SULPHUR AND PYRITE.

THE COVE CREEK SULPHUR BEDS, UTAH.

By WILLIS T. LEE.

GENERAL STATEMENTS.

Location.—The sulphur deposits here described are owned by the Utah Sulphur Company, of Salt Lake City, and are located in central Utah, at Sulphurdale, a small mining camp about 20 miles north of Beaver, Utah, the nearest important town. The camp is not permanent and is deserted during the winter or whenever mining operations cease. The deposits are situated about 4 miles south of the site of old Cove Fort and are locally known as the Cove Creek sulphur beds. They are conveniently reached by team from Beaver, but the railroad connection or shipping point is Blackrock, a station on the San Pedro, Los Angeles and Salt Lake Railroad about 24 miles northwest of Sulphurdale.

Occurrence.—The sulphur extends from the surface downward to a considerable though unknown depth in beds of soft rhyolitic tuff and varies in amount in different parts of the beds. An area of several acres has been exploited, the sulphur having been mined more or less continuously for 30 years, but the lateral extent as well as the depth of the deposits is unknown.

Neighboring deposits.—There are several more or less widely separated deposits of sulphur in the vicinity of Sulphurdale, ranging in a general northeast-southwest direction. One deposit 3 miles north of the camp is said to have been worked to some extent, but the other prospects have not been developed, although they are said to show indications of considerable quantities of sulphur.

GEOLOGY.

Formations.—The Paleozoic sediments of the plateau region probably occur at a considerable depth beneath the surface at Sulphurdale. Their nearest exposures are at the north end of Mineral Mountains and in the Beaver River range to the west, where they dip eastward beneath the extrusive rocks which cover the surface.

The Tushar Mountains, near the north end of which the sulphur beds occur, are composed of eruptive rock consisting, so far as examined, of flows, breccias, and tuffs of rhyolite overlain in places by andesite. Much of the tuff is soft, fine-grained, and snowy white. The rhyolites presumably rest upon sedimentary rocks, as in neighboring regions, and are apparently several thousand feet thick. The sulphur occurs in the white tuff, which some of the miners call "gypsum."

In the vicinity of Sulphurdale basalt overlies the rhyolites and andesites in slightly eroded flow sheets and crater cones. Two conspicuous cones having well-defined craters occur near the sulphur beds, one about 10 miles to the southwest, the other 3 miles west of the camp. Still other cones and associated flows are situated farther north, forming a linear group lying essentially parallel to the neighboring mountain ranges. The fresh appearance of the lavas and the slight amount of erosion of the cones indicate recent formation, and lavas of similar character near Blackrock rest upon the Bonneville beds, from which fact it seems probable that the cones were formed during late Quaternary time.

Structure.—There are reasons for believing that the sulphur beds are located in or near a zone of intense faulting and volcanic activity and that the conflicting forces causing the disturbances have not yet reached a state of equilibrium. Evidence of this is found not only in the vicinity of Sulphurdale, but for long distances both north and south of this place.

Along the western border of the high plateaus of Utah, from St. George northeastward, several basins have been formed by faulting, accompanied or followed by the movement of large crust blocks. Rush Lake Valley and Parowan Valley are perhaps the most conspicuous of these basins. The strata of the plateau to the east lie essentially horizontal, while those to the west dip eastward beneath the valleys. In the Beaver basin this simple relation is complicated by the great masses of effusive rock which cover the sediments, but west of the basin, in the vicinity of Minersville, and again at the north end of Mineral Range, the Paleozoic sediments appear underneath the effusives, dipping eastward beneath the basin. From this it is inferred that Beaver Valley, like those farther south, is due to crustal movement and that the great fault zone which follows the western margin of the plateau through Rush Lake and Parowan valleys, and along which displacements of thousands of feet are known to have occurred, probably continues through Beaver Valley, and thence northeastward past Sulphurdale.

Several phenomena noted mark this zone as one of recent disturbance. The line of sulphur beds, from which hydrogen sulphide is still escaping in large quantities, and less exactly the line of the recent

volcanic cones, coincide with it or lie parallel to it. The region between St. George and Fillmore is known as a zone of frequent and severe earthquakes, several shocks of sufficient force to destroy buildings having occurred there within the memory of men still living in this vicinity.

SULPHUR.

CHARACTER OF ORE.

Some of the sulphur occurs in cylindrical masses or cores 10 or 15 feet in diameter, having a rude radial structure, as if they had been formed about a central vent that extended downward into the beds of tuff, but it occurs mainly as a dark-colored impregnation or cementing substance in the rhyolitic tuff. In certain places it appears as irregular veins of nearly pure yellow sulphur ramifying through the beds. These veins, some of which are several inches thick, are usually banded parallel to the walls and are evidently filled fissures. The sulphur is apparently deposited in some way from solution, since in several places acid water, an analysis of which is given below, was found issuing from small fissures partly filled with yellow sulphur. Here and there a small cavity is lined either with flowers of sulphur or with sulphur crystals.

The ore varies greatly in richness; at some places there is only a trace, at others there are masses of practically pure sulphur. Samples taken at the extremities of the workings have been analyzed by E. C. Sullivan, of the United States Geological Survey, and found to contain, respectively, 80 and 65 per cent of sulphur. The first sample was taken from a horizontal sheet 8 feet thick and the second from a vertical dikelike body 4 feet thick. There is a large quantity of equally rich ore and much that is not so rich. Material having as low as 15 per cent of sulphur, however, is considered paying ore.

The cost of production is doubtless much greater than it would be if the mining were done on a scale sufficiently large to warrant the installation of modern machinery. The stripping to a depth of 10 feet or more is done entirely by horses and scrapers, much of the material having been moved several times, and the ore is removed by manual labor, whereas both operations might easily be performed with steam shovels at greatly reduced cost.

At the smelter the ore is placed in iron retorts and the sulphur melted out by steam, which is forced into it under a pressure of about 60 pounds, representing a temperature of 144° C. The melted sulphur finds its way to the bottom of the retort and is drawn off into iron receptacles, in which it cools and hardens into cakes weighing about 200 pounds each. In this form it is stored until needed, when it is ground into flour and sacked for shipment. The rate of extraction is slow, but experience has shown that an attempt to hasten it by raising

the temperature of the steam results in diminishing the output and in some cases has almost wholly stopped the process. The steam pressure employed varies somewhat with the kind of ore. Cedar wood, which grows in abundance in this vicinity, is used as fuel.

The sulphur as it comes from the retort has been analyzed by Herman Harms, State chemist of Utah, who reports the composition as follows:

Analysis of sulphur from retort at Sulphurdale, Utah.

Sulphur	99.71
Nonvolatile residue (silica, iron oxide, etc.)	.23
Free sulphuric acid	Trace.
Sulphurous acid	0
Arsenic	0
Moisture at 100° C	.06
	100.00

ORIGIN.

Several facts noted seem to point clearly to the mode of origin of the sulphur. The geologic relations, previously stated, indicate that the deposits are on or very near a fault line and are closely associated with volcanic rocks. The presence of a recently extinct volcano to the west, the flows from which extend within about a mile of the sulphur beds, suggests that the sulphur may have resulted from the eruptions of this volcano. Gas is now escaping here in large volumes; in some places through vents suggesting those supposed to have given rise to the cylindrical cores of sulphur; in other places through thousands of small jets from the porous beds of tuff, giving rise to the general dissemination of the sulphur through the beds. Wherever water stands in the excavations the gas boils up through it at short intervals. No sulphur dioxide (SO_2) was noted, but the disagreeable odor of hydrogen sulphide (H_2S) was strongly perceptible. The occurrence of large quantities of hydrogen sulphide suggests that this gas is the source of the sulphur. When it comes into contact with oxygen in the porous tuff near the surface it is probably oxidized, losing its hydrogen and dropping the sulphur as expressed by the simple formula:

$$H_2S + O = H_2O + S.$$

The sulphur being a solid remains where it is set free in the porous tuff. If this explanation is correct, continued oxidation would form a certain amount of sulphur trioxide ($S + 3O = SO_3$), which in combination with water forms sulphuric acid ($H_2O + SO_3 = H_2SO_4$). It is a matter of interest in this connection to observe that the water issuing from the beds is strongly charged with acid, as shown by the following analysis made by W. M. Barr, of the United States Geological Survey:

Analysis of water from Cove Creek sulphur beds.

[Parts per million.]

Dissolved solids at 180°	8,816
Dissolved solids at 130°	10,810
Suspended matter	52
Silica (SiO_2)	124
Ferrous oxide (FeO)	560
Ferric oxide (Fe_2O_3)	802
Aluminum (Al)	0
Calcium (Ca)	158
Magnesium (Mg)	232
Sodium (Na) } Potassium (K) }	144
Carbonate radicle (CO_3)	0
Bicarbonate radicle (HCO_3)	0
Sulphate radicle (SO_4)	7,602
Free sulphuric acid (H_2SO_4)	4,523
Chlorine (Cl)	79
Nitrate radicle (NO_3)	1.7
Free sulphur (S)	3.6

NOTE.—Constant loss of dissolved solids occurs when heated above 130°. Heated at 180° not constant. Sample had free hydrogen sulphide (H_2S) when collected, with possible presence of sulphur dioxide (SO_2).

The veins filled with yellow sulphur and the cavities lined with crystals or flowers or sulphur might be interpreted as indicating that the sulphur came up in melted or vaporized condition. The quantity occurring in this way, however, is very small compared with that contained in the tuff, and may be due to some secondary action.

CONCLUSION.

The facts and inferences regarding the occurrence and origin of the Cove Creek sulphur deposits may be summarized as follows:

There are valuable deposits of sulphur not only at Sulphurdale, where it is being extracted, but at several other localities in the same neighborhood. The Cove Creek sulphur beds have supplied the local market for about thirty years, their average annual output being estimated at 1,000 tons. The sulphur is probably the result of volcanic action, as is shown by its presence in a volcanic region where recent eruptions have occurred. It is presumably derived from hydrogen sulphide, which is still escaping in large quantities, and its concentration in the beds of rhyolitic tuff is probably due to the general dissemination of the gas through the porous material near the surface, where it comes in contact with oxygen which unites with the hydrogen to form water, leaving the sulphur as a cementing substance in the loose material. The process of formation and concentration is apparently active at the present time.

SURVEY PUBLICATIONS ON SULPHUR AND PYRITE.

The list below includes the important publications of the United States Geological Survey on sulphur and pyrite:

ADAMS, G. I. The Rabbit Hole sulphur mines, near Humboldt House, Nev. In Bulletin No. 225, pp. 497–500. 1904.

DAVIS, H. J. Pyrites. In Mineral Resources U. S. for 1885, pp. 501–517. 1886.

ECKEL, E. C. Gold and pyrite deposits of the Dahlonega district, Georgia. In Bulletin No. 213, pp. 57–63. 1903.

——— Pyrite deposits of the eastern Adirondacks, N. Y. In Bulletin No. 260, pp. 587–588. 1905.

MARTIN, W. Pyrites. In Mineral Resources U. S. for 1883–84, pp. 877–905. 1886.

RICHARDSON, G. B. Native sulphur in El Paso County, Tex. In Bulletin No. 260, pp. 589–592. 1905.

ROTHWELL, R. P. Pyrites. In Mineral Resources U. S. for 1886, pp. 650–675. 1887.

SPURR, J. E. Alum deposit near Silver Peak, Esmeralda County, Nev. In Bulletin No. 225, pp. 501–502. 1904.

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[Bulletin No. 315.]

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