DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 620—K

RECENT ALUNITE DEVELOPMENTS NEAR MARYSVALE AND BEAVER, UTAH

BY

G. F. LOUGHLIN

Contributions to economic geology, 1915, Part I
(Pages 237-270)

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RECENT ALUNITE DEVELOPMENTS NEAR MARYSVALE AND BEAVER, UTAH.

By G. F. Loughlin.

INTRODUCTION.

In 1910 certain deposits of "pink spar" about 7 miles southwest of Marysvale, Utah, were recognized as alunite, the double sulphate of aluminum and potassium. Since January, 1911, many alunite locations have been made in this region. Prospecting and development have been essentially continuous in the hope of developing a commercial source of potash salts, and this hope now appears to have been realized. The greatest amount of development work has been done on the Gillan-Custer group of claims, operated by the Mineral Products Corporation, of Marysvale.

A demonstration of the feasibility of extracting potassium sulphate from alunite, by W. T. Schaller, was published by the United States Geological Survey, on December 18, 1911.[1] This process has been worked out on a commercial scale by the Mineral Products Corporation, which recently erected the first mill for the treatment of alunite in the country and made its first production of potassium sulphate on October 7, 1915. On October 20 a carload of 28 tons of potassium sulphate, reported to be 93 per cent pure, was shipped in cotton bags to the Armour Fertilizer Works, at Jacksonville, Fla.[2] It is reported that at least one other company has plans for the erection of a mill.

The first discoveries on the Gillan-Custer group of claims were visited by C. W. Hayes, then chief geologist of the United States Geological Survey, in March, 1911, and were later examined by B. S. Butler and H. S. Gale, the results of whose work, including a general geologic reconnaissance of the Marysvale region, were published in 1912.[3] Public interest in the more recent developments prompted a second examination of the region in 1914, and this field work forms

[1] U. S. Geol. Survey Press Bull. 30, 1911.

[2] Telegram from Charles H. MacDowell, president Armour Fertilizer Works: Manufacturers Record, Oct. 21, 1915, p. 52. A private letter from Gascoyne & Co., Baltimore, Md., dated Nov. 10, 1915, reports that analysis of potash of this shipment showed 95.39 per cent of potassium sulphate.

[3] Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: U. S. Geol. Survey Bull. 511, January, 1912. See also U. S. Geol. Survey Press Bull. 30, Dec. 18, 1911.

the basis of the present report. In October, 1915, during the first days of operation of the Mineral Products Corporation, the region was visited by H. S. Gale and V. C. Heikes, of the United States Geological Survey. Mr. Gale's description of properties either inaccessible in 1914 or developed since then and Mr. Heikes's description of the mill are incorporated in the following pages.

The known alunite deposits in Utah are in Piute County, on the east side of the Tushar Mountains, and in Beaver County, on the west side, but only those in Piute County are at present of commercial importance. The deposits of Piute County are from 7 to 8 miles

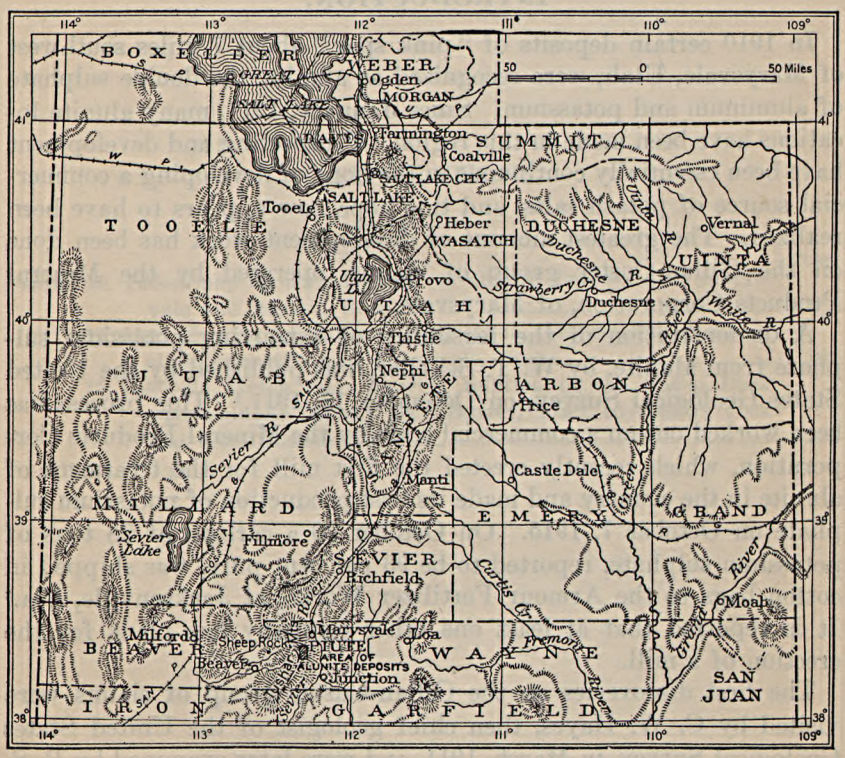

FIGURE 13.—Index map showing location of alunite deposits near Marysvale and Beaver, Utah.

southwest of Marysvale, in the Ohio and Mount Baldy mining districts, and those of Beaver County are about 10 miles northeast of Beaver, in the Newton mining district. (See fig. 13.)

Marysvale, at the terminus of the Marysvale branch of the Denver & Rio Grande Railroad, is about 120 miles south of the main line of the same system. Beaver is 40 miles southwest of Marysvale and about 35 miles east of Milford, on the San Pedro, Los Angeles & Salt Lake Railroad.

GEOLOGY OF THE TUSHAR MOUNTAINS.[1]

The Tushar Mountains form part of a long north-south range between the valley of Sevier River on the east and a broad desert valley on the west. The floor of Sevier Valley near Marysvale has an elevation of about 5,600 feet and that of Beaver Creek at Milford about 5,450 feet. From these depressions the mountains rise boldly, the highest summits of the range, situated northwest of Marysvale, attaining elevations of nearly 13,000 feet.

The range is composed of both sedimentary and igneous rocks. It is outlined by north-south faults and is thus like the ranges of the Great Basin province to the west. However, the bedded rocks, including sediments and volcanic flows, are not greatly tilted, and in this respect the structure is like that of the plateau province to the east.

The sedimentary rocks exposed along the mountain front west and southwest of Marysvale comprise limestones and quartzites having an aggregate thickness of perhaps 2,000 feet. These formations are regarded as of Jurassic age.

Resting on the eroded surface of the sedimentary rocks are effusive volcanic rocks comprising lava flows and tuffs. In general the lower part of the volcanic series is composed of dacite, but chemical investigation may show that some andesite also is present.

Above the dacite, forming the highest part of the range and, toward the north, extending far down the slopes, is a series of light-colored rhyolite flows and tuffs, locally called shale. Southeast of Beaver there are basalt flows that are younger than the rhyolite. The alunite veins of the region, so far as observed, are in that part of the volcanic series which lies below the rhyolite flows.

Of later origin than the rhyolite and tuff series are intrusive rocks which, though of diverse composition, are all related to quartz monzonite. These rocks occupy relatively small areas, but the mineral veins of the region are later than them and are undoubtedly related to them genetically.

The Tushar Range is delimited on the east and west by prominent faults, and within the range there has also been faulting and fissuring, which have affected all the rocks except possibly the basalts. In the main these faults within the mountains show northerly to northwesterly trends, but there are a few cross breaks.

The mineral deposits, consisting mostly of veins but including some irregular replacement bodies, conform in occurrence with the faulting and fissuring, and thus most of them show northerly to northwesterly trends. These deposits comprise two distinct mineralogic types, one containing no alunite and the other composed almost

[1] This description is summarized from U. S. Geol. Survey Bull. 511, already cited.

entirely of alunite or of alunite and quartz. In general the alunite deposits do not contain sulphides or related minerals in conspicuous amount, whereas the other veins do, and some of them have been worked for metals, principally silver and gold. Only the alunite deposits were examined by the writer. Those southwest of Marysvale are distinct though irregular veins, whose formation was accompanied by a minor amount of replacement, but the deposit at Sheep Rock, northeast of Beaver, is an irregular replacement body.

ALUNITE DEPOSITS SOUTHWEST OF MARYSVALE.

LOCATION AND EXTENT.

The best-known alunite deposits southwest of Marysvale are in secs. 8, 16, and 17, T. 28 S., R. 4 W. They lie in three roughly

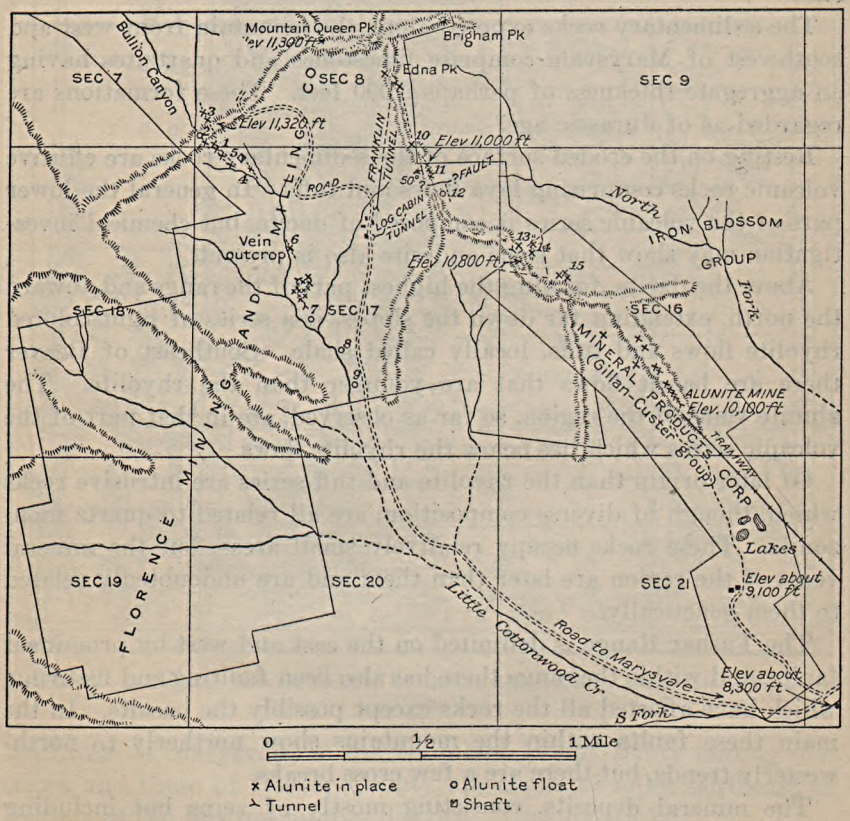

FIGURE 14.—Map showing location of prospects in the principal group of alunite deposits near Marysvale, Utah. Numbers refer to descriptions in text.

parallel zones of northerly to northwesterly trend, the eastern and middle zones on or near the crests of ridges near the headwaters of Little Cottonwood Creek and its North Fork, the western zone close

to the bed on the main stream. (See fig. 14.) The prospects along the main stream can be reached directly by a circuitous wagon road, with an ascent of about 5,000 feet. Prospects east of the creek (main fork) can be connected by short inclined tramways with this wagon road, or by long tramways, like that of the Mineral Products Corporation, extending to roads nearer Marysvale.

Other deposits, only little prospected in 1914, lie east and south of those just mentioned. The prospects on the Lost Horse and Mohawk group of claims are about 2 miles farther from Marysvale than those on the three main zones, and are reached by trail from the Little Cottonwood Canyon road. Still others have been reported to lie south of the divide between Little Cottonwood and Tenmile canyons.

CHARACTER.

GENERAL FEATURES.

All the deposits thus far found are doubtless veins cutting porphyry (altered dacite), though in only a few exposures have their true thicknesses and exact trends been determined. The alignment of prospect pits and trenches and the distribution of float, however, indicate for the most part trends of N. 20°–40° W., though at a few openings the trend is nearly due north. The dips of the different veins are for the most part 50°–70° W., but vertical dips have been noted at a few places and a steep easterly dip was recorded at one obscure exposure. None of the veins have been opened continuously along their strike, but the alignment of openings indicates probable lengths of 500 to 800 feet for continuous veins and of 1,500 to 5,000 feet for vein zones. The widths of the veins or vein zones are considerable, but the prospect trenches on all but the Custer vein did not, as a rule, afford a satisfactory estimate of the width or thickness. The Custer vein contains an average thickness of about 10 feet of high-grade alunite, on each side of which smaller veins or bands of alunite alternate with similar thicknesses of quartz or highly silicified porphyry.

The best exposure in the western zone is on the L. & N. No. 4 claim and shows an exposed thickness of 26 feet, of which 20½ feet is high-grade alunite and 5½ feet quartz. Other openings show thicknesses of 8 to 20 feet. The veins are distinctly banded, bands of nearly pure alunite alternating with bands of quartz. The alunite portions themselves are for the most part banded by parallel to concentric markings similar to those in travertine, or "onyx marble," and characteristic of open fissure fillings, but there is also evidence of replacement on a minor scale. The general distribution of the veins is indicated on the surface by elongate to irregular areas of silicifica-

tion, many of which appear to have determined the positions of ridges and prominent peaks through their superior resistance to erosion.

Three varieties of alunite have been noted in the veins—coarsely crystalline, fine grained to dense, and laminated. The coarsely crystalline variety is by far the most common. It is pink to reddish, and forms large masses of columnar to platy crystals as well as small veinlets that cut the other two varieties. It is practically pure but contains minute quantities of pyrite or limonite and silica (chalcedony and opal). It is most readily recognized in the field by these properties, together with its high specific gravity (about 2.82[1]), which is distinctly higher than that of calcite (2.71), the only mineral in the region that is likely to resemble it in crystalline form.

The fine-grained variety is pink to white and resembles porcelain where hard and chalk where softened by weathering. Under the microscope some specimens are seen to consist almost entirely of minute crystals of alunite with only an apparently negligible amount of pyrite, silica, and kaolin; but in other specimens these impurities are more conspicuous. The fine-grained variety may resemble kaolin, or miner's "talc," especially if enough kaolin is present to yield its characteristic odor; but the fine-grained alunite, like the coarse-grained variety, may be recognized by its high specific gravity.

The laminated or shaly variety differs from the fine-grained variety only in its structure, which is evidently due to shearing along the plane of the vein. Such a structure could have been developed in either of the other varieties.

DETAILED DESCRIPTIONS.

The following detailed descriptions of the alunite, associated quartz, and altered wall rock are given for the benefit of those especially interested in the mineralogy and genesis of the veins:

ALUNITE.

In the coarsely crystalline variety of alunite the crystals have a tubular form and occur in diverging columnar aggregates crossed by parallel lines or bands. In some places the larger crystals extend across these bands; in others the bands mark either interruptions or possibly sealed fractures. The diverging character of the crystal aggregates is even more noticeable under the microscope than in hand specimens. The rhombohedral faces of the crystals are not usually well developed, but in many places an open cavity between two bands shows well-developed rhombohedral faces, which, however, have commonly been etched by later solution. What in the hand specimen appear to be crystals are seen under the microscope to be composed of numerous smaller crystals diverging from a central axis, forming a striking plumose structure.

[1] This figure is near the average of several determinations of Marysvale alunite by W. T. Schaller, of the United States Geological Survey. According to Dana's Textbook of mineralogy (edition of 1900, p. 537) the specific gravity is 2.58 to 2.75.

The lines marking the separation of the bands forming the vein are seen under the microscope to consist of narrow bands of finely crystalline material of various orientation. Where the larger crystals or aggregates cross these lines without change in orientation, they give the impression that the fine material has been deposited in fractures breaking across the crystals. It is more probable, however, that a slight change in conditions interrupted deposition or altered its rate and caused the deposition of several minute unoriented crystals instead of the large crystals, after which a return of the original conditions permitted the largest crystals to continue their growth, while crystallization in part began at new centers. Some of the lines are due to a change in color without change in crystal character and are to be attributed to slight changes in the composition of the depositing solution, such as the presence or absence of a trace of iron oxide. Parallel wavy or concentric bands of this type are very common in cavern deposits such as stalactites, stalagmites, and crusts lining cave and fissure walls, and their presence in the alunite veins is regarded as proof that this variety of alunite was deposited as an open-fissure filling. Cavities between banded aggregates pointed toward each other mark places where the openings were not entirely filled.

The lines that mark the boundaries between crystal aggregates growing away from each other require a different explanation. There must have been a surface or narrow strip of material on which the aggregates began to grow but which is no longer present. It is suggested, from evidence presented in a subsequent paragraph, that there was formerly present a narrow strip or sheet of the fine-grained alunite, which has since disappeared by recrystallization into the coarsely crystalline variety.

As seen under a low power of the microscope the coarsely crystalline variety appears to be almost pure, but when it is studied under high power numerous yellow globular masses are revealed, most abundantly between the crystals or along minute fractures. These masses are probably limonite. Some small spaces and also certain lines of zonal growth across the crystals are filled or marked by cloudy material, some of which looks like kaolin, some like minute cubes of pyrite, and some like minute bubble inclusions, while much of it is in specks too small to warrant even a suggestion as to their character. A few minute crystals of undoubted pyrite are present in the alunite. It also includes numerous irregular microscopic masses of an undetermined mineral that appears to be isotropic and has an index of refraction below that of alunite. Some of these masses may be opal; others of similar appearance in ordinary light prove between cross nicols to be doubly refracting aggregates with a birefringence like that of quartz.

In one specimen from the mouth of the tunnel on the L. & N. No. 4 claim of the Florence Mining & Milling Co. the casts of several crystals of a tetragonal or orthorhombic mineral are present in coarsely crystalline alunite. The casts are as much as half an inch in length, about a millimeter in width, and square to diamond shaped in cross section. They are fringed by rows of alunite crystals growing normal to the edges of the casts and are partly filled with a brown powder, shown under the microscope to consist of an indeterminate amorphous material stained with brown iron oxide and containing scattered crystals of alunite. The crystal outline and mineral association suggest that the original mineral may have been diaspore.

The fine-grained, porcelain-like variety is seen under the microscope to be a granular mass composed of irregular crystals of alunite. No distinct grains of quartz were recognized in the few thin sections studied, although the only analysis of this variety shows the presence of 5.28 per cent silica. In some

thin sections distinct though minute grains of pyrite, partly or wholly oxidized to limonite, are thinly scattered through the alunite mass. The fine-grained variety in part forms thin bands between uniformly oriented bands of the coarsely crystalline variety but for the most part is cut by parallel and linked veinlets of the coarsely crystalline alunite.

Where the fine-grained material alternates with uniformly oriented bands of the coarse-grained material it probably represents changes in conditions of crystallization in an open fissure; where it is cut by veinlets of the coarse-grained alunite it was undoubtedly the first to form, and the veinlets were probably in part derived from it. Both megascopic and microscopic study of the latter phase show that the coarse crystals in these veinlets have formed in part, if not wholly, by recrystallization of the fine-grained mass, single large crystals growing at the expense of many small ones. Lenticular patches of the fine-grained type inclosed between coarse-grained veinlets diminish to mere lines between bands of crystals, and large crystals project into the fine-grained aggregates or may even inclose a few fine crystals just within their boundaries. So far as microscopic data are concerned, this process is one of simple recrystallization. The minute pyrite grains in the fine variety are no more than enough to account for the dusty patches and zonal groups, some of which are pyrite or limonite, in the coarse crystals. Silica is too scarce in either variety, so far as seen under the microscope, to be of much significance in this connection. The small amount noted in the coarsely crystalline variety was formed either at the same time as the alunite crystals or slightly later and may represent a small amount of submicroscopic silica in the fine-grained type. Further collection and study of impure phases of the fine-grained type are needed to throw definite light on this question.

No distinct transition between the fine-grained alunite and the silicified and alunitized wall rock was noted in the exposures of rock in place. Coarsely crystalline alunite was found in direct contact with silicified rock, both at the walls and within the veins. Loose fragments, however, along some of the prospect trenches consist of rather highly alunitized material which still preserves more or less distinctly the porphyritic texture of the local wall rock. This evidence suggests that there may be a transition between practically pure fine-grained alunite and the silicified and alunitized wall rock.

The shaly or schistose variety was noted only at exposures in and just northwest of the Gillan-Custer claims. It is microcrystalline and contains numerous slickensided partings, which indicate a strong shearing movement along the vein. It consists, like the other varieties, of almost pure alunite in which there are a few minute crystals of pyrite (or limonite). It also contains veinlets and small vugs of coarsely crystalline alunite, so arranged as to leave little doubt that they have resulted from local recrystallization of the sheared alunite where small fractures made conditions favorable.

QUARTZ.

The quartz bands that alternate with those of alunite have been noted in the western vein zone (see fig. 14) and in the Custer or eastern zone. Further developments will doubtless prove their existence in the middle zone as well. The bands consist of dense or microcrystalline quartz with a little pyrite in fine grains. In places they show a faint trace of porphyritic texture, suggesting replacement of porphyry rather than open-fissure filling. In the western zone, as shown on page 249, the quartz bands occur at irregular intervals throughout the width of the vein; in the Custer or eastern zone they alternate with smaller veins of alunite on each side of the main alunite body. The

contrast in character between this dense form of quartz, or highly silicified porphyry, and the pure crystalline alunite is striking and not satisfactorily explained from the evidence at hand.

WALL ROCK.

Alteration of the wall rock along the alunite veins is pronounced and extends for many feet on each side. The altered rock, dacite porphyry, is white to pale pinkish where not stained by iron oxides and of dull or chalky luster. The original porphyritic texture is distinctly preserved and is especially prominent on iron-stained surfaces, where the iron oxides have colored the groundmass but not the phenocrysts. The principal minerals present are quartz, alunite, and pyrite, with small amounts of limonite, kaolin, apatite, and zircon.

The alunite, as seen in thin section, occurs principally as interlocking aggregates of lath-shaped crystals, either pure or accompanied by some secondary quartz, replacing feldspar phenocrysts. These, as suggested by their outlines and by the character of feldspar phenocrysts in this type of rock in general, were probably mostly if not all of plagioclase, the soda-lime feldspar. Alunite also forms smaller aggregates and single crystals scattered through the groundmass but hardly in great enough amount to represent all the original feldspathic material of the groundmass.

The quartz occurs as original phenocrysts which have been only slightly, if at all, affected during the alteration process. The only suggestions of their alteration are where alunite laths penetrate their edges and where an alunite lath is found wholly within a quartz phenocryst. The penetrating alunite laths may merely represent small original embayments of the phenocryst by the groundmass, but the presence of an alunite lath within a quartz phenocryst suggests that the quartz may have been to a slight extent replaceable by the alunite. Quartz in very minute granular aggregates now forms the greater part of the groundmass and must have replaced at least a part of the original material, as no feldspar of any kind could be recognized. The groundmass is clouded by a very fine dust, which may be in part kaolin but is probably for the most part minute grains of pyrite and limonite. A few small veinlets and irregular aggregates of secondary quartz are present, and some of them contain a few laths of alunite which evidently grew at the same time as the quartz.

The presence in the same thin section of a parallel growth of secondary quartz and alunite and of primary quartz phenocrysts penetrated by alunite appears contradictory, but the material observed is so scant and in grains so small that no great significance can be attached to it.

The pyrite forms evenly scattered grains as much as 1 millimeter or more in diameter and constitutes 4 or 5 per cent of the rock. It is equally abundant in association with the alunite aggregates and with the secondary quartz in the groundmass, and it crystallized at the same time as these minerals. The prominence of pyrite in the wall rock is in marked contrast to its obscurity in the alunite veins. The absence of the black silicates, augite, hornblende, and biotite, in the altered wall rock is also noteworthy, and it may be that the iron originally present in these minerals is now largely contained in the pyrite.

Kaolin is present in varying though small amounts, probably as minute specks closely associated with alunite in the replaced feldspar phenocrysts. Its presence may be detected by the rather weak but characteristic odor of the moistened specimen. Limonite is present as brown surface stains and varies in amount with the degree of oxidation of the pyrite. Small apatite and zircon crystals, unaffected by the alteration process, are rather abundant in some thin sections.

It is clear from these data that the magnesia, lime, and soda originally in the wall rock were removed, while silica, the sulphide and sulphate radicles, and water were introduced. Until analyses of the fresh and altered rock can be compared it can not be determined whether aluminum, iron, or potassium were added or remained in practically their original amounts. Furthermore, although the alunite occurs mostly as a replacement of soda-lime feldspar, it is not known whether the alunite in the rock is the pure potassium variety, like that in the veins, or the sodic variety. In either case, some potassium was introduced into the feldspar phenocrysts, but the amount originally in the groundmass would doubtless have been enough to account for the potassium in sodic alunite, whereas some additional supply may have been necessary to account for potash alunite, especially where the alunitization of the porphyry is most pronounced.

A preliminary examination of the wall rock of other than alunite veins in the region has not disclosed the presence of alunite, though a more thorough study may do so. It may be noted, however, that metallic minerals are reported from prospects, now inaccessible, around Edna Peak (locally called Edna Geyser), where alunitization of the rock is pronounced.

CHEMICAL COMPOSITION.

The following analyses of Marysvale alunite, which are all at present available, show the character of the coarsely crystalline and dense white varieties:

Analyses of alunite from Marysvale region, Utah.

Crude alunite from Custer group.[a]

	1	2	3
Alumina (Al_2O_3)	37.18	34.40	37.0
Ferric oxide (Fe_2O_3)	Trace.	Trace.	.....
Sulphuric anhydride (SO_3)	38.34	36.54	38.6
Phosphoric anhydride (P_2O_5)	.58	.50	.....
Potash (K_2O)	10.46	9.71	11.4
Soda (Na_2O)	.33	.56	.....
Water above 105° C. (H_2O+)	12.90	13.08	13.0
Water below 105° C. (H_2O-)	.09	.11	.....
Silica (SiO_2)	.22	5.28	.....
	100.10	100.18	100.0

[a] Copied from U. S. Geol. Survey Bull. 511, p. 8.

1. Selected specimen of clear pink, subtransparent, coarsely granular crystalline alunite. Supposedly best material. W. T. Schaller, analyst.
2. Selected specimen of a light-pink, very finely granular rock, of almost porcelain-like conchoidal fracture and no distinct structure. W. T. Schaller, analyst.
3. Theoretical composition according to Dana, Textbook of mineralogy, 1900 edition, p. 537.

Coarsely crystalline alunite from Florence Mining & Milling Co.'s claims.

	4	5
Loss on ignition	42.8	42.1
Insoluble residue (alumina with perhaps a little silica)	39.3	37.6
Potassium sulphate (K_2SO_4)	16.8	18.5
Equivalent potash (K_2O)	9.1	10.0

4. 1,000-pound sample from Sunshine Fraction claim.
5. 1,000-pound sample from North Fork claim.

Calcined alunite.

[Said to represent the average of the coarsely crystalline alunite used in analyses 4 and 5. Determined by fusion with sodium carbonate.]

	4a	5a
Silica (SiO_2)	0.03	0.72
Alumina (Al_2O_3)	61.1	61.1
Ferric oxide (Fe_2O_3)	1.6	1.1
Sulphuric anhydride (SO_3)	19.0	18.1
Potassa (K_2O)	17.2	18.6
Lime (CaO)	None.	None.
Magnesia (MgO)	.29	.31
	99.22	99.93

[The same material determined by leaching.]

	4b	5b
Insoluble residue	61.8	62.2
Potassium sulphate (K_2SO_4)	32.6	32.0
Aluminum sulphate ($Al_2(SO_4)_3$)	4.4	5.0
	98.8	99.2

4 and 5, 4a and 5a, 4b and 5b made by Solvay Process Co. for Florence Mining & Milling Co.

Comparison of analyses 4 and 5 with No. 1 shows that the coarsely crystalline alunite in the prospects on the Sunshine Fraction and North Fork claims (Nos. 11 and 14, respectively, in fig. 14), south and southeast of Edna Peak, is practically identical in composition with that in the Gillan-Custer prospects and is almost entirely free from impurities. Microscopic examinations of coarsely crystalline alunite from prospects west of Edna Peak indicate a similar degree of purity. Material of this quality is fit for the extraction of both potash salts and alumina, as well as for the manufacture of alum and for use as fertilizer.

Analysis 2 shows that the fine-grained variety contains a considerable amount (5.28 per cent) of silica. More analyses of material of this type would doubtless show some variation in silica content. An amount of silica as great as 5 per cent is sufficient to increase considerably the cost of extraction of alumina in a form sufficiently pure to be used in the manufacture of metallic aluminum—so much, perhaps, as to render it unprofitable—but it does not unfit the material for the manufacture of alum or for use as fertilizer.

Recalculation of analysis 1 shows it to contain 92.74 per cent of the potash alunite molecule ($K_2O.3Al_2O_3.4SO_3.6H_2O$). The amount of soda present is equivalent to 3.98 per cent of soda alunite, but the total water in excess of that required by the potash alunite is not enough to satisfy this amount. Alumina in excess of the amount required by the total alunite amounts to 1.43 per cent, and the corresponding excess of the sulphate radicle is 0.88 per cent. Some of this

alumina may be combined with the sulphate, some with the phosphate radicle, and some with silica, but nearly or quite all such natural compounds contain water, which according to the analysis is not present. The silica, furthermore, is believed to represent the small amounts of quartz and opal noted under the microscope.

Recalculation of analysis 2 shows it to contain 85.28 per cent of the potash alunite molecule and 5.57 per cent of the soda alunite molecule, with excesses of 0.71 per cent of alumina, 1.36 per cent of the sulphate radicle, and 0.04 per cent of total water. The deficiency of water again precludes the expression of these excesses as natural minerals. The predominance of excess sulphate radicle in analysis 2 is in contrast to the predominance of excess alumina in analysis 1, and the discrepancy also indicates that these materials are not present as definite compounds but are probably occluded in the alunite. The silica in analysis 2 is greatly in excess of that required to form kaolin with the excess alumina and doubtless represents one or more varieties of free silica.

PROSPECTS.

PRINCIPAL GROUPS.

The principal groups of alunite prospects lie in three roughly parallel zones of northerly to northwesterly trend. (See fig. 14, p. 240.) The western and middle zones are within the property controlled by the Florence Mining & Milling Co., whose headquarters are at Philadelphia, Pa., but it is reported that some of the claims along the western zone have been relocated in 1915, and their ownership is at present in doubt. The eastern zone has its north end within the southeast corner of the same property but lies for the most part within the Gillan-Custer group of claims, which belong to the Mineral Products Co., of Chicago, Ill., and is operated by the Mineral Products Corporation, of Marysvale, Utah.

WESTERN ZONE.

The western zone trends northwestward and roughly parallels the north headwater branch of Little Cottonwood Creek. Alunite has been exposed at a number of places in this zone. Near the Little Cottonwood Canyon and Bullion Canyon divide, on the L. & N. No. 4 claim, a vein striking N. 40° W. and dipping about 40° W. is exposed for a distance of 40 feet along a N. 25° E. trench (No. 1[1]) and for 60 feet along a N. 70° W. tunnel.[2] The tunnel portal and the north end of the trench are at the northeast wall of the vein,

[1] Numbers in parentheses correspond to numbers in figure 14 (p. 240).

[2] It is reported that since the writer's visit this tunnel has been extended for 100 feet along the vein and is in alunite all the way. (Oral communication by W. A. Fitzpatrick, Florence Mining & Milling Co.)

but the southwest wall has not been found. The true width at this place is therefore not known but is at least 35 feet, and the corresponding true thickness is at least 25 feet. The following section, made along the trench, shows that the vein contains at this place about 80 per cent of high-grade alunite, the true thickness being 20½ feet of alunite and 5½ feet of quartz.

Section along trench at locality No. 1.

	Feet.
Northeast wall of alunitized and pyritized porphyry.	
Coarse crystalline alunite	2½
Quartz	2
Coarse crystalline alunite	1
Quartz	3
Coarse crystalline alunite	9½
Quartz	½
Coarse crystalline alunite	7½
	26

The alunite, quartz, and wall rock are typical and need no further description.

At 80 feet northwest of the tunnel portal float of alunitized porphyry and some well-crystallized alunite are exposed in a line of shallow trenches. Farther northwest, on the crest of the divide, alunite fragments are exposed in a small cut (No. 2). These occurrences suggest a forking of the vein or two or three parallel veins. Just north of the crest of the ridge and about 250 feet northeast of the cut last mentioned are two shallow cuts (No. 3), exposing alunite, which appears to be a vein of northwesterly trend, 8 feet wide.

Southeast of the tunnel alunite, mostly in loose fragments, has been exposed in three shallow trenches, the southeasternmost of which (No. 4) lies about 650 feet from the tunnel. An old shaft dump (No. 5) just northeast of the middle trench and 400 feet from the tunnel consists largely of alunitized rock. At none of these places has sufficient work been done to show the direction and width of the vein or its percentage of high-grade alunite. The position of the vein at the tunnel suggests either that the southeasternmost of the three cuts may represent a parallel vein, or that the vein has been offset by faulting.

The next exposure of alunite to the southeast is an outcrop (No. 6) close to the east bank of the creek, 1,500 feet from the cut last mentioned, and in line with the strike of the vein exposed in the tunnel. From 500 to 1,000 feet farther south alunite and alunitized rock have been exposed in a group of small cuts and in two short tunnels (No. 7). Alunite float has been reported along the east side of the creek for the next 1,500 feet southeastward (Nos. 8 and 9), but little or no development work had been done on it up to the fall of 1914.

MIDDLE ZONE.

The middle zone extends along the crest of the ridge which divides the North Fork from Little Cottonwood Creek. Alunite has been traced in this zone from Edna Peak southward to the fork of the ridge but has been prospected thus far only by shallow trenches.

At Edna Peak alunite has been found both on the northwest and southeast slopes. Only one vein, that on the southeast slope of the peak, has been traced, and no work has been done to determine whether the exposure on the northwest slope is a branch of the same vein or is a parallel vein which pinches out toward the south. About 900 feet south of Edna Peak the alunite vein, which strikes N. 15° E. and dips steeply to the east, is shown in a trench (No. 10) to have a width of over 15 feet, but neither wall is exposed. Farther south it is partly exposed in five trenches (No. 11) and has an average dip of about 50° W. The length exposed by the six trenches is about 650 feet; the length from Edna Peak to the southernmost of these trenches is about 1,550 feet. Beyond the southernmost trench the vein appears to have stopped abruptly, but the surface is so thickly covered by loose rock that it is impossible to determine on the surface whether the vein pinches out or is cut off by a fault, as suggested in figure 14. Nearly 400 feet farther south and a little east of the course of the vein a small amount of alunite has been exposed in three shallow trenches (No. 12), but not enough work has been done here to demonstrate the size of the vein. The abundance of alunite float down the slope east of these trenches suggests that the strongest vein at this place has not been uncovered. No further excavations have been made to test the southward extent of this zone. A partial analysis of coarsely crystalline alunite from this vein, on the Sunshine Fraction claim, is given in column 4 of the table on page 246.

EASTERN ZONE.

The eastern zone includes three distinct groups of exposures and probably three or more veins. It has been prospected on the spur southwest of the North Fork of Little Cottonwood Creek, as shown in figure 14. The prospects farthest to the northwest include three pits on the ground of the Florence Mining & Milling Co. The western pit (No. 13) exposes alunite, which is also represented by float on the knob directly to the south. About 200 feet due east of this pit are two shallow trenches (No. 14) mostly in loose fragments of alunite and altered rock but also exposing high-grade material in place. The strike of the vein here is N. 5° E., and the exposed width of high-grade alunite is 15 feet. The strike of the vein proves it to be distinct from the alunite exposed to the west. A partial chemical

analysis of the alunite is given on page 246, column 5, and agrees closely with the other analyses of high-grade alunite.

The remaining exposures in the eastern zone are in the prospects on the property of the Mineral Products Corporation, as shown in figure 14. These were the only developments in 1911, when the data for Survey Bulletin 511 were collected. Since then considerable work has been done on this property. It was idle when visited in 1914 but was examined in October, 1915, by Mr. Gale, whose description of the newer developments is as follows:

The developments on the Gillan-Custer group of claims have been by far the most active. They have included the opening of two principal tunnels in the effort to determine the extent and continuity of the alunite underground and the sinking of numerous shallow pits, shafts, and tunnels with the object of tracing the veins.

The first or lower tunnel on this property was run in below most of the surface croppings of alunite, in an effort to cut the main vein at depth. For a time it seemed as if the vein had been missed, but in the final developments on this level the ore was found and followed for some distance in line with and almost directly under the later development in an upper tunnel. Work at this level was discontinued pending further explorations higher up and nearer the outcrops.

The main tunnel, or present working mine (October, 1915), is about 200 feet higher than the old tunnel. Its portal lies just about over the last extension of the lower tunnel in the line of the vein. It starts on an exposure of massive crystalline alunite which trends about N. 55° W. and dips about 75° S. as measured on the bands of crustification in the vein. At the east side of the portal is siliceous wall rock containing some alunite and stained rusty red so that in appearance it is much like the ore. This tunnel was driven along the ore with the intention of following the footwall side but passed through several breaks or offsets whose origin and relation to the ore were not fully indicated. There was some difficulty in following the ore, but at the time of visit, late in October, 1915, the vein had again been picked up and mining and developments were proceeding in a very satisfactory way. These developments are following directly underneath the line of surface cuts, which expose wide sections of the alunite vein, as described in Bulletin 511.

The underground work done in the exploration and development of this property has disclosed a greater irregularity both in character and continuity of the main veins than was expected from the larger and apparently uniform exposures of crystalline alunite in the surface cuts above. However, it appears that these workings have now opened an ore reserve large enough to insure the operation of the plant for some time and that there is a good prospect of run-

ning into a larger body of high-grade ore beyond, where the surface exposures above are complete and apparently very regular.

It has not been satisfactorily determined whether the irregularities found in the alunite veins are due to faulting or offsets of the veins since their formation, or whether they are an original feature of the deposits. A number of fissures encountered in the present workings are filled with a smooth and very plastic red clay, in places containing angular fragments of the wall rocks. Here and there, however, the original crustification in the main alunite vein appears to pass these clay seams without offset. Some of these clay seams are accompanied by cross veins of crystalline alunite, which are evidently secondary to the main deposit. Owing to obscurity of the vein walls and of the relations at the points where discontinuity of the vein has been found, it can not yet be stated to what these irregularities are due, although doubtless this relation will become clear as mining developments proceed.

The mine as now equipped is capable of supplying 150 to 200 tons of milling ore a day and its capacity can be increased.

OTHER PROSPECTS.

Other indications and prospects thus far reported lie to the east and south of the zone just described. The following notes give the only available information on them at the time of writing:

Iron Blossom group.—The prospects on the Iron Blossom group of claims have not been seen by the writer. There are said to be two occurrences of alunite in place, one on each slope of the North Fork canyon, and one occurrence of alunite float between them close to the bed of the creek. The deposit on the southwest slope of the canyon is near those at the northwest end of the Mineral Products Corporation's ground and evidently belongs to the same vein zone. The other occurrences presumably represent two additional veins, but no definite information regarding them has been obtained.

Gillan's claims.—Alunite has recently been found on Tom Gillan's claims in the foothills 3 miles southwest of Marysvale and three-fourths of a mile east of the Deer Trail mine. According to Mr. Gale, the alunite occurs in veins and bunches associated with a silicified zone in porphyry of the same character as that which forms the country rock about the main alunite deposits higher up in the mountains. Both coarse and fine grained varieties of alunite are present, and the color ranges from white through yellow to pink. Although there are some large blocks of high-grade ore at this locality, the indications of an ore body are not so strongly marked by float as at the main veins of the district. A specimen sent to the writer by Mr. Heikes consists of the fine-grained variety, considerably sheared and accompanied by broken stringers of quartz.

Santa Kruze claims.—A specimen sent by A. Soyka, said to be from the Santa Kruze No. 4 claim, 4,000 feet southeast of the Krotki iron mine, was tested at the Survey laboratory and found to be alunite of good quality. This district doubtless deserves investigation.

Mohawk group.—The Mohawk group is located on the north side of Mill Fork of Little Cottonwood Creek, nearly due south of the prospects on the western vein zone. According to Mr. Gale, new developments on the property include a tunnel and a shaft. The shaft at the time of his visit was 30 feet deep, and in a short crosscut 10 feet to the south some fine-grained white material of uncertain alunite content had been exposed. Since Mr. Gale's visit it has been reported that the shaft had been sunk to a depth of 35 feet and had exposed some massive alunite. The tunnel was being driven N. 14° W. to reach the shaft at a depth of 200 feet below its present bottom.

Lost Horse group.—The Lost Horse group of claims extends along the east side of the crest of the range, south of Mill Fork and the Mohawk group. Alunite has been found in place at two prospects, and float has been followed at several others. These places lie in a nearly north-south zone but are hardly close enough together to be regarded as strong indications of a continuous vein, especially when the northwesterly trends of the vein farther north (see fig. 14) are considered. The alunite in place was found in the summer of 1914 by trenching into a slope where float was abundant, but not enough work was done to determine the width or trend of the vein. The alunite exposed here is a mixture of the coarsely crystalline and fine chalky varieties, the coarse material forming a network of veins through the fine. At the southernmost occurrence of float, on the saddle where the Beaver-Marysvale trail crosses the divide, three or four short trenches have been dug, exposing a considerable amount of the chalky variety, a small part of which is stained reddish or brown. The other float occurrences were not seen. No analyses of alunite samples from this property have been reported.

ORIGIN OF THE DEPOSITS.

So far as origin of the alunite veins is concerned, the evidence presented in the preceding pages practically confirms the statements of Butler and Gale,[1] that the veins were formed, for the most part, in open fissures and, in addition, suggests that a part of the fine-grained alunite may have been formed as a replacement of porphyry. In this respect, as well as in the alteration of the wall rock, the mode of deposition was similar to that of the Sheep Rock deposit, described on

[1] U. S. Geol. Survey Bull. 511, pp. 7, 20, 1912.

pages 258–264, but replacement accounts for practically all the Sheep Rock deposit instead of a part of it. Regarding the source of the alunite-forming solutions, no evidence has been found at variance with the hypothesis of Butler,[1] which is briefly as follows:

During and just subsequent to the consolidation of the intrusive masses all the rocks in the region, both sedimentary and igneous, were fissured. Along these fissures ascended heated solutions believed to have been derived from the intrusive magma. Within the intrusive mass they were highly heated, probably under considerable pressure, and deposited minerals characteristic of this condition. As they passed into the cooler overlying rocks both temperature and pressure were reduced, and the valuable metalliferous veins of the region were deposited. These veins were formed in two stages, the earlier one characterized by carbonate gangue minerals and the later by quartz and adularia. The adularia is of special interest, as it is a pure potassium-aluminum silicate and indicates a certain concentration of these elements during the later stages of vein deposition.

The alunite veins are thought to represent a still later stage of deposition, characterized by a much higher concentration of potassium and aluminum in the form of sulphate. Structural evidence indicating this relation of the alunite to the metalliferous veins is not yet complete. The relation is, however, suggested by the mode of occurrence of alunite in other regions, where general conditions indicate that the mineral was deposited at shallow depth and at moderate to low temperature. The relative rarity of alunite deposits compared with quartz-adularia veins in this country and abroad may be due to the fact that they are formed near the surface and consequently have in only a few places been preserved.

According to this interpretation, it is to be expected that in places alunite veins will be found superimposed on quartz-adularia veins. It might be supposed that the quartz bands which alternate with alunite bands in several exposures represent the quartz-adularia stage and that the alunite is a later deposit introduced after the quartz vein had been reopened by longitudinal fracturing. Such may prove to be the relation in some deposits, but no quartz bands in the veins have been found with the characteristic hackly structure of the quartz-adularia veins, and microscopic study of the wall rock shows simultaneous deposition of quartz, alunite, and pyrite. It is more probable, therefore, that the quartz bands were formed during the same stage of deposition as the alunite, as in the Sheep Rock deposit described on page 262.

Where alteration along the quartz-adularia veins was most intense potassium and aluminum were nearly or quite all removed from the

[1] U. S. Geol. Survey Bull. 511, pp. 21, 38, 1912.

wall rock. In the wall rock of the alunite veins, however, alunite appears to be sufficiently abundant to account for all the potassium of the original rock, and it is therefore certain that the rock immediately adjacent to the alunite veins did not supply the potassium to them by lateral secretion. In fact, where the wall rock has been replaced by the fine-grained alunite there must have been a considerable addition of potassium to the amount already present. It is possible, however, that at least a part of the potassium and aluminum content of the vein was derived from the wall rock at greater depth, where conditions were favorable to the leaching of these elements, and that the enriched solutions, rising into cooler zones, redeposited them in the form of alunite. This interpretation implies that the alunite bodies are deposits of relatively shallow type and may give out in depth or merge into a different type of vein. The fact that, although quartz-adularia veins are of common occurrence in the West, no important alunite deposits have been found associated with them except near Marysvale necessarily leaves this idea as a suggestion rather than a conclusion.

PERSISTENCE IN DEPTH.

As already stated, the characteristic features of alunite deposits in several parts of the world[1] indicate deposition at shallow depths. Recent developments at Marysvale on all but the Gillan-Custer group of claims have been merely superficial, and the deepest workings on that property are only about 260 feet below the lowest outcrops of alunite. The cautious attitude taken by Butler and Gale regarding the persistence of the veins in depth should therefore be maintained.

The foreign deposits that compare most closely in character with the alunite veins of Marysvale are those at Tolfa, Italy. The largest of these deposits, the Providenza vein, has been worked to a depth of more than 300 feet, where it becomes increasingly pyritic, and it ends within the next 60 feet. The downward continuation of the vein zone is marked by pyritic wall rock (trachyte). That in general a greater vertical range than that of the Tolfa deposits can be expected in the alunite veins of the Marysvale region is suggested by the observed distribution of outcrops with reference to the rugged topography. In the eastern zone near Marysvale the highest outcrops according to Gale's observations[2] are at least 1,000 feet above the lowest; in the middle zone the observed vertical distribution, according to surveys for the Florence Mining & Milling Co., is about 900 feet; in the western zone, according to the same authority, it is

[1] Descriptions of these deposits are reviewed by Butler and Gale (U. S. Geol. Survey Bull. 511, pp. 38–58, 1912).

[2] Op. cit., pl. 3.

over 700 feet, and the distribution of float indicates that it may be considerably more. There is no apparent reason why the actual range in depth should not equal or considerably exceed these amounts. It should be borne in mind, however, that the alunite deposits, like many metalliferous deposits, may occur in shoots with a distinct pitch, and that their lowest parts may happen to be along a line roughly parallel to the present surface slope. In this case the shoots in the higher parts of the veins may possibly end downward at levels higher than those of the present lower outcrops.

SUGGESTIONS REGARDING DEVELOPMENT.

Because of the existing uncertainty in regard to the vertical range of the deposits, the safest method of prospecting seems to be the driving of tunnels along the strike of the vein at various levels and the sinking of inclined winzes along the dip, rather than the driving of tunnels from points below the lowest outcrops with the hope of tapping the veins at greater depth. The eastern and western zones of the principal group are well adapted to this method of development. The middle zone, located on the crest of a high ridge, could be easily worked through a tunnel cutting the vein at considerable depth, provided there was certainty of sufficient continuity and regularity in depth. The Franklin tunnel (see fig. 14) on the Florence Mining & Milling Co.'s ground, driven several years ago and inaccessible at present, is excellently situated for such development. It extends, according to private survey records of this company, almost directly under the outcrops on Edna Peak. A crosscut of 200 or 300 feet should cut the vein zone on its dip at a depth of 1,000 feet or more below the outcrops, and determine whether alunite in commercial quantity extends to so great a depth. It is also possible that examination of the walls of the tunnel may result in the discovery of one or more additional alunite veins, cut long before the identity and possible commercial value of the mineral was recognized.

While the steam-shovel method may be satisfactory for the removal of thick accumulations of débris from the surfaces of the veins, there are objections to its use in the direct mining of alunite, because a considerable amount of siliceous impurity will thus be included in the high-grade material. This lowering of the grade of alunite may not be sufficient to interfere seriously with the extraction of potassium sulphate, or with the use of the insoluble residue in the manufacture of refractory brick, or with the use of crude or calcined alunite as a fertilizer, but it will greatly increase the cost of the manufacture of metallic aluminum. Furthermore, the pronounced western dip of the veins would involve an increasing amount

of dead work in the removal of an increasing amount of waste from the hanging wall as depth increases.

ESTIMATE OF TONNAGE.

The quantity of potash (K_2O) available in the Custer vein was estimated by Butler and Gale[1] at 30,000 tons for each 100 feet of depth. The openings seen by the writer along the middle zone do not afford sufficient data for more than a rough estimate of the tonnage of alunite available, and those along the western zone and other prospects are too obscure and scattered to warrant any estimate. The following figures are intended only to give a rough idea of the quantity of alunite within the limits of the ground actually prospected. The number of short tons for each foot of depth is calculated by assuming a specific gravity of 2.82, or a weight of 175 pounds a cubic foot. These are the figures given in Bulletin 511, on page 12. The alunite in the exposures represented in the table is practically identical with that used for the determination of specific gravity.

Estimated tonnage per foot of depth in alunite veins in middle and eastern zones.

Location.	Proved length of vein.	Average width of high-grade alunite.	Surface area.	Quantity of alunite per foot of depth.
	Feet.	*Feet.*	*Sq. feet.*	*Short tons.*
Edna Peak to No. 10	900	10	9,000	788
Openings at Nos. 10 and 11	650	10	6,500	698
Openings at No. 14	200	15	3,000	263
Gillan-Custer group (Butler and Gale's estimate)	.....	.....	.....	3,000
	1,750	.....	18,500	4,749

If the recoverable potash (as K_2O) is estimated at 10 per cent, the prospects on the middle zone will yield about 17,000 tons of potash for each 100 feet of depth, somewhat more than half the amount (30,000 tons) similarly estimated by Butler and Gale for the openings on the Gillan-Custer group. Recent underground developments have shown that the Gillan-Custer deposit is much more irregular than was indicated by the surface workings. In some places high-grade alunite may be practically absent, and in others it is much thicker than the average thickness (10 feet) assumed in the estimate; but the estimate will doubtless stand as a reasonable and satisfactory minimum of workable alunite for this group of claims. Future developments on the middle zone may show similar irregularities, and the figures given above should be regarded as representing a preliminary moderate estimate.

[1] Op. cit., p. 12.

It should be borne in mind that only those openings have been included in the estimate where the practical continuity of the veins has been demonstrated or is highly probable. Further prospecting along the strikes of the different veins, especially that exposed on the L. & N. No. 4 claim, in the western zone, will probably increase considerably the proved tonnage of alunite. According to the above estimates, the tonnage of the middle and eastern zones may, for each 100 feet of depth, amount to about one-fourth of the annual consumption of potash in the United States, which, figured as K_2O, was more than 185,000 tons in 1913, the latest normal year.

DEPOSITS ON WEST SLOPE OF MOUNTAINS.

LOCALITIES.

A few deposits of alunite have also been reported from the west slope of the Tushar Mountains, but that at Sheep Rock, northeast of Beaver (see fig. 13, p. 238), is the only one visited by the writer and the only one from which specimens containing alunite have been seen by him. One deposit, about 2½ miles southeast of the Beaver River Power Co.'s plant in Beaver Canyon and 13 miles east of Beaver, was at first thought by its discoverer to be the dense white form of alunite but proved on examination to be kaolin, formed through the superficial decomposition of rhyolitic volcanic rocks. A chemical analysis of the material showed only 0.13 per cent of potash (K_2O). One or two other deposits have been reported, but nothing definite has been learned of them.

The Sheep Rock deposit is a quartz-alunite rock of too low grade to be of immediate commercial importance as a source of alunite but of sufficient scientific interest to merit a rather detailed description.

SHEEP ROCK DEPOSIT.

LOCATION AND EXTENT.

Sheep Rock is situated in the Newton mining district, at the west base of the Tushar Mountains, about 10 miles northeast of Beaver. (See figs. 13 and 15.) It is a bare-topped ledge of nearly circular form, about 900 feet in diameter, and has a gently rounded summit composed of nearly white quartz-alunite rock, which in part has weathered into clusters of rounded residual bowlders. These when seen from a distance bear a striking resemblance to a flock of sheep and have given rise to the name Sheep Rock. The first knowledge of alunite here was obtained early in 1914, when a specimen from the northern part of the ledge was sent to the United States Geological Survey by W. A. Wilson, then manager of the Sheep Rock mine, and was found by B. S. Butler to be a mixture of alunite and

quartz containing 30 to 40 per cent of quartz.[1] The writer visited the deposit in September, 1914, and the present description is based on his observations.

CHARACTER OF DEPOSIT.

The relations of the deposit to the andesitic country rock are very obscure. Its west, south, and north sides are covered with talus and brush and pass beneath the alluvium of the valley. The saddle connecting it with the andesite foothills is covered with float and affords no opportunity to study the contact in place. Study of

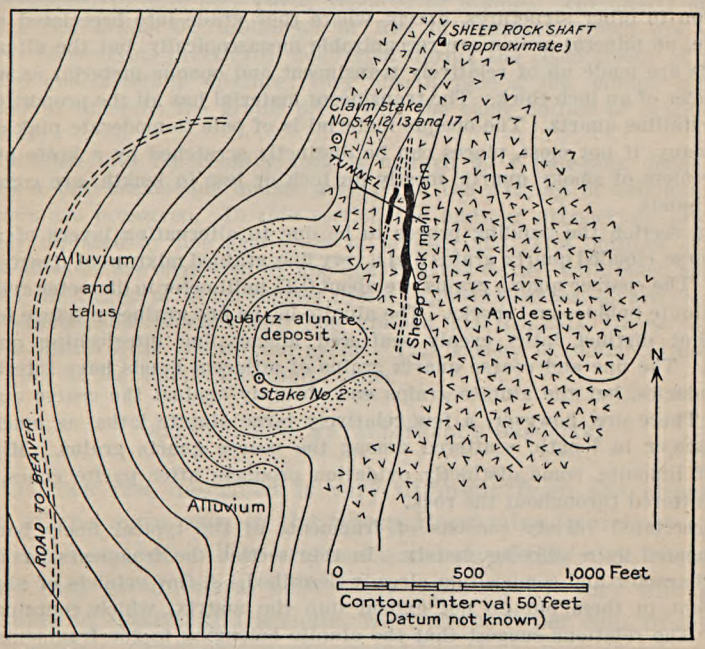

FIGURE 15.—Geologic sketch map showing relation of the Sheep Rock quartz-alunite deposit near Beaver, Utah, to country rock and metalliferous veins.

the float, however, shows that the two rocks merge within a short space, and that the Sheep Rock deposit was formed by the replacement of andesite. No definite connection with neighboring metalliferous quartz veins is apparent on the surface, and none has been made in the underground workings of the mine.

The material of the deposit as a whole is of uniform character, light-gray to pinkish color, and very fine grained, banded texture. A few textural variations, however, are present, including brecciated and concretionary phases and rock in which the porphyritic texture of the andesite is preserved. The alunite content also shows varia-

[1] Phalen, W. C., Summary of potash salts for 1912: U. S. Geol. Survey Mineral Resources, 1913. pt. 2, p. 91, 1914.

tions ranging from 10 per cent or less up to 60 per cent, but as a whole appears to be rather uniform and to average about 30 per cent, equivalent to 3.5 per cent of potash (K_2O).

DETAILED DESCRIPTION.

The typical material of the deposit, as viewed from a short distance, appears grayish white, but most unweathered specimens when closely examined are found to have a faint to decided pinkish tinge, a dense to very fine grained texture, and a distinct though rather fine banding. The banding strikes and dips in various directions over different parts of the ledge and in many places is highly contorted, the contortions showing no apparent order of arrangement or relation to other structures, except where they grade into brecciated rock. As a rule, no mineral grains are recognizable megascopically, but the alternating bands are made up of relatively translucent and opaque material as much as a quarter of an inch thick. The translucent material has all the properties of microcrystalline quartz. The opaque material is of pale to moderate pink color and in many, if not most, places can be distinctly scratched by a knife blade. Short veinlets of smoky quartz, mostly an inch or less in length, are common between bands.

In thin section the banding proves to be due to alternating layers of relatively coarse clouded quartz grains and a very fine grained mixture of quartz and alunite. The coarser quartz grains are about 0.25 millimeter in diameter and are full of minute bubbles and specks. The alunite in the fine grained mixture forms minute but distinct laths evenly scattered among fine interlocking quartz granules. The fine and coarse quartz grains of adjacent bands have interlocking boundaries, but the alunite grains end abruptly against the coarse quartz grains. There are, however, a few relatively large alunite laths, as much as 0.5 millimeter in length, scattered among the coarse quartz grains. Minute grains of limonite, some distinctly oxidation products after pyrite cubes, are thinly scattered throughout the rock.

The brecciated variety consists of fragments of the typical finely banded rock cemented by a siliceous matrix. In thin section the fragments have the typical character and composition already described. A few veinlets of alunite are present in them but do not extend into the matrix, which contains no alunite. The relations suggest that the alunite belonging to the fragments recrystallized locally in fractures, but that no second supply of it was introduced after the shattering.

Close by stake No. 2 the rock contains numerous white translucent patches and streaks of chalcedonic quartz ranging from minute spots to linear streaks a foot in length. In thin section the quartz is in part very fine and even grained and in part composed of radiating crystals, which have evidently grown by replacement of the quartz-alunite rock.

At a few places, especially in the bowldery ground about 100 feet west of stake No. 2 (see fig. 15), the rock has a marked concretionary structure, and banding is inconspicuous or absent. The concretions are as much as an inch in diameter and present a variety of shapes but are not conspicuously different in megascopic character from the matrix. As seen in thin section, they consist as a rule of rudely fan-shaped alunite crystals as much as 0.5 millimeter long, inclosing minute grains of quartz and separated by minute linear aggregates of quartz. The matrix consists mostly of the very fine grained quartz sprinkled with minute alunite laths in roughly concentric arrangement, suggestive of crowding by the growth of the concretions.

The highest-grade material, which has a more distinctly pink color than the rest of the deposit, was found in the talus on the north slope of the area. It has in part the typical banded structure and in part a blotchy appearance, the predominating bands or blotches of pink alternating with others of gray color. Some of the gray blotches contain small cavities representing a dissolved mineral, probably feldspar. In thin section the pink part is seen to consist mostly of a mass of alunite inclosing minute grains of quartz. The alunite occurs mainly as a felty mass of minute laths, in which are scattered larger crystals, single or in feathery aggregates as much as a millimeter long. The relation of the larger to the smaller crystals suggests that the former have grown at the expense of the latter. Alunite makes up about 60 per cent of the whole. The gray areas consist of very fine quartz aggregates, the borders of which appear to have been partly replaced by alunite. The quartz areas contain a few grains 0.5 millimeter or less in diameter, which are evidently quartz phenocrysts practically unaffected during the replacement of porphyry by the quartz-alunite mixture; they also include a few minute grains and streaks of limonite, the grains preserving the cubic outline of original pyrite crystals.

Gradation into the country rock is marked by a pale-pink dense rock in which a few megascopic quartz grains and the outlines of original feldspar crystals are preserved. In thin section the feldspar phenocrysts prove to be largely replaced by fine aggregates of alunite, and faint outlines of original black silicates are suggested by fine quartz areas dusted with black specks and grains, the largest of which suggest pyrite. Quartz phenocrysts are very scarce. The groundmass is extremely fine grained and consists almost wholly of quartz with a little alunite and pyrite. This variety is similar to the altered wall rock of the Marysvale alunite veins.

RELATION TO METALLIFEROUS DEPOSITS.

The rock last described is very different from the altered wall rock of the main vein in the Sheep Rock mine, which is a typical sericitized andesite. The original minerals of this rock, both phenocrysts and groundmass, have been replaced by very fine grained mixtures of quartz and sericite, with about 3 per cent of pyrite in small grains. This rock contains gold to the extent of a few dollars to the ton and is classed as milling ore.

No microscopic alunite was found in the sericitized rock, and there was no opportunity to study the relations between sericitization and alunitization or between the metalliferous quartz vein and the quartz-alunite body. The vein is of the same type as the metalliferous veins in the Marysvale district, and it therefore seems probable that the quartz-alunite body bears the same general relation to it as the alunite veins in the Marysvale region are thought to bear to the neighboring metalliferous veins, but here, as in the Marysvale region, no direct connection between the two types of deposits has been proved. It is hoped that future development along the Sheep Rock vein will disclose the relation.

ORIGIN.

In view of this deficiency of critical evidence, any statement concerning the origin of the Sheep Rock quartz-alunite deposit must be regarded merely as a working hypothesis. The shape of the deposit and its position with respect to the neighboring metalliferous veins, especially the worked vein of the Sheep Rock mine, suggest that the rising vein-forming solutions were locally impounded and deflected along a permeable bed beneath some impervious layer of porphyry which is now removed by erosion. Physical conditions at this place were such that well-crystallized quartz and sericite, which characterize the metalliferous veins, were no longer formed. Instead the porphyry was permeated by silica, accompanied by the sulphate and sulphide radicles. These radicles converted the potassium and aluminum largely into alunite and a small amount of the iron into pyrite. It is possible that, as in the Marysvale veins, some potassium and aluminum were introduced by the solutions, but the average percentages of these elements in the Sheep Rock deposit, as shown by analyses 1 and 2, on page 263, is little, if any, more than those in the original porphyry.

The banded structure of the deposit bears a strong resemblance to that of the siliceous ores seen by the writer in the Tintic mining district and recently described by Lindgren,[1] who attributes the banding to diffusion in the replacement body of colloidal silica while the mass was still in a soft state. If this mode of replacement is accepted for the Sheep Rock deposit, the numerous contortions in the banding may be attributed to deformation before the mass became rigid, and the brecciated parts to deformation after the mass as a whole had become rigid but while there was still sufficient fluid or gelatinous silica to enter the interstices and cement the fragments.

Along the original margins of the deposit, where the replacing solution was weak or was more rapidly consolidated, there was evidently insufficient opportunity for complete replacement and development of banding, and the porphyritic texture of the replaced rock was preserved. The local concretionary structure evidently marks a tendency of the alunite to concentrate, possibly while the mass was still gelatinous. The presence of alunite in cracks later than the banding and the presence of large alunite crystals growing at the expense of small ones indicate a tendency of the mineral to concentrate even after the rock had hardened.

As contrasted with the Marysvale deposits, the Sheep Rock deposit was formed almost wholly by the replacement of porphyry, and the two minerals, alunite and quartz, were intimately mixed, whereas

[1] Lindgren, Waldemar, Processes of mineralization and enrichment in the Tintic mining district: Econ. Geology, vol. 10, No. 3, pp. 233–235, 1915.

those near Marysvale were formed for the most part in open fissures, with ample opportunity for the segregation of pure alunite, and only to a minor extent by replacement. This comparison does not imply that the available alunite was the same in each locality. The solutions in the Marysvale area may have contained a larger amount of the constituents of alunite, in addition to being favored with a better opportunity to deposit the mineral in segregated masses.

CHEMICAL COMPOSITION.

The three following partial analyses of the quartz-alunite rock, two of average samples and one the high-grade variety, were made by R. K. Bailey, of the United States Geological Survey:

Analyses of quartz-alunite rock from Sheep Rock deposit.

	1	2	3
Silica (SiO_2)	60.83	70.78	30.12
Sulphate radicle (SO_3)	13.83	10.56	26.53
Potash (K_2O)	3.89	2.90	6.87

1. Average sample at summit of Sheep Rock.
2. Average sample around stake No. 2 (fig. 15).
3. High-grade sample, north slope of Sheep Rock.

In analysis 1 the ratio of the sulphate radicle to potash is almost exactly that of pure potash alunite. Calculation from these data gives over 13 per cent of alumina and 35.6 per cent of alunite. In analysis 2 there is an excess of 0.6 per cent of the sulphate radicle over the ratio between the sulphate radicle and potash for alunite. This small excess may have been present in the soda alunite molecule. The calculated percentage of alumina is only 9.5 per cent and of alunite 25.7 per cent. In analysis 3 the excess of the sulphate radicle is 3.2 per cent. This also may have been present in soda alunite. The calculated percentage of alumina in No. 3 is 22.3 per cent and that of alunite 60.3 per cent.

COMMERCIAL VALUE.

The percentage of alunite, and therefore of potash, is much too low throughout most of the Sheep Rock deposit to be of any commercial value. Only in the talus at the north end of the deposit has material of promising grade been found, and only a little of this is in sight. Even the high-grade material, however, contains so much silica that, when compared with the practically pure alunite in the veins near Marysvale, the cost of crushing and calcining it, to say nothing of the cost of transportation, will probably be prohibitive for any but local use. The presence of alunite in the Sheep

Rock deposit, however, indicates that the solutions which deposited alunite were active in the extreme western as well as the eastern part of the Tushar Mountains and that the hills around Sheep Rock will be promising ground for alunite prospecting.

UTILIZATION OF ALUNITE.

PRODUCTS.

Although alunite has been mined for many years in foreign countries as a source of potash alum, the principal attention has been given to it in this country as a possible domestic source of potash. The extraction of potassium sulphate from it on a commercial scale appears now to have been accomplished. Possible by-products in the extraction of potassium sulphate are alumina and sulphuric acid. The successful production of the alumina or its derived products on a commercial scale appears to be a possibility, but there is no prospect of the production of sulphuric acid at present.

POTASSIUM [redacted] SULPHATE

As already stated, a demonstration by W. T. Schaller that the simple potassium sulphate instead of potash alum could be easily extracted from alunite simply by leaching the calcined mineral with water was published by the United States Geological Survey on January 9, 1912.[1] Schaller's observations are as follows:

> Laboratory experiments showed that on igniting the powdered alunite all of the water and three-fourths of the sulphuric acid are volatized. On leaching the residue with water the potassium sulphate is dissolved, leaving the insoluble aluminum oxide behind.
>
> The average amount of potassium sulphate leached from the ignited mineral powder is 17.9 per cent of the original material used. As the coarsely crystallized alunite was found to contain 19.4 per cent of potassium sulphate, 92 per cent of the total potash present was obtained by simple ignition and subsequent leaching.
>
> It is worth noting that, according to the laboratory experiments, 32.7 per cent of the ignited alunite consists of available potassium sulphate, which can be extracted by simple water leaching and evaporation. The remaining 67.3 per cent consists of nearly pure aluminum oxide.

Waggaman[2] found that a large quantity of water was required to free the ignited residue of alunite from soluble salts and that the subsequent evaporation was tedious and expensive, but the process has finally been worked out on a commercial scale by the Mineral Products Corporation. The following description of the process

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[1] U. S. Geol. Survey Bull. 511, pp. 58, 61, 1912; also announced in a notice given to the press for publication on Dec. 18, 1911 (U. S. Geol. Survey Press Bull. 30).

[2] Waggaman, W. H., U. S. Dept. Agr. Bur. Soils Circ. 70, 4 pp., July 31, 1912.

is based on information furnished by V. C. Heikes, of the United States Geological Survey, who saw the plant in operation.

From the ore bins at the mill the alunite passes through a gyratory crusher, then through a set of rolls, and thence is delivered to a storage bin. This material is mixed with powdered slack coal and is fed into a rotary kiln in which it is roasted. The roasted material is elevated to a storage bin from which it is drawn off into a digester. In the digester it is mixed with water and the sulphate of potassium dissolved out. The charges from the digester are stored in wooden tanks. From these tanks the mixture is pumped into a filter press where the insoluble alumina and the water-soluble potash are separated.

The solution is then evaporated in triple-effect vacuum pans. The sulphate of potassium crystals are separated out, drained, and dried. The dried powder is pulverized, screened, and sacked for shipment.

The boiler plant uses slack coal for fuel. Boilers having a rating of 600 horsepower produce steam for driving three engines, running the machinery of the plant. The exhaust steam is used for evaporating the solutions and drying the product.

The capacity of the first unit of the plant is estimated to be from 25 to 35 tons of sulphate of potassium a day. In addition to the valuable sulphate of potassium, the operators expect to gain some return from the filter cake left after the potash solution has been removed from the calcined material. This cake consists of nearly pure alumina and may be used for making refractory brick, for it is reported to withstand temperatures as high as 2,020° C. It may also prove to be available for making aluminum.

The mill is reported to be the first of its kind built in the United States to treat alunite, and operation of the first unit was begun on September 15, 1915, when some alunite was put through the crusher. Thereafter each part of the machinery was gradually tested until, by October 6, fully 200 tons of alunite had been distributed through the plant. On October 5 about 20 tons of filter cake reported to contain about 65 per cent of alumina (Al_2O_3) was discharged, and the saturated solution of potassium sulphate, about 85,000 gallons, had accumulated in the evaporators, which were placed in commission on October 6. On October 7 the first potassium sulphate was produced and was said to be about 99 per cent pure and 2 tons in quantity. On October 20 the first carload, aggregating 28 tons of potassium sulphate that analyzed more than 93 per cent pure, is reported to have been shipped in cotton bags to the Armour Fertilizer Works at Jacksonville, Fla.[1] Three cars are reported to have been shipped within the first month.

[1] Manufacturers' Record, Oct. 21, 1915, p. 52.

The mill is situated about 5 miles southwest of Marysvale and 2 miles west of Sevier River, near the mouth of Little Cottonwood Canyon. The alunite vein, on the Gillan-Custer claims, is 4 miles farther west by wagon road. The mined alunite is conveyed by an aerial tramway 6,200 feet long, with a fall of 1,900 feet, to a bin at the creek level, from which it is carried by wagons over a downgrade road of 3½ miles to the mill. The tramway, under present conditions, has a rated capacity of 12½ tons of alunite an hour.

Plans are reported for the erection of a plant by the Utah Potash Co. for extracting potassium sulphate and alumina from the alunite in the deposits of the Florence Mining & Milling Co.

POTASH ALUM.

Potash alum is a hydrous sulphate of aluminum and potassium ($K_2O.Al_2O_3.4SO_3.24H_2O$) containing 11 per cent alumina, 10 per cent of potash, 34 per cent of sulphur trioxide, and 45 per cent of water. The quantities and values of alum (principally potash alum) and aluminum sulphate produced in the United States from 1910 to 1914, inclusive, and the total imports of aluminum salts are shown in the following table:[1]

Production and imports of aluminum salts into the United States, 1910–1914, in short tons.

Year.	Production.						Imports.[a]	
	Alum.			Aluminum sulphate.				
	Quantity.	Total value.	Value per ton.	Quantity.	Total value.	Value per ton.	Quantity.	Value.
1910	9,090	$300,763	$33.09	126,792	$2,447,552	$19.30	2,127	$53,671
1911	10,468	329,686	31.49	134,077	2,743,336	20.46	2,283	56,833
1912	9,246	293,995	31.80	150,427	2,909,495	19.34	3,342	84,606
1913	9,605	312,822	32.57	157,749	2,977,708	18.88	2,702	66,549
1914	18,238	565,989	31.03	164,954	2,942,572	17.84	2,891	73,028

[a] Includes alumina, aluminum hydrate, or refined bauxite, alum, alum cake, aluminum sulphate, aluminous cake, and alum in crystals or ground.

The potash in the domestic alum is imported, and the alumina is derived from bauxite mined chiefly in Alabama, Georgia, and Tennessee, with small quantities from Arkansas. Only bauxite containing less than 2 per cent of iron oxide is used in the manufacture of alum, aluminum sulphate, and other aluminum salts. The plants manufacturing potash alum and other aluminum salts are all east of Mississippi River, but the practicability of establishing a plant in Utah is worthy of careful consideration.

[1] Phalen, W. C., The production of bauxite and aluminum in 1914: U. S. Geol. Survey Mineral Resources, 1914, pt. 1, p. 208, 1915.

The description of the process of manufacturing potash alum from alunite in foreign countries, which was reviewed by Butler and Gale,[1] is here repeated for the reader's convenience.

A considerable amount of alum is prepared from alunite. Alunite contains the elements of potassium alum, basic aluminum sulphate, and free alumina. In Sicily it is made into heaps and calcined in the open air. At Tolfa, where the manufacture is carried out on a larger scale, the roasting is conducted in furnaces like limekilns, lined with refractory materials. The mineral is heated in large pieces by the flame without direct contact with the fuel until sulphur dioxide begins to escape. The calcination requires about six hours, the mass losing about 35 per cent of water. During the ignition the excess of alumina beyond that necessary to produce alum is rendered insoluble and no longer has the property of precipitating basic sulphates from the solution. The calcined mass is exposed to the air upon a clay floor for some weeks, during which time it is occasionally moistened. The mudlike product is agitated in boilers with water at 70° C., and the clear decanted liquid, of density 10°–12° B., is evaporated to 32° B. and crystallized in small wooden tubs. The crystals are cubic, opaque, and reddish from the presence of ferric oxide. This iron is, however, quite insoluble and may be separated by recrystallization; the soluble iron is said to be less than 0.005 per cent. In this way "Roman alum" was formerly largely produced. On account of their great purity the red crystals were much sought after.

Alunite is now largely converted into alum by treatment with sulphuric acid and addition of potassium sulphate. Guyot[2] has examined this process and recommends the following method:

On ignition of alunite the free alumina is first rendered anhydrous and soluble in sulphuric acid; at a higher temperature the basic sulphates become soluble, but if the temperature be allowed to rise too high the alumina becomes vitrified and is insoluble. Guyot recommends ignition at 800° C. for three hours as the best means of rendering the maximum of both these substances soluble. The composition of the calcined mass is determined, and acid is used in proportion to the amount of soluble sulphate contained. For a product of the following composition, K_2SO_4, 14 per cent; $Al_2O_3.3SO_3$ (present as alum), 26.55; $Al_2O_3.3SO_3$ (free), 6.56; Al_2O_3 (free), 18.58; OH_2, 11.90; Fe_2O_3, 0.80; siliceous residue, 21.61 per cent, the proportions given below would be most satisfactory. Into a clay oven is poured 12.5 tons of sulphuric acid of 52° B. diluted to 30° B. and heated to 80° or 90° C. Eight tons of the calcined mineral is then added in portions and well stirred. After the whole has been added the liquid is left for two hours then evaporated to 38° B. and treated with 2.7 tons potassium sulphate. The process up to this point occupies 10 hours; after a further period of 13 hours the clear liquid is decanted off; its density should not exceed 42° B. The muddy liquid remaining is reduced to 24° B. by the addition of mother liquor from a previous crystallization, stirred, allowed to settle, drawn off clear, mixed with the first decantate, and crystallized in a vat. After one day the crystals are removed, redissolved, and recrystallized. The muddy residue is crystallized out for a further crop of alum. The total yield of alum is about

[1] U. S. Geol. Survey Bull. 511, pp. 59–60, 1912; quoted from Thorpe, T. E., Dictionary of applied chemistry, London, 1890, p. 78.

[2] Guyot, M. P., Sur la richesse industrielle de l'alunite crue, en poudre: Paris Acad. Sci. Compt. Rend., vol. 95, pp. 693, 694; Expériences sur la calcination de l'alunite en poudre, destinée à la fabrication de l'alum et du sulfate l'alumine: Idem, pp. 1001–1003.

2.3 times the original weight of ore. The insoluble matter contains 3 per cent alumina and 2.01 per cent potassium sulphate, in addition to silica, etc.

According to C. Schwartz,[1] the best temperature for the roasting is 500° C., and the acid used should have a density between 1.297 and 1.530.

The summary concerning the utilization of the Australian deposit at Bullahdelah is contained in the following paragraphs:[2]

The following is a process by which alum is manufactured from alunite: The mineral is ground and then calcined in reverberatory furnaces, to dehydrate it and drive off part of the SO_3. It is next treated with a weak solution of sulphuric acid in lead-lined tanks, heated to boiling point by steam jets. The liquor is allowed to settle in the same vats, and the clear solution is run off into crystallizing tanks, which are kept in constant agitation while cooling, the alum crystallizing out and sulphate of alumina remaining in solution. The residue in the vat is boiled again with water, and the solution run off again in the same way. The liquor containing sulphate of alumina is then returned to the vats and sufficient of the calcined mineral added to completely neutralize any free acid. It is then heated to boiling point and ebullition continued until partial reversion takes place, the reversion being accompanied by a precipitation of the hydrated ferric oxide.

The alum, after collection, is washed and then refined in vats, similar to but deeper than those originally employed, and the concentrated solution is run into roaching tuns in which it is crystallized; it is then broken up and packed ready for the market.

The sulphate of alumina solution, after all the alum has been crystallized from it, is concentrated in small vats heated with steam coils, and the lower qualities of sulphate of alumina are formed by running the liquor onto lead tables and breaking the solidified material into blocks, the higher qualities (containing over 17 per cent of soluble alumina) being cast on copper trays. These higher qualities, which vary in color from yellow to green in the slabs, are then ground in a disintegrator, and the material assumes a snow-white appearance.

It is of course feasible, by the addition of K_2SO_4, to convert the whole of the alumina contained in the stone into alum if desired, but the more profitable method of treatment, when the better classes of sulphate of alumina can be sold at standard prices, is to make only so much alum as there is sulphate of potash present in the stone to produce, and convert the rest of the alumina into soluble sulphate of alumina (of commerce).

Sulphur may be obtained by distilling the mineral in the presence of any reducing gas like coal gas. Sulphuric acid may also be distilled from the mineral. Heating with carbonate of baryta produces aluminate of potash.

The following extract from a recent consular report[3] gives a little additional information on the industry at Bullahdelah:

The stone yields on an average 80 per cent of alum. According to the statistics for the mining industry of New South Wales, the output of alum for the years 1856 to 1908 was valued at $450,000 and for 1908 to the end of 1913 $190,000. Since the year 1908 about 1,200 tons of the rock have been taken out

[1] Ueber die Aufschliessung des römischen Alunits: Deutsch. chem. Gesell. Ber., vol. 17, p. 2887.

[2] Pittman, E. P., Alunite or alumstone in New South Wales: New South Wales Geol. Survey Rept., 1901, pp. 419–429.

[3] Sullivan, L. N. (consul at Newcastle, N. S. W.), Daily Cons. and Trade Repts. No. 199, p. 991, Bur. Foreign and Domestic Commerce, Aug. 25, 1915.

annually and shipped to England for treatment, where the alum could be extracted much more cheaply than was possible here. The Australian Alum Co. (Ltd.) is the operating company, with head offices at 109 Pitt Street, Sydney.

ALUMINA AND ALUMINUM PRODUCTS.

The possible derivation of alumina as a by-product in the extraction of potash from alunite has already been mentioned. Experiments on the direct extraction of alumina from high-grade alunite (see analyses 1, 4, and 5, p. 246) have shown that the process works well and may be a commercial success if freight rates from Utah to eastern aluminum-manufacturing plants are not prohibitive. As an offset to the freight rates, however, is the fact that the alumina produced from high-grade alunite is purer than the bauxite ores of the Southern States. The low-grade mineral, corresponding to analysis 2 on page 246, contains too much silica to be used as an ore of aluminum.

The question of erecting a western plant for extraction of aluminum may be found to deserve consideration. In a recent paper by Lyon and Keeny, of the United States Bureau of Mines,[1] the statement is made that "all processes for the extraction of aluminum from silicates are still very much in the experimental stage." As alunite is a sulphate, not a silicate, and can be obtained practically free from silica, its availability appears more promising. The extraction of both potash and alumina from the same lot of ore should apparently go further toward making a successful industry than the extraction of either product alone.

Other products, now obtained from the mineral bauxite, a hydrous oxide of aluminum, may also be derived from the residue left after the extraction of potassium sulphate from alunite. These are the different aluminum salts, refractory bricks, alundum (fused alumina), and calcium aluminate. In the manufacture of refractory bricks, the purer the alumina the more refractory the resulting product, but it is probable that the rather siliceous residues from the less pure grades of alunite, such as that represented by analysis 2, page 246, will be satisfactory for this purpose, whereas the residues practically free from silica are especially desirable for the manufacture of metallic aluminum. Alundum is used as an abrasive and is finding an extended use in the refractory industries. Calcium aluminate is used to give a quick set to plasters. It is possible that the alumina residue at the Marysvale plant may find a direct use, and it is reported that experiments to determine this point are under way. Further information on the production and manufacture of aluminum and its products is given in the annual reports on bauxite and

[1] Lyon, D. A., and Keeny, R. M., Electro-metallurgy of aluminum in the West (presented at September meeting of American Institute of Mining Engineers) : Abstract published in Min. and Eng. World Aug. 7, 1915.

aluminum by W. C. Phalen, of the United States Geological Survey, in Mineral Resources for the years 1908 to 1914, inclusive.

SULPHURIC ACID AND SULPHUR.

The manufacture of sulphuric acid in connection with the preparation of potassium sulphate and alumina has also been suggested, and in certain patents issued for apparatus for treating alunite means have been devised for conserving the fumes given off in roasting. It is stated by Phalen,[1] however, that owing to the expense of the process and to the small market for sulphuric acid in the West at the present time, it is very unlikely that the conservation of sulphuric acid from alunite will be seriously considered for some years at least.

It has been suggested that sulphur may be obtained by distilling the alunite in the presence of any reducing gas. The production of sulphur by such a method has evidently not been considered by those interested in the Marysvale deposits, and it is not likely to prove practical in view of the large amount of sulphur produced so cheaply in Louisiana and Texas, and for the further and important reason that the production of sulphur from its oxides (the "sulphur fumes" from smelters) has not yet progressed beyond the experimental stage.

FERTILIZER.

Owing to the slowness and expense of extracting potassium sulphate from alunite by leaching Waggaman[2] suggested that it might be more economical to use ignited alunite directly as a fertilizer. Experiments by Skinner and Jackson[3] afford some information on this question. These experiments show that raw alunite used in amounts equivalent to 25 to 500 pounds of K_2O per acre increased growth from 10 to 20 per cent. The growth when the raw alunite was used was not so good as with similar amounts of potassium sulphate and potassium chloride, but the increase in growth with calcined alunite ranged from 35 to 43 per cent, the average being 40 per cent, which was about the same as that with potassium sulphate and greater than that with potassium chloride.

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[1] Phalen, W. C., Potash salts, 1914: U. S. Geol. Survey Mineral Resources, 1914, pt. 2, p. 21, 1915.

[2] U. S. Dept. Agr. Bur. Soils Circ. 70, July 31, 1912.

[3] Skinner, J. J., and Jackson, A. M., Alunite and kelp as potash fertilizers: U. S. Dept. Agr. Bur. Soils Circ. 76, 5 pp., Apr. 10, 1913.