SPECULARITE-ALUNITE MINERALIZATION AT HICKEYS POND, NEWFOUNDLAND*

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Introduction

During the investigation of a deposit of specularite at Hickeys Pond, in southeastern Newfoundland, in the summer of 1938 for the Geological Survey of Newfoundland, alunite was found as an abundant associate of the specularite. In a review of the literature no example of a similar occurrence was found and this deposit is therefore of particular interest in connection with the origin of alunite, a subject of considerable discussion.

General Geology

Hickeys Pond lies about 5 miles west of the head of Placentia Bay, in southeastern Newfoundland. The nearest settlements are the small fishing villages on Barren Island and Woody Island along the west side of the bay. Hickeys Pond is reached by a trail from La Plante, a small cove between these two islands. In the vicinity of the pond the country has low relief, its rolling surface dotted with numerous small bogs and ponds. Hickeys Pond, three-quarters of a mile long and less than a quarter of a mile wide, is one of the largest of these. To the north and northeast, about 2 to 3 miles from the pond, the country becomes rougher and rounded hills rise several hundred feet above the level of the lower country.

Southeastern Newfoundland is composed chiefly of pre-Cambrian rocks with isolated patches of Cambrian and Ordovician sediments fringing the bays that deeply indent the coast. The oldest pre-Cambrian rocks are the Harbour Main volcanics, a thick series of basic and acidic flows, tuffs and breccias. These are succeeded by 25,000 to 30,000 feet of slates, quartzites, sandstones and conglomerates, known as the Avalonian series. Intrusive into the volcanics and the lower members of the Avalonian series in the neighborhood of Conception Bay, is a granitic batholith, the Holyrood granite, and associated minor bodies.[1] At St. Lawrence, on the southern end of the Burin Peninsula, post-Cambrian granite, probably Devonian in age, is intruded into the Avalonian and Cambrian rocks.[2]

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[1] Buddington, A. F., Pre-Cambrian rocks of southeast Newfoundland: *Jour. Geol.*, **27**, 449–479 (1919).

[2] Snelgrove, A. K., Mines and mineral resources of Newfoundland: *Newfoundland Geol. Survey, Information Circular No.* **4**, 27 (1938).

The pre-Cambrian has been thrown into a series of folds, the axes of which strike northeasterly. Cleavage is well developed in many of the shaly formations and the sandstones have been altered to quartzites in many places. Hickeys Pond is on the contact between a granitic mass to the northwest and greenstone and schist to the southeast. The border facies of the intrusion is granodiorite, but the exact composition of the rock nearer the center of the intrusion (that is, farther northwest) is not known. The contact between the granodiorite and metamorphic rocks strikes about N. 40° E. in the vicinity of the pond but is not a straight line, nor is the contact sharp, as the schist is granitized near the contact. Areas of schist are included within the main granodiorite mass, and outcrops of granodiorite and thoroughly granitized schist occur within the main schist area.

The metamorphic rocks comprise massive greenstones, schistose greenstones with agglomeratic facies, talc schists, and quartz-sericite schists. Metamorphism has obscured the original character of the rocks, but their composition and the presence in places of bedded agglomeratic facies points to a series of basic lavas, tuffs, and agglomerates.

The greenstones are made up of quartz, chlorite, sericite and epidote, with minor amounts of magnetite and apatite. Some facies contain hornblende. In the schistose varieties the chlorite and sericite are well aligned. Quartz is in small evenly distributed grains in most specimens, but in a few there are scattered large grains. Feldspar was not detected, though it may be present in the fine-grained groundmass. Epidote is in patches, or more characteristically, in veinlets which can be detected as streaks of yellowish green in the darker green of the massive varieties. Hornblende is in long laths. Agglomeratic facies are well developed in places and provide the only evidence of sedimentary origin. They are dark mottled green with abundant pebbles as large as an inch in diameter.

Talc schist and quartz-sericite schist are common and often associated with each other. Since the talc schist is soft and readily eroded it is responsible for falls in many places where streams flow across it. The lip of the falls may be massive or granitized greenstone, or resistant quartz-sericite schist associated with the talc schist.

The strike of the schistosity ranges from N. 5° E. to N. 60° E., averaging about N. 30° E. It everywhere dips between 60° and 80° NW. Where bedding is apparent, as in the agglomerates, it is parallel to the schistosity.

The granodiorite is a pink, medium-grained, granitoid rock. Biotite is the common dark mineral, but there are some hornblende-bearing facies. The granodiorite shows a clear orientation of minerals in many places. Near the contact with the schist, the average strike of the orientation, with some local variation, is N. 30°–40° E., with a steep dip to the northwest. Away from the contact the orientation averages about N. 5° W. This change seems not to be gradual, but to be due to shearing in a N. 40° E. direction near and parallel to the contact, superimposed on and obscuring what is probably an original N. 5° W. orientation. In places near the contact the granodrite is much sheared; elsewhere, although it appears unsheared megascopically, the microscope reveals strain shadows and mortar structure in the quartz. Diabase dikes, in some cases badly sheared to greenstones, are very abundant, but confined mostly to the granodiorite. A few occur in the contact zone. The strikes of most of them lie between N. 5° and N. 15° W.

At some time following the intrusion of the granodiorite there were strong shearing movements. In the greenstone these produced chlorite schist, or, in extreme cases, talc schist. In granitized areas where the composition of the rocks was more acid, the result has been quartz-sericite schist. Although outcrops of schist cannot be followed continuously, both the talc and sericite schists are found along a line near and parallel to the contact between granodiorite and volcanics. All of them lie near a line about six miles long connecting the two most widely separated zones. The major shear, then, was confined to this zone, striking N. 40° E. parallel to the contact, and might be thought of as a fault, although the total displacement along this zone is not known. It was perhaps not very great. The latest movement, as determined from a drag in a quartz vein close to a schist outcrop at Hickeys Pond, shows a downward movement of the southeast side.

Neither the age of the volcanics nor that of the granodiorite is known. The whole of the peninsula between Placentia Bay and Fortune Bay was originally mapped as pre-Cambrian by Murray and Howley[3] and is so shown by Snelgrove.[4] If the volcanic rocks are pre-Cambrian, they would probably be correlated with the Harbour Main formation of the Avalon Peninsula. Although the volcanics have not been traced southeastward across their strike, the rocks near the Placentia Bay shore are dark gray to brown slates, possibly belonging to the Conception slate of the Avalonian series. Recent work on the north shore of Fortune Bay, however, has brought to light the existence of a thick series of volcanics overlying the Cambrian, containing both acidic and basic

[3] Murray, Alexander, and Howley, J. P., Geological survey of Newfoundland from 1864–1880, *Stanford*, London **(1881)**.

[4] Snelgrove, A. K., Mines and mineral resources of Newfoundland: *Newfoundland Geol. Survey, Information Circular No.* **4,** pl. 2 (1938).

lavas.[5] Until further work is done, connecting the Hickeys Pond area with the Fortune Bay area, the possibility that the Hickeys Pond volcanics are Paleozoic is not excluded.

The age of the granodiorite may also be Paleozoic. Hickeys Pond lies between the Devonian granite of St. Lawrence and the pre-Cambrian granite of Conception Bay, and it is not at the present time possible to say with which it is correlative.

Specularite-Alunite Mineralization

The only abundant specularite-alunite mineralization is at Hickeys Pond, although small disseminations were found at two other places, 2 miles to the northeast and 2½ miles to the southwest, along the shear zone.

Hickeys Pond is nearly cut in half by a peninsula which extends about 500 feet into the pond from the southeast side and is 900 feet wide. The peninsula has a rounded dome-like surface rising to a maximum elevation of 60 feet above the surface of the pond. About a quarter of the peninsula is a smooth bare outcrop and the rest is covered only with moss or a thin soil. The neck of the peninsula is low with no outcrops, but immediately to the southeast are exposures of white sericite schist.

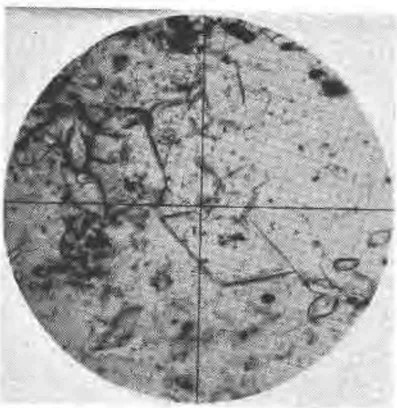
The rock of this peninsula is silicified schist and its resistant character is undoubtedly responsible for its not having been eroded by the glacial ice. Its isolated position and the absence of outcrops of similar rock in the area argue against the continuation of the deposit to the northeast and southwest under the waters of the pond. Outcrops close to the northwestern shore of the pond are granodiorite. To the southeast beyond the sericite schist is a greenstone schist, and at both ends of the pond are zones of granitized schist. This silicified body is along the contact, therefore, and represents a special case in the alteration of the volcanics by the intrusion.

The silicified rock has a gneissic structure with well-developed banding over a large part of the outcrops. The bands range from a quarter of an inch to several inches wide and are the result of the concentration in various proportions of specularite, alunite and quartz. In general the specularite and alunite vary proportionately: where there is much specularite the rock is strikingly banded in black and pink, the pink bands containing as much as 50 per cent alunite; where there is sparse specularite the banding is faint, the color of the rock is a dirty light gray, and there are only a few per cent of alunite and hematite. There is still an inherited schistose structure, however, and the sparse hematite

[5] White, D. E., Personal communication.

is strung out parallel to the schistosity. All three minerals are fine grained (0.01–0.2 mm.) and the rock has an aplitic appearance. In addition to these minerals there are minor quantities of talc, pyrite, and an unidentified yellow mineral in very minute grains.

The quartz of the altered rock is evenly fine grained (Fig. 2). Only a few scattered grains are larger than the average range of 0.01–0.1 mm. Some of these larger grains are corroded fragments of large single grains. The quartz grains show a distinct elongation parallel to the banding of the rock. Veinlets, a millimeter or so wide, of coarser quartz cut across the banding and the grains in these also show elongation parallel to the banding and at an angle to the direction of the vein.



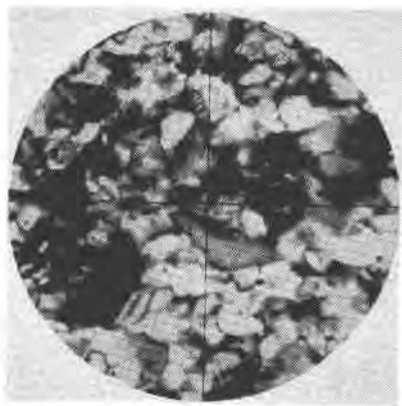


Fig. 1. Photomicrograph of a thin section showing alunite and a few grains of hematite in a groundmass of quartz. The large diamond-shaped alunite crystal near the center illustrates a common habit. In the upper left quadrant is a smaller grain with the basal pinacoid well developed. One nicol, ×51.

Fig. 2. Photomicrograph of the section shown in Fig. 1 taken with crossed nicols to show the texture of the quartz in the replaced rock. ×44.

The alunite commonly has good euhedral development. The common form is a rhombohedron, which appears as diamond-shaped crystals in a thin section (Fig. 1). The basal pinacoid is not uncommon, truncating the obtuse angle of the diamond. The basal cleavage and long dimension of the diamond-shaped cross sections are commonly parallel to the banding. Hexagonal cross sections also occur. The mineral is uniaxial positive, $\omega = 1.578$, $\epsilon = 1.601$, both $\pm .003$. It yields acid water in the closed tube and gives positive tests for aluminum and alkalies.

Specularite, as seen in thin and polished sections, occurs in ragged masses or individual grains and blades. With dark-ground illumination the granular character of the ragged masses can be clearly seen in polished sections. The specularite is distributed parallel to the banding, its blades oriented in the same direction.

Minute crystals of an unidentified yellow, anisotropic mineral with high indices of refraction are scattered through the rock and are closely associated with, or included in, the alunite. The crystals range in size from 0.005–0.02 mm. and are in most cases equidimensional, but there are a few slightly elongated prismatic forms. The habit resembles that of zircon, but larger identifiable zircon grains in the same rock have a somewhat lower relief and are colorless. The habit and relief do not correspond with those of jarosite. Turner[6] described minute brownish-red anhedral inclusions in the alunite of an altered andesite tuff at Tres Cerritos, California. An analysis of the alunite showed 0.40 per cent of TiO_2 and chemical tests on some of the separated grains showed they were rich in TiO_2 and were the probable source of that oxide in the analysis. Turner suggested that possibly the mineral was rutile, and this also seems the most probable identification for the Hickeys Pond mineral.

Pyrite in small crystals occurs chiefly in the specularite-poor silicified schist and is absent in most of the strongly alunitized and specularitized rock. Well-developed "pressure-shadows" occur around many pyrite grains. Plates of talc parallel to the banding are localized near the quartz vein to be described below.

Near the center of the peninsula there are numerous large quartz veins penetrating the silicified rock, striking N. 65° E. and dipping steeply NW. parallel with the banding. The contact of the vein zone to the southeast is sharp against the silicified schist. The latter is much contorted and in the contact there is a big roll, or drag fold, about 8 feet across, showing downward movement of the footwall. A zone of talc 2 or 3 inches wide follows the contact, and talc is present in masses an inch or so across in the edge of the quartz vein. In the 2 or 3 feet of the vein nearest the contact there are large masses of bladed specularite ranging in width from half an inch to 6 inches, and in length from a few inches to 4 feet. They have an average strike of N. 5° W., and dip 84° W. To the northwest of this specularite zone is a mass of barren white quartz, 8–9 feet wide, enclosing blocks and lenses of silicified schist. Beyond this for 20 feet the schist predominates and quartz veins are fewer until they die out entirely. Along the strike this wide zone of quartz veins narrows rapidly, and 250 feet to the northeast is represented only by a vein 3 feet wide with specularite blades up to a quarter of an inch in length.

[6] Turner, H. W., Rocks and minerals from California: *Am. Jour. Sci.* (Series 4), **5**, 424–425 (1898).

Beyond this point the veins were not seen. A few small quartz veins occur elsewhere on the peninsula, but are barren of specularite and in most cases are in the siliceous non-specularitic rocks. The quartz of the veins is in large grains with no evidence of crystal form. It shows strong strain shadows and incipient granulation. A few euhedral crystals of alunite can be found by microscopic study.

In the alteration of the original schist quartz is the earliest mineral formed. Hematite blades cut across the quartz grains and are in part later than the quartz. Alunite includes grains of hematite and thus seems to be somewhat later. Pyrite is definitely later than the specularite, since cubes of the former cut across the specularite bands, but its relation to alunite is not clear, as it is chiefly developed where the alunite is sparse. The plates of talc in the schist contain a few nests of alunite crystals which are probably later, having penetrated along the cleavages.

Two localities with minor amounts of mineralization lie in line with Hickeys Pond along the shear zone. At Chimney Falls, $2\frac{1}{2}$ miles to the southwest on Hickeys Brook, specularite is disseminated in a zone 8 feet wide in streaks parallel to the folia of the talc schist below the falls. Thin specularite bands are spaced from an eighth to a quarter of an inch apart. Quartz veins with specularite occur in this zone, most of them only 1 to 2 inches wide, but one lens measuring $1\frac{1}{2}$ feet across and 4 feet long contained alunite as well as fine-grained specularite. There has been very little silicification of the schist. On the schist planes the hematite has been sheared and slickensided.

Two miles to the northeast of the pond, Hickeys Brook crosses a chlorite-talc schist that is pyritized and cut by a few quartz stringers and lenses an inch or so wide containing a little fine-grained specularite. The schist zone is about 200 feet wide. The pyrite in the talc schist has been slickensided in the same fashion as the specularite at Chimney Falls.

It is clear that there has been movement and shearing since the alteration of the schist and injection of the quartz veins. The elongation of the quartz grains of the gneiss indicates recrystallization under stress, and so does the parallelism in the elongation of the quartz grains in the cross-cutting veinlets. Well-developed "pressure-shadows" of elongated quartz blades radiate from around pyrite grains. The specularite shows the same phenomenon, although less commonly, due to its rarer occurrence in large, strong grains. Specularite and pyrite have been slickensided. The large quartz vein at Hickeys Pond with the roll or fold in it, and the massive white quartz showing strong strain shadows and incipient granulation lend further support to the inference that some deformation followed mineralization.

The history of events, then, may be interpreted as follows:

1. Intrusion of granodiorite into greenstone with accompanying granitization. The contact runs roughly parallel to the structural trend of the region, about northeast.

2. Shearing along a zone which is parallel and close to the granodiorite-greenstone contact. The greenstones were changed to chlorite and talc schists, and the granitized rocks altered to quartz-sericite schists.

3. Silicification, specularitization and alunitization in zones determined by these shear zones. Where the mineralization was intense the schists were completely altered to a gneissic rock. Elsewhere specularite was the chief mineral introduced along the schist planes. The formation of the quartz veins was associated with this mineralization. The well-crystallized talc along the footwall of the large vein may be material absorbed from the schists and recrystallized near the wall of the vein.

4. Further movement along the shear zone folded the quartz vein and crumpled the silicified schist southeast of the footwall. The fine-grained quartz of the gneiss was recrystallized and elongated and the quartz of the cross-cutting veinlets was oriented in the same direction. The pyrite and specularite in the talc schist were sheared and slickensided.

Problem of Alunitization

Alunite is a characteristic product of solfataric action and is found as an alteration of acidic or intermediate lavas in many places. Silicification and the formation of kaolinite, or occasionally diaspore or bauxite, are usually associated with it. This view of its origin is supported by the known occurrence of sulphur dioxide as a constituent of the gasses of solfatara and the wide-spread occurrence of alunite in lavas.

De Launay,[7] however, presented good reasons for believing that the deposits at Tolfa, Italy, were due to the oxidation of pyritic veins in trachyte and the reaction of the sulphuric acid thus produced with the feldspar of the trachyte. In support of this he pointed out the deep ground water circulation, the passage of alunite veins into pyrite veins below the level of active circulation, and the gradation laterally of alunite into kaolinite, the normal weathering product of the trachyte, beyond the zone of pyrite concentration.

At Cripple Creek alunite and kaolinite are found only in the oxidized zone and probably have an origin similar to that of the Tolfa deposits.[8]

[7] De Launay, L., La metallogenie de l'Italie: *Compt. Rend., X Internat. Geol. Cong., Mexico*, **1,** 679–686 (1907); quoted in translation by Butler, B. S., and Gale, H. S., *U. S. Geol. Survey, Bull.* **511,** 51–55 (1912).

[8] Lindgren, Waldemar, and Ransome, F. L., Geology and gold deposits of the Cripple Creek district, Colorado: *U. S. Geol. Survey, Prof. Paper* **54,** 125 (1906).

At Goldfield, Nevada, alunite is one of the most characteristic minerals of the gold deposits and occurs both as a widespread rock alteration and as a vein mineral, closely associated with gold and sulphides. Ransome[9] discussed the origin of the alunite in detail. He dismissed the hypothesis that the alunite was formed from the oxidation of pyrite because of its quantitative insufficiency: there were no large sulphide bodies which could have produced sulphuric acid in the amount necessary to cause such widespread alteration. He also pointed out that alunite occurred 500 feet below the bottom of the weathered ores and was crystallized with pyrite throughout the rocks. Objections to a direct volcanic origin are less specific and refer to the improbability of the presence of sulphates in magmatic waters. The rarity of sulphate minerals as compared with sulphides, and of alunite in particular in metalliferous veins, and the absence of sulphuric acid in most hot springs are points favoring this improbability. Moreover, it is questionable whether waters rich in sulphuric acid would be efficient carriers of gold, sulphides and tellurides. He therefore concluded that hydrogen sulphide in rising solutions was oxidized near the surface to sulphuric acid and was recirculated downward, where it caused the precipitation of sulphides and the simultaneous formation of alunite.

The Goldfield district is apparently unique in the occurrence of alunite in the gold and sulphide-bearing veins. Elsewhere, however, alunite is not associated with sulphide minerals, other than pyrite, and it has been suggested that rising solutions carried the sulphate radical. In the San Cristobal quadrangle, Colorado, Larsen[10] round large masses of lavas, a square mile in area and extending 2000 feet vertically, altered to quartz and alunite with minor amounts of kaolinite, bauxite, and pyrite. The large volume of alteration, the absence of other oxidation products, the presence of pyrite, and the occurrence of hinsdalite ($2PbO \cdot 3Al_2O_3 \cdot 2SO_3 \cdot P_2O_5 \cdot 6H_2O$) in a nearby quartz-sulphide vein are all in favor of hot ascending sulphuric acid solutions. However, in view of the fact that such solutions were not generally thought by geologists to exist, Larsen did not think the evidence was sufficient to justify such an explanation, and gave as an alternative source for the alunite the mingling of hot ascending solutions or gasses carrying hydrogen sulphide with surface oxidizing waters.

The possibility of sulphuric acid in ascending waters received dis-

[9] Ransome, F. L., The geology and ore deposits of Goldfield, Nevada: *U. S. Geol. Survey, Prof. Paper* **66,** 129–133, 189–195 (1909).

[10] Larsen, E. S., Alunite in the San Cristobal quadrangle, Colorado: *U. S. Geol. Survey, Bull.* **530,** 179–183 (1913).

cussion and support by Butler and Gale[11] in their study of the deposits of alunite at Marysvale, Utah. The veins in the district are described as quartz-carbonate veins, many of them containing adularia and minor amounts of sulphides, sulpho-salts, etc. Exceptionally they contain alunite. In addition there are veins in which the filling is chiefly alunite. Alunite is an alteration in the wall rock of the veins and is sufficient in amount to account for the original potassium and aluminum content of the rock. The alunite of the veins must, therefore, be introduced from some distance. Moreover, adularia in the quartz-carbonate veins indicates that the hot ascending waters which formed them contained potassium and aluminum. Butler and Gale concluded that the alunite veins were deposited by ascending solutions. At what stage the sulphuric acid was formed could not "be positively stated, but it seems most natural to suppose that it was a part of the original solutions and that the potassium and aluminum were in part original in the solution and in part dissolved from the walls of the fissure at greater depth."[12]

At Hickeys Pond the origin of the alunite is clearly not due to the oxidation of pyrite. The outcrops are all polished glaciated surfaces and recent weathering is of the slightest. Furthermore, there are no large quantities of pyrite available.

The deposit has the appearance of being formed at a greater depth than any of the deposits described above. Butler and Gale[13] believed that the alunite deposits were formed near the surface, although of hypogene origin. Here, however, there is an absence of porosity or any cavities, the replacement has been complete, and the original texture has been obliterated except for the preservation of the earlier schistosity in the form of a gneissic banding. Movements along the shear zone after mineralization have the characteristics of shear at some depth rather than those of fault breaks at shallow depth. The sharp folding without brecciation of a massive quartz vein may be referred to in this connection.

Sulphates such as barite, celestite, anhydrite and hinsdalite (a member of the alunite group) are known to occur as primary minerals in veins of hypogene origin, and that the sulphate radical is even present in certain magmas is shown by its presence in minerals such as noselite, haüynite, lazurite and microsommite. Under what conditions sulphate may be present is not clear. The insolubility of such sulphates as barite make it seem probable that the barium is carried in some more soluble

[11] Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: *U. S. Geol. Survey, Bull.* **511**, 21–37 (1912).

[12] Butler, B. S., and Gale, H. S., *op. cit.*, 36.

[13] *Ibid.*, 36.

form, such as the chloride and precipitated rapidly when the sulphate radical makes its appearance. The same is likely to be true of alunite. The oxidation of sulphur to sulphate by the reduction of iron is apparently not a possible process at Hickeys Pond as the iron is all in the form of hematite. Solutions rich in oxygen possibly were the agents in this case, with the formation of sulphate at a deeper stage than is common. The oxidation of the sulphur is not complete, however, as there is some pyrite. As an alternative it may be suggested that the precipitation of alunite is due to the penetration of oxidized waters from the surface and their mingling with the rising solutions, although the absence of other oxidation products throughout the shear zones, mineralized or not, is unfavorable to this.

Economic Possibilities

The possibility of production of iron ore at Hickeys Pond is slight. The specularite in the quartz veins is restricted to a width of two feet and is not persistent along the strike. The gneissic specularitized rock is very low grade. Two channel samples of some of the most highly specularitized rock, assayed by the Newfoundland Government Laboratory, showed 3.42 and 2.87 per cent iron.

Small quantities of alunite have been mined as a source of potash at Tolfa, Italy, for more than 100 years. At various times production has been reported from Canada, Australia, Russia and Japan. In recent years large tonnages have been produced in Chosen (81,510 metric tons in 1935)[14] and in Spain (23,985 metric tons in 1931),[15] although the potash content of this material is not known. Alunite was mined at Marysvale, Utah, during the war, and a small quantity is still shipped every year for crushing and direct application as fertilizer, and for experimental purposes.

Alunite is also a possible source of alumina and sulphuric acid, although to date these have not been extracted commercially. Indeed, Hedges states that normally alunite "merits consideration only as an ore of aluminum, with potash as a valuable byproduct. Until such time as shifting markets, technologic improvements, exhaustion of cheaper source materials, or other changing conditions bring about utilization of alunite for production of aluminum, no important quantity of potash will be derived from this source."[16]

Both the Tolfa and Marysvale deposits are nearly pure alunite, but estimates at Marysvale showed that with high shipping costs the margin

[14] Minerals Yearbook, 1938, *U. S. Bur. Mines*, 1248 (1938).
[15] Minerals Yearbook, 1936, *U. S. Bur. Mines*, 1018 (1936).
[16] Minerals Yearbook, 1936, *U. S. Bur. Mines*, 1013 (1936).

of profit was small.[17] At Hickeys Pond the low content of alunite in the mineralized rock is not encouraging for development. No analytical data are available, but 20 per cent of alunite in the rock is a generous estimate, for although specimens were noted which contained as much as 50 per cent, a good deal of the mineralized area contains only sparsely disseminated alunite.

[17] Waggaman, W. H., and Cullen, J. A., The recovery of potash from alunite: *U. S. Dept. Agr., Bull.* **415,** 12–13 (1916).