ALUMINUM ORES.

ALUNITE IN GRANITE PORPHYRY NEAR PATAGONIA, ARIZONA.

By Frank C. Schrader.

INTRODUCTION.

The study of certain specimens collected in 1909, during a geologic survey of the Nogales quadrangle, in southern Arizona, has revealed a new occurrence of alunite. The mineral is disseminated in an altered granite prophyry at a locality 5 miles south of the town of Patagonia, the specimens studied being obtained from the 3 R mines, which are situated in the Palmetto mining district, in Santa Cruz County, about 10 miles north of the Mexican boundary. Patagonia is on the Benson-Nogales branch of the Southern Pacific Railroad.

RELIEF.

The 3 R mines are on the upper west slope of the north end of the Patagonia Mountains, one of the north-south desert ranges of the Great Basin type, at an elevation of about 5,400 feet. The topography, as expressed on the Nogales topographic sheet of the United States Geological Survey, is ruggedly mountainous, being of the type produced by uplift, faulting, and deep erosion of granitoid rocks. From the border of the gently westward sloping valley plain of Sonoita Creek, at the northwest base of the mountains, the surface rises about 2,000 feet to the summit in a distance of 2 miles. The most feasible means of approach is by way of 3 R Gulch, on the southwest, whence the rise to the mines is about 1,000 feet in a distance of one-third of a mile.

GEOLOGY.

The country rock in this part of the mountains is a medium to coarse grained gray granite porphyry. It occupies a north-south belt about 2 miles wide by 4 miles long, near the center of which the 3 R mines are located. Quartz and orthoclase in large phenocrysts and their aggregates constitute more than two-thirds of the rock;

the remainder seems to represent a fine-grained groundmass of the same minerals. Pyrite and chalcopyrite, which seem to be primary, occur in both the orthoclase and the quartz. Apatite and zircon are present as accessories.

The rock is vertically sliced by two systems of sheeting, of which the dominant system trends about north and south, parallel with the axis of the range and the Colossus lode, and the other about N. 75° E. Mineralized shear zones on which mines are located occur in both systems and are in places marked by conspicuous ledges, such as that of the Blue Rock No. 8, southeast of the 3 R mine and belonging to the east-west system. The rock, especially in the vicinity of the north-south shear zones, has also been pressed and sheared to a high degree, the resulting structure causing it to weather like a schist, which it locally resembles. It is cut by a few dikes of rhyolite and a younger granite porphyry. The rock was probably at one time a pegmatite, but it has been dynamically and otherwise altered, principally by sericitization and kaolinization.

THE ALUNITE.

The mineral alunite is a hydrous sulphate of aluminum and potassium, having the formula $K_2O.3Al_2O_3.4SO_3.6H_2O$. When pure it contains 11.4 per cent of potassa (K_2O), 37 per cent of alumina (Al_2O_3), 38.6 per cent of sulphuric anhydride (SO_3), and 13 per cent of water (H_2O).

The alunite here described occurs in the wall rock of the Evening Star prospect, belonging to the 3 R group of copper mines, in which deposits of rich chalcocite ore have recently been discovered. Here the altered granite porphyry, instead of being sericitized and gray, is alunitized and pink. The alunite almost wholly replaces the orthoclase, so that the rock consists chiefly of quartz and alunite with a little pyrite and chalcopyrite. The zone of alunitization extends at least several feet laterally from the vein fissure, and perhaps to a great distance. It was observed only incidentally in the course of examination of the copper deposits, and its width was not determined.

The rock in its present crushed and altered state presents a sort of graphic structure. It shows a general parallel pegmatitic arrangement of the minerals, quartz, and alunite alternating with each other in elongated lenslike bodies or discontinuous bands with irregular outline. These bands vary from about 0.1 to 0.4 inch in width. They are traversed at nearly right angles by a very close lamination or schistose structure, which amounts almost to cleavage and which is most conspicuous in the quartz. In the former feldspar areas the structure has been dimmed or largely effaced by the replacing aggregates of alunite, which is in part pseudomorphic after the orthoclase.

In or paralleling this schistose structure in the alunite occur also numerous veinlets of alunite having comb structure, by which a single crystal area is commonly sliced into six or eight or even ten to twelve sections. The veinlets are bilateral, with the comb structure locally interlocking. They are composed of slender elongated crystals, which are apparently made up of numerous smaller, almost cryptocrystalline aggregate forms, or successive zonelike stages of growth. The veinlets that extend into the adjoining quartz are generally less well developed.

Owing to the recent activity in the potash industry and the recognition of alunite as a possible source of potash, the interest in this occurrence centers in its potash as well as its alumina content. The rock from the Evening Star prospect was found by chemical test to contain abundant sulphates of aluminum and potassium. According to E. S. Larsen, who examined it microscopically and is familiar with the occurrence of alunite-bearing rocks in other fields, it is estimated to contain nearly half alunite.

The description here given is based mainly on office study of a few hand specimens collected from a deposit which was observed only incidentally in the field and which is not shown to be of commercial value. It serves to call attention, however, to the presence of the alunite in the porphyry and suggests that other deposits of the mineral may occur in this formation, which in the 3 R belt alone occupies an area of about 9 square miles. This porphyry belt would commend itself for prospecting in case a practical process is developed for the reduction of alunite to soluble potash salts, and in the light of the fact that "a study of the alunite deposits near Marysvale, Utah, and in other parts of the Western States by the United States Geological Survey indicates that the mineral alunite may become at some future time an important source of alumina."[1]

The occurrence of the alunite in the granite porphyry, a post-Paleozoic hypabyssal or plutonic rock, is unusual, as most of the known deposits of alunite, especially in the western United States, are in Tertiary volcanic rocks.[2]

The alunite here described seems to have been formed chiefly by the metasomatic replacement of the orthoclase feldspar in the granite porphyry, a process accomplished by hydrothermal solutions that ascended the fissure after the intrusion of the granite porphyry itself,

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[1] Phalen, W. C., The production of bauxite and aluminum in 1911: Mineral Resources U. S. for 1911, pt. 1, U. S. Geol. Survey, 1912, p. 924.

[2] Cross, Whitman, On alunite and diaspore from the Rosita Hills, Colorado: Am. Jour. Sci., 3d ser., vol. 41, 1891, pp. 466–475; Geology of Silver Cliff and the Rosita Hills, Colorado: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 314. Hill, R. T., Camp Alunite, a new Nevada gold district: Eng. and Min. Jour., vol. 86, 1908, pp. 1203–1206. Ransome, F. L., The geology and ore deposits of Goldfield, Nevada: Prof. Paper U. S. Geol. Survey No. 66, 1909, pp. 129–133, 193. Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: Bull. U. S. Geol. Survey No. 511, 1912. Larsen, E. S., Alunite in the San Cristobal quadrangle, Colorado: Bull. U. S. Geol. Survey No. 530, 1913, pp. 179–188.

or perhaps after the eruption of the later granite porphyry or the rhyolite of Red Mountain, near by on the east. The solutions were probably sulphurous and acidic, and the process was attended by some silicification. The deposition apparently took place in two periods or else during the deposition the rock was crushed and sheared, after which the veinlets traversing the earlier alunite bodies were deposited in the fractures. However, Ransome [1] and others have shown that alunite may be formed by very different processes, among which is the action on feldspar, as held by De Launay, or on sericite away from free oxygen, as held by Lindgren,[2] of downward-percolating meteoric waters charged with sulphuric acid by the oxidation of pyrite. In the locality here described the pyritic and highly sericitized character of the weathered porphyry admirably fulfills the conditions requisite for the formation of the alunite by the meteoric process.

In prospecting for alunite as suggested by Butler and Gale [3] it is well to examine (1) the so-called kaolin and talc deposits and also those of jarosite, associated with the feldspathic rocks in the oxidized zone; (2) phases of the Tertiary volcanic rocks containing potassium and aluminum silicates, in places where, as along fissures, they have suffered propylitic alteration by hydrothermal solutions and contain pyrite or chalcopyrite; (3) supposed spar, talc, or kaolin veins, especially in or near Tertiary volcanic rocks, whether associated with metallic veins or not.

Butler and Gale [4] give the following simple field test for the mineral alunite, suggested by W. T. Schaller:

Boil the powdered sample with water or with hydrochloric acid for several minutes; after allowing the powder to settle pour off the liquid and repeat the operation to insure the removal of all soluble sulphates. Dry the powder and heat to a dull red. Again boil in water and, after settling, pour off some of the clear liquid. To this add a small fragment or a solution of barium chloride. If the mineral is alunite, a heavy white precipitate will form. To be sure that the water used in this test does not contain sulphates in solution, it should be tested with barium chloride, and if it gives a marked precipitate it can not be used. For this test all that is required that is not included in a miner's or prospector's outfit is a little barium chloride, which can be carried in a small bottle or cartridge.

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[1] Op. cit., p. 132.

[2] Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Arizona: Prof. Paper U. S. Geol. Survey No. 43, 1905, pp. 119–120, 169, 193–194.

[3] Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: Bull. U. S. Geol. Survey No. 511, 1912, pp. 61–63.

[4] Idem, p. 63.

ALUNITE AT BOVARD, NEVADA.

By Frank C. Schrader.

INTRODUCTION.

Newly recognized occurrences of the mineral alunite continue to be reported from time to time, most of them revealed during the course of regular geologic studies in mining districts by members of the Geological Survey. The possible economic value of such deposits as a source of potash and of alumina makes them of more than purely mineralogic interest. During a brief visit to the Bovard district, Nevada, in the autumn of 1911 the writer collected some specimens of ore and gangue minerals, and later office study of these specimens has disclosed a new and somewhat unusual occurrence of the mineral alunite. The specimens were obtained at the Gold Pen mine and the Valley View prospect, and similar deposits were observed in two other prospects in the vicinity of the Valley View.

LOCATION AND MEANS OF ACCESS.

Bovard is a small mining district about 2 miles square in Mineral County, in southwestern Nevada. It is 17 miles south of Rawhide and about 20 miles northeast of Thorne, one of the nearest railway stations, on the Nevada & California Railroad (Southern Pacific system). Generally, however, travelers leave the railroad at Schurz, making the trip by way of Rawhide, a total distance of about 50 miles, over a better road, which is feasible for automobiles.

The district, as shown on the map of the Hawthorne quadrangle published by the United States Geological Survey, lies on the northeast slope of the Gabbs Valley Range between elevations of 4,800 and 6,600 feet. It is in a region of Tertiary volcanic rocks whose exposed section is nearly 2,000 feet in thickness. These rocks dip gently to the northeast and are underlain by highly disturbed Paleozoic limestone.

THE ALUNITE.

General character.—Alunite is a hydrous sulphate of aluminum and potassium, having the formula $K_2O.3Al_2O_3.4SO_3.6H_2O$. In its pure condition, which is rare in nature, it contains 11.4 per cent of potassa (K_2O), 37 per cent of alumina (Al_2O_3), 38.6 per cent of sulphuric anhydride (SO_3), and 13 per cent of water (H_2O).

The alunite at Bovard occurs in the form of vertical tabular sheets in fissures in the Tertiary volcanic rocks, especially the rhyolite, and in the Paleozoic limestone. The fissures form a system which trends northwest and southeast through the district, and they contain gold and silver bearing veins of the late Tertiary metallogenetic epoch. The gangue consists chiefly of quartz and brecciated rock, mostly rhyolite, much of which has been silicified and its minerals metasomatically replaced by infiltrated quartz. In a few places the quartz exhibits a laminated structure and is pseudomorphic after an earlier gangue spar mineral, calcite or barite.

In the croppings and oxidized zone the deposits are stained with or contain considerable limonite, hematite, chloropal, calcite, psilomelane, and some ocher-yellowish mineral that is utahite or perhaps jarosite. Locally they are sparingly streaked bluish with molybdenite stain. Adularia is probably associated with the pseudomorphic quartz.

The alunite occurs in the vicinity of the metalliferous veins, between well-defined walls, and is apparently of later origin than the ores. The occurrence of the alunite in association with the rhyolite is, to speak broadly, geologically normal for this part of the country, for most of the known occurrences of alunite in the Western States are in the Tertiary volcanic rocks,[1] from which in most camps the alunite has apparently been derived. This, however, seems to be the first instance reported of alunite in Paleozoic limestone or any other sedimentary rock. Such a mode of occurrence is not surprising, however, for there is no good reason why alunite should not be present in fissures, fractures, and bedding planes of sedimentary strata lying near alunite-bearing volcanic rocks which may supply the requisite materials.

The true character of the alunite was not recognized in the field, and little positive information can be given as to the actual extent of the deposits.

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[1] Cross, Whitman, On alunite and diaspore from the Rosita Hills, Colorado: Am. Jour. Sci., 3d ser., vol. 41, 1891, pp. 466–475.

Adams, G. I., The Rabbit Hole sulphur mines, near Humboldt House, Nev.: Bull. U. S. Geol. Survey No. 225, 1894, p. 500.

Cross, Whitman, Geology of Silver Cliff and the Rosita Hills, Colorado: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 314.

Cross, Whitman, and Spencer, A. C., The Geology of the Rico Mountains, Colorado: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 92–94.

Ransome, F. L., Association of alunite with gold in the Goldfield district, Nevada: Econ. Geology, vol. 7, 1907, pp. 667–692.

Hill, R. T., Camp Alunite, a new Nevada gold district: Eng. and Min. Jour., vol. 86, 1908, pp. 1203–1206.

Ransome, F. L., The geology and ore deposits of Goldfield, Nevada: Prof. Paper U. S. Geol. Survey No. 66, 1909, pp. 129–139, 193.

Larsen, E. S., Alunite in the San Cristobal quadrangle, Colorado: Bull. U. S. Geol. Survey No. 530, 1913, pp. 179–183.

Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: Bull. U. S. Geol. Survey No. 511, 1912, pp. 61–63.

Gold Pen.—The Gold Pen mine is in the northern part of the Bovard district, about half a mile north of the Bovard mine. Both mines are apparently on the same gold-bearing quartz vein, which dips steeply to the east.

At the Gold Pen there are about 400 feet of underground workings, including a shaft 120 feet deep. The mine has produced considerable rich gold ore. The country rock is a pale-reddish fine-grained or nearly aphanitic rhyolite which belongs in the upper part of the local geologic section. It consists chiefly of a cryptocrystalline or felsitic to glassy groundmass, in which are a very few scarcely megascopic crystals of quartz and orthoclase and a little apatite. The rock is much altered, the feldspar being changed to sericite, kaolin, quartz, and secondary feldspar.

The vein is of the fault-breccia type and is from 3 to 10 feet in width. It is composed of finely comminuted quartz, rhyolite, and other fragments all firmly cemented. The rock constituents are largely silicified and replaced by quartz. The vein and ore commonly show megascopic particles of free gold. The vein, as seen in the upper workings, is separated from its walls by sheets of whitish, consolidated, rocklike material, locally called "dry bone," from 3 inches to a foot or more wide.[1] A partial analysis (No. 1 in the following table) of a specimen of this "dry bone" shows it to be fairly pure alunite.

Except that it is a little low in SO_3, the analysis compares favorably with the analyses of selected samples from the deposit at Marysvale, Utah (Nos. 3 and 4), and of a sample from Red Mountain, Colo. (No. 5), and with the theoretical composition of the mineral alunite (No. 6).

Analyses of alunite.

	1	2	3	4	5	6
Al_2O_3	36.0	38	37.18	34.40	39.03	37.0
Fe_2O_3			Trace.	Trace.		
SO_3	33.50	38	38.34	36.54	38.93	38.6
P_2O_5			.58	.50		
K_2O	(a)	3	10.46	9.71	4.26	11.4
Na_2O		6	.33	.56	4.41	
H_2O+			12.90	13.08	13.35	13.0
H_2O-			.09	.11		
SiO_2		None.	.22	5.28		
Insoluble					.50	
	69.50	85	100.10	100.18	100.48	100.0

a Gives strong qualitative tests for potassium.

1. Gold Pen mine, Bovard district, George Steiger, analyst.
2. Valley View prospect, Bovard district, George Steiger, analyst.
3, 4. Marysvale, Utah. Butler, B. S. and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: Bull. U. S. Geol. Survey No. 511, 1912, p. 8.
5. Red Mountain, Colo. Hurlbut, E. B., on alunite from Red Mountain, Ouray County, Colo.: Am. Jour. Sci., 3d ser., vol. 48, 1894, pp. 130-131.
6. Theoretical composition. Dana, E. S., System of mineralogy, 6th ed., p. 974.

[1] Since this paper was put in type William Raines has reported that the width is in places at least 2½ feet.

The alunite in its relation to the vein and the wall rock at the Gold Pen mine is suggestive of gouge, but it is practically free from crushed rock, clay, quartz, and other materials common to gouge, though in places a few grains of quartz were noted. The alunite is massive and aphanitic. It has a porcelain-like appearance, a hackly or conchoidal fracture, and a hardness of about 4.

Valley View.—The Valley View prospect is in the southern part of the Bovard district, nearly a mile from the Gold Pen mine. It is in a small irregular area, about a fourth of a mile in diameter, of dark-blue or gray Paleozoic limestone which is locally the basal member of the geologic section. The limestone is medium to heavy bedded and strikes in general N. 75° W., with vertical or steep dips to the south. It is folded, faulted, slickensided, intruded by dikes of the surrounding overlying rhyolite, and in places silicified or silicated.

The alunite occurs in a fissure in the limestone. It is exposed in a 30-foot drift, known as the lower tunnel, on the Valley View No. 2 claim. Here, also, as at the Gold Pen mine, the mineral is found as a vertical sheet or vein in the east wall of the drift. It is a structureless or massive white substance, which extends the whole length of the drift and has a thickness of about 18 inches. This drift is situated near the northeast contact of the limestone with the rhyolite. Except for some blue limestone, most of which is silicified and very hard, the drift is almost wholly in oxidized material consisting of a blackish mixture of psilomelane, limonite, and hematite.

The partial analysis of this material, No. 2 on page 353, shows the mineral to be a relatively pure alunite nearly free from silica. A distinctive feature shown by the analysis is its high sodium content, which according to W. F. Hillebrand and S. L. Penfield [1] makes the mineral a natroalunite.

Apparently the highest percentage of sodium in alunite hitherto recorded in the literature is that noted by Hurlbut in the alunite from Red Mountain, Colo., the analysis of which is No. 5 in the accompanying table and shows 4.41 per cent. Alunite containing 4.32 per cent of sodium is reported by Cross [2] from the Rosita Hills, Colo. At Vindicator Mountain, Goldfield, Nev., Ransome [3] noted sodium-bearing alunite in which the molecular ratio of soda to potash is as 40 to 45.

[1] Clarke, F. W., and others, Contributions to mineralogy from the United States Geological Survey: Bull. U. S. Geol. Survey No. 262, 1905, pp. 38–40.

[2] Cross, Whitman, Am. Jour. Sci., 3d ser., vol. 41, 1891, p. 473.

[3] Ransome, F. L., The geology and ore deposits of Goldfield, Nev.: Prof. Paper U. S. Geol. Survey No. 66, 1909, p. 131.

The alunite of the Valley View prospect is very close-grained but not hard. It resembles kaolin or chalk and may be pulverized between the fingers to a fine flourlike powder, which, much like that of talc or graphite, is smooth to the feel.

Locally the deposit shows streaks of buff or gray, often with a reddish tinge on the slickensided surfaces. To the finger the colored material is as smooth as the white and is apparently nearly as pure.

The deposit is separated from the limestone country rock by a considerable thickness of earthy oxides of iron and manganese on either side.

The deposit at this place was not traced far beyond the drift by which it is opened, but so far as observed the vein shows no indication of diminution or pinching.

Other occurrences.—About 300 feet south of the Valley View prospect and about 200 feet higher up the hillside a 30-foot tunnel exposes some material which apparently is very impure alunite. The deposit is on a minor fault fissure in limestone, close to a contact with intrusive rhyolite. The fissure contains fragments of impure and altered limestone, oxides of iron and manganese, and a substance believed to be alunite, which for the most part appears to have replaced limestone.

At the Mohawk, a prospect 900 feet east of the Valley View, a shallow cut has been excavated for 16 feet along the contact of limestone with overlying rhyolite, exposing material similar to that just described. The limestone here dips 80° S. and the deposit pitches southeastward into the ridge.

Microscopic character.—The powder of the alunite from the Gold Pen mine and Valley View prospect, when examined under the microscope with high power, is seen to be composed of very fine whitish or colorless crystalline grains with the rhombohedral habit of alunite. The grains have a weak birefringence and their refractive index as determined by E. S. Larsen is 1.567. The grains are too small for the further determination of their optical properties. The crystalline form is best shown in the alunite from the Valley View prospect. The powder also contains a few minute hexagonal scales which apparently are likewise alunite.

CONCLUSIONS.

As little is known of the actual extent of the alunite of the Bovard district, no prediction of its possible commercial value is justified. Furthermore, as a source of potash the occurrence is not, from the evidence at hand, to be considered promising. The deposit in the Valley View prospect, although it may be assumed to represent a considerable quantity of material, has been shown to consist of a potassium-sodium alunite in which the potash content probably does not run high enough to be of value by itself. As to the possibility of its value as a source of alumina there is little precedent to afford a basis for an opinion. A pure alumina free from silica, if it could be derived in considerable quantity from such a deposit, might possibly prove of sufficient value for the manufacture of the metallic aluminum to justify its extraction and treatment, but this suggestion is put forth rather as a possibility than as an estimate of value which the deposit is believed to represent. Suggestions for prospecting are given on page 350.

SURVEY PUBLICATIONS ON ALUMINUM ORES—BAUXITE, CRYOLITE, ETC.

The following reports published by the Survey or by members of its staff contain data on the occurrence of aluminum ores and on the metallurgy and uses of aluminum. The Government publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications (except the folio) may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.; the folio only from the Director of the Survey.

Burchard, E. F., Bauxite and aluminum: Mineral Resources U. S. for 1906, 1907, pp. 501–510. 50c.

——— Fluorspar and cryolite in 1912: Mineral Resources U. S. for 1912, 1913.

Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: Bull. 511, 1912.

Canby, H. S., The cryolite of Greenland: Nineteenth Ann. Rept., pt. 6, 1898, pp. 615–617.

Hayes, C. W., Bauxite: Mineral Resources U. S. for 1893, 1894, pp. 159–167. 50c.

——— The geological relations of the southern Appalachian bauxite deposits: Trans. Am. Inst. Min. Eng., vol. 24, 1895, pp. 243–254.

——— Bauxite: Sixteenth Ann. Rept., pt. 3, 1895, pp. 547–597. $1.20.

——— The Arkansas bauxite deposits: Twenty-first Ann. Rept., pt. 3, 1901, pp. 435-472. $1.75.

——— Bauxite [in Rome quadrangle, Georgia-Alabama]: Geol. Atlas U. S., folio 78, 1902, p. 6. 5c.

——— The Gila River alum deposits: Bull. 315, 1907, pp. 215–223. 50c.

Hunt, A. E., Mineral Resources U. S. for 1892, 1893, pp. 227–254. 50c.

Larsen, E. S., Alunite in the San Cristobal quadrangle, Colo.: Bull. 530, 1913, pp. 179–183.

Packard, R. L., Aluminum and bauxite: Mineral Resources U. S. for 1891, 1892, pp. 147–163. 50c.

——— Aluminum: Sixteenth Ann. Rept., pt. 3, 1895, pp. 539–546. $1.20.

Phalen, W. C., Bauxite and aluminum in 1912: Mineral Resources U. S. for 1912, 1913.

Schnatterbeck, C. C., Aluminum and bauxite: Mineral Resources U. S. for 1904, 1905, pp. 285–294. 70c.

Spurr, J. E., Alum deposits near Silver Peak, Esmeralda County, Nev.: Bull. 225, 1904, pp. 501–502. 35c.

Struthers, J., Aluminum and bauxite: Mineral Resources U. S. for 1903, 1904, pp. 265–280. 70c.