

MINERALOGICAL NOTES

LAZURITE, TALC AND CHLORITE IN THE GREEN RIVER FORMATION OF WYOMING¹

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Authigenic minerals that clearly formed in undeformed lake beds but that are known to have formed elsewhere only, or predominantly, in entirely different geologic environments are worthy of note. An impressive number of such authigenic minerals has already been reported by others from the Eocene Green River formation of Wyoming, Colorado, and Utah. I have recently found three more, lazurite, talc, and chlorite, in one of the salt beds in the lower part of the Wilkins Peak member of the formation in Wyoming.

The core samples studied came from a salt bed 21.5 feet thick (the 14th major salt bed up from the bottom of the series) in the William T. Rogers No. 1 trona core hole, located 200 ft. east of W. $\frac{1}{4}$ cor., sec. 19, T. 15 N., R. 111 W., Sweetwater County, Wyoming. These core samples, at 1 foot intervals through the bed, were sent to me by J. D. Love of the U. S. Geological Survey, who obtained them from the operators, Stroock and Rogers.

Halite makes up the great bulk of this bed but it contains many thin layers of trona and much of the halite contains randomly dispersed crystals of trona and exceedingly minute crystals of calcite. Love and I both thought if potash minerals were to be found this was a promising place to look, but none was found. Clastic minerals in this salt bed are very scarce and those few presumably were blown into the original brine by the wind. They include pyroxene, hornblende, quartz, and feldspar, no one of which is noticeably more common than the others.

The lazurite ($3\text{NaAlSiO}_4 \cdot \text{Na}_2\text{S}$) occurs always as inclusions in colorless, platy aggregates of talc, chlorite and saponite(?). At several levels in this salt bed the talc-chlorite flakes are moderately common. They consist of a random intergrowth of laths and polygonal plates and range in size from about 40 to more than 300μ across. The facts that these plates, or flakes, are of relatively large size, are unworn, have margins made up largely of sharply angular crystal boundaries, and are not accompanied by a comparable number of clastic grains, persuade me that they are authigenic.

The major constituent of these flakes was identified as talc by its optical properties (indices of refraction, one a little below 1.55 and one above 1.56, biaxial (-), and 2 V small) and by its x-ray powder pattern,

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which was identified for me by Miss Mary Mrose of the U. S. Geological Survey. Working with cleanly isolated flakes she reported that talc was the dominant pattern, chlorite next strongest, and lines that fitted either saponite or stevensite were present, but very weak.

So far as I am aware, the presence of talc and chlorite as authigenic minerals in lacustrine salt beds has not heretofore been reported. Talc has been reported, however, as an authigenic constituent of marine salt beds, first by F. H. Stewart (1949, pp. 643-645, 665-669) in the Permian salt beds of Yorkshire, England, and only a month later by R. K. Bailey (1949, pp. 757-759) in the Permian potash-bearing salts of the Salado formation, near Carlsbad, New Mexico. Stewart later (1951, p. 567) reported having found "chloritic and clay material" in the English potash-bearing beds, but gave no further details.

The lazurite inclusions range in number for one to more than 20 per talc-chlorite flake and in size from a little less than 1 to nearly 17μ long. Most common are grains 6 to 8μ across, which consist of an aggregate of minute, anhedral crystals. Some of the larger inclusions, however, consist of single, more or less euhedral crystals. All have an intense blue color, the largest grains being azure in transmitted light and virtually black in reflected light.

The identification of these blue inclusions as lazurite rests on their optical and physical properties and is less satisfactory than if either their x-ray characteristics or chemical composition had also been possible to obtain. All the grains are isotropic. Single crystals, accidentally broken free from the talc-chlorite flakes, have an index of refraction very close to 1.515. This is somewhat higher than the $1.50 \pm$ given by Larsen and Berman (1934, p. 49). The most nearly euhedral crystals have both cube and unidentifiable faces. They fracture as though completely homogeneous and show no cleavage. In dilute hydrochloric acid their blue color disappears almost instantly; even from those still imbedded in the talc-chlorite flakes.

The presence of sulfur was detected first by J. D. Love as a marked sulfur smell when he broke the salt cores to obtain the samples sent to me for study. Sulfur was also identified in a single inclusion by Isidore Adler, of the U. S. Geological Survey, with the electron probe. That this grain was not pyrite was established by the fact that the Fe peak for this grain was very low—much too low for pyrite.

Because the index of refraction of these grains is so much higher than the published value of $1.50 \pm$, I was prompted to measure the index of refraction of two specimens of lazurite from well-known localities. Dr. George Switzer of the U. S. National Museum gave me samples of lazurite from the old Persian (Afghanistan) locality and from the vicinity of

Lake Baikal in Siberia. The Afghanistan lazurite has an index of refraction of almost exactly 1.50, whereas the Lake Baikal lazurite has an index of $1.527 \pm .002$. The two appear to be identical except for the indices and for the fact that the Lake Baikal variety has slightly lighter blue color.

The well-known variability in the composition of lazurite (see for example Jaeger, 1929) and the paucity of information on the optical and physical properties of the mineral indicate a need for further study of lazurite from a number of localities. Joseph J. Fahey of the U. S. Geological Survey has already begun this study.

Presumably the talc-chlorite-saponite(?) flakes grew in the concentrated brine occluded between the halite and trona crystals, which formed as evaporite beds during one of the extreme low stages of Gosiute Lake. These highly concentrated sodium carbonate-sodium chloride brines evidently held in solution considerable amounts of Mg, Si and much smaller quantities of Al. The Al necessary to form the observed small amounts of lazurite might, however, have come from reactions between the alkaline brine and the few grains of greenish pyroxene, most of which are overgrown with long acicular crystals of acmite. Sulfur, necessary for the formation of lazurite and a very small amount of pyrite, came either from decomposing organic matter or reduction of sulfates, for bacterial cells are abundant in some of the halite and most of the chalcedony found in this salt bed. It is not illogical to assume an excess of S, as H_2S , over that required for both the available Fe and Na, as Na_2S , in lazurite. Apparently the tendency for both acmite and pyrite to form established a competition for the available Fe. Perhaps this inferred limitation on the amount of Fe permitted the formation of lazurite rather than the more expectable pyrite—a common constituent in most of the trona beds.

From the evidence presently available it is not possible to say at what stage of diagenesis the talc-chlorite-lazurite assemblage formed. One might speculate, however, that talc and chlorite instead of a highly hydrated magnesium silicate, such as stevensite or saponite, indicate that the assemblage formed after the lake beds had been deeply buried and most of the water had been expressed by compaction. Indeed, one might speculate that the earliest flaky mineral formed may have been saponite or stevensite and that the chlorite and talc replaced it after maximum burial of the salt.

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ADDITIONAL NOTES ON MARGAROSANITE

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Armstrong (1963) has reported crystal data on margarosanite, $(\text{Ca}, \text{Mn})_2\text{PbSi}_3\text{O}_9$. The present authors have determined a unit cell in essential agreement with Armstrong's using material furnished by the Smithsonian Institution, U. S. National Museum: Catalogue C6412 (Franklin Furnace, N. J.).

TABLE 1. PROPERTIES OF SOME COMPOUNDS BASED ON X_3O_9 RINGS

A. Hexagonal, Pseudo Hexagonal and Rhombohedral Series									
Formula and name		Symmetry	(Å) <i>a</i>	<i>b</i>	<i>c</i>	Reference			
BaTiSi ₃ O ₉	Benitoite	Hexagonal	6.60	—	9.71	1			
BaTiGe ₃ O ₉	Low Temperature	Hexagonal	$6.77 \times \sqrt{3}$	—	10.0	2			
BaTiGe ₃ O ₉	High Temperature	Hexagonal	6.77	—	10.0	2			
SrGeO ₃		Rhombohedral	7.29	—	10.55×3	3			
α -CaSiO ₃	Pseudowollastonite	Triclinic Pseudo-Hexagonal	6.82	—	9.825×2	4			

B. Triclinic Series									
Formula and name		α	β	γ	<i>a</i>	<i>b</i>	<i>c</i>	Z	Reference
α -CaSiO ₃	Pseudo-wollastonite	90°24'	90°24'	119°18'	6.82	6.82	9.83×2	12 ¹	4
Ca ₂ BaSi ₃ O ₉		88°22'	111°03'	102°20'	6.72	6.73	9.70	2 ²	5
(Ca, Mn) ₂ PbSi ₃ O ₉	Margarosanite	88°30'	110°35'	102°0'	6.75	6.77	9.64	2 ³	6

¹ Space group either $P1$ or $P\bar{1}$.

² Space group known to be $P\bar{1}$.

³ Z not stated, but is almost certainly = 2. Cell axes and angles interchanged to facilitate comparison with other members of this family.

- Zachariasen (1930).
- Robbins (1960).
- Hilmer (1960).
- Jeffery (1953).
- Glasser (1961).
- Armstrong (1963).