The Gunnison Forks Sulfur Deposit, Delta County, Colorado

by

McClelland G. Dings

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THE GUNNISON FORKS SULFUR DEPOSIT DELTA COUNTY, COLORADO[1]

by

McCLELLAND G. DINGS[2]

INTRODUCTION

The presence of a small sulfur deposit in the Dakota sandstone near Delta, Colorado, has long been known, but no description of the deposit has been published. In November 1946 the writer, assisted by J. M. Cattermole, spent about 2 weeks in a study of the deposit and the surrounding area. This work was done by the U. S. Geological Survey in cooperation with the Colorado Geological Survey Board and the Colorado Metal Mining Fund.

The deposit, which for convenience here will be called the Gunnison Forks sulfur deposit, is in south-central Delta County, Colorado, (see fig. 1) near the junction of the north and south forks of the Gunnison River. More specifically it is in sec. 36, T. 14 S., R. 94 W., and about one-half mile south of State Highway 92 at a point 14.4 miles east of Delta.

The general geologic setting of the area is shown on the regional geologic maps (scale 1:125,000) of Lee[3] and Weeks.[4] Weeks shows the location of two gas seeps in this general area, but does not mention the sulfur specifically.

Although the deposit has been credited, according to rumor, with large reserves of sulfur and metallic minerals, these reports have proved to be exaggerated. Sulfur is conspicuous in the deposit, but the only product recovered thus far commercially is a sulfur-bearing mixture of sandy shale, carbonaceous shale, and sandstone. This is crushed and sold as a soil conditioner by the General Agricultural

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[1] Published by permission of the Director of the Geological Survey, United States Department of Interior, in cooperation with the State of Colorado through the Colorado State Geological Survey Board and the Colorado Metal Mining Fund.

[2] Geologist, U. S. Geological Survey.

[3] Lee, W. T., Coal fields of Grand Mesa and the West Elk Mountains, Colorado: U. S. Geol. Survey Bull. 510, plate 1, 1912.

[4] Weeks, H. J., Oil and water possibilities of parts of Delta and Mesa Counties, Colorado: Colo. Geol. Survey Bull. 28, plate 1, 1925.

Products Co. of Delta under the name of "Gapco Sulfor Base Soil Conditioner."

A plane-table map of the deposit and surrounding area is shown in figure 2, and a larger-scale map of the quarry area is shown in figure 3. Altitudes for the maps were determined from U. S. Coast and Geodetic Survey monument D 178, located about one-half mile to the northeast of the area mapped.

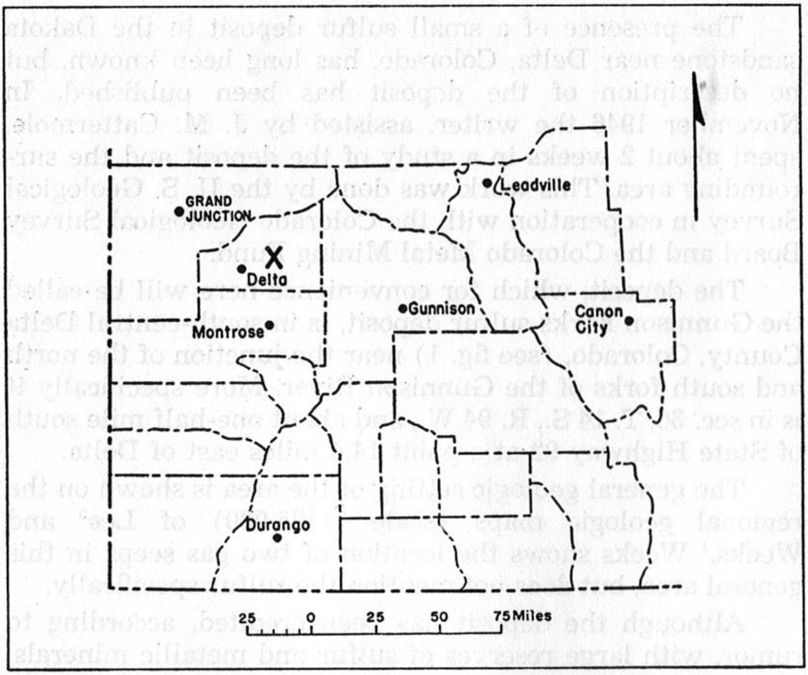
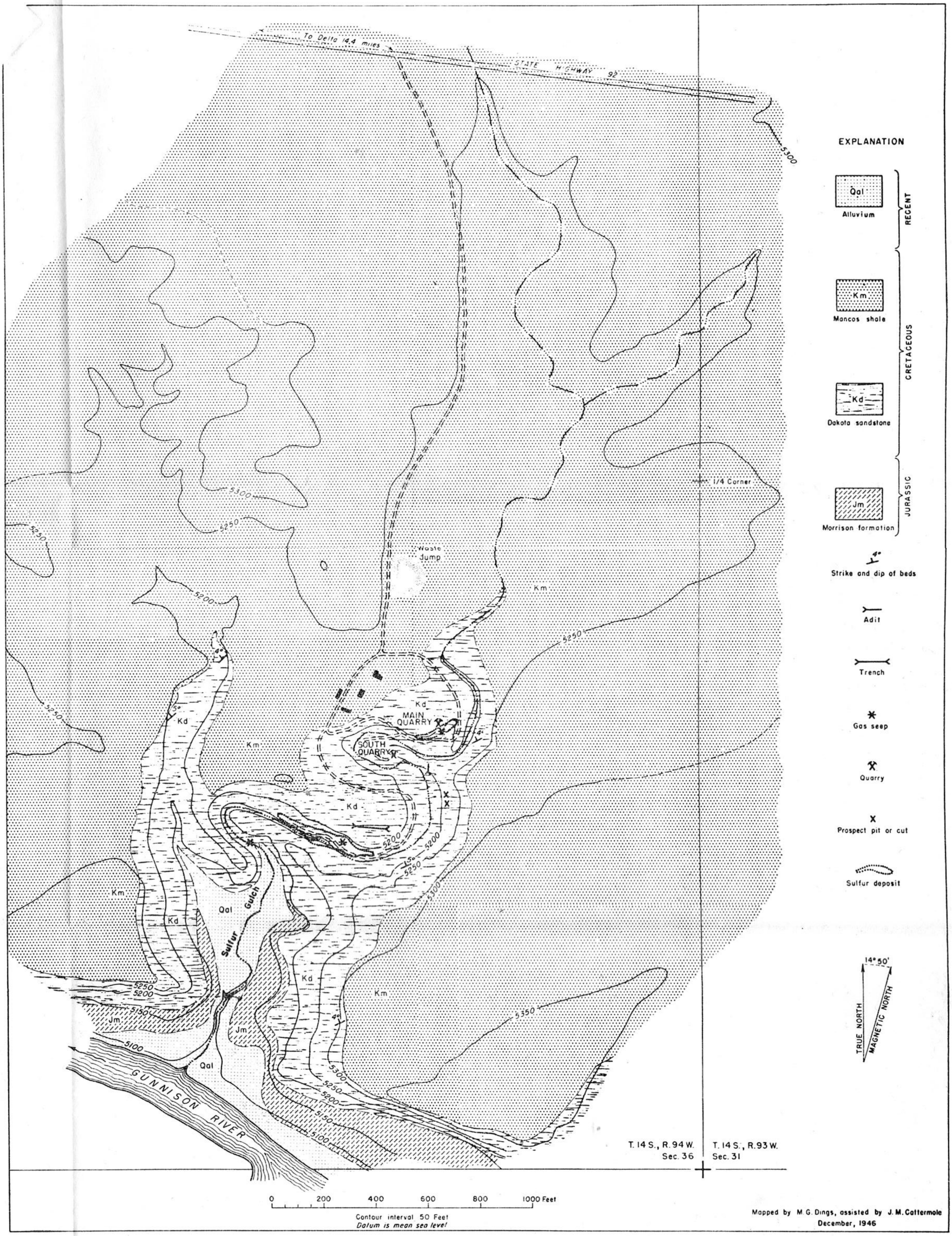


FIG. I - Index map of southwestern Colorado, showing location (by X) of the Gunnison Forks sulfur deposit

Acknowledgment is due especially to Mr. J. M. Cattermole who assisted the writer during most of the field work. Thanks are due to Mr. A. C. McDonald of the General Agricultural Products Co., who gave much information concerning the area and the materials quarried.



Mapped by M. G. Dings, assisted by J. M. Cattermole
December, 1946

FIG. 2 - Geologic map of the Gunnison Forks sulfur deposit and vicinity, Delta County, Colorado

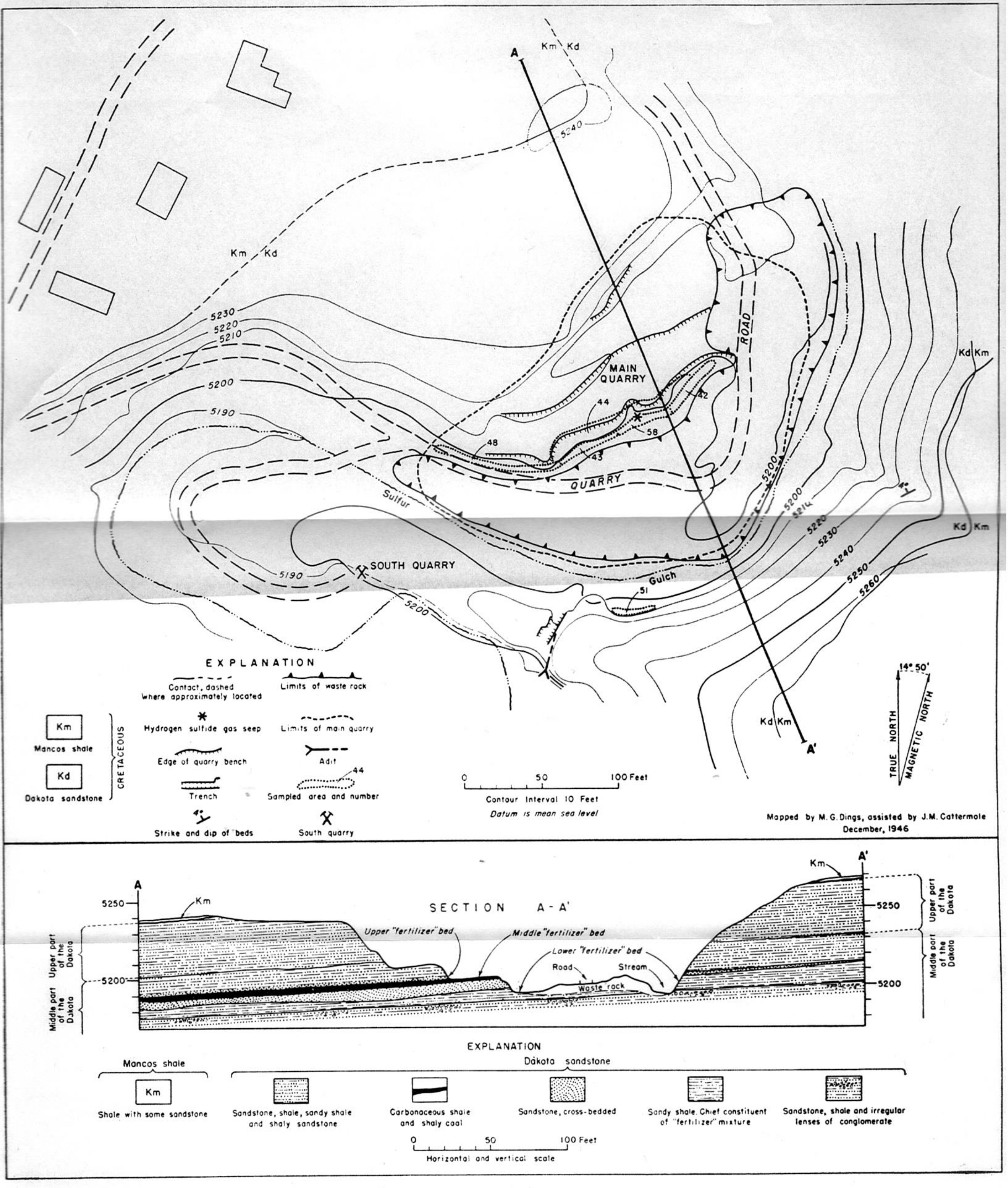


FIG. 3 - Geologic map and cross section of the quarry, Gunnison Forks sulfur deposit, Delta County, Colorado

TOPOGRAPHY

The area surrounding the Gunnison Forks sulfur deposit, at an average altitude of 5,200 feet, is a rolling upland surface that is cut to a depth of about 250 feet by the steep-walled canyon of Gunnison River, and to lesser depths by gulches tributary to the river. The quarry is in a gulch, here called Sulfur Gulch for convenience of reference, 50 to 100 feet below the upland surface. The upland area is underlain by shale that is easily weathered and eroded, and forms smooth, bare, rounded hills. The underlying sandstone forms small but steep cliffs at the sides of Sulfur Gulch and the gulch tributary to Sulfur Gulch near the Gunnison River. Sulfur Gulch has the form of an incised meandering stream, the channel of which is now occupied by an intermittent stream. Steep cliffs border the Gunnison River on the north, and the lower slopes are almost entirely covered by talus.

Minor variations in topography occur where resistant beds of sandstone in the shale form small benches and ledges. A hard standstone, ranging from 2 to 4 feet in thickness, commonly forms a pronounced ledge and less commonly a dip-slope surface.

GEOLOGIC FORMATIONS

The bedrock formations in the vicinity of the Gunnison Forks deposit include the Morrison formation (Jurassic), the Dakota sandstone (Cretaceous), and the Mancos shale (Cretaceous). Recent aluvium mantles the bedrock in a narrow belt along the Gunnison River and in the bottom of Sulfur Gulch near its junction with the river. Most of the area is underlain by the lower part of the Mancos shale, and only in the walls and valleys of Sulfur Guich and the Gunnison River are the Dakota sandstone and a little of the Morrison formation exposed.

Morrison formation

The Morrison formation is very poorly exposed in this area, as it is largely covered by talus from the Dakota sandstone or by alluvium. The uppermost beds are exposed locally, but at most places only an approximate contact can be drawn between the Morrison and the overlying Dakota sandstone. The top 35 feet of the formation, the maximum exposed, can be seen near the base of the steep east-facing slope about 300 feet north of the mouth of Sulfur Gulch. At this place the basal conglomeratic sandstone of the Dakota sandstone is underlain by a massive, fine-grained, white standstone bed at least 10 feet thick. This white sandstone is underlain by beds of red sandy shale and very light gray shale. No evidence of an unconformity between the Morrison and the Dakota was observed.

Dakota sandstone

The Dakota sandstone as recognized in this report corresponds to that used by Weeks[7], who included the transitional beds at the top as well as the basal conglomeratic sandstone in the Dakota.

The Dakota sandstone as a whole is a resistant formation underlain and overlain by much softer beds, and it therefore forms prominent cliffs. The complete section, which is on the average 120 feet thick, is exposed best on the spur 300 feet north of the mouth of Sulfur Gulch. The rocks are principally quartz sandstone, conglomeratic sandstone, shaly sandstone, sandy shale, and shale, and minor beds or leses of quartzite, conglomerate, carbonaceous shale, coal, shaly coal, and bentonite.

Many of the beds are lenticular, particularly the sandstone beds. Some of the dark carbonaceous shales also are lenticular, although several of these beds can be traced for 1,000 feet or more along the walls of Sulfur Gulch. Most sandstones weather light brown to reddish brown and are cross-bedded.

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[7] Weeks, H. J., op. cit., p. 19.

The Dakota sandstone in this area has three main divisions or units that are rather distinctive when considered as a whole. The basal unit is a conglomeratic sandstone; the middle unit is a series of interbedded sandstones and shales that locally contain numerous dark carbonaceous shales, shaly coal, and coal; the upper unit comprises thin-bedded sandstones and shales, the sandstones generally being harder and thinner than those in the middle unit, and the shales less carbonaceous and therefore lighter-colored.

The conglomeratic sandstone of the basal unit is about 25 feet thick. It is chiefly a white to gray, medium-grained, prominently cross-bedded sandstone that commonly weathers gray to brown. It is composed chiefly of subrounded quartz grains, but irregular patches of the sandstone are conglomeratic, and contain scattered rounded to subangular granules and pebbles of white quartz and gray to black chert. Most of the pebbles are less than three-quarters of an inch in maximum dimension. Lenticular beds of conglomerate a foot or less thick are sparse and irregularly distributed in the unit.

The middle unit of the Dakota sandstone consists of interbedded sandstones and shales about 60 feet thick. This unit is very well exposed along the walls of Sulfur Gulch from the quarry southwest to its contact with the underlying basal conglomeratic sandstone. The sandstones are quartzose and fine- to medium-grained. Some are tightly cemented and flinty; others are loosely cemented and moderately soft. The rock commonly weathers light brown to reddish brown. Many of the sandstones are prominently cross-bedded and lenticular. One bed well exposed along the wall of Sulfur Gulch southeast of the quarry decreases in thickness from 15 feet to 1 foot within a distance of 60 feet. Partings and thin lenses of dark-gray to black carbonaceous shale occur in many of the sandstones. Some of these shaly beds contain poorly preserved plant remains.

The shales of the middle unit are dark gray to black, depending on the amount of carbonaceous material present.

Many of them are sandy and grade into shaly sandstones. A few of the more carbonaceous beds grade into impure coal. The carbonaceous beds contain plant remains and a few pyrite concretions as much as 2 inches in diameter. They commonly contain plates of gypsum, chiefly as a narrow filling in fractures. A bed of bentonite about 8 inches thick occurs in the upper part of the middle unit and is exposed at several places near the quarry. The middle unit grades into the upper unit, and at most places the boundary between the two must be drawn arbitrarily.

The upper unit of the Dakota sandstone is about 35 feet thick. In general it is not nearly as well exposed as the other two units, although the uppermost sandstone bed of this unit is exceptionally well exposed. This unit differs from the middle unit in that it is thinner-bedded and lighter in color. The alternate beds of sandstone and shale most commonly are from 1 to 8 inches thick. The shale is less carbonaceous and therefore slightly lighter in color than that of the middle unit; it closely resembles the gray shales of the overlying Mancos shale. The sandstone beds are much harder than those in the middle unit. The uppermost bed of sandstone is generally the thickest sandstone bed in the unit, ranging from 2 to 4 feet in thickness. It is a hard, quartzitic, brown-stained sandstone, and locally it is cross-bedded and ripple-marked.

Mancos shale

Most of the area shown in figure 2 is underlain by beds of the lower 100 feet of the Mancos shale. The rocks are mainly thin-bedded, gray to dark-gray shale with minor thin beds of sandy shale, shaly sandstone, and sandstone. One bed of hard sandstone, about 10 feet above the base of the formation and about 10 inches thick, is resistant to erosion and locally forms a dip slope in the southern part of the area. The Mancos shale weathers easily and good outcrops are rare. It weathers to a gray to buff soil that in many places contains abundant residual gypsum plates.

Alluvium

A broad belt of alluvium borders the Gunnison River. It consists of subrounded to rounded boulders, as much as a foot or more in length, mixed with clay and sand. At the mouth of Sulfur Gulch the deposit has been cemented locally into a compact conglomerate composed chiefly of cobbles of many types of rock, mostly crystalline rocks foreign to the immediate vicinity. At the lower end of Sulfur Gulch, younger alluvium that consists of thin-bedded clays, silts, and sands covers this older alluvium.

STRUCTURE

The structure of the rocks in the vicinity of the Gunnison Forks sulfur deposit is relatively simple. In general the beds strike about N. 65° E., and dip 4°-5° NW. In the west-central part of the area the upper beds of the Dakota strike about N. 45° E. Local deviations from this attitude appear to be due to slumping or cross-bedding. In the north half of the area no reliable strike or dip readings could be taken because the few outcrops of Mancos shale all appear to have slumped.

Both folds and faults are rare and are so small that they are believed to be of no importance. Joints, however, are conspicuous in the sandstones in the southern half of the area. The most prominent joints strike N. 10°-35° E., and many of them strike about N. 18° E. The joint planes are vertical or dip very steeply northwest or southeast. Another set of joints that is much less well developed and not nearly so extensive has an average strike af about N. 80° W. Joint planes in this set are vertical or dip steeply to the north or south.

ECONOMIC GEOLOGY

The only product of economic importance in the district is rock that is used as a soil conditioner or "fertilizer." No attempt has been made to mine the native sulfur because of the small size, irregular shape, and low sulfur content of the deposits. No metallic minerals have been mined; probably no economically important deposits of any metallic mineral will be found in this area.

"Fertilizer" rock

The sulfur-bearing rocks in the vicinity of the quarry were used as a fertilizer by local residents as early as 1930, but probably no more than 100 tons was dug between 1930 and the summer of 1945. During that time the property, consisting of 14 unpatented claims, was leased by M. V. Thomas from Joseph and Ira Markley. In 1945 the General Agricultural Products Co. of Delta, Colo. was organized, with Mr. A. C. McDonald of Delta as general manager. This company obtained an operating agreement with the claim holders and began to quarry and sell "fertilizer" rock. Their first production was made in May 1945. Total output from May 1, 1945, to November 30, 1946, was 1,150 tons.[8]

Buildings on the property consist of a small mill for grinding the rock, a storage house, a combination office and chemical laboratory, and a residence.

Most of the material produced has come from the large quarry shown in figure 3. The quarry face, which trends northeast, is 200 feet long, and two main benches about 30 feet wide have been cut in it. A small quarry about 200 feet southwest of the main quarry, near the end of the road shown in figure 3, has been cut southeast along the cliff for about 40 feet. In the description that follows, this quarry will be referred to as the south quarry, and the large quarry will be called the main quarry.

Main quarry.—Section A-A′, figure 3, drawn through the quarry shows the stratigraphic positions and relative thicknesses of the three "fertilizer" beds or zones worked.

The lowest zone is a series of gray, thin-bedded, sandy shales, shales, and sandstones. It is about 10 feet thick along the line of section but thins to 3.5 feet about 15 feet to the

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[8] History and production data furnished by A. C. McDonald, Oral communication December, 1946.

southwest. Small crystals of sulfur and thin plates of gypsum are disseminated through the rock and also partly coat many of the joints, fractures, and bedding planes. The shale also contains pyrite concretions as much as 2 inches in diameter. The lowest "fertilizer" zone is underlain by a mottled gray sandstone that contains lenses of conglomerate, and is overlain by a prominently cross-bedded white sandstone containing abundant thin lenses and seams of black carbonaceous shale.

The middle bed, quarried for "fertilizer," is about 2 feet thick, and consists of black carbonaceous shale that in places grades into shaly coal or thin (6 inches or less) seams of a poor grade of bituminous coal. Thin lenticular streaks of pyrite and poorly preserved plant remains are common. This bed could not be traced beyond the quarry, but dark carbonaceous beds of similar appearance, except that they contain little or no coal, occur at about the same stratigraphic horizon to the south in the walls of Sulfur Gulch.

The upper "fertilizer" bed immediately overlies the black carbonaceous shale. It is a gray, somewhat platy, fine-grained sandstone about 2 feet thick. The sandstone is overlain by a thin bed, 6 to 10 inches thick, of light-gray to white bentonite. Neither the sandstone nor bentonite bed could be recognized on the opposite slope of Sulfur Gulch southeast of the quarry. The bentonite bed in the quarry is overlain by about 50 feet of interbedded sandstone, shale, shaly sandstone, and sandy shale of the middle and upper units of the Dakota sandstone, and the basal Mancos shale.

South quarry.—A small quantity of rock, probably less than 25 tons, has been quarried for "fertilizer" from the south quarry at the western end of the bluff about 200 feet southwest of the main quarry. The material quarried is about 6 feet thick, and consists of thin beds of gray to nearly black sandy shale interbedded with minor sandstone and carbonaceous shale. It is somewhat similar to the sandy shale in the large quarry that is used in the soil-conditioner mixture, but is 10 to 15 feet lower stratigraphically. The sandy shale section in the South quarry is underlain by a bed, 2 to 4 feet thick, of hard sandstone that in places grades into conglomeratic sandstone or conglomerate. The upper part of the bluff, which immediately overlies the sandy shale section, consists of interbedded shale, sandy shale, and sandstone. This section differs from the underlying section by containing a larger percentage of sandstone beds that on the average are much thicker, commonly ranging from 2 to 12 inches.

Extent of the quarry beds.—The three beds of "fertilizer" material in the main quarry occur within a stratigraphic interval of about 20 feet near the top of the middle unit of the Dakota sandstone; the uppermost of these beds is about 45 feet below the base of the Mancos shale. It was not possible to trace any of the "fertilizer" beds with certainty more than 100 feet beyond the quarry, because of the lack of distinctive features in the beds, their lenticularity, and, to a less extent, the scarcity of exposures. The rocks at the same stratigraphic position elsewhere in the mapped area are mostly interbedded shales, sandy shales, and sandstones that are also lenticular and show only a very general lithologic similarity to the beds in the quarry. Therefore the beds being quarried probably pinch out in a relatively short distance.

Composition of the "fertilizer" mixture.—The "fertilizer" soil conditioner is a pulverized mixture of sandy shale, dark carbonaceous shale, and sandstone, with some gypsum and sulfur. According to Mr. McDonald[9] a ton of the "fertilizer" mixture consists of about 1,500 pounds of sandy shale, 200 pounds of black carbonaceous shale, and 300 pounds of sandstone. Some of the "fertilizer," however, contains as much as 500 pounds of the black carbonaceous shale to the ton. Mr. McDonald states that the black shale helps to build up the carbon content of the soil and is especially beneficial for sugar beets and fruit trees.

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[9] McDonald, A. C., Oral communication December, 1946.

It was beyond the scope of the brief examination made of the area to evaluate the fertilizing qualities of the various beds or combination of beds. A thorough evaluation would require extensive sampling supported by many fairly complete and costly chemical analyses of numerous combinations of rocks. Furthermore, the lenticularity of most of the beds would necessitate many more analyses than probably would be required for beds that persisted with the same general thicknesses and mineralogical compositions throughout the area. Mr. McDonald[10] stated that his company usually has to make many chemical analyses in order to keep the "fertilizer" at the desired composition. The average composition of the General Agricultural Products Co.'s "fertilizer" mixture was not available, but the mixture is marketed under a label that contains the following statement: *"Contains 10% active sulphur, also colloidal phosphate, iron oxide, calcium, magnesium, copper, iron sulfate, aluminum sulfate, potash, and nitrate, as well as animal and vegetable matter. pH3.5."* The product is sold as a soil conditioner rather than a commercial fertilizer because it does not meet the legal requirement that a product sold as fertilizer must have a combined total of 12 percent or more of available nitrogen, phosphorous pentoxide, and potassium oxide.

Gas Seeps

Three gas seeps occur in Sulfur Gulch in a northeast-trending zone about 900 feet long (fig. 2). They issue from fractures in the Dakota standstone and, particularly the middle seep, emit a strong odor of hydrogen sulfide. Sulfur occurs in the sedimentary rocks around the seeps, but in minor quantity at the southwesternmost one. The gases were not analyzed, but they probably contain carbon dioxide as well as hydrogen sulfide. One carbon dioxide-hydrogen sulfide gas seep is shown in this area on Week's[11] map,

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[10] **McDonald, A. C., Oral communication December, 1946.**

[11] **Weeks, H. J., op. cit., plate 1.**

and another gas seep of similar type is shown about one-half mile to the west.

About 4 miles east of the mapped area, on the north bank of the North Fork of the Gunnison River, Headden[12] has described a series of springs, the Doughty Springs, that discharge moderate quantities of gases. The gases were not analyzed, but all have a decided odor of hydrogen sulfide. These gases are of no economic value at present.

The origin of the gas seeps is discussed on following pages along with that of sulfur.

Sulfur

Native sulfur is irregularly and widely distributed throughout most of the Dakota sandstone in the vicinity of the Gunnison Forks area, although generally in minor quantities. The only two deposits with moderately significant concentrations of sulfur known in the are are outlined in figure 2. The northern deposit is in the quarry, and the southern one is in Sulfur Gulch about 600 feet southwest of the quarry. The two deposits are described separately in the following pages, and are referred to as the quarry sulfur deposit and the southern sulfur deposit. The southern sulfur deposit, however, is not in the south quarry previously described. These sulfur deposits are the only two estimated to contain 5 percent or more of native sulfur that are large enough to be shown clearly on the map. Fairly rich concentrations of sulfur occur at several other localities, but their areal extent is small. Sulfur may be, and probably is, present in the Dakota sandstone in the cliffs north of the Gunnison River, but the grade is unknown because these beds are almost entirely inaccessible.

The quarry sulfur deposit is in the upper part of the middle unit of the Dakota sandstone, and the southern sulfur deposit is in the upper part of the basal unit. Sulfur

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[12] Headden, W. P., The Doughty Springs, a group of radium-bearing springs on the North Fork of the Gunnison River, Delta County, Colorado: Colo. Sci. Soc. Proc., vol. 8, pp. 1-30, 1905.

is scarce in the uppermost unit of the Dakota, and where present, generally occurs as a paper-thin coating along fracture or joint surfaces.

Quarry sulfur deposit.—The northermost sulfur deposit shown in figure 2 is in the main quarry. The beds that contain most of the native sulfur are the sandy shales, which are the main constituent of the "fertilizer" mixture, and the overlying cross-bedded sandstone (see section A-A′, fig. 3). These beds are strongly fractured and jointed, and sulfur partly to completely coats many of these surfaces. During quarrying operations, the rocks generally break along these sulfur-coated fractures, and an exaggerated impression of the quantity of sulfur is obtained. Most of the sulfur coating the fractures is in the form of small, yellow, well-developed pyramidal crystals, which are 0.01 to 0.04 inch long, and occur as single crystals or as crystalline aggregates. Sulfur also occurs disseminated in the rocks as single grains or small irregular patches, and a little sulfur occurs as crystal lining in small cavities.

The native sulfur content of the rocks in the quarry area varies widely, as shown in the table below.

Native sulfur content of samples from the quarry area
Charles O. Parker, anlayst

Sample	*Sulfur (percent)*
42	4.05
43	7.32
44	2.39
48	1.33
51	0.40
58	26.13

The outline of each area sample is shown in figure 3. The samples represent the average of a mixture of many chips obtained by a systematic method of channel sampling. Samples 42, 43, 48, and 58 are all from the sandy shale bed used in the "fertilizer" mixture. The sulfur content, as can be readily noted, is greatest near the gas seep and diminishes to the southwest and the northeast, although in the latter direction quarry waste limited the extent of sampling.

It is estimated from these samples that the average sulfur content of the sandy shale bed is about 8 percent in the quarry area. The only other bed of any appreciable thickness in this area that contains much native sulfur is the cross-bedded sandstone immediately overlying the sandy shale. Sample 44 from this bed shows an average sulfur content of 2.39 percent, which is believed to be fairly representative of this bed, although the rock near the gas seep was observed to contain more sulfur than the rock to the northeast or southwest. The average sulfur content of the deposit in the quarry area, as outlined in figure 2, is estimated to be about 5 percent. This area of relatively high sulfur content coincides rather closely with the sampled areas.

Southern sulfur deposit.—Native sulfur occurs locally in fairly high concentrations in a zone, which is about 400 feet long and averages 30 feet wide, in the conglomeratic sandstone of the lower unit of the Dakota sandstone about 600 feet southwest of the quarry. The deposit is outlined in figure 2, but the outlines of the sampled areas are not shown. The highest sulfur concentration is found along the lower slopes of the northeast wall of Sulfur Gulch. Although some of the sulfur is in single crystals or crystalline aggregates on fracture and joint surfaces, most of it occurs as an irregular filling in the interstices of the coarser-grained parts of the conglomeratic sandstone. Some sulfur grains are as much as 0.1 inch in maximum dimension.

The native sulfur content of the rocks in the southern deposit also varies widely, as shown in the table below. It is most abundant in the southeastern half of the deposit near the hydrogen sulfide gas seep, where the sulfur-bearing rocks are locally as much as 15 feet thick and contain 20 to 27 percent sulfur. Sample 55, collected a few feet from the gas seep, contained 27.53 percent sulfur, the highest in the entire area. The 3.68 percent of sulfur shown by sample 62 is probably much greater than the minimum content of sulfur of the deposit as a whole because some patches appear

Native sulfur content of samples of conglomeratic sandstone from the southern sulfur deposit
Charles O. Parker, anlayst

Sample	*Sulfur (percent)*
53	21.51
54	27.06
55	27.53
62	3.68
63	12.25

53. Composite sample of area 50 feet long and 40 feet wide centered around gas seep.
54. Composite sample of area 35 feet long and 20 feet wide centered about 190 feet N. 68° W. from gas seep.
55. Single sample collected 5 feet east of gas seep.
62. Composite sample of area 120 feet long and 30 feet wide centered about 100 feet N. 75° W. from gas seep.
63. Composite sample of area 40 feet long and 25 feet wide centered about 50 feet S. 55° E. from gas seep.

to be almost barren of sulfur. A small area in the northwest part of the deposit represented by sample 54 also contains a rich sulfur concentration in an otherwise low-grade part of the deposit. The average native sulfur content of the entire southern sulfur deposit, as outlined in figure 2, was computed to be about 9.5 percent.

Origin of sulfur deposits.—Many theories have been advanced to explain the origin of native sulfur. The more important ones, as given by Clarke,[13] include (1) deposition as a volcanic sublimate by reactions between sulfur dioxide and hydrogen sulfide; (2) formation of sulfur a short distance below the surface by the incomple combustion of hydrogen sulfide; (3) imperfect oxidation of hydrogen sulfide in mineral springs, the hydrogen sulfide having been generated either through the reduction of sulfates by microorganisms or by the action of acid waters upon sulfides; (4) deposition of sulfur in fresh-water basins from waters containing hydrogen sulfide and calcium carbonate; (5) reaction between sedimentary limestones and ascending sulfurated waters, producing native sulfur, gypsum, and possibly calcite; and (6) the incomplete oxidation of hydrogen

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[13] Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 770, pp. 586-588, 1924.

sulfide in the presence of limestone, producing native sulfur, gypsum, and possibly calcite.

In the Gunnison Forks area the concentration of sulfur around gas seeps strongly indicates that the sulfur was derived from the hydrogen sulfide of the seeps. It is believed that the deposits were formed a short distance below the surface by the incomplete oxidation of hydrogen sulfide, probably in accordance with the equation[14] $2H_2S + O_2 = 2H_2O + 2S$. In such a reaction hydrogen sulfide is completely oxidized at the surface and sulfuric acid is formed, but a short distance below the surface oxygen is deficient and sulfur is liberated. Clarke[15] believes, however, that the actual conditions are probably more complex than these simplified reactions, and that some sulfur dioxide must be produced.

Evidence of the origin of the hydrogen sulfide in the gas seeps of the Gunnison Forks area is scanty and inconclusive. Any future attempts to explain the origin of the gases should include, in addition to analyses of the gases, a careful examination of much of the surrounding region for at least 15 miles along the Gunnison River from Delta to Hotchkiss, because gas seeps, small sulfur deposits, and mineral springs were reported to the writer by local residents as occurring in this region, and some are mentioned or described by Headden[16] and Weeks.[17] The origin and source of the hydrogen sulfide in the Gunnison Forks seeps may be the same as that for Doughty Springs. Headden[18] believed that these mineral springs represent waters coming from considerable depths, but he does not postulate the origin of the gases or mineral-bearing solutions.

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[14] Clark, F. W., op. cit., p. 586.

[15] Clarke, F. W., op. cit., p. 587.

[16] Headden, W. P., op. cit., pp. 1-30.

[17] Weeks, H. J., op. cit., p. 40.

[18] Headden, W. P., op. cit., p. 4.

Potash and Magnesia Alums

Potash alum.—Colorless, fibrous potash alum [$KAl(SO_4)_2.12H_2O$] is present at a few places in the quarry. It forms lenticular seams less than 0.3 inch thick, and seldom more than a few inches long, most commonly at the contact between sandstone and shale beds. The alum was probably formed by the action of waters that contained sulfuric acid upon rocks containing aluminum and potassium silicates. The acid waters probably migrated through the porous sandstone beds and formed alum at the contact with shales that contained the aluminum and potassium silicates necessary for the formation of potash alum.

Pickeringite.—The magnesia alum, pickeringite [$MgSO_4.Al_2(SO)_4)_3.22H_2O$], is widely distributed in the middle unit of the Dakota sandstone where it forms small white powdery patches or white, fibrous incrustations as much as 3 inches thick. The incrustations are particularly conspicuous on the cliffs on the south side of Sulfur Gulch about 100 feet southeast of the southern sulfur deposit. The pickeringits probably was formed by the same process as the potash alum, but waters that contained sulfuric acid reacted with magnesium-bearing rather than potassium-bearing aluminum silicates in the sedimentary rocks.

Near Doughty Springs, Headden[19] found alum intermediate in composition between the soda alum, mendozite, and the magnesia alum, pickeringite. Headden is uncertain as to whether the alum was deposited from mineral springs of deep-seated origin or from surface waters charged with chemicals derived from the sediments, although his statements seem to slightly favor deposition from mineral springs. No clarifying evidence regarding the origin of the alums was found in the Gunnison Forks area by the writer.

Metallic Minerals

According to local reports, the Gunnison Forks deposit is supposed to contain metallic minerals as well as sulfur,

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[19] Headden, W. P., op. cit., pp. 18-21.

but a careful search revealed only pyrite, marcasite, and a little iron oxide. Some of the sandstone is irregularly stained by hydrated iron oxide, and a very few specimens examined contained scattered small black particles that probably are grains of hematite or magnetite that were deposited contemporaneously with the sand grains.

Pyrite is most common in the middle unit of the Dakota sandstone, and occurs in the sandy shale, carbonaceous shale, and shaly coal beds. Most of it forms concretions ranging from a fraction of an inch to as much as 2 inches in diameter. This occurrence, and the association with carbonaceous beds, suggest that the pyrite was formed by groundwater.

Marcasite was found only in a narrow fissure, 1 to 2 inches wide, in the quarry near the gas seep. The fissure filling consists of radiating fibrous layers and botryoidal nodules of marcasite around which gypsum plates as much as 1 inch long have been deposited. Yellow crystals of native sulfur, less than 0.05 inch long, line most of the numerous cavities, and also partly coat much of the marcasite-gypsum mixture. The association and mode of occurrence of marcasite and gypsum suggest that both probably were formed by deposition from circulating meteoric waters. The sulfur may also have been a product of the reaction, but its mode of occurrence suggests later deposition from hydrogen sulfide gas.

Gold assays showing values of as much as $6.00 a ton were reported by Mr. McDonald[20] from a bed, 2 to 4 feet thick, of conglomeratic sandstone encountered in the short adit (shown in fig. 2) about 150 feet south of the quarry. Assays of a composite sample of the sandstone collected by the writer showed only a trace of gold, and this was probably deposited as placer gold during the deposition of the sandstone.

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[20] McDonald, A. C., Oral communication, December 1946.

Several samples from beds in the vicinity of the quarry were analyzed by spectrograph for gold, silver, copper, lead, zinc, ferric oxide, and manganous oxide. The results are given in the table below, which shows that gold, silver, and zinc are absent, and that minute quantities of lead are present only in three samples and copper in one.

Spectroscopic analyses of rocks near the quarry
K. J. Murata, analyst, U. S. Geol. Survey
Figures in percent

Sample	Au	Ag	Cu	Pb	Zn	Fe_2O_3	MnO
42	—	—	—	0.001	—	4.0	0.003
43	—	—	—	—	—	0.9	0.002
45	—	—	0.001	—	—	1.5	0.002
46	—	—	—	—	—	2.4	0.003
48	—	—	—	0.001	—	2.5	0.005
51	—	—	—	0.001	—	0.9	0.002
52	—	—	—	—	—	3.0	0.002

42, 43, 48, 51. Sandy shale (lower "fertilizer" bed). Composite samples collected from areas shown in figure 3.

45. Carbonaceous shale (middle "fertilizer" bed). Single sample collected 30 feet north of gas seep.

46. Gray sandstone (upper "fertilizer" bed.) Single sample collected 40 feet northwest of gas seep.

52. Interbedded sandstone and shale. Single sample collected at South quarry.

The small quantity of precious and base metals in the area strongly suggests that the metals were probably deposited as syngenetic constituents of the sediments, or else by deposition in minor quantities from meteoric waters, and that deposition by hydrothermal solutions from deep-seated sources is unlikely.

FUTURE POSSIBILITIES

The future of the Gunnison Forks sulfur deposit depends largely on the demand for it as a source of sulfur-bearing rock for use as a soil conditioner. The scope of this examination, which was strictly of a geologic nature, did not include agricultural experimentation and the many chemical analyses necessary to pass fair judgment on the quality or quantity of the rocks as a "fertilizer." Production of the type of material now quarried probably can continue at the present rate for a number of years, if the product can compete with other soil conditioners, and if the beds now quarried remain constant in chemical composition for reasonable distances.

The sulfur deposits are too small and too low grade to be worked economically for sulfur under present conditions.

Field observations and supporting chemical analyses indicate that metallic elements occur in the mapped area in quantities too small for profitable exploitation.