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Uranium, rare-earth, and thorium mineralization at the Hope Mine, eastern Bristol Mountains, San Bernadino County, California

by

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Abstract

High-grade uranium, rare earths, thorium, and a diverse suite of other trace metals have been found at the Hope Mine in the eastern end of the Bristol Mountains near Amboy, California. Mineralization occurs along a sheared contact zone between an alkalic quartz syenite and Paleozoic dolomite. Spectrographic and delayed-neutron activation analyses show that uranium contents ranging from 0.5 percent to perhaps as much as 4.7 percent occur in silicified, fluorite-impregnated pods in carbonate gouge. Uranophane was identified by X-ray diffractometry. Total rare-earth content in one sample was about 2 percent. Thorium values as high as 1500 ppm are present. Boron, lithium, scandium, niobium, yttrium, lead, and zirconium occur in anomalous amounts. The high background radioactivity of the syenite, the presence of an extensive contact altered zone, evidence for uranium, thorium, and rare-earth mineralization at other prospects, and the numerous fault and fracture zones in the area suggest that further evaluation of the eastern Bristol Mountains for mineralization is warranted.

Introduction

Fluoborite with associated uranium and other minerals were first reported at the Hope Mine northeast of Amboy, San Bernadino County, California (fig. 1) by Chesterman and Bowen (1958). In their brief description of the property and its mineralogy they noted...

> "The fluoborite has formed at the contact between nordmarkite and dolomite and occurs associated with forsterite, fluorite, clinohumite, diopside, tremolite, calcite, dolomite, brucite, serpentine minerals, magnetite, uranophane, beta-uranotil and an unidentified uranium-yttrium mineral."

A later report by H. F. Bonham, Jr. (written commun., 1959), which resulted from a mineral survey of lands partly controlled by the Southern Pacific Land Co., describes a brief examination of the Hope property. He expanded on Chesterman and Bowen's observations noting:

> "Small shears have probably controlled the later deposition of the fluorine-boron minerals and the uranium minerals . . . according to L. R. Benson (oral communication) of Amboy, California, owner of the claims, several pods of high-grade uranium ore have been developed in the inclined shaft. Several samples were obtained from the dump of the main shaft. They consist of white to tan silicified dolomite, colored pale to dark purple by finely crystalline fluorite. Yellow uranium minerals occur as fracture coatings. One sample had five times background activity."

Bonham stated that they did not visit the subsurface workings, but concluded that the uranium potential was small and that the best possibility was rare-earth minerals.

In addition, in a report on the area directly to the west, R. T. Laird (written commun., 1959) described a copper-fluorite prospect and a uranium propsect. He suggested that these prospects represented the western extension of the known fluoborite metasomatized rock. He stated that the radioactivity at the uranium prospect is twice normal background. One sample contained 0.41 percent uranium. Several representative rock samples from the area were scanned with a scintillometer and the fluoborite- and uranium-bearing tactite

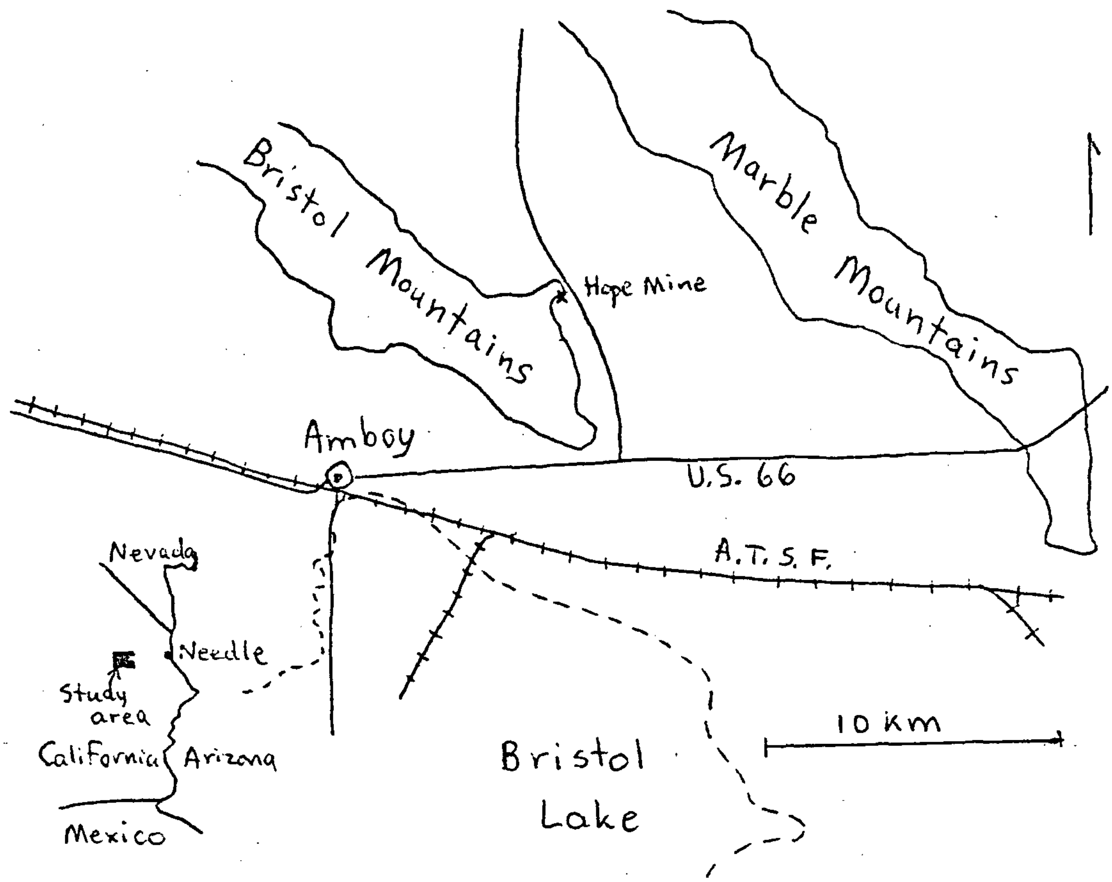

Figure 1.--Location map for the Hope mine

rocks gave a reading of 15 MR/hour. In addition, the syenite gave a slightly higher background count.

The authors visited the property in early February 1978. We examined the dump and found mineralization similar to that previously described. We also examined and sampled the accessible portions of the inclined adit. The shaft workings were inaccessible. Two weeks later Otton spent two days in the east Bristol Mountains examining known prospects in the area and mapping the accessible underground workings at the Hope Mine. The following discussion is based on those examinations, analysis of the samples collected and the geologic maps accompanying the reports of H. F. Bonham, Jr. (written commun., 1959) and R. T. Laird (written commun., 1959).

Geology of the eastern Bristol Mountains

The east part of the Bristol Mountains is underlain by a large syenitic pluton which has intruded Precambrian metaigneous rocks and Paleozoic carbonate rocks (H. F. Bonham, Jr., written commun., 1959; R. T. Laird, written commun., 1959). Chesterman and Bowen (1958) described the intrusive as a nordmarkite (quartz syenite). Whole-rock analyses and CIPW norms of a sample from the Hope mine area (table 1) suggest that the intrusive is an alkalic quartz syenite. Further work on the pluton seems warranted. The pluton is Late Jurassic in age as suggested by biotite K-Ar ages of 151±2 m.y. and 139±4 m.y. for a sample from the Hope mine and an outcrop along highway U.S. 66 at the southern end of the range, respectively (J.P. Calzia, oral commun., 1978).

The Paleozoic carbonate includes both dolomitic and calcitic units and has undergone pervasive contact metamorphism. Many large xenoliths of carbonate occur within the syenite. A contact-metasomatic magnetite iron prospect (Black Jack) occurs about 2 kilometers south of the Hope mine (N, NE, NW, sec. 30, T. 6 N., R. 13 E.). Other small iron prospects were observed. Prospecting and quarrying of exceptionally pure, coarsely crystalline limestone has occurred at a property about 3 kilometers south of the Hope Mine (NE1/4NE1/4SE1/4 sec. 30, T. 6 N., R. 13 E.).

Numerous high-angle normal faults cut the crystalline terrain. They generally exhibit N. 30° E. to N. 50° E. and N. 25° W. to N. 45° W. trends. The age of this faulting is unknown.

Geology of the mine area

The Hope mine is on the northwest side of a southeast-trending ridge that plunges beneath alluvium a few hundred meters southeast of the mine. The workings at the mine include an inclined shaft that followed a steep northeast-trending, southeast-dipping fault zone, a lower adit to the west that intercepted the fault zone about 30 or 40 meters from the portal, and a vertical shaft just to the northeast of the inclined shaft. Syenite forms the hanging wall of the fault whereas altered dolomitic marble occurs on the foot wall.

The syenite on the hanging wall is coarsely crystalline, pale brownish gray (5YR 7/1), and, in hand specimen, is composed of an interlocking network of feldspar grains with lesser interstitial quartz, biotite, and a dark greenish-black amphibole or pyroxene. Adjacent to the fault and along minor fractures that extend away from the fault the syenite has been bleached white. Feldspar grains in the bleached rock are white to very pale orange (10 YR 8/2). Green mafic minerals have been altered to an unidentified pale yellowish-brown material. Textures and quartz content appear unchanged in hand specimen.

Table 1.--Whole-rock analysis and CIPW norms for quartz syenite (Sample NB78-9A)

[Rapid rock analysis, R. V. Mendes, analyst. Calculated by M. H. Staatz]

Analysis (percent)		Norms (percent)	
SiO_2	69.7	Orthoclase	36.14
Al_2O_3	15.7	Albite	38.77
Fe_2O_3	1.9	Anorthite	3.89
FeO	0.52	Quartz	16.38
MgO	0.45	Magnetite	0.23
CaO	1.2	Hematite	1.76
Na_2O	4.6	Diopside	0.86
K_2O	6.2	Hypersthene (Mg)	0.7
H_2O^+	0.06		98.73
H_2O^-	0.34		
TiO_2	0.54		
P_2O_5	0.06		
MnO	0.06		
CO_2	0.02		
TOTAL	101.35		

In the inclined shaft the fault zone is well-exposed in a pillar that crosses the stope (fig. 2). The hanging wall is composed of bleached syenite. Syenite is separated by a sharp fault break from 10 cm of sheared white clay gouge. Adjacent to this is 12 cm of crushed red-purple silicified dolomite. Next is a zone about 0.7 meters wide composed of two rock types: clayey, partly silicified iron-stained dolomite with minor fluorite veining and highly silicified, crushed dolomite with abundant fluorite veins and yellow staining. This latter rock type appears to form irregular pods in the fault zone. The footwall side is composed of sheared altered dolomite.

The fault zone can be traced in outcrop for about 100 meters southwest from the portal opening of the inclined shaft. The fault zone is exposed in the adit. Here the fault zone is 2 to 3 meters wide and consists of highly sheared and crushed, altered, iron-stained, clayey dolomite.

Northeast of the portal of the inclined shaft the trace of the fault is covered by the mine dump, colluvium, and alluvium. Although exposed for a little more than 100 meters, the true lateral extent of this fault zone is unknown. The mapping by H. F. Bonham, Jr. (written commun., 1959) and R. T. Laird (written commun., 1959) shows a northeast-trending fault about 1.6 km long along the ridge to the northwest of the mine.

Geochemistry and mineralogy

Several samples of rocks from the mine area were collected for analysis. Table 2 gives uranium and thorium analyses for samples from the inclined shaft area and the adit, table 3 gives rare-earth data, table 4 all other elements, and table 5 gives X-ray mineralogy for samples from the fault zone in the inclined shaft.

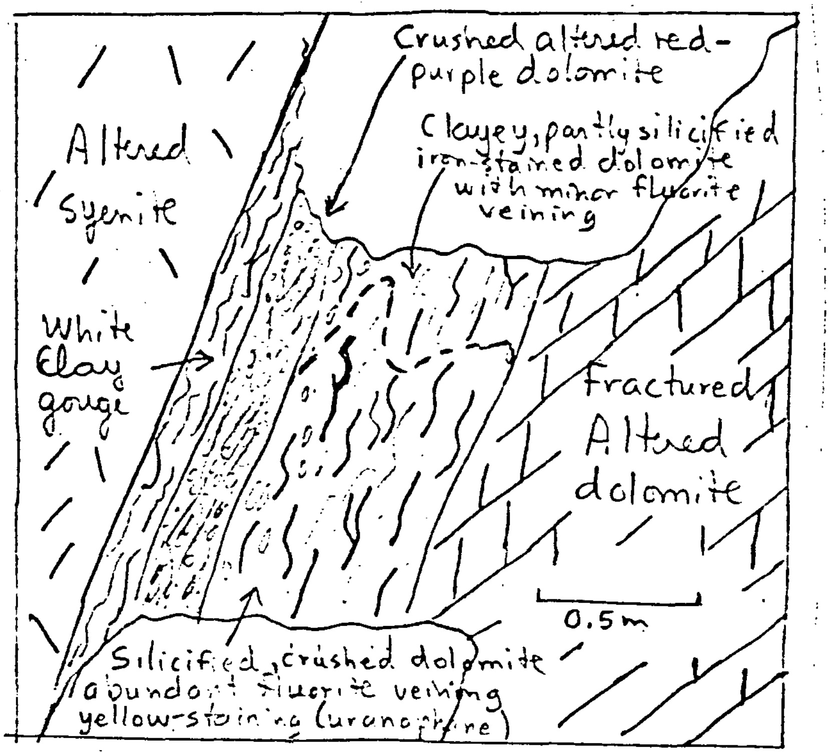

Figure 2.--Sketch of pillar across fault zone in the inclined adit.

Table 2.--Uranium and thorium analyses of samples from the Hope Mine

Sample no.	Rock type	Uranium		Thorium	
		Spec.[1]	DNA[2]	Spec.[1]	DNA[2]
NB78-9B	Altered carbonate in ore pod	15,000	--	500	--
9C	Altered carbonate in ore pod	30,000	<47,000	1,500	*4,900
9D	Altered clayey carbonate in shear zone--------------------	N	--	N	--
9E	Altered clayey carbonate in shear zone--------------------	2,000	1,050	N	*330
9F	Altered carbonate in ore pod	15,000	13,000	1,500	*6,100
NN78-8A	Altered clayey carbonate in shear zone--------------------	--	280	--	*51
8B	Altered carbonate-fluorite in ore pod--------------------	--	4,890	--	*4,100
8C	Altered carbonate in footwall	--	3.05	--	2.5
8D	Quartz syenite of hanging wall	--	2.72	--	19.2
8E	Bleached quartz syenite of hanging syenite wall--------------------	--	3.78	--	21.8
8F	Quartz syenite of hanging wall	--	1.70	--	16.6
8G	Altered carbonate in shear zone, lower adit----------------------	--	95.5	--	*21
8H	Altered carbonate in shear zone, lower adit----------------------	--	101	--	*21
8I	Altered carbonate, in shear zone, lower adit----------------------	--	11.9	--	29.0

[1]Spec. = Uranium and thorium by semiquantitative six-step spectrographic analysis, L. A. Bradley, analyst. N, Not detected--not analyzed.

[2]DNA = Uranium and thorium by delayed neutron activation, H. T. Millard, C. McFee, C. Bliss, M. Coughlin, B. Vaughn, M. Schneider, and W. Stang, analysts. Presence of fluorite in some samples made analyses for uranium impossible or unreliable.

Where Th-U <1, thorium data are not considered reliable (*).

Table 3.--Emission spectroscopy analyses for rare earth and related elements in samples from the Hope Mine (in parts per million)

[NB samples analyzed by Leon Bradley, Denver; NN samples analyzed by J. J. Seeley, Menlo Park; N, not detected; L, less than detection limit; leaders (--) indicate not analyzed]

Sample no.	La	Y	Ce	Yb	Pr	Nd	Sm	Gd	Dy	Ho	Er	Sc	Nb
NB78-9B	300	300	3,000	70	--	1,500	300	200	150	50	150	N	L
9C	1,500	1,000	7,000	20	1,000	5,000	1,000	700	300	150	300	N	L
9D	500	70	1,500	7	--	300	N	N	N	N	N	30	N
9E	150	150	700	7	--	300	N	N	N	L	N	N	N
9F	700	1,000	7,000	150	700	3,000	700	500	300	10	300	N	10
NN78-8A	1,000	150	3,000	--	--	--	--	--	--	--	--	20	<25
8B	200	300	1,500	--	--	--	--	--	--	--	--	15	<25
8C	20	10	100	--	--	--	--	--	--	--	--	<10	<25
8D	140	76	300	--	--	--	--	--	--	--	--	<10	30
8E	50	90	200	--	--	--	--	--	--	--	--	15	<25
8F	200	99	500	--	--	--	--	--	--	--	--	12	<25
8G	300	500	10,000	--	--	--	--	--	--	--	--	30	<25
8H	100	100	500	--	--	--	--	--	--	--	--	<10	<25
8I	200	74	700	--	--	--	--	--	--	--	--	<10	<25

Table 4.--Emission spectroscopy analyses for other elements in samples from the Hope Mines
(Fe, Mg, Ca, K, Na, and Ti in percent; all others in parts per million)

[NB samples, Leon Bradley analyst; NN samples, J. L. Seeley, analyst. N, not detected; L, less than detection limit; leaders (--) indicate not analyzed]

Sample no.	Fe	Mg	Ca	K	Na	Ti	Mn	B	Be	Ba	Co	Cr	Cu	Ni	Pb	Sr	V	Zr	Li	Ga	Ge
NB78-9B	0.7	7.0	G	N	0.2	0.05	500	30	N	30	15	20	3	15	300	300	15	150	300	N	N
-9C	3.0	10.0	5.0	1.5	0.3	0.1	700	150	N	50	30	20	L	15	1000	150	15	300	700	N	N
-9D	1.5	10.0	G	N	0.15	0.02	300	L	5	30	L	30	L	5	N	30	70	15	100	L	15
-9E	0.7	7.0	G	N	0.01	0.03	200	L	N	20	L	30	L	10	30	150	L	15	150	N	10
-9F	1.5	5.0	2.0	0.7	0.15	0.07	700	70	N	30	30	30	3	30	500	100	15	300	300	N	N
NN78-8A	1.2	15.0	12.0	2.0	0.17	0.007	700	150	7	350	5	5	<1	10	<10	70	20	50	200	20	--
-8B	1.1	11.0	17.0	0.15	<0.15	0.042	1100	200	<1	85	<1	7	<1	10	300	300	7	150	500	<10	--
-8C	0.14	13.0	22.0	<0.08	<0.15	0.005	440	<10	<1	3	<1	9.4	21	9.1	<10	41	15	<20	<200	<10	--
-8D	1.7	0.26	1.0	6.4	4.0	0.36	500	<10	1.8	300	<1	<1	1	<1	70	29	<10	320	<200	70	--
-8E	0.39	0.96	1.8	<0.08	5.3	0.4	200	<10	2.7	39	<1	<1	3	<1	<10	100	22	370	<200	70	--
-8F	2.1	0.31	1.1	7.3	4.8	0.42	850	<10	1.2	340	3	5	3	<1	50	30	33	420	<200	50	--
-8G	1.9	10.0	20.0	<0.08	<0.15	0.09	1700	70	3	100	7	5	<1	30	<10	200	50	70	300	<10	--
-8H	0.80	7.3	31.0	0.10	<0.15	0.02	1100	50	2	70	5	7	3	20	70	300	7	50	<200	<10	--
-80	0.88	14.0	13.0	1.0	0.70	0.04	570	70	12	100	5	5	2	12	29	41	74	40	300	<10	--

Table 5.--X-ray mineralogy of selected samples from the Hope Mine

[Identifications by R. K. Glanzman. Minerals listed in approximate order of abundance. Question mark where identification is uncertain]

Sample no.	Minerals identified
NB78-9B	Quartz, calcite, fluorite, trioctahedral smectite, dolomite, beta-uranophane(?), antigorite.
-9C	Calcite, fluorite, trioctahedral smectite, beta-uranophane, antigorite.
-9D	Calcite, dolomite, quartz, fluorite, smectite, muscovite.
-9E	Calcite, dolomite, quartz, trioctahedral smectite.
-9F	Quartz, calcite, dioctrahedral and trioctahedral smectite; antigorite, fluorite(?), beta-uranophane(?).
-9G	Feldspar(?), trioctahedral smectite (saponite), sepiolite, calcite, quartz, serpentine.

The uranium and thorium data (table 2) suggest that the high-grade zones within the fault gouge range from about 0.5 percent uranium (Sample NN 78-8B) to perhaps as much as 4.7 percent uranium (Sample NB 78-9C). This upper value is uncertain because of interferences due to mineral fluorescence. In the three high-grade samples (Sample NB-78-9B, 9C and 9F) beta-uranophane was identified. Outside of the high-grade pockets the uranium content appears to be substantially lower, 0.1 percent or less (Samples NB-78-9D, E, and NN78-8A) in the inclined shaft and less than 0.01 percent (Samples NN78-8G, H, I) in the adit. Hanging-wall syenite was low in uranium content, 1.7 to 3.8 ppm (Samples NN78-8D, E, F). Footwall carbonate rocks were also low, 3.1 ppm (Sample NN78-8C). Thorium values probably are covariant with uranium, reaching a maximum of about 1500 ppm in the high-grade uranium samples.

The rare-earth data (table 3) suggest that within a high-grade pocket (Samples NB78-9B, C, F, NN78-8B) the uranium and rare-earth contents are covariant but in the other fault gouge rock the rare earths are erratically distributed. The highest indicated cerium content (10,000 ppm) occurs in a lower adit sample containing 95 ppm uranium. Lanthanum, cerium, and neodynium are the principal rare earths present. Highest total rare-earth content is about 1.8 percent (Sample NB78-9C). The rare-earth mineralogy is unknown.

Other trace elements are present in anomalous amounts (tables 3 and 4). They include boron, lithium, lead, and zirconium. Fluorine is also present, as expected from the mineralogy (table 6). These elements also appear to be covariant with uranium in the fault gouge.

Samples from the fault zone showed a varied mineralogy that included calcite, dolomite, quartz, fluorite, dioctahedral and trioctahedral smectite, muscovite, sepiolite, feldspar(?), beta-uranophane, and antigorite (table 5). The contact metasomatic mineralogy described by Chesterman and Bowen

Table 6.--Lithium and fluorine contents of selected samples from the Hope Mine

Sample no.	Li(ppm)	F (percent)[2]
NB78-9B	20	--.
9C	306	3.0
9D	11	--.
9E	13	--.
9F	14	--.
9G	58	2.1

[1]Flameless atomic absorption spectroscopy, A. L. Meier, analyst.

[2]Specific ion electrode, A. L. Meier, analyst. Leaders (--) indicate not analyzed.

(1958), with the possible exception of the serpentine minerals, appears to have been destroyed by shearing and hydrothermal alteration in the fault. Systematic variations in mineralogy with increasing uranium content cannot be discerned except for the presence of beta-uranophane and antigorite in the highest grade samples. The clay gouge next to the fault surface (Sample NB78-9G) contained feldspar, saponite, sepiolite, calcite, quartz, and serpentine. This sample had a fairly high fluorine content (2.1 percent, table 6).

The uranium and thorium contents of the syenite samples (NN78-8D, 8E, 8F) seem unusually low (1.7 to 3.8 ppm uranium, 16.7 to 21.8 ppm thorium) for alkalic rocks. It may be that the syenite near the contact had lost its uranium and thorium. Syenite elsewhere shows high background radioactivity (to 800 counts per second). The syenite also appears to be anomalous in rare-earth content with some evidence for loss of rare earths in the bleached syenite (compare NN78-8D and 8F with 8E).

Other differences between the fresh and bleached syenite are evident (Table 4). Bleached syenite contains much less K and some less Mn, Ba, and Pb than fresh syenite, but contains more Ca, Mg, and Sr. These data suggest that the quartz syenite may have been a source for the rare earths and lead present in the fault zone, but leave open the question of the source for uranium, thorium, boron, fluorine, and lithium. Further work on the content and distribution of uranium and thorium in the syenite is necessary.

Other prospects

H. F. Bonham, Jr. (written commun., 1959) and R. T. Laird (written commun., 1959) indicated that several prospects in the eastern Bristol Mountains are uranium or placer uranium claims. Many of these properties showed anomalous radioactivity but others did not. A sample of altered quartz-feldspathic gneiss from the Original and Pack Saddle claims (SW1/4SE1/4SW1/4, sec. 31, T. 6 N., R. 13 E.) showed a uranium content of 9.5 ppm, a thorium content of 152 ppm, a lanthanum content of 240 ppm, and a cerium content of 500 ppm. This analysis suggests that mineralization may be related to the quartz syenite which crops out nearby. Underground workings on the claims were inaccessible.

Another prospect 2 km west of the Hope mine (SW1/4SE1/4NW1/4 sec. 13, T. 6 N., R. 12 E.) had two types of veins: copper sulfides in feldspar gangue and purple fluorite. Both vein types cut metaigneous rocks about 200 meters west of the contact with the quartz-syenite intrusive. A sample of the fluorite vein with metamorphic country rock (NN78-9A) contained 10.3 ppm U, 513 ppm Th, 780 ppm La, 1000 ppm Ce, 1000 ppm Zr, and 1200 ppm Ba. The feldspar vein rock contained 2.7 ppm U, 11.7 ppm Th, 7000 ppm Cu, 100 ppm La, and 300 ppm Ce.

Discussion

The origin of these deposits is uncertain. The uranium-boron-fluorine-lithium association, clay alteration and fluorite-quartz gangue mineralogy suggest a relatively low temperature of mineralization. Although the geochemical data for the syenite and the presence of thorium and rare-earth mineralization at the other prospects suggests a genetic relation of that mineralization to the intrusion of the syenite, the source for the uranium-boron-fluorine-lithium enrichment is unknown. Nearby outcrops of the Tertiary section in the Marble Mountains and elsewhere are enriched locally in uranium, lithium, and boron; thus a period of Tertiary mineralization seems possible. Detailed work on the mineralogy to define the paragenesis of the Hope deposit seems to be the next step.

Mineral potential

The environment surrounding the quartz-syenite intrusive in the eastern Bristol Mountains appears to be an excellent target for rare-earth and thorium mineralization and perhaps uranium mineralization. Detailed mapping, radiometric reconnaissance, and geochemical sampling of the contact zone between the syenite and the carbonate and fault zones cutting the two units will probably be the most effective techniques for exploration.

We believe that the Hope mine needs further evaluation for mineral potential. Although uranium mineralization appears to die out along the fault zone southwest of the shaft and inclined shaft area, the fault zone clearly has not been fully evaluated by the lower adit workings on the southwest side of the ridge. In those workings, the fault zone is wider and high rare-earth contents persist. Additional work, including core drilling, would seem warranted.

We did not examine the underground workings associated with the vertical shaft. The size of the dump suggests that they are considerably more extensive than the accessible inclined shaft and adit workings. Mapping of those workings and exploration drilling to define the extent of the mineralized fault zone in the mine area and to the northeast beneath alluvium seems justifiable.

References

Chesterman, C. W. and Bowen, O. E., Jr., 1958, Fluoborite from San Bernadino County, California [abs]: Geological Society of America Bulletin, v. 69, no. 12, pt. 2, p. 1678-1679.