MINERALOGY OF SOME BLACK SANDS FROM IDAHO, WITH A DESCRIPTION OF THE METHODS USED FOR THEIR STUDY.

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INTRODUCTION.

The term "black sand" is used commonly in gold placer mining districts to indicate the heavy concentrate from the placer gravels which accumulates with the gold in sluice boxes and on concentrating tables. The name, which is in very general use, comes from the fact that the predominant constituent is usually black in color. This black constituent, although commonly magnetite is sometimes largely ilmenite or in regions of serpentinous rocks it may consist in considerable part of chromite. Where the dominant constituent is not black in color local miners usually designate their heavy residues by some more appropriately descriptive name. Thus in southeastern Alaska much of the gold is recovered from "ruby sand" consisting predominantly of garnet; in the Florence and Warren districts in Idaho the heavy sand consisting very largely of colorless zircon is called "white sand" and sand rich in monazite in the placers of the Boise Basin is locally designated "yellow sand." In the present treatment these several varieties are referred to collectively as black or heavy sands.

These sands consist ordinarily of the heavier and rarer constituents concentrated from a great volume of disintegrated rock and may contain a great variety of unusual minerals. Many of these, in addition to being of high specific gravity, are quite hard, and as a consequence the heavy sands concentrated from stream gravels are in many places aggregates of glittering faceted crystals of minerals of various colors. Even relatively soft minerals occurring in the sands at times show few signs of abrasion, having escaped wear doubtless because of their small size and the rapidity of erosion.

The writer began an examination of the sands from Idaho preserved in the United States National Museum as part of the work of preparation of a lengthy manuscript on the minerals of that State. While of absorbing interest, the work proved to be tedious, and the limit to the amount of data obtainable from the study of the sands is prescribed by the amount of time available for their investigation. A single gram of the material may contain hundreds or even thousands of crystals which can not all be thoroughly examined in several days of steady work. The results obtained are not as complete or as conclusive as might be wished, but even thus they seem to indicate that some previous investigators have made errors in their identifications of some of the minerals. Under the circumstances this is far from surprising. Identifications must rest almost entirely upon the recognition of visible characters under the microscope and an ordinary monocular microscope is unsatisfactory for this purpose because of its limited field of vision and lack of focal depth. Chemical examinations of the aggregated minerals of a sand of mixed character are obviously little better than worthless and no single grain which may be selected has sufficient substance usually to yield distinctly visible qualitative or measurable quantitative chemical reactions. The modern methods of optical research by the use of immersion media of known refractive index, which are so indispensable in the study of fine-grained mineral aggregates are almost inapplicable in the study of these sands. This is due to the fact that nearly all of the minerals of interest are either opaque or have such exceedingly high indices of refraction as to fall well above the range of the series of stable immersion media available to any but a few specialists in optical mineralogy. In the present investigation the writer used a highly improved modern binocular microscope of the type recently manufactured by the Spencer Lens Company, of Buffalo, N. Y. This instrument presents a broad field with a splendid depth and sharpness of focus and it is possible to work in the field selecting individual grains and crystals with a wax tipped wire or a pair of forceps. Crystals were mounted in approximately vertical position on the wire and it was then the work of but a short time to orient them correctly for measurement on a Goldschmidt two-circle goniometer. The identity of some crystals was not even suspected until the angles measured had been carefully plotted and the symmetry thoroughly worked out.

The scheme of examination adopted, aside from the use of the goniometer, is relatively simple. The sands should be concentrated as far as possible by panning, or some other simple means of gravity concentration, thus eliminating the uninteresting lighter materials, as quartz, fragments of feldspar, micas, chlorite, etc. The remaining heavy concentrate should be carefully dried and then worked over with a good magnet. The magnetic portion is usually largely magnetite, but some ilmenite is commonly magnetic. If platinum is sought the magnetic portion should be carefully examined, as a part or all of the platinum may be magnetic. The magnetite may also contain many grains of nonmagnetic materials, carried mechanically by the cohering particles of magnetite, but these are usually only accidental grains of the minerals most abundant in the nonmagnetic residue. Some minerals, not themselves magnetic, are very frequently rendered magnetic by the presence of small magnetite inclusions. The nonmagnetic residue may then be examined with a good lens or with a low to medium power microscope, using incident light from above the stage. A binocular microscope is best, if one is available. Many of the more common minerals may be readily identified by their form and color. Except in unusually coarse or water-worn sands, grains of the constituent minerals can be found which are bounded by bright crystal faces. By taking these up on a wire tipped with wax and tilting them backward and forward or rotating them, so as to observe the reflection of light from the faces, an idea can usually be gained relative to the symmetry of the crystal which may serve to identify the mineral when compared with the crystal figures in a textbook or with the drawings accompanying this paper. Gold and the platinum metals are easily recognizable, and their identifications can be confirmed by applying a drop of concentrated nitric acid and observing, through the microscope, whether it has any action.

Perhaps the greatest difficulty will be found in distinguishing between relatively opaque dark nonmagnetic grains, which may include chromite, ilmenite, limonite, and a number of rarer columbates, tantalates, titanates, etc., and which often are quite devoid of crystal form. By carefully transferring any certain grain to a surface of unglazed porcelain and crushing it with a hard object there is obtained a powder which, when rubbed fine, may have a distinctive colored streak which will prove of diagnostic value. The presence of uranium or thorium in any appreciable quantity in any of the minerals can be shown by sprinkling some of the sand on a fresh photographic plate which is well wrapped in light-proof paper and allowing it to stand undisturbed for a week or more. When the plate is developed, the presence of radioactive minerals is shown by small clouded exposed spots on the resulting negative varying in intensity with the size of the particle and its degree of radioactivity which is directly proportionate to its content of uranium or thorium.

Methods of goniometric study on such minute crystals can be applied only by a crystallographer with improved apparatus and to grains or crystals having bright faces. The results are usually conclusive, but unfortunately this is not invariably the case. In the present study it was found impossible to determine whether many tetragonal crystals were zircon, rutile, xenotime, or thorite by crystallographic measurements. The angles of the commonly occurring pyramids on these minerals are more closely similar than the measurements usually obtained from adjacent faces of the same crystal. This may be shown by comparing the angle from the pole to the unit pyramid on each of these minerals as given below:

Theoretical angles of similar tetragonal minerals.

Zircon	$c(001) \wedge p(111) = 42° \ 09'$.
Thorite	$c(001) \wedge p(111) = 42° \ 10'$.
Xenotime	$c(001) \wedge z(111) = 42° \ 12'$.
Rutile	$c(001) \wedge s(111) = 42° \ 19'$.

The spectroscope is of very doubtful value in distinguishing between these troublesome tetragonal minerals because of its predominantly qualitative character. A crystal of either of the four minerals mentioned above will ordinarily yield spectroscopic reactions for the essential constituents of each of the others. The microspectroscope is open to the same serious objection.

The following table is put forth in the hope that it will be of service in aiding in the identification of some of the commoner constituents of black sands, especially when used in conjunction with the descriptions and figures of the following pages. The determinative table is almost entirely confined to the minerals observed during the examination of some 50 sands from Idaho localities, and there are very numerous others which might reasonably be expected to occur in heavy residues of this sort. When the sands of any region are found to have any important content of any unusual looking or unidentificable minerals they should be submitted to a competent mineralogist for study.

Table of visible properties of minerals occurring in heavy sands.

Extracted by a common magnet:
- Color black:
  - Form isometric (octahedrons, etc.); magnetite.
  - Form trigonal (hexagonal and triangular, tabular); ilmenite.
  - Form broken or irregular; magnetite, ilmenite.
- Color white to gray, opaque, metallic; platinum metals.

Not extracted by a common magnet:
- Opaque or nearly so:
  - Color black:
    - Form trigonal; ilmenite.
    - Form isometric; chromite (streak brown), limonite (streak brown), hematite (streak red).
    - Form tetragonal, prismatic:
      - Crystals dull; tapiolite (?).
      - Crystals brilliant, striated; rutile.

Not extracted by a common magnet—Continued.
- Opaque or nearly so—Continued.
  - Color black—Continued.
    - Form orthorhombic, prismatic, or tabular:
      - Crystals brilliant; columbite.
      - Crystals dull, pitted; samarskite.
      - Crystals with light external coating; polycrase.
    - Form monoclinic, prismatic:
      - Crystals vitreous, sharp; allanite.
      - Crystals frayed to fibrous; hornblende.
    - Form broken or irregular; limonite, hematite, ilmenite, tapiolite, cassiterite, rutile, columbite, samarskite, polycrase, uraninite, etc.
  - Color gray to white, luster metallic:
    - Grains malleable; platinum metals.
    - Grains brittle; arsenopyrite.
  - Color yellow, luster metallic:
    - Grains clear yellow, malleable; gold.
    - Grains pure yellow, brittle; chalcopyrite.
    - Grains greenish yellow, brittle; pyrite.
- Transparent to translucent:
  - Color red:
    - Deep red to nearly black, form prismatic or irregular; rutile.
    - Light rose to brownish red:
      - Form isometric; garnet.
      - Form tetragonal; zircon.
    - Color brownish to vermilion red or grayish, translucent to nearly opaque, form irregular; cinnabar.
  - Color yellow:
    - Pale yellow to greenish yellow:
      - Form monoclinic, flat; titanite.
      - Form orthorhombic, prismatic; olivine.
      - Form broken or irregular:
        - Luster greasy; titanite, scheelite.
        - Luster vitreous; olivine.
    - Amber yellow to brownish yellow:
      - Form monoclinic:
        - Habit prismatic or equidimensional; monazite.
        - Habit pyramidal, very flat thin; titanite.
      - Form broken or irregular:
        - Luster resinous; monazite.
        - Luster greasy; titanite.
        - Luster dull; scheelite.
  - Color green:
    - Deep green to dull green, form prismatic, frayed, or fibrous; hornblende.
    - Bright green to yellow green and yellow:
      - Form orthorhombic, prismatic; olivine.
      - Form monoclinic:
        - Habit thin, flat; titanite.
        - Habit prismatic:
          - Luster resinous; monazite.
          - Luster vitreous; augite.

Not extracted by a common magnet—Continued.
- Transparent to translucent—Continued.
  - Color green—Continued.
    - Bright green to yellow green and yellow—Continued.
      - Form broken or irregular:
        - Luster vitreous; augite, olivine.
        - Luster greasy; titanite.
  - Color blue of various shades, varying to lavender and gray:
    - Form hexagonal; corundum.
    - Form bladed; cyanite.
  - Color gray to brownish gray:
    - Form tetragonal; zircon.
    - Form isometric, rounded; pyrochlore (?), microlite (?).
    - Form broken thin chips, glassy; obsidian.
  - Color white or colorless (varying to smoky or faintly pink):
    - Form isometric; diamond.
    - Form hexagonal (prismatic or pyramidal); quartz.
    - Form tetragonal, various; zircon.
    - Form monoclinic, prismatic; monazite.
    - Form broken or irregular:
      - Luster vitreous; quartz.
      - Luster adamantine; zircon.
      - Luster resinous; monazite.

The sands studied, about 50 in number, were those preserved in the United States National Museum reference collections. These have been accessioned from various sources, but mainly by transfer from the United States Geological Survey, most of which are those examined by Day in the work cited below. A few are sands received from miners or prospectors for examination and report which have been of sufficient general interest to deserve preservation. The sands in most cases are not accompanied by data as to how they were concentrated or what processes they have been subjected to in the laboratory since they were collected. It seems certain that almost all have been more or less worked over by screening, gravity, and magnetic concentration, and that some are merely fractional portions of the original sand which have been separated by one of the above processes. It is therefore impossible to surmise, in most cases, the quantitative amounts of the several minerals originally present. Thus, it is not known whether the predominance of ilmenite over magnetite, commonly shown in the samples, is actual or due to the magnetite having in large part been extracted by a magnet. Similarly, some samples show considerable amounts of gold, while others, which from their nature and locality might be expected to be highly auriferous, contain none, the natural inference being that this metal has been removed by amalgamation.

The localities represented by samples in the collection studied are not as scattered as might be considered desirable, the sands, with a few exceptions, falling into three groups, the first from the bars of the Snake River; the second from the gold placer region of the Boise Basin, and the third from the placer-mining region centering about Pierce City, in Clearwater County.

The source of the minerals occurring in the sands of the bars of Snake River is somewhat problematical. Very fine gold is known to occur in these sands throughout the length of the river and many attempts have been made to work the deposits, but, owing to the extremely fine state of subdivision of the metal, these efforts have not met with much success. The occasional olivine and abundant augite in the sands may be derived from the basaltic lava which covers hundreds of square miles of the upper Snake River Valley or may have been concentrated from earlier sedimentary deposits derived from older formations in the foothills. It is noteworthy that the black sand from Minidoka, which contains a higher proportion of augite and more olivine than any other examined during the present investigation, was shown by Day [1] to contain appreciable amounts of platinum. Bell [2] has discussed the occurrence of platinum in the fine sands of the Snake River and has shown that it is not present in commercial amount.

The minerals found in the heavy sands of the Idaho Basin are probably all derived from the granitic rock which underlies the region or from the dikes of several types which intrude the granite. The placer districts of Clearwater County are largely derived from the rock of the northern extension of the same granitic batholith. The magnesium minerals, pyrope garnet, and augite, which occur in some sands from the latter section, are in all probability derived from local intrusions of basic magnesian rocks.

The minerals identified in the sands studied are described in some detail below, since the exact form and character of the constituent minerals of such sands have not heretofore been adequately set forth. The numerous figures accompanying these descriptions have been drawn from actual measurements made on crystals selected from the sands. The isometric forms of garnet, magnetite, and pyrite are not figured, as the habits of these minerals in the sands are precisely those illustrated by the figures given of these minerals in any standard textbook of mineralogy. It is hoped that the figures reproduced here may be of some assistance to future workers in identifying the minerals of such heavy sands under the microscope.

ILMENITE.

Ilmenite is abundant in the heavy sands, probably being present in excess of magnetite in all of those examined except in one from

[1] Day, David T., and Richards, R. H., Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906, p. 1195.

[2] Bell, Robert N., Mining Industry of Idaho for 1906, p. 116, Ann. Rept. State Inspector of Mines, Boise, 1907.

Bear Creek, in Camas County. In part the mineral occurs in irregular grains, and it can not then be distinguished from similar grains of numerous other opaque black minerals. The majority of the ilmenite is in more or less distinct tabular crystals which are hexagonal-trigonal in form. In the monazite-bearing sands of the Boise Basin and the Clearwater region ilmenite is present in amount greatly in excess of magnetite. Here this mineral occurs in fine to coarse grains, which are, for the most part, distinctly tabular in form with three or six sided bright basal pinacoids present although the edges are dull or etched and rarely show good crystal faces. Often the basal pinacoid shows triangular markings which are very characteristic. A typical crystal is shown in the orthogonal and perspective drawings of figure 27. The angles measured on a crystal similar to this are given below:

Angles of ilmenite crystal from Rhodes Creek, Pierce City district.

Letter	Miller.	Reflection.	Measured.		Calculated.	
			φ	ρ	φ	ρ
			° ′	° ′	° ′	° ′
c	0001	Very good..	0 00	0 00	0 00	0 00
p	$11\bar{2}1$	Good......	30 00	57 51	30 00	57 58
	$\bar{1}122$	Very poor..	29 54	38 18	30 00	38 38
a	$10\bar{1}0$	...do.......	0 46	90 00	0 00	90 00

Although the general aspect does not differ greatly, the forms present vary somewhat from crystal to crystal. A second crystal measured gave the following forms and angles:

Angles of ilmenite crystal from Idaho City.

Letter.	Miller.	Reflection.	Measured.		Calculated.	
			φ	ρ	φ	ρ
			° ′	° ′	° ′	° ′
c	0001	Very good..	0 00	0 00	0 00	0 00
u	$50\bar{5}1$	Very poor..	0 00	72 50	0 00	77 46
	$\bar{2}241$	Very good..	29 29	72 50	30 00	72 38
K	$41\bar{5}1$	Poor.......	11 38	76 58	10 53	76 42

The ilmenite of the monazite sands, which is in all probability derived, as are the associated monazite and zircon, from the granitic rock of the Central Idaho batholith, is not attracted to a magnet. In the fine sands of the Snake River about one-half of the total amount of black iron ore is extracted by a magnet, both the nonmagnetic and the magnetic portions being composed of irregular black grains and disseminated brilliant thin tabular crystals of ilmenite. Only rarely does a magnetic grain show the typical octahedral form of magnetite, and it may be that the black mineral is practically all ilmenite. The ilmenite of the Snake River sands thus is in considerable part magnetic as contrasted with the nonmagnetic character of the same mineral in the sands of the granite regions.

The source of this mineral in these fine sands of the Snake River is not certain. It is noteworthy, however, that the thin sections of the diabasic rock, which occurred abundantly in sand from Minidoka, contained numerous scattered tabular crystals of ilmenite, as noted under "augite."

GARNET.

Garnet is almost if not quite invariably present in the sands examined, occurring either as grains, irregular fragments, or rough to highly perfect crystals. As seen under the binocular this mineral is of two varieties, which are distinguished by a very striking difference of color. The most abundant and widely distributed variety is clear bright red to slightly brownish red in color and is probably almandite. It occurs most abundantly in many of the sands, being especially prominent in those which carry abundant monazite, as in samples from Centerville, Idaho City, and other localities in Boise County. Here it is in part in small, irregular worn, or broken grains, but for the most part the grains are small, highly perfect limpid and transparent crystals which are either trapezohedrons, dodecahedrons, or combinations of the two. In the sand from Bear Creek almandite garnet occurs in rare small model-perfect crystals up to a millimeter in diameter, associated with titanite and allanite. In the fine sands of the Snake River similar brown-red almandite is present in subordinate amount as small irregular grains. The abundant garnet of these sands is rather pale rose pink in color when in small grains. This pink garnet is present in greater or less amount in every Snake River sand examined, in some cases being the only garnet present, while in other sands both varieties occur. Aside from the Snake River samples pink garnet was noted only in a few sands from the vicinity of Pierce City and Orofino, in Clearwater County. In some of the coarser sands from these latter localities the garnet occurs in masses up to 1 centimeter in diameter, and in the larger grains its color is rose purple, being comparable to that of the rhodolite garnet from North Carolina. The pink or purple variety in the heavy sands is more or less coincident in occurrence with augite, and this fact, together with its color and general appearance, supports the conclusion that it is probably a magnesian variety, high in the pyrope molecule. As contrasted with the abundant and highly perfect crystals of the brown-red garnet, the pink variety rarely occurs in recognizable crystals, being usually in water-worn grains or angular broken fragments. Such few crystals as were seen were much rounded, with deeply striated and pitted faces, the forms being but dimly distinguishable.

MAGNETITE.

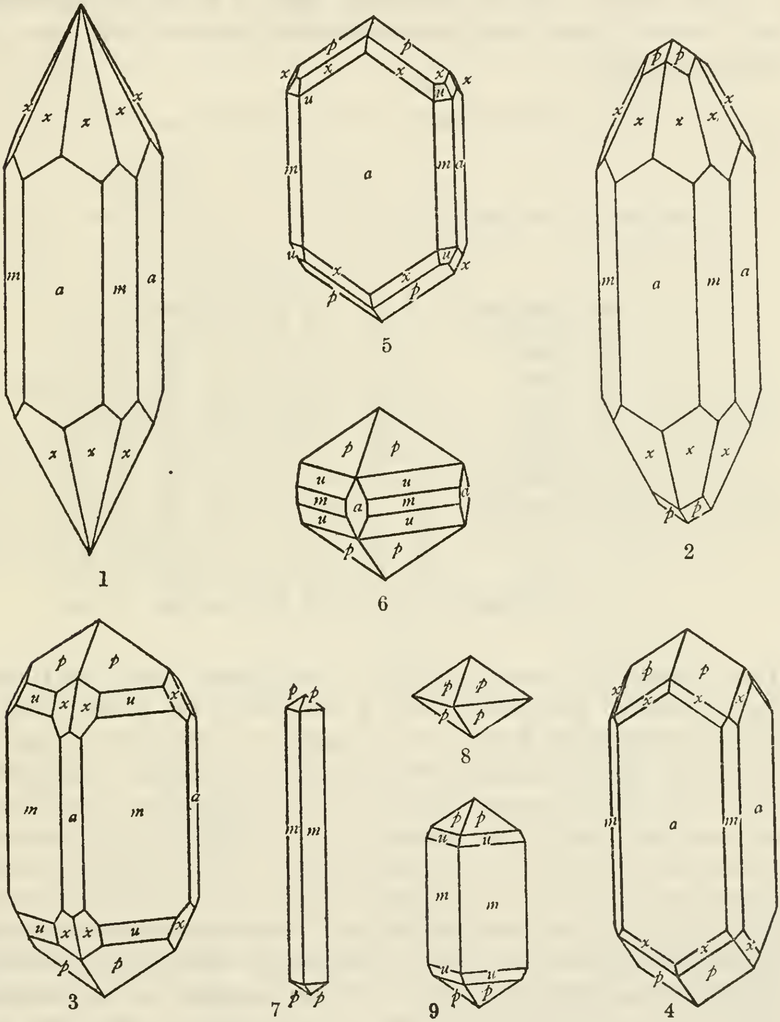
Magnetite is much less abundant in the materials examined than it is in black sands from most localities. In the lot from Camas County magnetite in irregular grains and octahedral crystals is the most abundant constituent, making up approximately four-fifths of the whole, but this is the only example found in which magnetite is present greatly in excess of ilmenite. The fine sands from the Snake River contain varying amounts of black iron ore up to about 30 per cent. This is in large part in irregular dull-black grains and it is not possible to determine in what part these grains are magnetite. About one-half of the total amount of black material is removed by a magnet. When this magnetic portion is examined it is found to consist mainly of rough irregular grains with occasionally a brilliant black tabular crystal of ilmenite. Other crystals of ilmenite are non-magnetic. Rarely the magnetic material shows octahedral crystals of magnetite. Magnetite is present in negligible amount in the many monazite-bearing sands of the Boise Basin and of the Pierce City region, the black mineral being almost entirely ilmenite, which in these sands is not attracted to a magnet. Where the magnetite is in distinct crystals, it is in the form of octahedrons, which may be more or less distorted. In some coarse sands the magnetite is in small fine granular masses and in rare cases this mineral forms pseudomorphs after well defined pyrite crystals.

ZIRCON.

One of the most interesting and widespread constituents of the heavy sands is zircon, which occurs in greater or less amount in every sand examined. Ordinarily the mineral is clear and colorless, and it is invariably in beautifully sharp crystals, most of which are very transparent and brilliant. It occurs in considerable amount in the sands from the gold placers of the Boise Basin, where it is associated with monazite, but it is still more abundant, according to Lindgren,[3] in some placer districts, notably those near Florence and Warren, where the heavy residues are called "white sand" because of its presence. While commonly colorless, the zircon in the sands of the granite region varies from smoky gray to pale flesh red. The smoky crystals are much like smoky quartz in appearance and the color is often unevenly distributed. Inclusions are frequent, the most highly transparent and brilliant forms containing minute spherical

[3] Lindgren, Waldemar, U. S. Geol. Survey, 20th Ann. Rept., pt. 3, p. 234, 1899.

bubble-like cavities and also minute microlite-like prismatic crystals of a transparent colorless mineral having a lower index of refraction than the zircon. Many of the translucent smoky-gray crystals appear to owe their color to minute inclusions of iron oxide. In form the zircons are most frequently prismatic, with the length three or four times the diameter, and the most abundant types show the first order



FIGS. 1–9.—CRYSTALS OF ZIRCON.

prism $m(110)$ and the second order prism $a(100)$ in almost equal development and are terminated by the ditetragonal pyramid $x(311)$, either alone (fig. 1) or together with the unit pyramid $p(111)$. Crystals of these habits are by far the most abundant in the monazite-bearing sands and also occur, though in lesser amount, in all other sands examined, including the monazite-free samples from numerous localities along Snake River and the titanite and allanite bearing sand from Bear Creek. While, except as before mentioned, these crystals are usually colorless, a sand concentrate consisting largely of monazite, from Idaho City, contains abundant zircons of this form, which are yellow, being very like the monazite in color. A typical crystal, having this habit, from a monazite concentrate from Grimes Creek near Centerville was measured and gave the following angles:

Angles of zircon crystal from Centerville (fig. 2).

Letter.	Miller.	Reflection.	Measured.				Calculated.			
			φ		ρ		φ		ρ	
			°	′	°	′	°	′	°	′
a	100	Very good..	0	00	90	00	0	00	90	00
a	100	Medium....	0	01	90	00	0	00	90	00
a	100	Good......	0	08	90	00	0	00	90	00
a	100	Poor.......	0	11	90	00	0	00	90	00
m	110	Fair........	44	50	90	00	45	00	90	00
m	110	Good......	44	47	90	00	45	00	90	00
m	110	Poor.......	45	07	90	00	45	00	90	00
x	311	Medium....	18	38	63	19	18	26	63	43
x	311	Good......	19	31	64	03	18	26	63	43
x	311	Very poor..	17	59	64	03	18	26	63	43
x	311	Very good..	18	12	64	19	18	26	63	43
x	311	...do.......	18	27	63	44	18	26	63	43
x	311	...do.......	18	02	63	29	18	26	63	43
x	311	Very poor..	18	20	63	29	18	26	2	43
x	311	Very good..	18	25	63	05	18	26	2	43

The crystals vary considerably in development from the typical forms illustrated in figures 1 and 2, the first order prism being in some cases the larger form with its angles truncated by the second order prism (fig. 3), while in other crystals the relative development of the two prisms is reversed (fig. 4). The terminations vary also in some cases the ditetragonal pyramid x(311) being merely truncated at its extreme summit by the pyramid p(111), while in other crystals the unit pyramid p(111) is largely developed reducing the ditetragonal pyramid to mere line faces (fig. 3). Not infrequently these two extremes are observed to opposite ends of the same crystal yielding a peculiarly hemimorphic aspect. Some variants in the common development are difficult to orient, as, for instance, when the adjacent faces of the form x(311) are very unequally developed and reduce the prism faces to irregular polygons of small size. The pyramid u(331) is occasionally present as small faces which are dull and irregular and give poor measurements. A coarse-screened portion of a sand from Idaho City consisting largely of ilmenite contained translucent crystals of zircon of two types, both of which are somewhat different from the normal transparent crystals occurring in finer screenings of the same lot of sand. The most abundant of these two types is peculiarly tabular to a face of the second order prism *a*(100), as shown in figure 5. The average angles obtained upon measurement of a crystal of this type are given in the following table:

Average angles of tabular crystal of zircon from Idaho City.

Letter.	Miller.	Reflection.	Measured.		Calculated.	
			φ	ρ	φ	ρ
			° ′	° ′	° ′	° ′
a	100	Poor	0 13	90 00	0 00	90 00
m	110	....do	45 07	90 00	45 00	90 00
p	111	Very good	45 03	42 06	45 00	42 09
u	331	Very poor, approximately	47 00	69 07	45 00	69 47
x	311	Very poor	18 19	63 16	18 26	63 43

Other crystals from the same lot have a short pyramidal habit with *p*(111) prominent and *u*(331), *m*(110), and *a*(100) about equally developed, as shown in figure 6. These are irregular and appear as though made up of numerous very small individuals in parallel position. The reflection from the faces are consequently not very good. The angles measured on a crystal of this habit are given below.

Angles of zircon crystal from Idaho City (fig. 6).

Letter.	Miller.	Reflection.	Measured.		Calculated.	
			ϕ	ρ	ϕ	ρ
			° ′	° ′	° ′	° ′
m	110	Very good	45 00	90 00	45 00	90 00
a	100	Good	0 02	90 00	0 00	90 00
p	111	Medium	45 00	41 58	45 00	42 09
u	331	Fair	45 00	69 29	45 00	69 47

Although the majority of the tetragonal crystals in the Snake River sands are similar to those shown in figures 1 to 4, several other types were seen. A sand from Rosa, Bingham County, contains scattered translucent crystals of a brownish color which are short prismatic, with the length about twice the thickness. These show the prism *m*(110) and the pyramids *p*(111) and *u*(331) developed as shown in figure 9. A crystal of this type yielded the following measurements:

Angles of zircon crystal from Rosa, Bingham County (fig. 9).

Letter.	Miller.	Reflection.	Measured.		Calculated.	
			φ	ρ	φ	ρ
			° ′	° ′	° ′	° ′
m	110	Good......	45 00	90 00	45 00	90 00
p	111	Poor.......	45 00	42 20	45 00	42 09
u	331	Very poor..	45 00	70 11	45 00	69 47

This looks very much like zircon, but the angles are nearer those of rutile, although the measurements are not sufficiently exact that it may be referred to that mineral. One or two crystals having the same form as the last and an orange-red color were seen in a sand from Minidoka but were not measured. One of the most unusual types of tetragonal crystals seen occurs in the Minidoka sand and is long acicular, the length being 10 to 20 times the diameter. These crystals show only the unit prism *m*(110) and the pyramid *p*(111), as shown in figure 7. The crystals of this long prismatic type are all pale pink in color. One which was measured gave the following angles:

Angles of zircon crystal from Minidoka (fig. 7).

Letter.	Miller.	Reflection.	Measured.		Calculated.	
			φ	ρ	φ	ρ
			° ′	° ′	° ′	° ′
m	110	Very good..	45 00	90 00	45 00	90 00
p	111	...do.......	45 00	42 00	45 00	42 09

The only other type of tetragonal crystals seen was bipyramidal showing no prism faces, only the form *p* (111) being present. This habit is illustrated by figure 8. Crystals of this habit having an orange-red color occurred rarely in a sand from Snake River in Ada County and a few having a brownish-white color were seen in the samarskite-columbite concentrate from Idaho City. Accurate measurements could not be obtained from these crystals owing to their small size and imperfect faces.

While all of the above-described tetragonal minerals are referred to zircon, comparison of the angles will show, as previously mentioned, that several of the types, especially the latter less common ones which have orange or brown colors may equally well be thorite, xenotime, or a light-colored rutile. The measurements were in no case sufficiently accurate or dependable to serve as evidence for differentiating between these tetragonal minerals which differ only a few minutes from each other in angles. It is comparatively certain, however, that zircon is the only abundant tetragonal mineral present in the sands examined and that, if these similar minerals occur at all, it is only as rare and scattered crystals.

MONAZITE.

The presence of monazite in heavy sands in Idaho was first recognized by Lindgren [4] in the gold placers of the Boise Basin, where he found it as a resinous brown mineral in subangular grains in part exhibiting crystal faces. Roughly quantitative analyses by Hillebrand made upon the purified sand showed the principal constituents to be phosphoric acid and cerium earths, with a small amount of thorium. The absence of yttrium earths showed that xenotime probably was absent. Later, Day in his work on the black sands of the Pacific Slope,[5] reported the mineral from 37 localities in 10 counties in Idaho. Some of these are in error, since several of the sands listed are from Snake River localities and a reexamination of the same samples failed to detect any monazite. Schrader [6] has recently described the occurrence of monazite in Nez Perce County in northern Idaho.

The monazite occurs most abundantly in the gold-placer region about Centerville, in Boise County, and preparations were made some years ago by the Centerville Mining and Milling Company to recover and clean the sand for market. The plant which was built was burned before any important production had been made and the commercial outlook was not sufficiently bright to encourage its rebuilding. The Idaho monazite is seemingly lower in its content of thoria, which is the only valuable constituent, than similar sands from Brazil, with which it can not compete in the very limited market.

The work of the several investigators who have examined the Idaho monazite-bearing area seems to indicate conclusively that the monazite is an original mineral present as an accessory constituent in the granitic rock of the great central Idaho batholith and it is probably more or less present in every drainage basin within this great granitic area. Lindgren panned crystals of both monazite and zircon from angular granite soil formed by disintegration of the granite on slopes where these minerals could have no other source.

During the present examination monazite was noted abundantly in sands from Grimes Creek and elsewhere near Centerville and from Idaho City, in Boise County, from Pierce City and Orofino, in Clearwater County, and from French Creek, in Nez Perce County. It is a noteworthy fact that in the examination of Snake River sands from nine localities in five counties no trace of the mineral was found.

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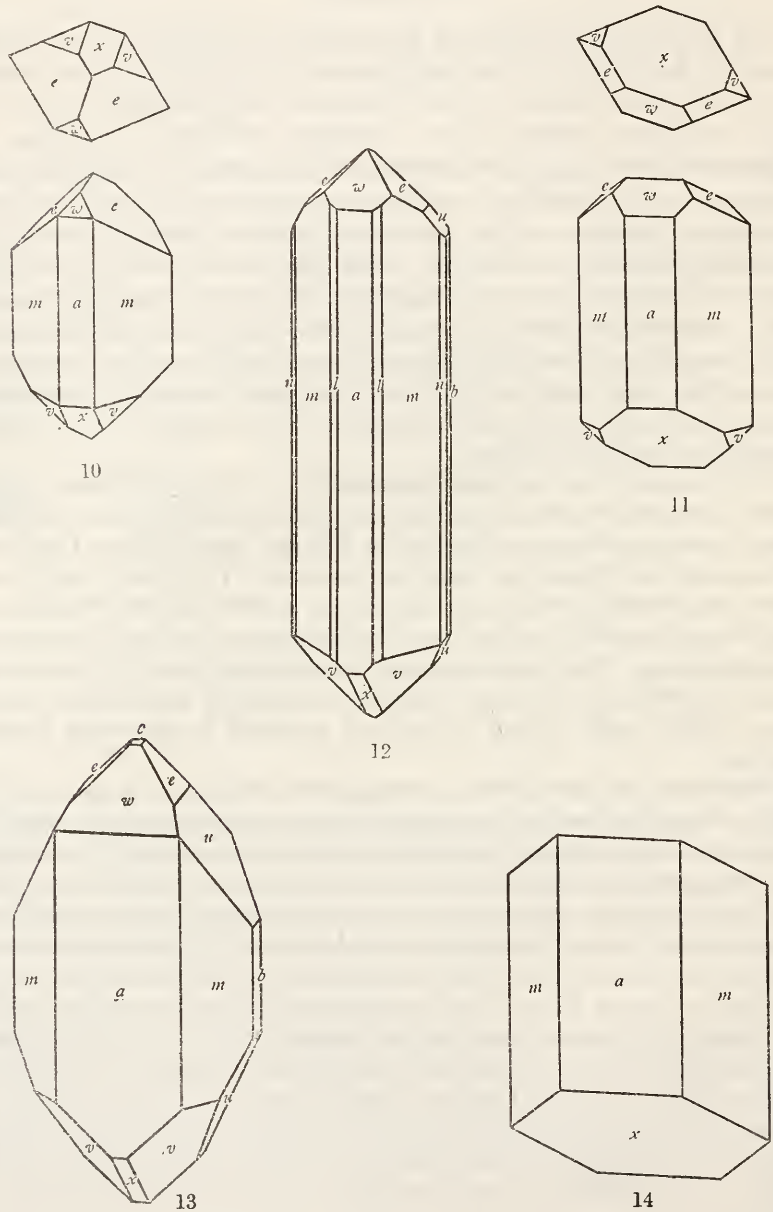
[4] Lindgren, Waldemar, U. S. Geol. Survey, 18th Ann. Rept., pt. 3, pp. 677–679, 1898.

[5] Day, D. T., and Richards, R. H., Mineral Resources U. S. for 1905. U. S. Geol. Survey, 1906, pp. 1195–1201.

[6] Schrader, F. C., Bull. U. S. Geol. Survey No. 430, p. 185, 1910.

In color the monazite is commonly resinous golden yellow to amber or orange brown. Only a few crystals were found which had what could accurately be described as a greenish tinge, the associated



FIGS. 10–14.—CRYSTALS OF MONAZITE.

greenish grains usually being either augite, titanite, or olivine. A few green and a few perfectly colorless transparent monazite crystals were seen in the samarskite-columbite concentrate from

Idaho City described below. The monazite is, for the most part, in sharp and perfect crystals although many of the larger crystals are broken or abraded. The average diameter in the mineral in the screened sands studied is less than 1 mm., but in one "oversize" sample rough crystals up to 5 mm. in diameter were observed, and larger masses may have been discarded by screening. In form the monazite from all of the several localities represented is very similar. The figures reproduced were all drawn from measurements made upon crystals selected from a sand from Centerville, and subsequent examination of the numerous other sands did not reveal any additional forms, combinations, or habits. The smaller crystals are often flawless and perfectly transparent, while the larger individuals are more or less opaque from the presence of numerous cracks and rifts. The forms noted on the crystals are few in number and perhaps 90 per cent of the crystals seen had almost precisely the habit shown in figure 10, and 9 per cent had the form shown in figure 11. Figures 12, 13, and 14 represent quite unusual habits. The very simple habit shown in figure 14 is characteristic of some of the very largest as well as of the colorless and green monazite crystals seen in the samarskite concentrate. The more prominent faces on the majority of the crystals gave fairly good reflections and the agreement between the angles measured and the theoretical angles completely dissipates any doubt which may remain regarding the identity of the Idaho mineral. The averages of the angles measured on the several crystals examined are compared with the theoretical angles in the following table:

Angles of monazite from Idaho.

Letter.	Miller.	Reflection.	Measured.		Calculated.	
			φ	ρ	φ	ρ
			° ′	° ′	° ′	° ′
a	100	Very good..	90 00	90 00	90 00	90 00
b	010	.....do.....	0 00	90 00	0 00	90 00
c	001	Very poor..	89 58	13 23	90 00	13 40
m	110	Very good..	46 44	90 00	46 43	90 00
n	120	Good......	27 35	90 00	27 58	90 00
l	210	Very poor..	69 15	90 00	64 47	90 00
e	011	Good......	14 25	43 37	14 43	43 44
w	101	Very good..	90 04	50 43	90 00	50 48
v	$\bar{1}$11	Good......	38 43	49 43	38 37	49 50
u	021	Very good..	7 36	61 38	7 29	61 49
x	$\bar{1}$01	.....do.....	90 09	36 31	90 00	36 29

The monazite of one sample from Pierce City is in unusually coarse, imperfect crystals which have an internal grating structure which may be due to multiple or polysynthetic twinning. Inclusions are not abundant, and the monazite is rarely attached to any other mineral. In one case a hexagonal tablet of biotite was seen imbedded in a crystal and another crystal was penetrated by a tabular crystal of ilmenite.

TITANITE.

Titanite is not rare as a constituent of the heavy sands, although it is nowhere very abundant and its distribution is not so universal as might be expected. It occurs in the nonmagnetic portion of the sand from Bear Creek, Camas County, along with zircon, allanite, and gold, as small irregular grains and flat crystals which vary from yellow through various shades of green in color. Except for a certain greasy appearance and luster the irregular grains are hard to distinguish from irregular grains of augite and olivine which are common in other sands. The majority of the titanites, however, show some crystal faces, and the form is quite characteristic, being unmistakably different from the forms assumed by olivine and augite. The titanite crystals show the familiar "envelope" combination of the base *c*(001), the clinopinacoid *a*(100), and the unit pyramid *n*(111), the appearance of the crystals being as shown in the drawing, figure 26. Usually the thin edges and corners of the crystals are more or less worn and broken, and where this is not the case the interfacial angles often have a rounded or fused appearance. The basal pinacoid is usually irregular or dull and pitted. The angles measured by which the several forms were identified are as follows:

Interfacial angles of titanite from Bear Creek, Camas County.

Angle.	Reflections.	Measured.		Calculated.	
		°	′	°	′
$n(111) \wedge n(111)$	Very good∧very good........	43	38	43	49
$n(111) \wedge n(111)$	.....do........................	43	32	43	49
$c(001) \wedge a(\bar{1}00)$	Very poor∧poor..............	120	21	114	03

Flat crystals of this same form are abundant also in a sand from Cow Creek, in the Pierce City district, which contains much ilmenite with rose-pink pyrope in much-rounded crystals, and some monazite. It also occurs in small amount in most of the monazite-bearing sands of the Boise Basin region. In these latter sands the titanite has a pale-brown color not very different from the color of the monazite. It may be distinguished from the monazite by differences in luster and crystal form.

SAMARSKITE.

A sample of a heavy concentrate from a sand from Idaho City ("P654, olivine") was found to be distinctly radioactive. Careful microscopic examination showed this material to be composed in large part of a coal-black glassy mineral with a brown streak and conchoidal fracture. The mineral occurs in rounded grains and in dull pitted square prismatic crystals which are either broken at the ends or are terminated by a chisel-shaped dome. All of the grains and crystals are very much corroded and are dull and brownish in color on the outside. One of the smoothest of the crystals was measured by reflected light from the faces and gave approximate measurements of 90° between the pinacoids and 86° between the faces of the dome, which compares well with the angle $e(101) \wedge e'(\bar{1}01)$ 87° for samarskite. The radioactivity of the mineral, its crystal form, and its physical properties suggest that it is samarskite. The identity is by no means definitely established, however, and it is to be understood that this and several other of the rare-earth minerals of these sands are but tentatively referred to the species under which they are described. The hardness of the samarskite is 5–6. The streak is dark brown. When powdered and examined under the microscope the mineral is found to have a dark-brown color and to be transparent on very thin edges. It is isotropic throughout, as are most such rare-earth minerals. The form and appearance of the crystals are as shown in figure 15, which also shows the tendency of two or more crystals to occur in parallel position. The samarskite makes up about 60 per cent of this material, which apparently is the heaviest fraction of a concentrate from a sand obtained from a dredge operating at Idaho City. In addition to the 60 per cent of samarskite, this concentrate contains about 10 per cent of columbite in sharp crystals, the remaining 30 per cent consisting of various other unidentified rare-earth minerals, zircon, monazite, garnet, and much metallic lead, the latter evidently being fragments of solder, babbitt, or of lead bullets. Quartz is frequently attached to the samarskite, and in a few instances what appears to be monazite is intergrown with it. Several other samples which were labeled "P654 chromite," "P654 garnet," etc., are apparently other fractional concentrates from the same original lot of sand. The one labeled "garnet" consists of about 50 per cent by volume of pale to deep brownish-red almandite in sharp trapezohedral crystals, the remaining 50 per cent being largely samarskite and columbite. The columbite is relatively more abundant than in the first sample examined. The samarskite is entirely like that already described, showing rounded pitted grains and rough crystals. Some of these have grains of quartz and crystals of muscovite attached to them, while others seem to show either two minerals or two generations of samarskite, some of the grains, where broken, showing an inner crystal surrouned by an outer shell of a similar substance. The sample

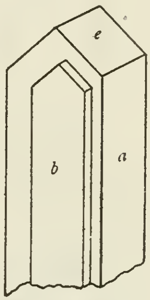
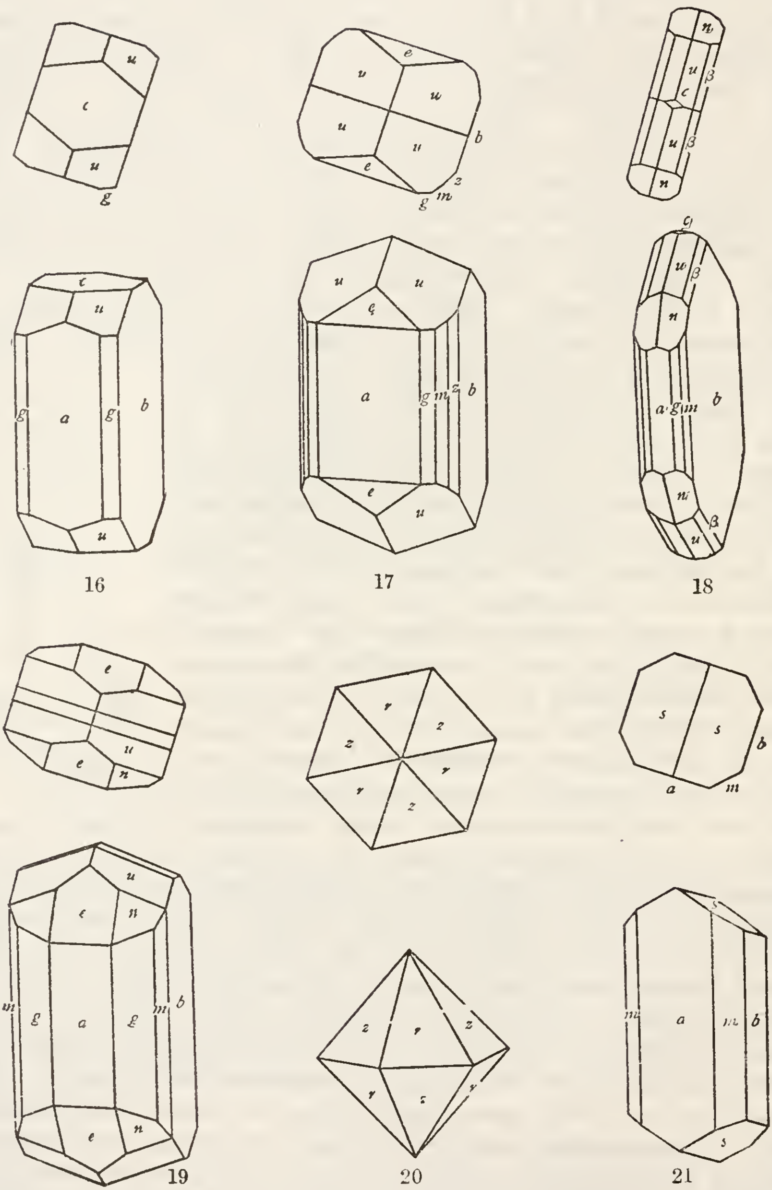


FIG. 15.—CRYSTAL OF SAMARSKITE (?) FROM IDAHO CITY.



Figs. 16–21.—16–19, Columbite from Idaho City; 20 quartz, and 21, augite from Snake River.

labeled "chromite" contains a little samarskite, but is for the most part composed of ilmenite.

COLUMBITE.

The samarskite concentrate from Idaho City described above contains important amounts of a mineral in black crystals which proved, upon measurement, to have the angles of columbite. Aside from the difference in form, which is not always manifest, this mineral greatly resembles ilmenite, which occurs commonly in the sands. The columbite makes up about 10 per cent of the high samarskite sand and is more abundant than samarskite in the garnet-bearing sand. The crystals vary considerably in habit, ranging from tabular parallel to the pinacoid *b*(010) to square prismatic. The common forms and habits are illustrated in the drawings (figs. 16 to 19, inclusive). The color is black, and the luster is more vitreous than metallic. The prismatic planes are usually very brilliant, but the terminal faces are frequently more or less dull and pitted. This is especially true of the unit pyramid *u*(111), the faces of which are most frequently dull and often show rounded depressions. Under the microscope the powdered mineral is translucent on thin edges, with a brown color. Frequently several similar crystals are grown together in parallel position and many crystals are attached to small masses of quartz and muscovite. In the coarse polycrase-bearing sand from Centerville crystals up to 1 cm. in length occur sparingly which have the form and appearance of columbite. These are invariably dull with a grayish-black color and more metallic luster. They also are more opaque than those described above. Judging from appearance alone it seems probable that these crystals from Centerville are more nearly pure iron columbate, while the brilliant black crystals from Idaho City are probably higher in their content of tantalic acid, and possibly they contain some manganese. The forms and angles measured on crystals from Idaho City are given in the following table:

Forms and angles of columbite from Idaho City.

Letter.	Miller.	Reflection.	Measured.				Calculated.			
			φ		ρ		φ		ρ	
			°	′	°	′	°	′	°	′
a	100	Very good..	90	00	90	00	90	00	90	00
b	010	.....do.....	0	00	90	00	0	00	90	00
c	001	Poor........	0	00	0	06	0	00	0	00
g	110	Very good..	68	14	90	00	68	05	90	00
m	130	.....do.....	39	32	90	00	39	38	90	00
z	150	Poor........	28	20	90	00	26	26	90	00
u	111	Fair........	68	23	43	23	68	05	43	48
n	211	Good......	78	35	61	16	78	37	61	09
β	121	Poor........	52	04	48	36	51	11	48	48
e	201	Good......	90	00	60	29	90	00	60	39

POLYCRASE.

A sample of "oversize" coarse sand from Centerville contains abundant grains and rough crystals of a dark-brownish or greenish-black mineral not very different in appearance from the samarskite. The crystals, which reach 1 cm. in diameter, are orthorhombic in aspect and vary from square prismatic to thin tabular. They are all coated with an exterior crust of a pale-yellow alteration product. Within this shell the crystals and grains consist of a brownish-black glassy material having a conchoidal fracture and a brown streak. Under the microscope thin fragments are transparent, isotropic, and brown in color. The mineral is intensely radioactive. Mr. Frank L. Hess had previously recognized this or a similar mineral in placer gravels from Centerville, and recently has turned his sample over to the present writer for chemical investigation, which it is hoped may yet be undertaken. The properties and appearance of the mineral are identical in most respects with the polycrase from Marietta County, N. C., and for the present it will be referred to that mineral. This mineral, recognizable by its light-colored coating, occurs sparingly also in the samarskite and columbite bearing concentrates from Idaho City. A crystal from this lot gave measurements on the pinacoids and on two pyramid faces indicating roughly the form *s*(111) of polycrase. The remaining faces were coated. The form and appearance of this crystal, which was tabular, are shown in the drawing (fig. 22). There was, as shown in the figure, a smaller crystal in parallel position projecting from the face of the larger individual.

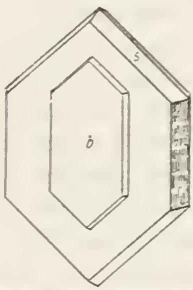


Fig. 22.—Crystal of polycrase (?) from Idaho City.

OTHER RARE-EARTH MINERALS.

In addition to the rare earth minerals described above under the headings "samarskite," "columbite," and "polycrase," it is probable that a number of others occur in lesser amount in the sands. In the columbite-samarskite material certain glassy to resinous grains without crystal form gave light-brown internal reflections and had a light-brown streak, while other grains gave green internal reflections and fragments were brownish green under the microscope. These may include euxenite and yttrotantalite or possibly fergusonite. One small crystal which was noted under the microscope appeared to have the tetragonal form and pyramidal hemihedrism of fergusonite. In the polycrase-bearing sand from Centerville, in addition to the abundant polycrase, there are occasional grayish iron-black tetragonal crystals having dull faces, which may be one of the minerals related to tapiolite. Other grains appeared to be much worn isometric crystals of a brownish-gray color, resembling microlite or pyrochlore. When all the recognizable rare-earth minerals had been picked out of a sample of this sand, the residue was found to still be radioactive and to contain heavy opaque gray-black grains with submetallic luster.

PYRITE.

Unaltered pyrite was seen only as one or two grains in one sand, but pseudomorphs preserving the crystal form of pyrite perfectly are present in greater or less number in almost every sample of sand examined. These are often deceptively lustrous and black in color, with polished faces, but occasional particles in each sand are brownish in color or have an ocherous external coating. Most of the pseudomorphs consist of limonite, as is shown by their brown streak, but a few are attracted by a magnet and consist wholly or in part of magnetite. The forms exhibited by these pyrite pseudomorphs are cubes, or cubes with the corners truncated by octahedral planes in the majority of the sands, but those in monazite sand from Centerville are octahedral and are frequently much elongated and distorted. The most complex forms occur in the titanite and allanite bearing sand from Bear Creek. In this sand the altered pyrite crystals, which are abundant, show combinations of the cube, octahedron, and pentagonal dodecahedron, with possibly other forms. They would be exceedingly hard to identify by form alone were it not for the presence on all of them of the highly characteristic striations and grooves produced by oscillation between the cube and the pyritohedron. Altered pyrite crystals are sparingly present in all of the fine sands from Snake River and are very abundant in some of the coarser sands of the Boise Basin region.

ALLANITE.

Allanite was positively identified only in a sand from Bear Creek, in Camas County, although crystals of the same form and habit were noted in small number in several other sands, especially those from Minidoka and other Snake River localities. This mineral is difficult to distinguish by its form from certain prismatic black crystals of hornblende which occur occasionally. The Camas County sand consisted largely of magnetite, which, when extracted with a magnet, left a light-colored residue consisting mainly of irregular fragments of quartz. Scattered through this residue were crystals of titanite, zircon, garnet, etc., together with small black prisms with wedge-shaped terminations, which resembled augite crystals. One of these crystals upon being measured on the goniometer gave approximately the angles of epidote, which suggested that it might be allanite. A crystal was accordingly crushed and embedded in an oil having an index of refraction of 1.695 and examined with a petrographic microscope, when it was found to be doubly refracting almost throughout and distinctly pleochroic in tones of pale dirty brownish green and greenish black. Its indices of refraction were all distinctly lower than that of the oil, suggesting that the mineral was allanite (n=1.68 Larsen) rather than epidote (n=1.73–1.77 Larsen). Since the identity and orientation of the crystal were not suspected when it was measured, the direction of elongation was mounted as polar. The angles measured are given below as interfacial angles.

Angles of allanite crystal from Camas County (fig. 28).

Angle.	Reflections.	Measured.	Calculated.
		° ′	° ′
n ($\bar{1}11$)$\wedge n$ ($\bar{1}11$)	Good∧poor	70 54	71 35½
c (001)$\wedge a$ (100)	Very poor∧poor	65 20	64 59
c (001)$\wedge a$ (100)	Poor∧fair	65 32	64 59
c (001)$\wedge i$ ($\bar{1}02$)	Fair∧maximum illumination.	37 19	34 15½
a' ($\bar{1}00$)$\wedge r$ ($\bar{1}01$)	Poor∧fair	51 43	51 37

RUTILE.

Common red-black to deep-red rutile is unusually rare in these sands, the titanium being present mainly as ilmenite, with some titanite. Rare rounded prisms of deep-red rutile were found in a sand from Rhodes Creek, near Pierce City, and in a Snake River sand from Minidoka. A steely-lustered prismatic crystal 6 mm. long, found in the polycrase-bearing sand from Centerville, was identified as rutile. The prismatic zone is deeply striated, the forms present being a(100), m(110), and l(130). The crystal is terminated by the pyramid e(011). This crystal is shown in the drawing (fig. 23). It was peculiar in showing greenish internal reflections and when the crystal was crushed and examined in transmitted light the color was yellowish green, a very unusual color for rutile. As emphasized under "zircon," some of the light-colored crystals which have been described as that mineral may be rutile, the angles of rutile and zircon being so similar that very accurate measurements are necessary to distinguish between them.

AUGITE.

Augite is common in all of the Snake River sands examined and also occurs in lesser amount in several samples from Clearwater and Nez Perce Counties. It was not found in any of the sands from the

Boise Basin. This mineral coincides roughly in distribution with the rose-pink or purple variety of garnet referred to pyrope. In several Snake River sands augite is the most abundant ingredient. Those from Wapi and Minidoka especially containing 6 per cent or more of the mineral. The augite-bearing sands frequently contain more or less olivine in clear yellow crystals.

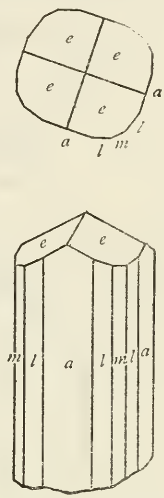


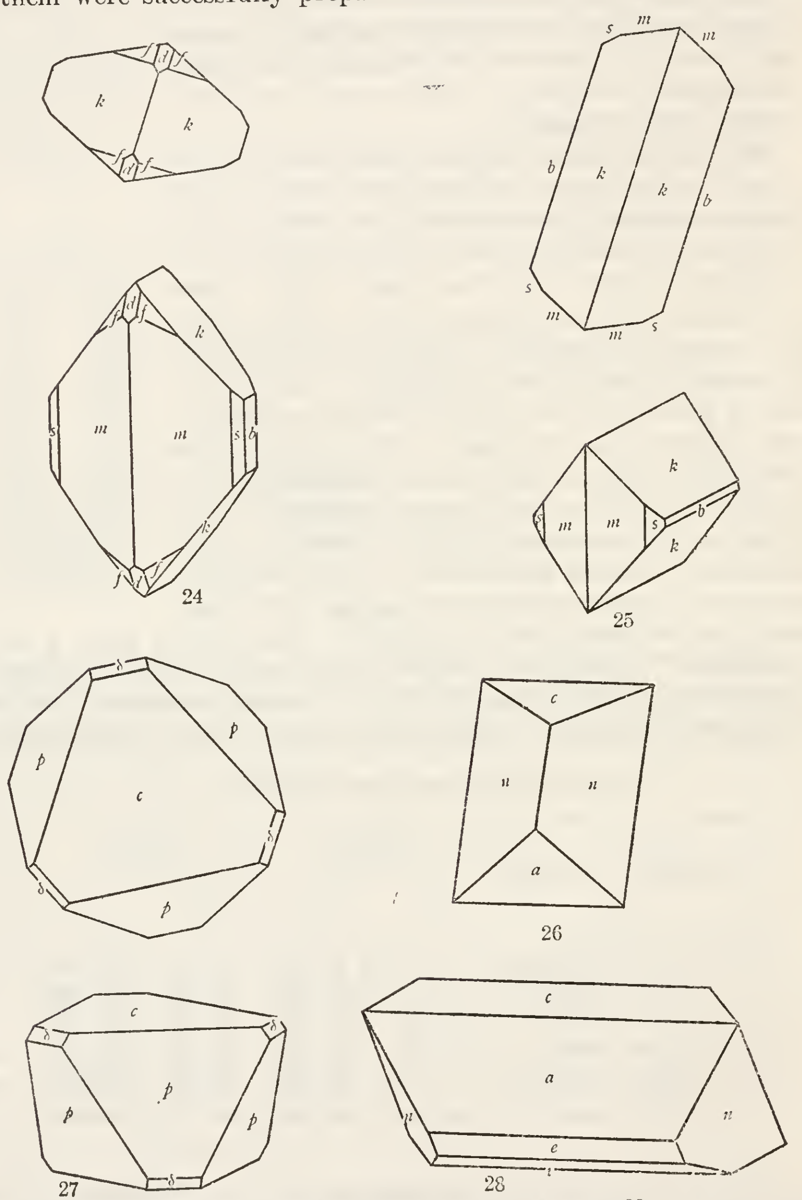
FIG. 23.—RUTILE CRYSTAL FROM CENTERVILLE.

The augite occurs in irregular grains and imperfect crystals which vary from emerald green through various shades of pistachio and olive green in color. They are very similar in color to some of the titanite occurring in the sand from Bear Creek, Camas County, but differ in form and luster. The crystals are commonly prismatic in form and are etched and corroded so that, although bright and glassy, very few of them have faces which yield measurable signals. There is no cleavage visible and the glassy green grains and crystals were at first thought to be olivine. Careful search, however, revealed crystals which could be measured and these gave the angles of augite. The few measurable crystals found gave fairly good signals in the prism zone but the terminal faces are invariably etched and dull. One crystal gave a faint "schimmer" reading on a terminal face which indicated approximately the negative pyramid $s(\bar{1}11)$. The angles measured on this crystal which identify it as pyroxene are given in the following table:

Angles of augite crystal from Minidoka (fig. 21).

Letter.	Miller.	Reflection.	Measured.		Calculated.	
			ϕ	ρ	ϕ	ρ
			° ′	° ′	° ′	° ′
m	110	Very good..	43 27	90 00	43 33	90 00
m	110	Good......	43 52	90 00	43 33	90 00
m	110	Very good..	43 36	90 00	43 33	90 00
a	100	Poor.......	90 02	90 00	90 00	90 00
a′	$\bar{1}00$	Good......	90 12	90 00	90 00	90 00
b	010	...do.......	0 00	90 00	0 00	90 00
b	010	Very poor..	1 07	90 00	0 00	90 00
s	$\bar{1}11$	...do.......	28 54	33 30	25 07	33 04

Several of the coarser unscreened sands from Minidoka, which were rich in augite, contained small pebbles, the great majority of which were seen under the binocular to consist of a cellular gray rock containing glassy-green grains in a light gray ground. The grinding of thin sections of these small pebbles, which averaged about 3 millimeters in diameter, was difficult, but about a half dozen of them were successfully prepared. These sections were all alike



FIGS. 24–28.—24–25, OLIVINE; 26, TITANITE; 27, ILMENITE; 28, ALLANITE.

and consisted of a fresh rock of marked ophitic texture having laths of twinned plagioclase feldspar in a ground of glassy augite. The sections also contained scattered comparatively large tabular crystals of ilmenite.

OLIVINE.

Olivine occurs sparingly in all of the sands from Snake River localities as clear pale-yellow angular grains. In several samples from Minidoka it is present as clear pale lemon-yellow crystals with highly lustrous faces. These resemble small topazes or crystals of chrysoberyl and their identity was not suspected until they were measured and found to have the angles of olivine. The dominant forms present are the prism $m(110)$ and the dome $K(021)$ with the prism $s(120)$ and the brachypinacoid $b(010)$ less prominent. The machrodome $d(101)$ and the pyramid $f(121)$ occur rarely as very small faces, as shown in figure 24. The combination of forms is the same on all of the crystals measured, but they vary in development, ranging from short prismatic parallel to the vertical axis (fig. 24) to moderately long prismatic by elongation on the a axis (fig. 25). Similar clear-yellow olivines from other samples of Snake River sands do not show measurable faces. Occasionally the brilliant yellow crystals of olivine have an outer coating of pale brown clay. Many of the crystals contain abundant small included grains of black iron ore. The forms present were identified by the following angles:

Angles of olivine from Minidoka.

Letter.	Miller.	Reflection.	Measured.		Calculated.	
			ϕ	ρ	ϕ	ρ
			° ′	° ′	° ′	° ′
b	010	Good......	0 00	90 00	0 00	90 00
m	110	Very good..	65 11	90 00	65 01	90 00
s	120	Good......	47 19	90 00	47 01	90 00
K	021	...do.......	0 00	49 16	0 00	49 33
d	101	Very poor..	90 00	50 48	90 00	51 32

QUARTZ.

Quartz in the form of angular dirty white or brownish sand occurs abundantly in the sands which have not been too far concentrated, this being the most abundant of the lighter constiuents eliminated by panning. This mineral also occurs frequently in concentrates of the heavy materials as small brilliant transparent colorless crystals formed by the combination of the plus and minus rhombohedrons without prismatic planes, as shown in figure 20. Many of these crystals resemble octahedral crystals of diamond where the hexagonal form is not easily distinguishable. Just why they should persist in the heavy concentrate rather than be eliminated by panning is not clear.

HORNBLENDE.

Although also a lighter constituent which is usually eliminated in concentrating, hornblende is occasionally present in the heavy concentrates. The mineral is usually in imperfect pale green prismatic forms which have an opaque weathered and frayed appearance. Fresher greenish-black cleavages of hornblende were noted in some samples, especially in Snake River sands from Wapi and Minidoka.

CORUNDUM.

Corundum is a mineral which has probably been removed from the sands by screening, as it ordinarily occurs in crystals much larger than the average grain of the sands and owing to its hardness and tenacity it is seldom reduced to small size by wear. This mineral was noted only as one or two crystals having the form of rounded hexagonal tablets in the sand from Rosa, Bingham County. Corundum is known to be common in many gold-bearing gravel deposits in the region around Pierce City and near Resort, in Idaho County. A placer mine near Meadows, in Washington County, has also yielded numerous crystals of corundum, some of gem quality. Specimens of corundum from Resort which are preserved in the United States National Museum are rough hexagonal crystals up to 1 inch in diameter having gray to blue and lavender colors. One crystal is tabular and brown in color with a bronzy metalloidal sheen.

CHALCOPYRITE.

Chalcopyrite was found as angular grains in a sand from Wapi on the Snake River. The broken fragments are without definite form and they all have a thin translucent enamel-like coating of some dull green material which resembles a colloidal iron silicate rather than an oxy-compound of copper. Broken irregular grains of chalcopyrite occur also in the radioactive samarskite concentrates from Idaho City.

OBSIDIAN.

While not a mineral, volcanic glass deserves mention as one of constant though not abundant constituents of the lighter sands from Snake River localities. It occurs as thin chips of a smoky gray to black color which have sharp edges and show traces of conchoidal fracture. The chips are not at all water-worn.

GOLD.

Gold in grains, flakes, and nuggets occurs frequently in the sands, and in many of those which contained no visible gold it was probably originally present having been removed by amalgamation. Flat flakes of gold are of frequent occurrence in sands from Rosa, Bingham County, and less abundantly so in other Snake River sands from Wapi and Minidoka. Small rounded grains of a deep yellow color were noted in the nonmagnetic residue of a sand from Bear Creek, in Camas County. An "oversize" sample of coarse material from Centerville, consisting of pebbles of garnet, granular magnetite, irregular ilmenite, and several radioactive uranium minerals contained several slightly worn rusty quartz pebbles containing abundant pale-colored gold.

CYANITE.

While not properly a mineral of the heavy sands, cyanite was seen as grayish-blue blades in a rusty granular quartz matrix in one pebble from an unscreened sand from Snake River at Minidoka.

EPIDOTE.

Epidote may occur sparingly in some of the sands examined, being similar in appearance to augite and olivine, from which it could not be distinguished by its appearance alone. Pebbles of pale-green epidote in massive granular form were noted in the coarser portion of sand from Rosa, Bingham County, associated with pebbles of similarly fine-grained brown garnet, both evidently being fragments of a metamorphic hornfels.

CINNABAR.

Cinnabar occurs sparingly in a sand from Pierce City, which consists largely of ilmenite in brilliant black grains and also contains rutile, monazite, and zircon. The cinnabar is deep red in color with a grayish metallic cast. The majority of the grains are rounded pebbles of fine granular, massive cinnabar, but many of them are more or less transparent fragments of single cinnabar crystals and a few are crystals bounded by imperfect faces which could not be identified. It seems probable that much of the cinnabar of the original gravel was in larger masses which were eliminated by screening.

The United States National Museum collections contain pebbles of impure massive cinnabar up to 1 inch in diameter from a placer near Resort. Small rounded grains of cinnabar were noted in small number in the polycrase-bearing sand from Centerville.

LIST OF LOCALITIES AND COMPOSITIONS OF HEAVY SANDS EXAMINED.

The following list gives the locality, average size of grain, and chief minerals of the 52 sands from Idaho localities which were examined during the course of the present work. Each sand is assigned a new serial number, and the original number accompanying the sand is given. It is to be remembered that none of these are natural sands, all having been greatly concentrated by gravity processes or separated magnetically before coming to the museum. In many instances the samples are merely fractional products of several successive concentrating and purifying processes. The arrangement is by localities, the counties being listed alphabetically.

ADA COUNTY.

1. Snake River, near Boise. Original number P 114. Abundant quartz; rare obsidian, biotite, pyrope, augite, olivine, chalcedony, and hornblende. Probably tailings from a concentrating table. Average grain diameter 0.5 mm.
2. Same locality. Original number P 114. Abundant quartz; common augite and olivine; rare biotite and obsidian. Evidently also tailings. Average grain diameter 0.75 mm.
3. Same locality. Original number P 114. Abundant quartz and ilmenite; rare pyrope, almandite, biotite, magnetite, olivine, augite, and obsidian. Average grain diameter 0.5 mm.

BINGHAM COUNTY.

4. Snake River, at Rosa. "Auriferous sand." Cat. No. 53,625 U. S. N. M. Abundant ilmenite, magnetite, pyrope; occasional augite, almandite, and quartz; rare zircon, gold, olivine, corundum. Average grain diameter 0.1 mm.

BOISE COUNTY.

5. Centerville. "Monazite sand." No number. Abundant monazite, ilmenite, quartz, and zircon; occasional almandite. Grain diameter 0.3–0.5 mm.
6. Grimes Creek, Centerville. Original number P 249. Abundant quartz; common monazite, biotite, ilmenite; rare almandite and zircon. Grain size, average, 0.5 mm.
7. Centerville. "Monazite separated by Lovett separator." Cat. No. 90,480 U. S. N. M. Abundant monazite, zircon, ilmenite; occasional magnetite and quartz. Average grain diameter 0.50 to 0.75 mm.
8. West side of Grimes Creek, ¼ mile north of Centerville. Original number P 657*a*. Abundant quartz, kaolinized feldspar; rare muscovite, almandite, ilmenite, biotite, hornblende, and epidote. Average grain diameter 1 mm. Probably tailings.
9. Centerville. Original number P 771 "oversize." Common polycrase, ilmenite, samarskite; rare gold, uraninite (?), tapiolite (?), microlite (?), pyrochlore (?), monazite, hematite, magnetite. Average grain size 5 mm.
10. Oaks Placer Mine, Centerville. Original mark "P 670, ilmenite, 2.3 amperes." A magnetic concentrate. Abundant biotite; common monazite and zircon; rare epidote, quartz, limonite pseudomorphs after pyrite, and almandite. Grain size averages 1 mm.
11. Centerville. Originally marked "monazite 5 amperes." Abundant monazite, with rare zircon, muscovite, biotite, and feldspar. Grain size 0.50 to 0.75 mm.
12. Centerville. Original No. P 670. Marked "zircon, under tails, 20.2." Abundant zircon; rare quartz, garnet, monazite. Grain size varying from 0.10 to 2 mm.
13. Idaho City dredge, Idaho City. Original No. P 654. Mainly monazite with common ilmenite and zircon. Grain size 0.10 mm.

14. Same locality. P 654. Abundant monazite; common zircon; rare muscovite, polycrase (?), samarskite (?). Average grain size 0.50 mm.
15. Same locality. P 654. Marked "magnetite." Chiefly magnetite, with rare almandite, monazite, zircon, and ilmenite. Average grain size 0.10 mm.
16. Same locality. P 654. Marked "garnet." Almost wholly almandite; rare columbite, ilmenite, and samarskite. Grain size averages 2 mm.
17. Same locality. P 654. Marked "chromite." Abundant ilmenite; common almandite; rare chromite (?), columbite, polycrase, zircon. Grain size variable up to 2 mm.
18. Same locality. P 654. Marked "garnet." Abundant almandite, columbite, samarskite; rare limonite, zircon, monazite, polycrase. Maximum grain diameter 3 mm.
19. Same locality. P 654. Marked "monazite, through 80 on 100 mesh, 2.5 amperes." Abundant monazite; rare biotite, zircon, ilmenite, hornblende, titanite. Grain size, average, 0.10 mm.
20. Same locality. P 654. Marked "monazite, special, through 60 on 80 mesh, 3.50 and 3.75 amperes." Abundant monazite; rare zircon, muscovite, biotite, and ilmenite. Grain size 0.25 mm.
21. Same locality. P 654. Marked "olivine." Abundant samarskite, columbite; rare yttrotantalite (?), fergusonite (?), polycrase, monazite, cinnabar, chalcopyrite, zircon. Grain size, average, 2 mm.
22. Same locality. P 654. Marked "monazite, special, through 60 on 80 mesh, 4.00, 4.25, 4.50, 4.75, and 5.00 amperes." Abundant zircon and monazite; occasional ilmenite and muscovite. Grain size, average, 0.25 mm.
23. Same locality. P 654. Marked "monazite, special, through 60 on 80 mesh, 2 amperes." Abundant monazite, ilmenite, samarskite, zircon; occasional muscovite and biotite. Grain size, average, 0.25 mm.
24. Same locality. P 654. Marked "monazite, special, through 80 on 100 mesh, 4.50, 4.75, and 5.00 amperes." Abundant zircon, monazite, and quartz; common muscovite. Grain size, average, 0.2 mm.
25. Same locality. P 654. Marked "monazite, through 80 on 100 mesh, 3.75 amperes." Abundant monazite; occasional zircon, quartz, and muscovite. Grain size, average, 0.10 mm.
26. Same locality. P 654. Marked "monazite, through 80 on 100 mesh, 4.00 and 4.25 amperes." Abundant monazite; occasional zircon; rare quartz, muscovite, and ilmenite. Grain size, average, 0.10 mm.
27. Same locality. P 654. Marked "monazite, through 60 on 80 mesh; 3.25 amperes." Abundant monazite; common zircon; rare muscovite, biotite, chlorite, samarskite.
28. Centerville. Cat. No. 90,480 U. S. N. M. Abundant monazite, ilmenite; occasional zircon and magnetite. Average grain size 0.75 mm.

CAMAS COUNTY.

29. Bear Creek. Abundant magnetite, quartz; common almandite, limonite pseudomorphs after pyrite; rare gold, allanite, titanite, and zircon. Average grain size 1 mm.

CLEARWATER COUNTY.

30. Cow Creek, Pierce district. Original number P 280. Abundant ilmenite, pyrope; common quartz, monazite, and titanite; rare augite and zircon. Average grain size 1 mm.

31. Cow Creek, Pierce district. Original No. P 280*a*. Abundant ilmenite, monazite, and pyrope; occasional quartz; rare titanite. Grain size varying from 0.20 to 2 mm.
32. Pierce City. Original No. P 292. Predominant ilmenite; common monazite; rare gold, zircon, cinnabar, rutile. Grain size, average, 1 mm., maximum, 3 mm.
33. Rich Hill Mining Co., Pierce City. Original No. P 292. Marked "cinnabar." Abundant ilmenite and quartz; rare magnetite, muscovite, zircon, monazite, and cinnabar. Average grain size 2 mm.
34. Rhodes Creek, Pierce City. Original No. P 293. Predominant ilmenite; rare monazite, titanite, pyrope, zircon. Grain size, average, 0.5 mm.
35. Pierce City. Marked "oversize." Abundant ilmenite, pyrope, and quartz; occasional magnetite. Grain size, average, 5 mm.

ELMORE COUNTY.

36. Big Rock placer claim, Wood Creek. Original No. P 273. Marked "zircon." Predominant zircon; abundant garnet (pyrope?), monazite, and ilmenite. Grain size, average, 0.25 mm.

IDAHO COUNTY.

37. Resort. Original No. P 641. Marked "4.5 amperes." Predominant monazite; common black hornblende; rare ilmenite, biotite. Average grain size, 1.20 mm.
38. Salmon River. Original No. P 235. Marked "zircon." Predominant zircon; common gold, garnet, ilmenite, augite; rare olivine, monazite. Grain size, average, 0.10 mm.
39. Baboon placer, Elk City. Original No. P 219. Marked "monazite." Abundant monazite, titanite; common samarskite (?), ilmenite; rare polycrase (?), biotite, muscovite. Grain size, variable, 0.25 to 3 mm.
40. Same locality. P 219. Marked "zircon." Predominant zircon; abundant monazite; occasional ilmenite; rare almandite, gold, cinnabar. Grain size, average, 0.10 mm.

MINIDOKA COUNTY.

41. Riverside placers, Snake River, 8 miles east of Wapi. Original No. P 275. Predominant ilmenite; rare gold, zircon, augite, almandite, pyrope, quartz, olivine. Average grain size, 0.10 mm.
42. Same locality. Original No P 275. Predominant ilmenite; occasional pyrope, quartz, almandite, augite, zircon. Grain size, average, 0.10 mm.
43. Same locality. Original No. P 275. Predominant quartz; abundant ilmenite; occasional pyrope, almandite, augite, obsidian. Average grain size, 0.20 mm.
44. Same locality. Original No. P 275. Crushed oversize. Predominant quartz; rare muscovite, obsidian, limonite, chlorite. Average grain size, 2 mm.
45. Minidoka. Original No. 839*a*. Marked "Snake River gravel." Abundant ilmenite and augite; common olivine, pyrope, quartz; rare allanite (?), zircon, and magnetite. Average grain size 0.25 mm., unscreened and variable.
46. Same locality. Original No. 839*c*. Abundant quartz; common augite; rare olivine, limonite, obsidian. Variable grain, sand averaging 0.25 mm., but numerous small pebbles averaging 3 mm.

47. Same locality. Original No. 839*c*. Abundant ilmenite; common quartz; augite and pyrope; rare gold, almandite, magnetite, allanite (?). Sand averaging 0.50 mm., pebbles of various rocks up to 1 cm. in diameter.
48. Same locality. Original No. 839*y*. Abundant quartz; frequent augite, allanite (?); rare olivine, ilmenite, pyroxene. Grain size, average, 0.20 mm.
49. Snake River, Wapi. Original No. P 275. Abundant augite, pyrope, ilmenite; common quartz; rare olivine, biotite, magnetite, almandite, limonite, allanite (?). Average grain diameter, 0.30 mm.

NEZ PERCE COUNTY.

50. Early Bird placer, on Clearwater River, near Lewiston. Original No. P 627. Abundant pyrope; common ilmenite, hornblende, almandite; rare augite, olivine. Average grain diameter, 0.50 mm.
51. French Creek. Original No. P 664. Abundant ilmenite; common quartz; rare zircon, magnetite, monazite, titanite (?). Average grain diameter, 0.50 mm.

ONEIDA COUNTY.

52. Fall Creek placer, Snake River. Original No. P 236. Abundant quartz; common augite, ilmenite; rare muscovite, biotite, gold, almandite, obsidian, magnetite, pyrope, olivine. Average grain diameter, 0.20 mm.