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WOOD TIN IN THE TERTIARY RHYOLITES OF NORTHERN NEVADA.[1]

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Tin ore has recently been found in northern Lander County, Nev. The stanniferous mineral is wood tin, occurring in narrow veinlets, traversing a series of rhyolite lavas of middle Tertiary age. The wood tin of these deposits is the first recorded occurrence of this mineral in place in the United States. To point out the hydrothermal origin of the deposits, the association of an unusual number of varieties of silica with the wood tin, and certain features of colloidal deposition that are strikingly exemplified by the deposits, is the purpose of this paper.[2]

THE RHYOLITE COUNTRY ROCK.

The rhyolites that enclose the veins are markedly porphyritic, the phenocrysts forming nearly half the bulk of the rocks. Quartz and sanidine dominate, and oligoclase ($Ab_{70}An_{30}$) occurs sporadically. Ferromagnesian minerals were rare and apparently consisted in the main of hornblende, now pseudomorphously altered to hematite. The rhyolites are rather porous and lithophysal; they commonly show flow-layering and in places are flow-brecciated; in short, they bear abundant evidence that they consist of a superposed succession of lava flows. According to W. H. Emmons[3] they are the oldest Tertiary lavas in this part of Nevada and their eruption probably began early in Miocene time.

The following partial analysis shows clearly the siliceous, alkalic character of the rhyolites:

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

[2] The general geology of the deposits is described in "Tin Ore in Northern Lander County, Nev.," U. S. Geol. Survey Bull. 640-G, 1916.

[3] A reconnaissance of some mining camps in Elko, Lander and Eureka counties, Nev., U. S. Geol. Survey Bull. 408, p. 31, 1910.

PARTIAL ANALYSIS OF RHYOLITE FROM LANDER COUNTY, NEV.

(A. A. Chambers, analyst.)

SiO_2	76.25
CaO	.44
Na_2O	4.05
K_2O	5.18

THE TIN-BEARING DEPOSITS.

The tin-bearing veinlets traversing the rhyolites are narrow, but at some places enough veinlets occur to form stringer lodes. The stanniferous mineral is exclusively wood tin, which is inclosed in stringers, generally an inch or so wide, associated with specular hematite, chalcedony, lussatite, tridymite, and opal; the vein-forming minerals are generally limited to the stringers, but locally the adjoining rhyolite has been replaced by wood tin, hematite, and the various silica minerals. The groundmass has been wholly replaced but the phenocrysts of quartz and feldspar have remained intact.

Specular hematite is abundant in the stanniferous veinlets and is intergrown with all the other minerals present. It is embedded in the wood tin in amounts ranging from microscopic particles to masses that make up the larger part of the wood-tin individuals. Chalcedony seems to the unaided eye to be the dominant gangue mineral in the veinlets, but under the microscope a large part of the fibrous silica is found to correspond closely to lussatite.

The name lussatite was given by Mallard[4] to a fibrous variety of silica, whose average refractive index is 1.446, whose birefringence is somewhat less than that of quartz, and whose fibers show positive optical elongation—properties that serve to distinguish it easily from chalcedony. As seen under the microscope the lussatite in the tin-bearing veinlets is of globular habit and in parallel light resembles the opal occurring with it: it has the same high relief, light brownish color, and well-marked concentric structure, as may be seen in Fig. 35. Between crossed nicols it

[4] Mallard, E., "Sur la lussatite, nouvelle variété minérale cristallisée de silice," Soc. franc. de Mineralogie, Bull., Vol. 13, pp. 63–66, 1890.

shows a finely fibrous spherulitic structure, like chalcedony (Fig. 36) but the elongation of the fibers is positive, its birefringence, as determined by means of the interference chart, is about 0.006. The refractive index was found by the oil immersion method to be approximately 1.45. The mineral is therefore identified as lussatite. All stages are represented between completely isotropic

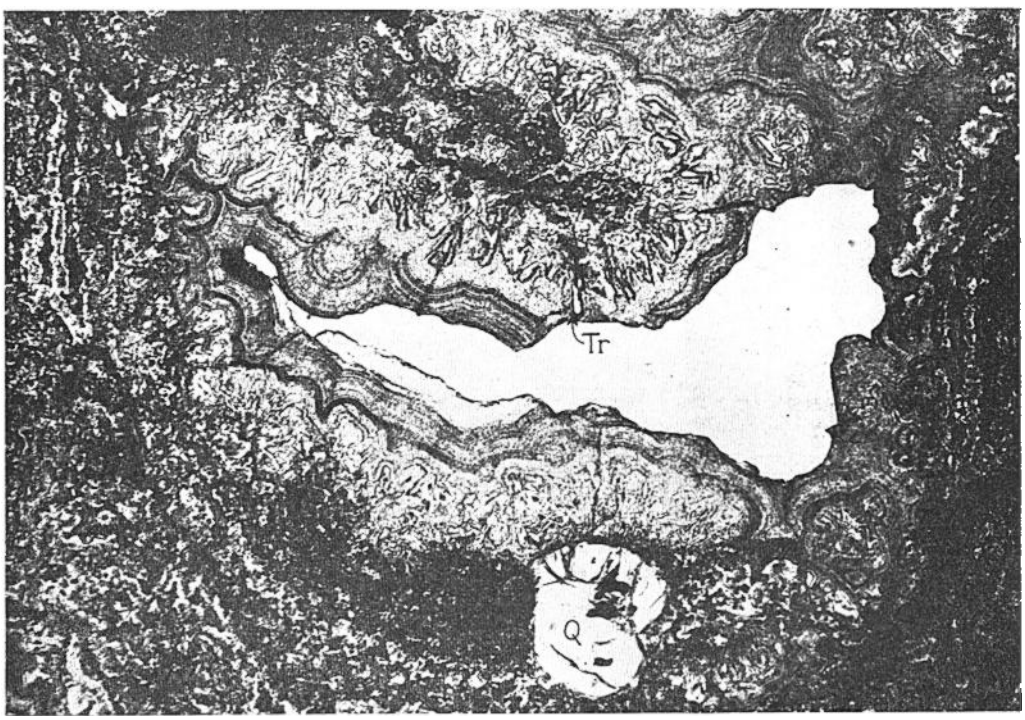

FIG. 35. Sussatite surrounding a vug in silicified rhyolite. *Tr* indicates one of the many plates of trydymite enclosed in it; *Q* indicates a quartz phenocryst residual from the original rhyolite. Parallel light; magnification, 32 diameters. Modoc prospect.

opal and the most strongly birefringent spherulites, and there can be little doubt that the lussatite has resulted from the crystallization of opal.

Where chalcedony and lussatite occur associated together, they

are invariably sharply individualized and there is no gradation between them, nor are there any features that even suggest the possibility of such a gradation. The chalcedony is a clear limpid mineral, in parallel light resembling quartz; its refractive indices,

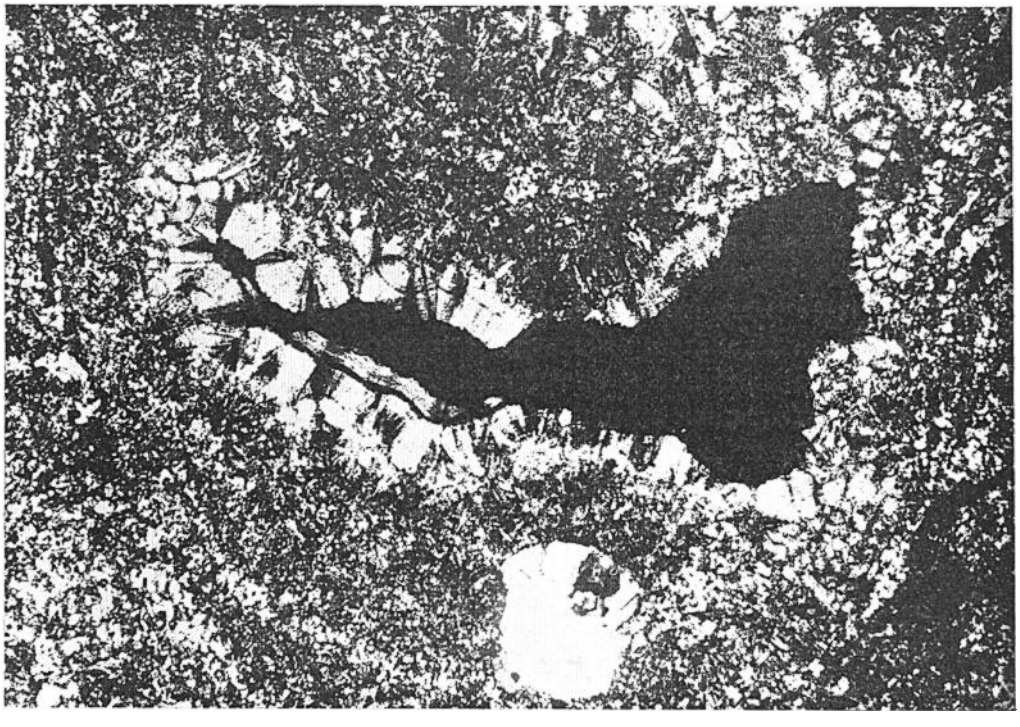

FIG. 36. Same, with nicols crossed, showing the radial fibrous structure of the lussatite.

as determined by immersion in oils, slightly exceed 1.53, however, The distinction between lussatite and chalcedony is in places very striking, especially in vicinity of plates of hematite. Each plate of hematite is completely surrounded by a layer of lussatite, whose light brownish tint and strong relief sets it off sharply from the embedding matrix of colorless chalcedony. Slavik[5] has

[5] Slavik, F., "Ueber die wahrscheinliche Identität von Lussatite und Tridymit," *Centralbl. Mineralogie,* p. 690, 1901.

suggested that lussatite is a fibrous form of tridymite in which the fibers are elongated parallel to the *c-axis*. This suggestion has much to commend it, but the birefringence of lussatite—about three times that of tridymite—militates against its acceptance. Whatever may be the relation of lussatite to the other crystallized varieties of silica, it appears certain that in the Nevada occurrence it has resulted from the crystallization of opaline silica.

The opal associated with the wood tin is a white or creamy-white variety; its refractive index is approximately 1.448, though adjoining layers are of slightly different indices. A noteworthy constituent of the gangue is tridymite; in places it occurs as a macroscopic component in aggregates of thin plates, but as a rule is only recognizable microscopically. In places well-defined plates of it are inclosed in lussatite. Although silica minerals are so abundant in the tin ore, quartz, though common as a phenocrystic relict, is rare as an epigenetic mineral, occurring in fact only in microscopic amount.

The wood tin invariably shows the characteristic concentric banding that resembles the annual growth-rings of wood. In color it ranges from dark reddish to brown, and differences in shade of this order generally determine the banding, which, however, is not equally marked in all specimens. The wood tin is generally in globular masses, or in the different modifications of this form that are termed botryoidal, mammillary, and reniform. As seen on polished surfaces and in thin sections, the particles of wood tin commonly contain nuclei of hematite. Some of these nuclei are surrounded by opal, then by hematite, and then by wood tin. Hematite, however, forms not only the nuclei but is also scattered abundantly throughout the wood tin.

ANALYSIS OF WOOD TIN FROM LANDER COUNTY, NEV.
(A. A. Chambers, analyst.)

SnO_2	85.14
SiO_2	1.03
Fe_2O_3	13.42
MnO	.02
H_2O-	.20
H_2O+	.05
	99.86

An analysis of a nugget of wood tin is given in the accompanying table. The specimen was selected because free from inclusions of hematite and because of its homogeneity.

The analysis shows that the wood tin is highly ferriferous, comparable in this respect to specimens of Mexican wood tin analyzed by Genth.

Under the microscope much of the wood tin proves to be opaque. The banding is seen to be due principally to the alternation of opaque or nearly opaque bands with fairly translucent bands. The translucent bands are deep yellowish brown, and react on polarized light, giving a shadowy extinction, suggestive of an ill-defined radial fibrous structure. What is the origin of the banding? Has it resulted from the growth of the wood tin by the periodic addition of new layers of differing composition, or is it a diffusion effect—the Liesegang phenomenon of rhythmic precipitation?[6] The complexity of the banded structures and the general independence of these structures to the walls of the veinlets harmonizes best with the hypothesis that the banding is a diffusion effect. Each particle of wood tin is characterized by its own peculiar banded pattern. Under the microscope the banding is found to be intimately related to the included plates of hematite. The banding completely envelops the inclusions and forms a series of concentric circles and ellipses around them. If the banding were due to "crustification," however, each band would be merely deflected by an inclusion and would envelop the inclusion only part way round, instead of completely surrounding it. This is believed to be a valid criterion by which banding due to the Liesegang phenomenon may be distinguished from banding due to crustification.

The inclusions evidently acted as nuclei from which some compound diffused centrifugally and induced rhythmic precipitation within the stannic oxide in which they were imbedded. If this explanation is correct, then in accordance with the known phenomena of rhythmic precipitation, the banding should be most

[6] Liesegang, R. E., "Geologische Diffusionen," pp. 81–159, 1913. Review in ECON. GEOL., Vol. 8, pp. 803–806, 1913.

closely spaced near the nuclei and progressively wider spaced at increasing distances from them; and this relation is in fact found to be generally true. These facts are believed to prove conclusively that the ultimate origin of the banding is due to rhythmic precipitation in a medium of colloidal stannic oxide.

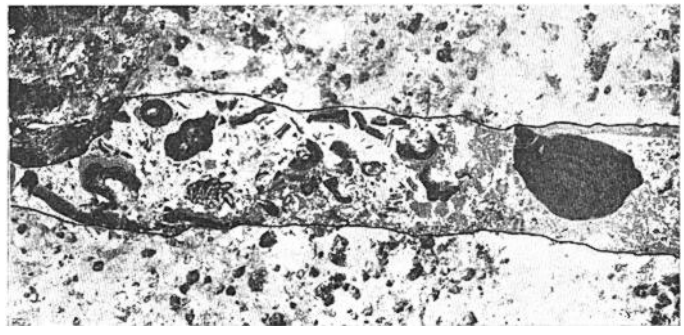

FIG. 37. Veinlet containing wood tin; the walls are indicated by the inked lines. The black particles within the veinlet are wood tin and the gray are hematite; the black particles without the veinlet are the quartz phenocrysts of the enclosing rhyolite. Enlarged 1⅓ diameters. Modoc prospect.

Inspection of Figs. 37 and 38 will show the diverse form characteristic of the particles of wood tin and how remarkable some of these forms are. There are angular particles suggestive of post-mineral brecciation; there are particles shaped like broad interrogation marks and like broken annuli. These queer structures and the apparent post-mineral brecciation are interpreted here as having resulted from the bursting of colloidal membranes by osmotic forces, as in the well-known example of the bursting of Traube cells. If a drop of concentrated copper sulphate solution is placed in a dilute solution of potassium ferrocyanide, it will surround itself with a membrane of copper ferrocyanide. The membrane thus formed is permeable only to water, whose continued ingress into the cell soon causes the membrane to burst. At the point of rupture the cell immediately heals, however, by forming a new membrane of copper ferrocyanide, and thus the cell grows for some time by alternate rupture and repair. That

certain seemingly brecciated agates very probably originated in an analogous way has been clearly shown by Liesegang.[7]

That the wood tin was deformed and ruptured while still in the plastic colloidal state is strongly indicated by the broken ring-like forms already mentioned and is proved beyond reasonable doubt by the deformation shown by some of the layers that

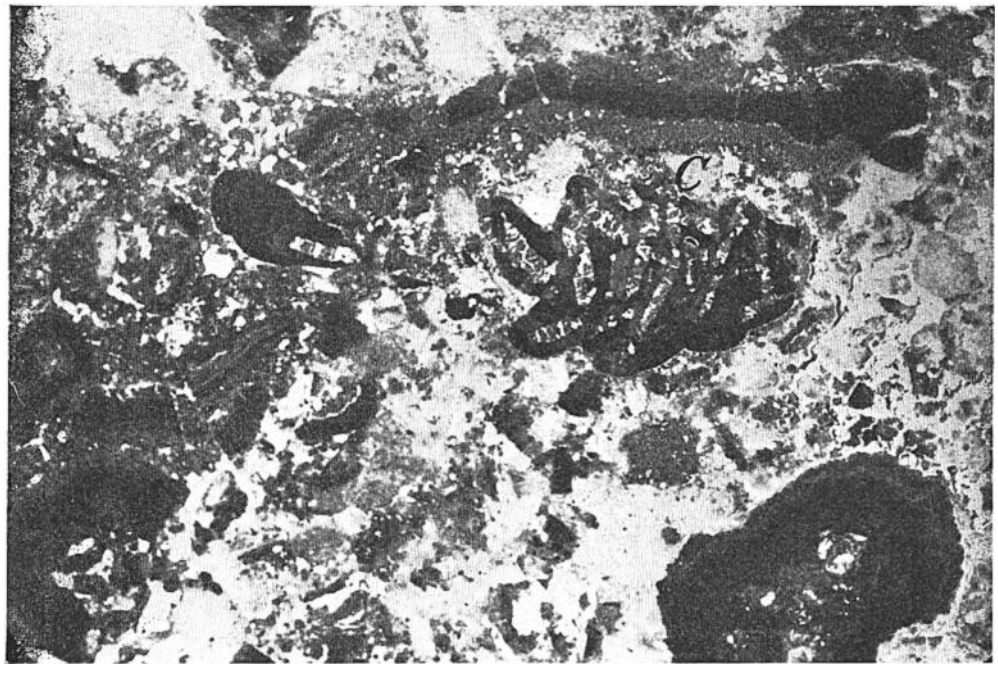

FIG. 38. Details of same veinlet shows the remarkable shapes of the particles of wood tin, which indicate that the wood tin was deformed while still a plastic colloid. *C* shows a complex cellular growth of wood tin, whose interior is filled by hematite and subordinate opal.

formerly lined the walls of certain veinlets: they have been deformed so that they resemble the conventional diagram of an overturned anticlinal fold. The complex, many-walled cell shown below *C* in Fig. 38, is doubtless an unusually well-developed

[7] Liesegang, R. E., "Ein Membrantrümmer-Achat," *Centralbl. Mineralogie,* pp. 65–67, 1912.

analogue of a Traube cell that has grown to considerable dimensions by alternate rupture and repair. The interior of the cell is filled with hematite and a little accessory opal. High magnification shows that the exterior wall of the cell is broken slightly at a few places; it shows further that the outer wall and the numerous inner walls are all delicately banded parallel to their sides—a feature that can be reasonably accounted for only by the hypothesis of diffusional rhythmic precipitation previously advanced. Although these processes—rhythmic precipitation and the bursting of colloidal membranes of stannic oxide by osmotic forces—are clearly indicated by the wood tin occurring in the veinlets, their chemistry is yet obscure.

GENESIS OF THE DEPOSITS.

That the tin-bearing veins were deposited from aqueous solutions is shown by the presence of opal in them, and that these solutions were hot is indicated by the tridymite, a mineral which has been repeatedly synthesized in aqueous solutions at temperatures ranging from 300° to 400° C. According to Daubrée, however, tridymite occurs embedded in the hyalite opal that has formed in the pores of the Roman bricks altered by the hot springs of Plombiéres.[8] If Daubrée's identification of the mineral as tridymite is correct, it establishes that tridymite may be formed in nature as low as 73° C., the temperature of the springs of Plombiéres. From Daubrée's observations and Koenigsberger and Müller's[9] experiments, in which they found that 360° C. is the highest temperature at which they were able to synthesize opal (quartz, chalcedony, and tridymite being obtained with it at the same time), it follows that the stanniferous veinlets were formed at temperatures probably between 73° and 360° C.; and the presence of the specular hematite in the veinlets indicates that

[8] Daubrée, A., "Sur la presénce de la tridymite dans le briques zeolithiques de Plombiéres," *Soc. géol. France,* Vol. 4, 3d ser., p. 523, 1876; "Geologie experimentale," p. 195, 1879.

[9] Koenigsberger, J., and Müller, W. J., "Versuche über die Bildung von Quarz und Silikaten," *Centralbl. Mineralogie,* p. 371, 1906.

more likely they were deposited near 360° than near the lower limit. The stannic oxide separated from solution in the colloid state and subsequently, in part at least, has become crystalline; the ferric oxide was deposited mainly as a crystalloid (hematite) but partly as a colloid entangled with the stannic oxide; and the silica was deposited both as crystalloid and as colloid, but mainly as a colloid (opal) which has later crystallized to lussatite.