Specimen No. 9988.—Figure 3 represents a plate with a length of 164 mm. The greatest width is 50 mm. The plate shows fine lines radiating from a common center to the periphery, the highest point being at the center. The surface is covered with small pits or dots. It resembles very much the frontal plate of *Onychodus sigmoides* Newb, as figured by Dr. Newberry,[7] in having lines radiating to all parts from a common center, except that the radiating ridges are not so pronounced, and in that the specimen is relatively long for its width. It resembles *Megalichthys hibberti* in having the surface covered with fine pits or dots.[8]

Specimen No. 9900.—A long slender bone (fig. 5) constricted on each side of the middle, which is swollen on one edge resembling a point of articulation. The ends flare out on one side to a thin convex fan, the planes of the expanded portions being twisted at an angle of about 70°. Length about 160 mm., diameter at narrowest point 9 mm., diameter at swollen portion 13.5 mm.

Specimen No. 9987.—Figure 4 represents the impression of the inside of a cycloidal scale showing oval outlines parallel to the periphery. Length 76 mm., width 35 mm. The impression resembles the inner aspect of a scale of *Rhizodus ornatus* Trq. figured by Woodward.[9] If this specimen belongs to the same form as the folded teeth, the greater affinity is with the Megalichthyidae rather than with the Osteolepidae, as the scales are of cycloidal shape.

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[7] Newberry, J. S., U. S. Geol. Surv. Mon., Vol. 16, pl. 37.
[8] Trans. Roy. Soc. Edinb., Vol. XIII, p. 194.
[9] Woodward, A. S., Catlg. of Fos. Fish. Brit. Mus., Vol. II, Pl. XII, fig. 9.

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BENITOITE, A NEW CALIFORNIA GEM MINERAL.

BY
GEORGE DAVIS LOUDERBACK,
WITH CHEMICAL ANALYSIS BY
WALTER C. BLASDALE.

The mineral which is the subject of this note was discovered early in this year by Mr. Hawkins and T. Edwin Sanders, who were prospecting in the southern part of the Mt. Diablo range, near the San Benito-Fresno County line, about latitude 36° 20′. It was first brought to the writer's attention by Shreve & Company, who had purchased one of the cut stones from a lapidary and who were later offered some of the rough material as sapphire. They soon determined that it was not sapphire but were unable to place it, and so sought the aid of the University. Sufficient material for the chemical analysis and for the crystallographic and other determinations was kindly supplied by Mr. Hal Sanders of San Francisco, a brother of one of the original discoverers. The writer is also indebted to Professor O'Neill for the privileges of the chemical laboratory and for many courtesies.

As the progress of the investigation has shown that it is a new mineral species, it has been called benitoite, as it occurs near the head waters of the San Benito River in San Benito County.

The most striking characteristic of the mineral is its blue color, and selected crystals cut in the right direction produce a beautiful gem stone that rivals the sapphire in color and excels it in brilliancy. The color, however, although fairly characteristic, is not an essential property, for very commonly parts of a crystal are colorless, while occasionally perfectly colorless small crystals are found. The color also varies in intensity in different crystals or in parts of the same crystal. When pale it is a rather pure blue. When more intense it assumes a violet tint. In addition to this variation in color in different parts of crystals, there is a difference at any one point, depending on the direction in which the light passes. In other words, the mineral is strongly dichroic, the ordinary ray being colorless, the extraordinary, blue. A section cut parallel to the basal plane is practically colorless, while sections parallel to the principal axis show the deepest color. To get the finest effect, therefore, gems should be cut with the table parallel to the principal axis, and this is in contrast to the sapphire, which shows its color best when cut perpendicularly thereto. If such a section, cut so as to give the strongest color effects, be examined with a dichroscope, the contrast between the images is most striking. The image of the extraordinary ray being freed from the colorless image of the ordinary ray, presents a remarkable intensity of color, very much deeper, of course, than can be seen by looking at the mineral in any direction with the unaided eye. In the lighter parts this color of the extraordinary ray is a slightly greenish blue inclining to indigo as it becomes darker, and is very similar to one of the axial colors shown by some cordierites; but in the more highly colored or thicker parts it is an intense purplish blue.

The color is not affected by heat up to the melting point of the mineral. Fragments heated to a rather bright red and maintained at that heat, just short of fusion, for five minutes showed no change whatever on cooling.

Benitoite occurs generally in individual simple crystals scattered through the matrix and varying from a few millimeters to about two centimeters across. The matrix being translucent white, the blue transparent crystals stand out prominently and often show crystal faces.

It crystallizes in the hexagonal system, trigonal division. The observed forms are the basal plane, the plus and minus

trigonal pyramid and the corresponding trigonal prisms. The normal angle between the basal plane and the pyramid is about 40° 14′. If the pyramid be taken as a unit pyramid of the first order, this would yield an axial ratio of .7327, if of the second order, .8460.

The most common habit is pyramidal, one pyramid being the chief form, the other occurring as a small but regular and brilliant truncation. One or both prisms may be present as narrow truncations and also a small triangular basal plane.

Occasionally the base is developed into a broad plane, the crystals then having a more nearly tabular habit. The outline of the base may then be hexagonal but the edges corresponding to one pyramid will be considerably longer than the others.

Only one crystal was found where the two pyramids were nearly equally developed. The development of the faces at one end of the principal axis always corresponds so well with those at the other, that it gives the impression that the horizontal plane of symmetry is present. No tendency towards a prismatic habit was observed. The angles between two adjoining pyramid faces at one end of axis is 68° 1′. There is an imperfect pyramidal cleavage. The fracture is conchoidal to subconchoidal. The hardness is $6\frac{1}{4}$-$6\frac{1}{2}$; distinctly above orthoclase and labradorite and below chrysolite and quartz; density, 3.64-3.65.

The refractive index is quite high, which adds greatly to the beauty of the cut stone. For the ordinary ray it is about 1.77 (sodium light), for the extraordinary, about 1.80. The double refraction is therefore very strong and the mineral optically positive. Basal sections show a perfect uniaxial cross which gives a distinct positive reaction with the mica plate. The pleochroism has already been described and evidently the absorption is $e > o$. Some difficulty was experienced in getting a value for ϵ, as sodium light is strongly absorbed even in light colored specimens a couple of millimeters thick.

The mineral fuses quietly to a transparent glass at about 3. It is practically insoluble in hydrochloric acid, but it is quite easily attacked by hydrofluoric acid, and dissolves readily in fused sodium carbonate.

The mineral has proved to be of considerable interest from the standpoint of its chemical composition. Professor Blasdale, who kindly undertook the chemical analysis, reports:

	A.	B.	Average.	Mol. Ratios.
SiO_2	43.56	43.79	43.68	.723
TiO_2	20.18	20.00	20.09	.250
BaO	36.34	36.31	36.33	.237
	100.08	100.10		

The suggested formula is $BaTiSi_3O_9$, which yields the following calculated values:

SiO_2	43.71
TiO_2	19.32
BaO	36.97
	100.00

Professor Blasdale also reports that the mineral is easily decomposed by hydrofluoric acid, but only slowly attacked by molten potassium pyrosulphate.

Benitoite is then a very acid titano-silicate of barium, and stands in a class by itself, both as regards acid silicates and titano-silicates. The possibility of the titanium acting as a base was considered, but the summation of the analyses and the fact that the crystals are often perfectly colorless seem to point definitely to the above interpretation. The blue color of much of the material may be due to a small amount of titanium in the sesquioxide condition.

Associated with benitoite is a black or brownish black prismatic mineral that also appears to be new. Its most striking characteristic is a very perfect prismatic cleavage of 80° 10′. Its hardness is between 5 and 6 and it melts easily, at about 1.5, giving a sodium flame and becoming a lustrous black enamel bead. It appears to be monoclinic, is biaxial, and gives an extinction angle of about 10 degrees on the cleavage face. Its cross sections are six-sided, the four cleavage traces being truncated by a lateral pinacoid. In thick pieces it is opaque, but in moderately thin ones it is a deep rich red, which changes to a brownish or ocreous yellow as the thickness decreases. Pleochroism is prominent. On a cleavage plate the ray vibrating near the prism

axis is yellowish brown or ocreous yellow to reddish brown, the one perpendicular to this light yellow, absorption $\mathfrak{c}' > \mathfrak{a}'$ in which $\mathfrak{c}'$ lies nearest the prism axis. The refractive index is high—at least greater than that of monobromnaphthalene, 1.654.

The name carlosite is suggested for this mineral, from the nearby San Carlos peak, one of the highest points of that part of the range.

Benitoite and carlosite occur as individual disseminated crystals in narrow veins in a basic igneous rock or in a schist which has been considerably altered by the solutions that formed the veins. The benitoite is apparently restricted to the veins, the carlosite also occurring in the neighboring parts of the wall rock. The chief gangue of the veins is a soda rich zeolite. The properties of carlosite and the nature of the gangue were determined on small and unsatisfactory quantities, as the collectors were interested in the supposed sapphires and not in its matrix. The writer has recently been able to collect specimens of the matrix and crystals of carlosite and expects shortly to make a more extensive report on the properties of benitoite and carlosite, their paragenesis, etc.

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