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AN OCCURRENCE OF SPADAITE AT GOLD HILL, UTAH[1]

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INTRODUCTION

During the survey of the Gold Hill quadrangle in west central Utah, several specimens of an unusual type of gold ore were collected by one of us (T. B. N.). On microscopic examination these specimens were found to contain considerable quantities of a fine-grained shreddy mineral which could be referred only to the very rare mineral spadaite on the basis of optical and chemical tests (by W. T. S.). This mineral was described[2] by von Kobell in 1843, as occurring with wollastonite at Capo di Bove, near Rome, Italy. The only other recorded occurrence of spadaite is that given[3] by Fischer who identified it by its qualitative chemical composition in amygdular dolerite at Sasbach, Kaiserstuhl, Germany. He differentiated it from steatite by its blowpipe fusion to a white enamel, with bubbling, and by its decomposition by HCl acid with separation of sandy silica.

The occurrence in Utah, here described, is therefore the third recorded identification of spadaite. The mineral may be more widespread in its occurrence than is recognized and may have been erroneously determined as serpentine.

OCCURRENCE AND ASSOCIATION

The geology of the region has been briefly described by Butler[4] and by Kemp and Billingsley[5] and will be treated in more detail in

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[1] Published by permission of the Director, U. S. Geological Survey.

[2] See Dana, *System of Mineralogy*, 6th ed., p. 682.

[3] Fischer, C., *Neues Jahrb. f. Min., Geol. u. Pal.*, **1865**, p. 442.

[4] Butler, B. S., Ore deposits of Utah: *U. S. Geol. Survey, Prof. Paper* **111**, pp. 469–482, 1920.

[5] Kemp, J. F., and Billingsley, P., Geology of Clifton mining district and vicinity, Tooele County, Utah: *Econ. Geol.*, vol. **13**, pp. 247–274, 1918.

a Geological Survey publication by one of the writers.[6] A considerable thickness of complexly faulted and folded Paleozoic sedimentary rocks was intruded in early Tertiary time by a stock of quartz monzonite. Several kinds of ore deposits were formed as an after effect of the intrusion. In one of these—gold-bearing lodes in rather thoroughly silicated limestone—spadaite occurs locally in considerable quantity.

This type of gold ore was mined at the Cane Springs, Alvarado, and Midas mines, all of which are now idle. At all three, the geology is more or less similar. One or more beds of limestone have been rather completely converted to a rock composed of wollastonite, garnet, diopside, and other silicates. Shoots of gold ore are localized in these beds by pre-ore faults at the Midas and Cane Springs mines, and by an irregular dike-like mass of quartz monzonite at the Alvarado mine.

Spadaite occurs only in the ore shoots, associated with the silicates mentioned, quartz, various sulphides (chiefly chalcopyrite and bornite) and their oxidation products, and small quantities of native gold. The spadaite forms dense, almost porcellanous, cream or pink colored masses in the ore shoots. These dense masses of spadaite generally contain blebs of garnet, diopside, and other silicates. Irregular areas and veinlets of quartz with associated metallic minerals also traverse the spadaite.

Thin sections of specimens containing spadaite show clearly that it is later than the silicate minerals which have been formed by the metamorphism of the limestone bed, a conclusion that is also indicated by the absence of spadaite in altered limestone away from the ore shoots. Wollastonite is the most common of the older silicate minerals and it appears to be preferentially replaced by the spadaite, for blebs of garnet and of diopside of about the same size and habit as blebs of the same minerals in unreplaced wollastonite are found in the spadaite. The incomplete replacement of wollastonite by spadaite is shown in Fig. 1. The shreddy spadaite incloses many irregularly shaped residua of wollastonite. The spadaite is clearly older than the quartz, in many places being veined by it. Locally also calcite veinlets are found in the spadaite masses.

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[6] Nolan, T. B., Geology and ore deposits of the Gold Hill quadrangle, Utah: *U.S. Geol. Survey report,* in preparation.

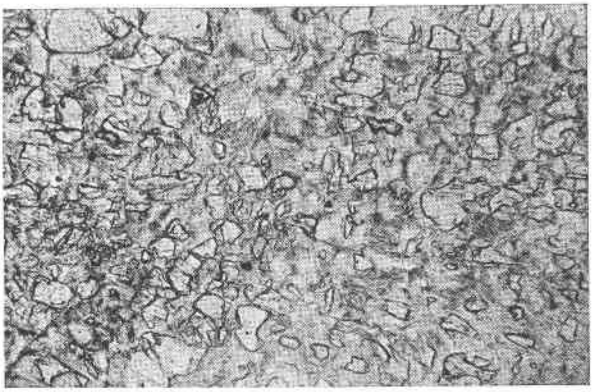

FIG. 1. Microphotograph of spadaite inclosing residua of wollastonite. Plain light, ×87.

PROPERTIES

Under the microscope the spadaite is seen to have a felted shreddy habit, like that of sericite, from which it differs, however, in its much lower indices of refraction and lower birefringence. It is indistinctly platy, somewhat columnar, rather than fine fibrous. The mineral is colorless and non-pleochroic. The extinction is nearly parallel, though some fragments show a distinct but slightly inclined extinction. The refractive indices were determined by Dr. C. S. Ross to be: $\alpha=1.521$, $\beta=1.525$, $\gamma=1.545$; all ± 0.003. 2V small to medium. Optically positive, elongation positive. Larsen gives[7] $\beta=1.53\pm 0.01$ for spadaite from Italy.

The refractive indices, after heating to 110° and driving off half the water, are nearly the same but seem to be very slightly (not more than 0.01) higher. Apparently some minerals can lose half their water without appreciable change in their optical properties. Thus Winchell[8] states for talc:

"After losing half its water content the mineral has practically the same optic properties."

The density of the specimen analyzed is 2.32. Allowing for the insoluble garnet and diopside and for the soluble wollastonite, the density of spadaite is about 2.2.

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[7] Larsen, E. S., *U. S. Geol. Survey, Bull. No.* **679,** 0. 135, 1921.

[8] Winchell, A. N., *Elements of optical mineralogy,* Part II: Descriptions of minerals, **1927,** p. 228.

COMPOSITION

The mineral fuses before the blowpipe flame, with slight bubbling, to an opaque white enamel. It is soluble in HCl without gelatinization, yielding sandy silica. Neither dilute nor concentrated acid, hot or cold, caused any gelatinization.

A preliminary separation with heavy solution yielded about 4 per cent of heavy minerals (chiefly diopside and garnet) but the sample analyzed still contained nearly 9 per cent of these minerals, so that about 13 per cent of minerals insoluble in HCl are present in the hand specimen. Boiling the powdered sample for 15 minutes with a 10 per cent solution of Na_2CO_3 yielded 0.41 per cent of soluble silica, which is ascribed to opal. The lime is referred to wollastonite. A mere trace of carbonate is also present.

The analysis of the mineral is given below in the first column and, in the second column, the analysis is recalculated after deducting the impurities (insoluble garnet and diopside, wollastonite and opal).

TABLE 1. ANALYSIS OF SPADAITE FROM UTAH

Analysis		With impurities deducted[a]	Ratios		Calculated for $SiO_2 \cdot MgO \cdot 2H_2O$
Insol. residue	8.68	—			—
SiO_2 sol. in Na_2CO_3	0.41	—			—
SiO_2	43.28	47.57	.7915	1.13 or 1	44.06
Fe_2O_3	0.22	—			—
FeO	0.27	0.31	.0043		—
CaO	1.58	—		1.00 or 1	—
MgO	24.72	28.28	.7017		29.54
H_2O-	10.36	11.85	.6583	0.93 or 1	13.20
H_2O+	10.51	12.02	.6678	0.94 or 1	13.20
	100.03	100.03			100.00

[a] The impurities consist of 8.68 per cent insoluble residue (diopside and garnet), 3.27 per cent wollastonite (based on the CaO percentage), 0.41 per cent opaline silica (soluble in 10 per cent Na_2CO_3 solution), and 0.22 Fe_2O_3 as limonite.

The ratios came out approximately to 1:1:2, yielding the formula $SiO_2 \cdot MgO \cdot 2H_2O$, which may be written $H_2MgSiO_4 \cdot H_2O$, half of the total water being given off at 110°.

The question as to how the water given off at 110° functions is one that cannot be answered for this mineral at present. The fact that the optical properties do not seem to vary to any great extent, when this water at 110° is driven off, cannot be given too much weight as the character of the material is such that the optical properties cannot be determined sufficiently accurately and fully to make such a criterion of much value.

Assuming that this water at 110° is unessential to the mineral and deducting it, and recalculating the remainder to the same total (100.03), the resultant analysis agrees fairly closely with the only recorded analysis of spadaite.

TABLE 2. COMPARISON OF ANALYSIS OF SPADAITE FROM UTAH, WITH THE WATER GIVEN OFF AT 110° DEDUCTED, WITH THE ANALYSIS OF SPADAITE FROM ITALY, AND WITH THE CALCULATED COMPOSITION FOR $SiO_2 \cdot MgO \cdot H_2O$.

	Spadaite from Utah with H_2O at 110° deducted	Spadaite from Italy	Calculated for $SiO_2 \cdot MgO \cdot H_2O$
SiO_2	53.96	56.00	50.76
FeO	0.35	0.66	—
MgO	32.08	30.67	34.04
H_2O	13.64	11.34	15.20
Al_2O_3	—	0.66	—
	100.03	99.33	100.00

The ratios of SiO_2:MgO:H_2O in the analysis of spadaite from Italy (Table 2) are 1.21:1.00:0.82, with a considerable variance from the 1:1:1 ratio. The ratios are close to the formula given, namely, $6SiO_2 \cdot 5MgO \cdot 4H_2O$; being 5.99:4.95:4.05. The ratios of the analysis of spadaite from Utah (Table 2), with H_2O at 110° deducted, are 5.48:4.89:4.63, a poor agreement.

In von Kobell's paper describing spadaite from Italy he makes no mention of drying the sample at 100° before analysis, but this practice was so common at that time that it can probably be safely assumed that his sample was so dried and that consequently the spadaite from Italy contained more water than is reported in the analysis. The 0.66 per cent Al_2O_3 reported has to be considered and it may be that by making the proper allowance for the Al_2O_3 and for the water lost, if his sample was dried at 100°, the ratios would come closer to a 1:1:2 ratio than those calculated from his recorded analysis.

It is, therefore, believed that the same mineral is represented by the two occurrences and that the correct formula of spadaite is $SiO_2 \cdot MgO \cdot 2H_2O$ (as shown in Table 1) even though both analyses show an excess of silica and the quantity of water inherently present in the mineral is not definitely known.

A number of mineral names are listed in fine print on page 675 of Dana's *System of Mineralogy* whose analyses approach the simple formula $SiO_2 \cdot MgO \cdot H_2O$, such as hampshirite, aphrodite, and cerolite (or kerolite). But as described by Schrauf,[9] most of these are mixtures of serpentine and opal, unless Schrauf also confused spadaite with serpentine. Some analyses of cerolite are close to the analysis of spadaite from Utah (Table 1) and may represent the same mineral. The recorded analyses of deweylite are similarly close.

Our knowledge of the hydrous magnesium silicates is still very incomplete. The following tabulation suggests a possible grouping:

THE HYDROUS MAGNESIUM SILICATES

$\frac{SiO_2}{MgO} = <1.$	Serpentine (incl. chrysotile and antigorite)	$2SiO_2 \cdot 3MgO \cdot 2H_2O$.	
	Dewelylite	$3SiO_2 \cdot 4MgO \cdot 6H_2O$.	
$\frac{SiO_2}{MgO} = 1.$	Spadaite	$1SiO_2 \cdot 1MgO \cdot 2H_2O$.	Simple formula here proposed.
	Cerolite	$2SiO_2 \cdot 2MgO \cdot 3H_2O$(?) or same as spadaite (?)	
$\frac{SiO_2}{MgO} = >1.$	Sepiolite	$3SiO_2 \cdot 2MgO \cdot 2H_2O$	β-sepiolite
	Parasepiolite	$3SiO_2 \cdot 2MgO \cdot 4H_2O$	α-sepiolite
	Talc	$4SiO_2 \cdot 3MgO \cdot 1H_2O$ or $5SiO_2 \cdot 4MgO \cdot 2H_2O$(?) (Winchell).	
	Spadaite	$6SiO_2 \cdot 5MgO \cdot 4H_2O$(?) Old formula.	

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[9] Schrauf, A., Beiträge zur Kenntniss des Associationskreises der Magnesiasilicate: *Zeit. f. Kryst., Min.*, vol. **6**, pp. 321–388, 1882.