principally to selective transportation,dilution, selective attrition, and selective weathering during periods when the detritus is temporarily at rest on the valley floor. Commonly two or more of these processes are in operation in the same stream at the same time. The following discussion is based on observations of stream segments in which it was possible, under favorable conditions, to arrive at an approximate evaluation of each of the different processes. In the selective sorting process outlined earlier the average rate of movement of the heavy minerals along the streambed, over a period of years, is slower than that of the light minerals in the same size range. But in a graded stream, in which the channel deposits mantling the valley floor are reworked over and over as the stream shifts laterally, this "running ahead" of the light minerals does not cause a change in the composition of the sand fraction of the bed load in a downstream direction. The heavy minerals move more slowly into a given segment of the valley, but they also move more slowly through and away from that segment, and the average composition of the sand fraction of the channel deposits is the same as though all the grains moved at the same rate.

In the aggrading stream, on the other hand, the heavy-mineral grains, which are last lifted and first deposited in the seasonally expanding and contracting channel, actually lag behind the light grains because the raising of the level of the stream bed means that the deposits are not subject to continuous reworking. There is, in other words, a "permanent withdrawal from circulation" of the slower moving part of the bed load, and a resulting decrease in the proportion of the heavy minerals in the sand fraction in a downvalley direction.

Monazite serves best to show this relationship because the other factors, such as attrition, which affect the survival of this mineral are negligible in any short travel distance. In the Bear Valley and Cascade areas, where drilling data permits a comparison, the content of monazite decreases by 50 percent in a distance of a mile in Pleistocene valley-fill deposits, while there is no significant change in the content of monazite in the same distance in modern valley-floor deposits formed by graded streams.

Reduction by dilution in the weight percent of a given placer mineral in the heavy-mineral concentrate may be due to the entry of side streams which erode rocks low in content of heavy minerals or to the sidewise cutting of the trunk stream in bedrock or in older deposits containing lesser amounts of that mineral. The quantitative effects of dilution by side streams are obvious and need no discussion. The effect of exchange between the bed load and the materials forming the banks is well shown on Bear Creek, where the reduction in the weight percent of monazite is about twice as rapid in a segment where the creek is cutting laterally in barren glacial outwash as where the stream is meandering in its own alluvial deposits. It is evident that any general evaluation of the dilution effects of exchange must be in terms of the rate of bank cutting.

Monazite is in all respects the most durable of the radioactive placer minerals of central Idaho.In the Cascade area, for example, this mineral can be traced in alluvial deposits from a well-defined source for a distance of 25 miles (40 km) through areas from which local contributions of monazite to the stream are negligible. Monazite grains in pan samples in headwater rills in the source area are euhedral crystals and angular fragments of crystals in the 0.2 to 1.0 mm size range. The grains are very slowly rounded in transit along the streams. The median grain size decreases only by an estimated 50 percent in 25 miles (40 km) of stream travel, and an unknown but perhaps considerable part of this decrease in size may be due to selective transportation rather than to attrition. Even at this distance from the source, some of the grain boundaries are crystal faces.

Euxenite panned from residual soil in the Bear Valley area is in the form of euhedral crystals and angular fragments of crystals with a very wide range in grain size, from 0.1 to 5.0 mm. The grains in the soil commonly carry a tan coating of gummitic material of the order of 0.01 mm in thickness; the fact that the completeness of coating decreases downward through the soil profile indicates that it is due to weathering. It is removed from the edges and flat surfaces of the grains within the first 1,000 feet (300 m) of travel along stream beds, remaining only in reentrant angles of irregular microfissures that characterize this mineral.

The average size of the larger euxenite grains decreases by 3 to 4 times, from 5.0 mm to 1.5 mm, within the first mile (1.6 km) of movement along the stream beds. Five miles (8 km) from the source area the average larger grain size is 0.8 mm, and a very few of the larger grains show crystal faces. In another 5 miles (8 km) the larger grains are reduced to about 0.5 mm. The next 15 miles (24 km) of travel causes little further reduction in size. The very rapid decrease in the size of the larger grains in the first 10 miles (16 km) of transportation (from 5 mm. to 0.5 mm) is due primarily to breakage under the impact of pebbles and boulders--the tendency of euxenite to shatter readily is probably due in part to microfissuring associated with the metamict state of the mineral. Because the finer particles produced by shattering move with the suspended load, the weight percent of euxenite in the placer deposits decreases much more rapidly in a downvalley direction than the weight percent of the less brittle heavy minerals, as monazite.

The minerals of the thorite group occur in the residual soil and placer deposits of the Hailey area as crystals and fragments of crystals, euhedral to subrounded, ranging from 0.1 to 1.5 mm in greater dimension. The minerals vary widely in physical properties; the several varieties, probably including uranothorite and orangite, cannot be identified by sight in the pan concentrates. Field estimates of tenor were therefore based largely on scintillation-counter readings. A sharp decrease in tenor downvalley from the source area is certainly due in part to attritional wear, but it is also due in part to dilution and other factors. The laboratory studies needed for an evaluation of the factors have not been completed.

Although there are variations from place to place, magnetite and ilmenite are present in approximately equal amounts in residual soils and headwater stream deposits in the granitic terranes, where these two minerals usually make up about 90 percent of the total heavy-mineral concentrate. But placer deposits formed by trunk streams draining the same areas may contain only a few percent of magnetite in a heavy-mineral concentrate consisting predominantly of ilmenite. Because magnetite is the least valuable of the heavy minerals, its drastic reduction in weight percent in the concentrate has the effect of a natural beneficiation, and is therefore a matter of considerable practical importance.

A first clue to the manner of destruction of the magnetite is provided by the fact that a stream entering a wet mountain meadow with a magnetite-ilmenite ratio of 1:1 may lose nearly all of its magnetite within a mile (1.6 km) of meandering on the meadow floor. Upstream from the meadow the magnetite is in the form of angular to subrounded crystals and grains with or without a film of hematite developed by oxidation in the normal weathering process. Samples of gravel taken from below the water table under the meadow-peat layer show no magnetite, or show only deeply pitted, skeletal grains with no hematite coatings--the associated sand and gravel are notably bleached. Numerous pH determinations of the meadow ground water range from 6.2 to 5.5 and average 6.0, in contrast with a fairly consistent 7.1 for the stream water. These relations indicate that the magnetite is dissolved by the semistagnant acid water under the peat that mantles the flood plain. The vigor of the process is suggested by the fact that, at places where the meadow water is aerated as it seeps out from fresh meander cuts in the bleached gravel, a thick layer of ochreous ooze accumulates within a period of a few months. It should be noted that the reduction in the amount of magnetite along the channel is not in any sense due to destruction of the mineral in the channel environment--it is due wholly to exchange, incident to lateral shifting of meanders in alluvium, in which the magnetite is destroyed by acid water.

Several lines of evidence, too involved for discussion here, indicate that in a wet-meadow peat environment, the weight percent of magnetite in the heavy-mineral suite in a gravel deposit may be reduced very nearly to zero in a few hundred years.

AVERAGE HEAVY-MINERAL COMPOSITION OF THE PLACER DEPOSITS

The heavy-mineral composition of the placer deposits is dependent on the mineral content of the source rock and on several physiographic factors bearing on concentration; namely, preliminary eluvial concentration by selective weathering, differences in the effectiveness of channel concentrations in graded and aggrading streams, selective transportation, dilution, selective attrition, and selective weathering during periods when the detritus is temporarily at rest on the valley floors. In the Bear Valley area, alluvial fills formed as a result of glacial derangement of drainage contain the following quantities of heavy minerals in pounds per cubic yard (kilograms per cubic meter); euxenite 1.0 (0.6); monazite 0.5 (0.3); columbite 0.2 (0.1); zircon 0.05 (0.03); garnet 5 (3); ilmenite 20 (12); magnetite 5.0 (3.0). In the same terms, the heavy-mineral content of deposits in valleys blocked by Pleistocene basalt flows in the Hailey areas is as follows: thorite 0.5 (0.3); zircon 0.5 (0.3); sphene 1.0 (0.6); garnet 0.1 (0.06); magnetite 10 (6.0). The Cascade deposits, which accumulated in a basin formed by block faulting during Pleistocene time, contain: monazite 1.5 (0.9); zircon 0.2 (0.1); garnet 5.0 (3.0); ilmenite 40 (24); magnetite 1.0 (0.6).

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