AN OCCURRENCE OF JAROSITE IN ALTERED VOLCANIC ROCKS OF STODDARD MOUNTAIN, SAN BERNARDINO COUNTY, CALIFORNIA

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ABSTRACT

The hydrated sulfate of potassium and ferric iron, jarosite, has been identified as a minor constituent of pneumatolytically altered quartz porphyry of Juratrias age that outcrops on the south slope of Stoddard Mountain in the Barstow-Victorville district, San Bernardino County, California. The mineral has been identified on the basis of optical and goniometric measurements, and this diagnosis has been verified by chemical tests.

FIELD OCCURRENCE

Jarosite-bearing quartz-tourmaline rock outcrops in a lenticular, N–S trending body measuring approximately 100 by 400 feet. Most of this body consists of grayish-white quartzose rock abundantly spotted with radial groups of bluish black tourmaline averaging eight mm. in diameter. In some places tourmalinization has been more complete and discrete crystal groups tend to grade into a reticulated mass of coarsely acicular tourmaline. The tourmalinized zone grades gradually into sericitized quartz porphyry containing little or no tourmaline or jarosite, and finally into relatively unaltered quartz porphyry having a felsitic groundmass. Dikes of greenish gray, deuterically altered hornblende quartz monzonite, have penetrated both the volcanic rocks now tourmalinized and the adjacent relatively unaltered volcanic rocks. The granitic intrusives themselves are tourmalinized and sericitized in some places clearly indicating that these alterations followed the episode of granitic emplacement. Dikelets of granite pegmatite and aplite also occur in the vicinity although none outcrop close to the tourmaline-jarosite zone.

In many places irregular bands of tourmaline can be seen along large and small fractures showing that penetration of replacing vapors or solutions took place along fracture lines as well as by diffusion between the grains. Jarosite is seldom recognizable in hand specimen although the minor accessory rutile is sometimes conspicuous.

The field locality is close to the Keystone Mine on the south slope of Stoddard Mountain in the SE$\frac{1}{4}$ Sec. 18, T7N, R4W, S.B.B. and M. Stoddard Mountain is a 4800-foot landmark lying 14 miles NE of the town of Victorville, San Bernardino County, California. The terrain is typical of the southwestern Mojave Desert.

PETROGRAPHIC OCCURRENCE

For the most part, jarosite occurs as highly irregular, sometimes globular crystals, averaging 0.2 mm. in diameter, that are frequently grouped into clusters or aggregates in which there is no preferred orientation of the individuals (Fig. 1*B*). Here and there sharply euhedral crystals of rhombohedral aspect have formed (Fig. 1*A*) and very occasional narrow veinlets of the mineral were observed. Jarosite appears to be distributed haphazardly throughout the rock, although in some thin slices it is often intimately associated with radiate aggregates or prismatic crystals of tourmaline, and less often with clusters of stumpy prisms of pale yellow rutile.

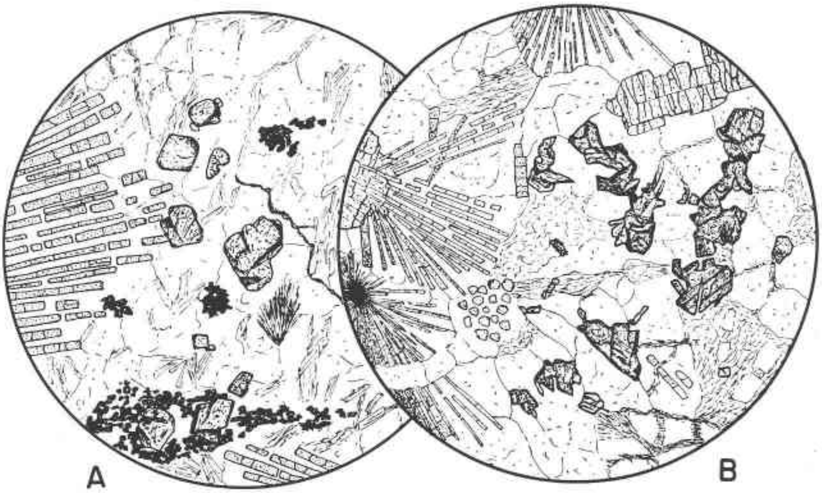

FIG. 1. The usual modes of occurrence of jarosite in tourmalinized quartz porphyry from Stoddard Mountain are illustrated in *A* and *B* above. Note the development of a high degree of idiomorphism in the jarosite in *A* and the absence of it in *B*; also observe the development of rutile in clusters in *A*.

MINERALOGY

The most abundant minerals associated with jarosite are quartz in allotriomorphic and interlocking grains, fine flaky sericite, tourmaline, and kaolinite. Tourmaline occurs in closely radiating aggregates—tourmaline suns—and also as isolated prismatic crystals with characteristic triangular cross-sections. The mineral exhibits a wide range of grain size and composition, and the latter is clearly shown in the variety of absorption tints for the vibration direction of the ordinary ray, *viz.* from deep blue, brownish blue, and greenish blue to palest blue to colorless. Symmetrical and unilateral zoning are both common and frequently peripheral zones of brown tourmaline enclose a blue variety; a reversal of this arrangement is also found.

The more deeply colored varieties were concentrated by a Frantz magnetic separator in a weak field, *viz.* 0.2 and 0.3 amperes, whereas faintly colored or imperceptibly colored crystals were found in those fractions concentrated at 1.2 amperes. For a crystal of intensely colored, and supposedly ferriferous, tourmaline, the following physical properties were determined:

N_o	1.658 ± 0.002
N_e	1.633
N_o–N_e	0.025
D_{25°	3.13 ± 0.01
E	very pale blue to grayish blue
O	deep blue

For a faintly colored crystal concentrated in an intense magnetic field the following properties were found:

N_o	1.638 ± 0.002
N_e	1.618
$N_o - N_e$	0.020
D_{25°	3.06 ± 0.01
E	colorless
O	very faint blue

The intense blue color of many of the tourmaline rosettes of the Stoddard Mountain locality is rare among tourmalines of the Barstow-Victorville area. Pegmatite and high temperature vein tourmalines are generally pleochroic in shades of brown. Blue or blue-gray shades have not been noted elsewhere in the area.

Among the accessory constituents the presence of the following minerals was verified:

Opaque iron ores, chiefly ilmenite, minute allotriomorphic crystals of barite, kyanite, globular or drop-like particles and stumpy crystals of rutile that are almost universally twinned, colorless zircon, very rare prisms of apatite, and ragged grains of pyrite. Barite is also conspicuously present as fracture filling.

SEPARATION AND PROPERTIES OF JAROSITE

Owing to the scarcity of jarosite, concentration was found to be necessary, and to accomplish this task approximately one pound of the rock containing the mineral was in turn run through a jaw-crusher, rollers, and a pulverizer, thus reducing the material to a grain-size less than 200-mesh (U.S.S. screens). After an appropriate degree of elutriation to get rid of dust, the powder was centrifuged in bromoform of density 2.88. Unfortunately concentration of jarosite was still too low to allow segregation of adequate material for study and, therefore, it was necessary to resort to electromagnetic fractionation. After removal of ferromagnetic material most of the jarosite was concentrated in the more magnetic portion segregated by the Frantz Separator set as follows: slope 10°, tilt 5°, current 0.1 ampere. From this fraction a nearly pure sample was readily prepared by hand-picking.

The following properties were determined for jarosite:

N_o	1.815 ± 0.001
N_e	1.714 ± 0.003
$N_o - N_e$	0.101
$2V$	0°, but angles between 5–10° were observed in individual crystals.
X	very pale yellow
Z	deep golden yellow
$Z >$	X

Extinction parallel to distinct basal cleavage.

$D_{24°}$ 3.18 ± 0.03. This figure was found for pure unaltered material but much of the jarosite was decidedly denser than this owing to superficial alteration to limonitic products.

In connection with the biaxial character occasionally found it should be noted that such crystals appeared to be single and homogeneous and there was no indication of twinning or segmentation in this instance, and thus the crystals did not resemble in any respect the features displayed in natrojarosite from Chuquicamata (Bandy, 1938, pp. 755–756), or jarosite from the Tintic District, Utah (Means, 1916, pp. 126–127).

Interfacial angles were measured for several crystals with the universal stage, and angles of approximately 54° and 91° were found; such angles are close to those recorded by Ford (1932, p. 769) for jarosite, *viz.* cr $0001 \wedge 10\bar{1}1$, 55° 16′, and $r\ r'$ $10\bar{1}1 \wedge \bar{1}101$, 90° 45′. It should be noted, however, that Gordon (1925) found the interfacial angle cr to be 53° 12′.

On a qualitative basis (SO_4), H_2O, Fe''', potash, and a trace of soda were found to be present, but aluminum was absent. Spectrographically no more than a trace of lead was found.

Taken together these properties would seem to compare favorably with those previously recorded for pure jarosite (Winchell, 1933, p. 114; Tyler, 1936, p. 60), and in this instance veritable absence of aluminum, and traces only of sodium and lead exclude the possibility of the presence in solid solution of natrojarosite, alunite, or plumbojarosite.

ORIGIN

Jarosite has been reported to occur under a variety of circumstances, a few of which are as follows: Filling in cavities in Triassic arkoses at

Blanot (Lacroix, 1915, pp. 129–130); as an alteration of sulfides in the Tintic Area of Utah (Butler *et al.*, 1920, p. 116); as an efflorescence on recent lavas at Vesuvius (Zambonini, 1921); in the oxidation zone of lead ores at Leadville, Colorado (Emmons *et al.*, 1927, p. 155); as an oxidation product in altered quartz porphyry, Potosi, Bolivia (Lindgren and Creveling 1928, p. 253); associated with other sulfates in bedded cherts in the Calico Hills, San Bernardino County, California (Foshag, 1931, p. 353); in plant-bearing stratified tuffs, Potosi Mountain, Bolivia (Milton, 1935, pp. 176–178); as a member of the heavy mineral assemblages in the St. Peter Sandstone, Wisconsin (Tyler, 1936, p. 60); in oxidized zones at Chuquicamata and other mines in Northern Chile (Bandy, 1938, pp. 754–755); as a surface alteration to pyrite ornaments that had been buried for a considerable period (Pough, 1941, pp. 563–564); in Eocene clays at Refsnaes, Denmark (Bøgvad, 1942, pp. 108–114); and as an oxidation product of pyrite deposits in the Urals and other localities in Russia (Breshenkov, 1946, pp. 329–332).

In the occurrence described in this note jarosite is a constituent of a highly altered acid volcanic rock type and only the merest trace of sulfides in the form of pyrite has been found therein. It is believed that the association between tourmaline and jarosite is not coincidental but has genetic significance in spite of the occasional presence of jarosite in veinlets. However, it is thought that the time during which the jarosite crystallized probably post-dates the period of introduction of aqueous solutions containing boron that brought about subsequent crystallization of tourmaline, sericite, and possibly rutile and kyanite.[1] It is perfectly clear, however, that the pronounced development of zoning in the tourmaline indicates that the crystallization history in this instance has been a complex one. All occurrences of jarosite familiar to the writers appear to indicate that the mineral has formed from solutions at low temperatures; in fact, it is pertinent to point out that Fairchild (1933, pp. 543–544) was able to prepare pure jarosite in the laboratory at temperatures as low as 110° C. The association of barite and jarosite in this rock is also of interest since a somewhat similar association has been found in Jurassic arkoses by Lacroix (1915), although the genesis of the sulfates in this particular instance is quite distinct. Barite in these Southern Californian rocks possibly owes its origin to the same sulfate-bearing solutions that resulted in crystallization of jarosite, and it is believed that these solutions may represent the very latest or hydro-

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[1] Grosemans (1948) has shown that kyanite, usually considered to owe its origin to the conditions of dynamothermal metamorphism, may be of hydrothermal or pegmatitic origin.

thermal phase of the long and varied sequence of crystallization and metasomatism, the early stages of which, however, did not continue for a sufficient period to allow development of pegmatites comparable to those recognized by Varlamoff (1946, p. B. 122) as Type 9.

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