UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Radioactive Black Sand Placer Deposits of the Challis $1^{o}x2^{o}$ Quadrangle, Idaho

By

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Open-File Report 86-0633

1986

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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Introduction

This report is one of many products of a 5-year study of the Challis $1^\circ x2^\circ$ quadrangle (hereafter referred to as the Challis quadrangle) (fig. 1) central Idaho, conducted under the Conterminous United States Mineral Assessment Program (CUSMAP) of the U.S. Geological Survey. The report is, for the most part, a chapter from an extensive manuscript on the geology and mineral-resource potential of the Challis quadrangle, a manuscript under preparation for publication as a U.S. Geological Survey Professional Paper. The section on radioactive placer deposits is being placed on open-file in order to meet public request for a timely release of the information.

Published information on the Challis quadrangle study includes the geologic map of the quadrangle (Fisher and others, 1983), and U.S. Geological Survey Bulletin 1658 (McIntyre, 1985).

Geology

The vast Idaho batholith, of Cretaceous age, underlies most of the western part of the Challis quadrangle (Fisher and others, 1983), and is the principal source of the black sands that are concentrated in various alluvial deposits in or near the quadrangle. Principal rocks of the batholith beneath or near the alluviated valleys are biotite granodiorite and muscovite-biotite granodiorite (Kiilsgaard and Lewis, 1985). Plutonic and hypabyssal rocks of Tertiary age also contribute black sand minerals to the placer deposits (Bennett and Knowles, 1985), but these rocks are not as widely exposed and have not yielded as large a volume of black sand minerals as older rocks of the Idaho batholith.

Radioactive Placer Deposits

Extensive radioactive black sand placer deposits occur in many alluviated valleys of the Challis quadrangle. As used here, "black sand" is chiefly ilmenite and magnetite, but it also contains other heavy minerals, some of which are radioactive. Monazite and euxenite are the principal radioactive minerals in the deposits. Other radioactive minerals that have been identified include brannerite, xenotime, and samarskite (Shannon, 1926; Kline and Carlson, 1954; and Kline and others, 1955). At Bear Valley, heavy black minerals that appeared to be members of a series of uranium-bearing rare earth columbates and tantalates were not identified by Schmidt and Mackin (1970) but were referred to collectively as "radioactive blacks." The exact mineralogy of some of these heavy black minerals has never been determined. Other heavy minerals of economic interest include columbite-tantalite, garnet, and zircon. Some of the largest and richest deposits are in the western part of the quadrangle, along the eastern edge of Long Valley. The Long Valley deposits are along westerly-flowing streams that have eroded granitic rocks of the Idaho batholith and some deposits extend beyond the western boundary of the Challis quadrangle (pl. 1).

All of the placer deposits are of alluvial origin and most are of Pleistocene age. They represent the accumulation of valley-fill from transporting streams. The deposits formed where the transporting stream gradient decreased to a level at which the streams could not transport the alluvial load. The decrease in stream gradient resulted from blockage of the streams: commonly either by faulting, as in Long Valley (Mackin and Schmidt,

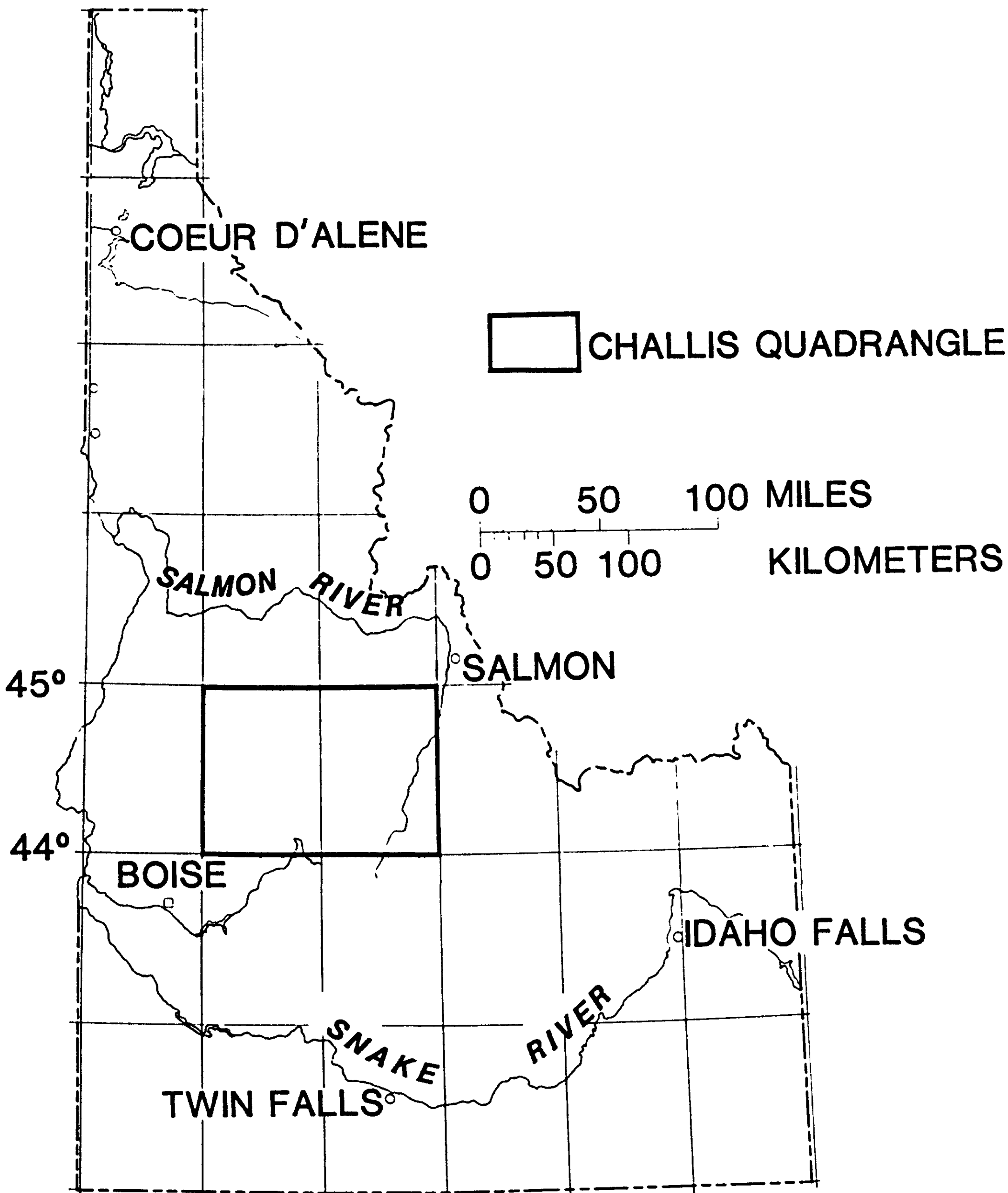

Figure 1.--Map of Idaho showing location of the Challis quadrangle.

1956); by Pleistocene glacial ice or moraine damming as in Bear Valley; by landslides; or by the damming action of basalt flows as in Boise Basin. Placers normally are thicker at the downstream end, where blockage originally occurred. Some placers extend to unknown depths. The deepest hole drilled at the Pearsol Creek deposit (pl. 1, table 1) went to 120 ft without meeting bedrock. A nearby water well, drilled west of the deposit, went more than 400 ft in alluvium without reaching bedrock (Kline and Carlson, 1954).

Gravel size in alluvium of radioactive placer deposits is small. Most of the heavy minerals are in lenses and beds of coarse sand and fine gravel, the larger pebbles of which are rarely more than 2 in. in diameter. Beds of fine sand and clay are common in the deposits and normally contain lesser amounts of heavy minerals than coarser sand and gravel. Presently degrading stream beds may contain larger boulders, transported by floods, but boulders are uncommon in deeper parts of the deposits. Larger boulders also are found at the mouths of aggrading tributary streams, whose outwash fans may cover parts of the older alluvial deposit in the main valley.

Radioactive minerals are found throughout most alluvial deposits. Degrading streams that have eroded upper parts of the deposits winnow the lighter minerals away leaving a concentration of the heavier radioactive minerals near the surface. Holes drilled in various deposits, however, show concentrations of radioactive minerals to greater depths. At the Pearsol Creek deposit in Long Valley, monazite values were found to a depth of 120 feet, the deepest hole drilled, although a more consistent content of monazite was found at depths ranging from 15 to 55 feet (Kline and Carlson, 1954). In the central part of Bear Valley, monazite was found in the two deepest holes, BV 20 and BV 21, both of which were drilled to a depth of 100 feet without reaching bedrock (Kline and others, 1953).

Radioactive minerals in the placer deposits originated in granitic rocks of the Idaho batholith. The minerals were disseminated throughout the batholith and were released from their original sites through the processes of weathering, rock decomposition, and erosion. As heavy resistant minerals, they tended to settle in decomposing surficial material, whereas the lighter minerals were more readily removed by erosion. This lag effect in erosional transport formed an enriched mantle on pre-Pleistocene surficial areas of batholithic rock that was available to accelerated periglacial erosion brought on by Pleistocene glaciation. The richest placer deposits are those of early Pleistocene age, formed by erosion and transport of the pre-Pleistocene surficial material. Late Pleistocene and recent deposits usually contain lesser quantities of heavy minerals, although some are enriched locally in heavy minerals through the winnowing action of the transporting stream.

The most common heavy mineral in the black sands of radioactive placer deposits is ilmenite ($FeTiO_3$). This is contrary to what might be expected, as magnetite ($FeFe_2O_4$) is more common in the granitic host rock. Magnetite in low-gradient placer deposits, however, is dissolved by acidic ground water (Schmidt and Mackin, 1970) and is largely removed. Ilmenite content in placers varies widely, ranging from 2 lbs ilmenite per cubic yard of gravel in Horsethief Basin to 16 lbs of ilmenite per cubic yard of gravel in the Pearsol Creek deposit (pl. 1, table 1). Ilmenite from 9 deposits in Long Valley averaged 46.1 percent TiO_2 (Storch and Holt, 1963). Other black-sand minerals in Idaho placer deposits are discussed by Savage (1961).

Table 1.--Radioactive placer deposits in the Challis quadrangle that have been explored by drilling

Deposit	Area sq yd	Average depth yd	Volume cu yd	Average mineral content lbs/cu yd: Ilmenite	Garnet	Zircon	Monazite	Monazite ThO_2 --percent--	Monazite U_3O_8 --percent--	Resources of ThO_2 in monazite, short tons
Deposits that contain 0.50 or more lb monazite per cu yd of alluvium										
Big Creek[1,9]	3,570,000	20	71,400,000	14	2.10	.70	1.50	4.2	.13	2,250
Pearsol Creek[2,9]	6,500,000	20	130,900,000	16	.40	.10	1.60	4.4	--	4,580
Corral Creek[3,9]	6,350,000	19	120,700,000	4	.10	.10	1.80	4.4	.10	4,780
Upper Clear Creek[4]	640,000	5	3,200,000	6	5.00	.20	1.20	4.1	--	80
Lower Clear Creek[4]	5,000,000	16	80,000,000	5	5.00	.10	.70	4.1	--	1,150
Hull's Big Creek[5]	1,100,000	4	4,400,000	2	.60	.30	3.40	4.1[6]	--	310
Scott Valley[7]	7,500,000	13	97,500,000	10	1.90	.70	.80	4.1	.17	1,600
Horsethief Basin[7]	3,000,000	13	39,000,000	2	.30	.30	1.30	4.7	.11	1,190
Little Valley of Gold Fork[4]	10,600,000	10	106,000,000	7	6.00	.50	.50	4.8	--	1,270
Bear Valley (Big Meadows)[8]	4,800,000	14	67,200,000	12	2.80	--	.75	4.6	.27	1,160
Central Bear Valley[9]	13,300,000	12	160,000,000	7	1.40	.06	.60	4.6	.27	2,210
White Hawk Basin[5]	800,000	4	3,200,000	3	5.00	--	.80	4.2[6]		50
Gold Creek-Williams Creek[9]	1,600,000	15	24,000,000	4	--	--	.90	4.2[6]	--	450
									Total:	21,080
Deposits that contain less than 0.50 lb monazite per cu yd of alluvium										
Paddy Flat[5]	2,400,000	16	38,400,000	12	3.0	--	.40	4.2[6]	.18	320
Lower Bear Valley[9,11]	16,400,000	10	164,000,000	4			.10	4.6	--	380
Pigtail Cr. (Meadows)[5]	2,200,000	17	37,400,000	.6	--	--	.10	4.2[6]	--	80
Deadwood Valley[9]	16,400,000	10	164,000,000	4	.4	.10	.10	4.2[6]	--	340
Peace Valley[9]	2,500,000	4	10,000,000	2	--	--	.30	4.2[6]	--	60
Garden Valley[9]	9,000,000	27	243,000,000	2	--	--	.20	4.2[6]	--	1,020
Stolle Meadows[9]	3,900,000	15	58,500,000	2	--	--	.20	4.2[6]	--	250
Kelly Creek[9]	24,000	5	120,000	3			.10	4.2[6]	--	--
Stanley Creek[9]	1,400,000	15	21,000,000	3	--		.20	4.2[6]	--	90
Payette Placer[10]	3,240,000	25	81,000,000	11[11]	4[12]					
									Total:	2,540
									Grand Total:	23,620

[1]Kline and others, 1951a
[2]Kline and Carlson, 1954
[3]Kline and others, 1955
[4]Unpublished U.S. Bureau of Mines data
[5]Unpublished Defense Minerals Exploration Administration data
[6]Estimate
[7]Kline and others, 1951b
[8]R. D. Porter, written communication, 1985
[9]Storch and Holt, 1963
[10]Kiilsgaard and others, 1970
[11]Black sand, not ilmenite
[12]Total nonmagnetic fraction

Monazite, a rare-earth mineral whose principal components are cerium, lanthanum, and neodymium oxides but which also contains thorium and uranium, along with other elements, was the principal mineral mined from the Long Valley placer deposits in the early 1950's. At that time, the market price for monazite concentrates that contained 60 percent combined rare-earth oxides was about $0.18 per pound and a placer had to contain at least 1 pound of monazite per cubic yard of gravel to be considered economically exploitable. Average monazite content of different placers and average ThO_2 and U_3O_8 content of monazite in some of the placers is shown in table 1. Three bucket-line dredges worked on the Big Creek deposit (pl. 1) from 1950 to 1955 and are estimated to have dredged 12,880,000 yd^3 of gravel, from which was recovered 7,085 short tons of monazite that yielded 297 short tons of ThO_2 (Staatz and others, 1980). The three dredges also produced 77,300 short tons of ilmenite, 4,510 short tons of garnet, and 2,580 short tons of zircon. Dredge mining at the Big Creek deposit ceased in 1955 when government contracts for monazite were completed (Eilersten and Lamb, 1956).

Alluvial deposits in three contiguous areas along Bear Valley Creek (pl. 1) contain radioactive and niobium- and tantalum-bearing minerals. Of the three deposits, the one farthest upstream (Big Meadow) is the largest and most enriched in radioactive black minerals. Euxenite is the predominant ore mineral at the Big Meadow deposit, along with lesser quantities of monazite and columbite. Drilling of the deposit in 1951 and 1952, by the U.S. Bureau of Mines (Kline and others, 1953), and subsequent dredging from 1955 to 1959 show that richer concentrations of euxenite occur along the upper eastern side of the deposit, whereas monazite is more concentrated along the western side. Mackin and Schmidt (1956) describe euxenite crystals and grains in upstream parts of Bear Valley and note that size of the grains decreases by 3 to 4 times within the first mile of downstream transport. The grain-size reduction may be attributed to the hard and brittle nature of euxenite and its tendency to break up during alluvial transport. Monazite, on the other hand, is a durable mineral and grains of it are only slightly affected by stream transport.

Euxenite along the eastern side of Big Meadow deposit probably was derived chiefly from Tertiary intrusive rocks that crop out near the head of Cache Creek, a tributary to Bear Valley Creek. Petrographic studies and radiometric counts show that these Tertiary intrusive rocks contain more radioactive minerals than the Cretaceous plutonic rocks they intrude. An alluvial fan near the mouth of Casner Creek contained the highest concentration of euxenite mined from the Big Meadow deposit. Casner Creek heads in an area which is partially covered by Pleistocene glacial moraine, and which contains gravels derived from Tertiary intrusive rock that was scoured from the headwaters area of Cache Creek.

Euxenite, a niobate and tantalate of the yttrium group of rare-earth minerals, also contains varying amounts of uranium. Analyses of the Big Meadow euxenite and columbite, provided by R. P. Porter (Porter Brothers Corporation, written commun., 1985) are:

Euxenite			Columbite		
Nb_2O_5	27.07	percent	Nb_2O_5	60.84	percent
Ta_2O_5	3.01	"	Ta_2O_5	7.64	"
TiO_2	20.91	"	TiO_2	2.09	"
U_3O_8	10.25	"	U_3O_8	1.50	"
ThO_2	2.80	"			
SiO_2	3.24	"			
$RE_2O_3+Y_2O_3$	18.86	"	Re_2O_3	1.89	"
P_2O_5	0.98	"			
MnO_2	1.00	"	MnO_2	7.91	"
MgO	0.44	"			
Fe_2O_3	5.30	"	Fe_2O_3	11.74	"
Al_2O_3	1.07	"			
Unclassified	5.07	"	Unclassified	6.39	"
	100.00			100.00	

According to Porter (written commun., 1985) the rare earth ($Re_2O_3+Y_2O_3$) fraction of euxenite is composed of the following oxides:

Y_2O_3	57.9	percent	Tb_4O_7	1.3	percent
La_2O_3	2.4	"	Dy_2O_3	7.4	"
CeO_2	5.9	"	Ho_2O_3	1.9	"
Pr_6O_{11}	0.8	"	Er_2O_3	3.3	"
Nd_2O_3	3.8	"	Tm_2O_3	0.9	"
Sm_2O_3	2.2	"	Yb_2O_3	3.2	"
Eu_2O_3	0.1	"	Lu_2O_3	0.4	"
Gd_2O_3	5.9	"			

The Porter Brothers Corporation began dredging the Big Meadow deposit with one bucket-line dredge in 1955 and installed a second bucket-line dredge in 1956. Dredging capacity of the two dredges was 7,000 to 8,000 yd^3 per day. Approximately 6,500,000 yd^3 of placer alluvium was dredged from the deposit, from which was recovered 2,049 short tons of euxenite, 83.5 short tons of columbite, and 54,862 short tons of ilmenite (Staatz and others, 1980). Records on the amount of monazite recovered are not available. Big Meadow dredge production made Idaho the largest producer of niobium and tantalum in the United States during the late 1950's (Parker, 1964). Dredging ceased in 1959, when Porter Brothers Corp. fulfilled their contract to provide 1,050,000 pounds containing 90 percent niobium-tantalum pentoxides to the U.S. Government General Services Administration stockpile. Porter Brothers Corp. estimates that about 67,000,000 yd^3 of dredgable alluvium remain at Big Meadow, the average grade which is about 0.40 pounds of euxenite and columbite and 0.75 pounds of monazite per cubic yard (R. B. Porter, written commun., 1985).

Most of the deposits listed in table 1 as containing 0.50 or more lbs monazite per cubic yard also contain minor quantities of columbite-tantalite. Chemical analyses show the columbite-tantalite content of the ilmenite fraction of Custer and Valley County deposits (those in the Challis quadrangle) to range from 0.18 to 0.40 percent Nb_2O_5 (Storch and Holt, 1963, table 1). The total resources of niobium and tantalum in Idaho placer deposits are estimated at 20,000 tons of combined pentoxides, making Idaho one of the largest sources in the United States (National Academy of Sciences--National Research Council, 1959, p. 65). Most of these resources are in the Big Meadow deposit of Bear Valley (Parker, 1964).

Dredging has been soundly criticized for impairing the beauty of mountain valleys. Such criticism is warranted at many localities; however, little harm is done to the valley surface if care is taken to remove the soil cover prior to dredging and then to level the piles of dredge tailings, restore the soil cover, and plant grass after dredging is completed. Such restoration action was taken at Big Meadow and parts of the dredged site were difficult to distinguish from natural meadow in 1985.

Alluvial deposits that have been tested by drilling and are known to contain significant quantities of heavy minerals, ThO_2, and minor amounts of U_3O_8 are listed in table 1. Deposits that contain 0.5 lb or more monazite per cubic yard are shown separately as they would be the more likely candidates for exploitation, should economic conditions make dredging feasible. Volume estimates for the deposits are considered conservative as overall depths of most deposits probably exceed averages shown in the table. Deposits containing an average of less than 0.5 lb monazite per cubic yard would be dredgable only in case of a very high price for thorium. Present dredge laws and pollution restrictions in Idaho make bucket-line dredging unlikely.

The following model is based on the foregoing information; it represents an attempt to summarize pertinent characteristics of radioactive placer deposits.

Descriptive model

Ore body

Size: These alluvial deposits may range from hundreds of feet to a mile or more in width, be several miles in length, and range from a few feet to more than 100 feet in thickness.

Shape: A flat, alluvial blanket that conforms more or less to the shape of the valley floor but which varies considerably in thickness.

Yardage and grade: To be economically exploitable, a deposit should be large enough to support a dredging operation for several years. It should contain at least $n \times 10^6$ yd^3 and a minimum of 0.5 lb monazite or other radioactive minerals per yd^3.

Mineralogy

Ore minerals: Monazite, euxinite-polycrase, brannerite, samarskite, xenotime, fergusonite, uranophane, columbite, allanite, ilmenite, magnetite, zircon, garnet and gold.

Major commodities

Listed in decreasing order of importance: ThO_2, rare-earth oxides, niobium and tantalum pentoxides, U_3O_8, ilmenite, zircon, garnet, gold.

Character of ore

Heavy minerals of the black sand group of minerals, some of which are referred to as radioactive blacks. Individual black-sand grains are chiefly minus 16-mesh in size and may be present in amounts ranging from less than 1 lb/yd^3 to more than 30 lbs/yd^3 of alluvium. Ilmenite is the chief black-sand mineral; present in lesser amounts are magnetite, radioactive minerals, and other heavy minerals. Because the minerals are present as individual crystals or grains they may be readily separated and concentrated by various gravity or electromagnetic-electrostatic methods.

Lithology of the deposit

Alluvium, principally of Pleistocene age and consisting chiefly of sand and pebbles of granitic rock. Deposits are in areas of low stream gradient and contain few boulders, although surface and near-surface areas may consist of Holocene (Recent) alluvium containing more boulders transported by high-energy streams. Also, older alluvial deposits may be overlain in part or completely by late Pleistocene glacial moraine.

Controlling structures and other features

An impediment or blockage of stream flow that has reduced stream gradient and allowed deposition of the heavy minerals being transported by stream action. Heavy minerals at some deposits have been further concentrated by the winnowing action of flowing water that has removed light minerals and left heavier ones behind.

Mineral indicators

The principal indicator in a stream bed is black sand, which may be concentrated by panning the alluvium. Magnetite may be identified with a magnet and red garnet by visual inspection. Radioactive minerals may be identified with a geiger counter or a gamma-ray spectrometer. Some heavy minerals require microscopic study or X-ray analysis for identification.

Geophysical indicators

Gravity surveys give information on the overall depth of alluvium deposits and seismic refraction surveys define the depth to bedrock beneath a deposit more exactly. A proton precision magnetometer survey may aid in delineating the course of enriched paleochannels within the alluvium.

Resource Appraisal

Appraisal methods and definitions

Appraisal of the potential for radioactive placer resources in the Challis quadrangle is based on considerable field work in the area and geologic knowledge accumulated over many years of prior work in central Idaho. The appraisal method is subjective and allows for differing interpretations of the observed data. Definitions of key terms used in following sections of the report are as follows:

Resource--a naturally occurring concentration of materials from which a usable commodity or commodities can be extracted now or potentially in the future.

High mineral resource potential--exists where geologic, geochemical, and geophysical characteristics favorable for resource accumulation are known to be present, or where enough of these characteristics are present to give strong support to genetic models favorable for resource accumulation and where evidence shows that mineral concentration--mineralization in the broad sense--has taken place. (Taylor and Steven, 1983).

Moderate mineral resource potential--exists where geologic, geochemical, and geophysical characteristics favorable for resource accumulation are known or can reasonably be interpreted to be present but where evidence for mineralization is less clear or has not yet been found (Taylor and Steven, 1983).

Low mineral resource potential--exists in areas where geologic, geochemical, and geophysical characteristics are unfavorable, where evidence indicates that mineral concentrations are unlikely, or where requirements of genetic models cannot be supported (Taylor and Steven, 1983).

Diagnostic criteria--present in all, or nearly all, known deposits, and in most cases considered to be required for the presence of a mineral deposit of this type. The known absence of such criteria may either severely limit or definitely rule out the possibility of the presence of a deposit (NB--known absence requires definite negative information) (Pratt, 1981).

Permissive criteria--present in enough known deposits that they may be considered to favor the presence of a deposit, although they are not required (Pratt, 1981).

Eight sequential steps were utilized to assess the resource potential. These are:

(1) identify terranes and describe their geology
(2) identify alluvial deposits known or suspected to occur in each terrane
(3) describe each radioactive placer deposit
(4) list the recognition criteria for radioactive placer deposits
(5) divide the criteria into diagnostic and permissive using the above definitions
(6) delineate areas on the map where diagnostic criteria are present
(7) score areas on the basis of the presence or absence of diagnostic and permissive criteria
(8) rank the areas based on their scores and on subjective weighing of geologic knowledge and experience

Areas of diagnostic and permissive criteria were plotted on the Challis quadrangle base map, scale 1:250,000, and scored as follows: for each area the widespread presence of a criterion was assigned a value of 1, the known absence of a criterion was given a value of -1, and a lack of sufficient information to determine the presence or absence of the criterion was tallied as zero. The presence of the criterion in only part of the area was given a value of 1/2. The scores for each area were then summed, the sums representing relative favorability. The sums for the diagnostic and permissive criteria were considered separately because, by our definitions, the presence of permissive criteria enhances the favorability only if diagnostic criteria are also present in the area. Where permissive criteria are lacking, the favorability is not lessened if diagnostic criteria are present. Using the scores and any other available geological knowledge, a resource potential of high, moderate, or low was assigned to each area.

The radioactive mineral potential of alluvial deposits in the Challis quadrangle was appraised as follows: the location of deposits known to have produced radioactive minerals or to have been explored by drilling was plotted on the geologic map. Significant alluvial deposits were outlined on the geologic map and their location with respect to surrounding geology, stream deposition, and source was considered. Published and unpublished information on alluvial deposits was studied. On the basis of these investigations, 18 areas (labeled A-R, fig. 1) that contain significant alluvial deposits were identified as study areas. The resource potential of each study area was then appraised, using the following criteria.

Diagnostic criteria

1. Alluvium contains monazite or radioactive minerals.
2. Alluvial deposit is large; contains more than 10 million yd^3.
3. Alluvium is derived from an area that was extensively glaciated.
4. Alluvium is in valleys of low stream gradient.
5. Alluvium is underlain by or near extensive exposures of granitic rock, from which the alluvium was derived.

Permissive criteria

1. Source streams eroded extensive pre-Pleistocene land surface of decomposed granitic rock.
2. Contributing drainage basin contained glacial moraines and outwash fans that were fed and eroded by periglacial streams.
3. Gradient of transporting streams permitted winnowing of lighter minerals and rock fragments.
4. Deposit is in or at the edge of a basin containing Miocene sedimentary rocks.
5. Deposit contains more than 0.5 lb of monazite or other radioactive minerals per yd^3 of alluvium.
6. Deposit contains 5 lbs of ilmenite per yd^3.

Criteria 5 and 6 are not truly permissive, as defined by Pratt (1981), but they were placed on our permissive list in order to present additional pertinent information. Minimal mineral content is a primary consideration in appraising the potential of a placer deposit.

Scores of the appraisal criteria are tabulated in table 2. From these semiquantitative scores, the resource potential of the study areas is interpreted as:

High potential: study areas A and H.
Moderate potential: study areas B, C, D, E, G, J, K, L, and O.
Low potential: study areas F, I, M, N, P, Q, and R.

Study area A extends along the eastern side of Long Valley and contains the productive Big Creek deposit as well as several other deposits that have been explored by drilling (pl. 1, table 1). Within the area are large tracts of alluvium that have not been explored, but which have geologic characteristics similar to those of deposits that have been explored, and therefore are rated as having an excellent potential for radioactive mineral resources. The Big Meadow deposit of Bear Valley in study area H also has produced notable amounts of radioactive minerals (table 1). Downstream alluvial deposits of Bear Valley have been tested by drilling; and are known to contain resources of radioactive minerals. Of particular interest is deep alluvium in the lower central part of Bear Valley, which is shown by deep drill holes to contain concentrations of monazite (Storch and Holt, 1963). Parts of study area H that have not been tested but are geologically favorable include alluvium beneath meadows along Elk Creek and Porter Creek, Ayers Creek, and along lower reaches of Fir Creek.

A moderate potential is interpreted for study areas B (Garden Valley), C (South Fork of the Salmon River), D (Deadwood Valley and upper Johnson Creek Valley), E (Whitehawk basin), G (Sulphur Creek), J (Payette River placer), K (Beaver Creek-Cape Horn Creek locality), L (Sawtooth Valley), and O (Warm Springs Creek Valley). The Williams Creek-Gold Creek deposit in Sawtooth Valley is exceptionally rich for this area and constitutes a significant known resource of radioactive materials, but exploration elsewhere in the valley, as at the Kelly Creek and Stanley Creek placers (table 1) and along Meadow Creek (Storch and Holt, 1963), was not encouraging. Extensive glacial moraines and outwash fans of late Pleistocene age along Sawtooth Valley (Williams, 1961) overlie older alluvium thereby masking it and making exploration difficult. A gravity survey of the region indicates that alluvium in Sawtooth Valley may extend to considerable depths (Mabey and Webring, 1985).

Area J contains the Payette River placer, which is along the South Fork of the Payette River, near Grandjean, and above the confluence of Trail Creek and the South Fork. The placer is almost entirely within the Sawtooth

Table 2.--Appraisal criteria for radioactive placer deposits, Challis quadrangle

Resource area pl. 1	Contains radioactive minerals	Large size	Extent of Pleistocene glaciation	Low stream gradient	Underlain by or near granite	Total	Weathered land surface	Outwash from Pleistocene glaciers	Stream winnowing	Presence of underlying Miocene sediments	More than 0.5 lb radioactive minerals per yd^3	More than 5 lbs ilmenite per yd^3	Total
A	1	1	1	1	1	5	1	1	1	1	1	1	6
B	1	1	-1	1	1	3	1/2	-1	1	1	-1	-1	-1/2
C	1	1	1/2	1	1	4 1/2	1	1/2	1/2	-1	-1	-1	-1
D	1	1	1	1/2	1	4 1/2	1	1	1	-1	-1	-1	0
E	1	-1	1	1	1	3	1	1	-1	-1	1	-1	0
F	1	-1	1	-1	1	1	1	1/2	-1	-1	0	0	-1/2
G	0	1	1	1/2	1	3 1/2	1/2	-1/2	1/2	-1	0	0	-1/2
H	1	1	1	1	1	5	1	1	1	-1	1	1	4
I	1	-1	1	-1	1	1	1/2	1/2	-1/2	-1	0	0	-1/2
J	1	1	1/2	1/2	1	4	1/2	1	1/2	-1	-1	-1	-1
K	0	1	1	1/2	1	3 1/2	1/2	1	1/2	-1	0	0	1
L	1/2	1	1	1	1	4 1/2	1/2	1	1/2	-1	-1/2	-1	-1/2
M	0	-1	1/2	-1	1/2	-1	1/2	1/2	-1/2	-1	0	0	-1/2
N	0	-1	1/2	-1	1	-1/2	1/2	-1	1/2	-1	0	0	-1
O	1	1	1/2	1/2	1/2	3 1/2	1/2	1	1	-1	-1	-1	-1/2
P	0	1/2	1/2	-1	1/2	-1/2	-1/2	-1/2	-1/2	-1	0	0	2 1/2
Q	0	1	1/2	1/2	-1	1	-1/2	-1/2	1	-1	0	0	-1
R	0	1	-1	-1	-1	-2	1/2	-1	1/2	-1	0	0	-1

Wilderness (Kiilsgaard and Coffman, 1984). Holes drilled in the placer have outlined an enormous volume of low-grade material. Cuttings from 12 holes that ranged from 40 to 110 ft deep averaged 11.16 lb black sand per yd^3 and 4.02 lb of heavy nonmagnetic material per yard. The heavy nonmagnetic fraction was analyzed and found to have an average content of 0.320 lb Nb_2O_5 per yd^3, 0.0015 lb Ta_2O_5 per yd^3, and 0.0004 lb U_3O_8 per yd^3 (Kiilsgaard and others, 1970).

Area O contains The Meadows placer deposit, which is on Warm Springs Creek at its confluence with Pigtail Creek. The deposit is about 3.5 mi long and 0.5 to 1 mi wide, and was explored in 1957 under a Defense Minerals Exploration contract. Twenty holes drilled in the deposit indicate that depth to bedrock would exceed 100 ft over most of the deposit. Heavy-mineral concentrate from the holes ranged from 2.73 to 89.71 lb per yd^3 of placer material. Analyses of the heavy-mineral concentrate indicated an average of 0.001 lb U_3O_8 per yd^3, 0.004 lb ThO_2 per yd^3, 0.003 lb Nb_2O_5 per yd^3, 0.001 lb Ta_2O_5 per yd^3, and 0.021 lb rare earth oxides per yd^3. The exploration program showed the deposit to be subeconomic at then-current prices and costs, but it nevertheless contains significant amounts of uranium, thorium, niobium, and tantalum.

Alluvium in areas of low potential generally is along streams of high gradient. Such alluvial deposits are not thick, and commonly contain a large proportion of boulders that inhibit dredging. Many low-potential deposits show little surficial evidence of concentrations of radioactive minerals whereas others are miles distant from large exposures of granitic source-rock, or from glacial moraines.

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