OKLAHOMA GEOLOGICAL SURVEY

CARL C. BRANSON, *Director*

MINERAL REPORT 35

Gypsum in the Weatherford-Clinton district, Oklahoma

by

WILLIAM E. HAM and NEVILLE M. CURTIS, JR.

NORMAN

June, 1958

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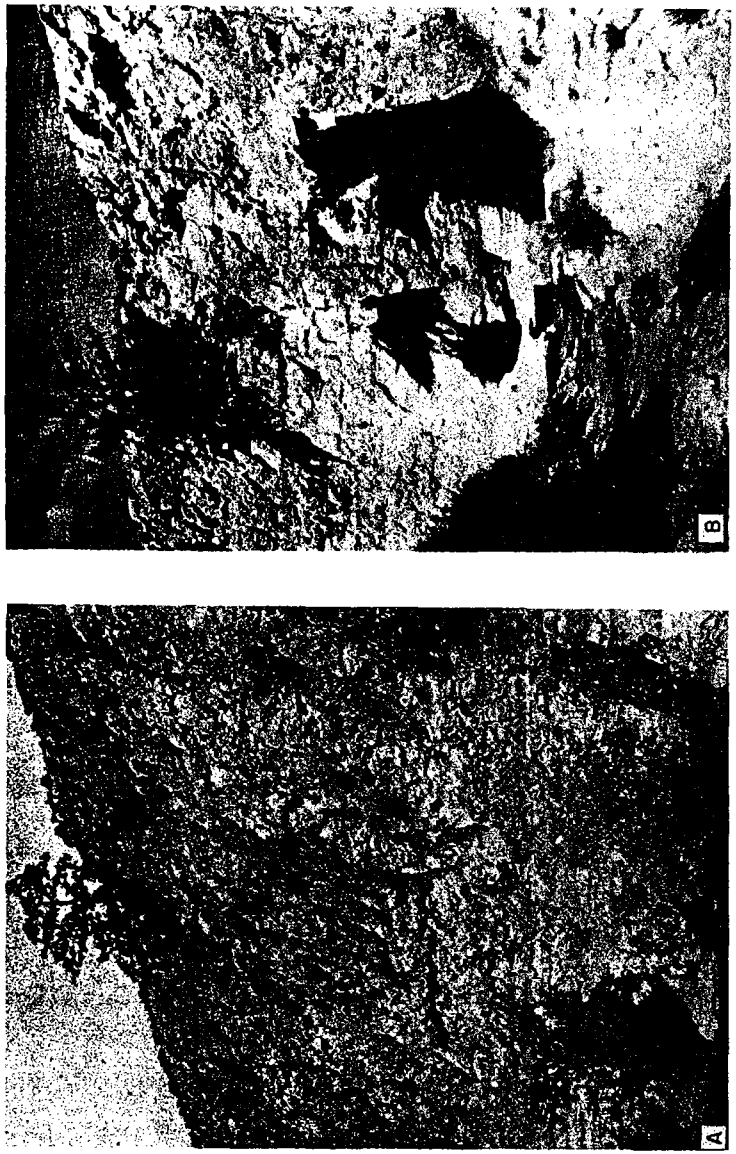


Outcrop views of Cloud Chief gypsum on Harms farm, SE¼ NW¼ sec. 5, T. 11 N., R. 15 W.

A. Bluff exposure 55 feet high on east bank of unnamed stream, showing massive character and faintly defined bedding of massive gypsum.

B. Entrance to Water Cave, a subterranean channel of stream shown in foreground, cut in lower part of the gypsum. Note well-defined high-angle joints.

Gypsum in the Weatherford-Clinton district, Oklahoma

by

William E. Ham and Neville M. Curtis, Jr.

Abstract

The area here described covers approximately 59 square miles in the southeastern part of Custer County, between the towns of Weatherford and Clinton, in central western Oklahoma. The gypsum deposits are in a single thick bed of evaporites in the lower part of the Cloud Chief formation of middle(?) Permian age. The evaporite bed has a maximum thickness of 118 feet and is nearly flat lying. On the outcrop it is overlain and underlain by reddish-brown shales and fine-grained sandstones, into which it grades down dip to the west and northward along the strike.

Most of the bed is uniform grayish-pink medium-granular gypsum and compact fine-grained alabaster. Locally in subsurface the lower part of the bed is composed of anhydrite as much as 40 feet thick, distinctly separated from the overlying gypsum by a sharp contact.

Through geological mapping and exploratory drilling, the gypsum in the Cloud Chief formation is shown to have a maximum thickness of 92 feet and an average drilled thickness of 40 feet, and to extend in workable thickness over an area of 24 square miles. Over the workable deposits overburden ranges in thickness up to 25 feet and averages 7 feet.

From a series of 9 profiles constructed through the drilled holes it is calculated that the workable gypsum over the 24-square mile area is 36.17 feet thick and that the gypsum reserves are 1.3 billion tons. Forty-eight chemical analyses representing 718 feet of gypsum cores and cuttings from 17 holes show that the average composition is 91.28 percent gypsum, 1.38 percent anhydrite, 5.34 percent calcium and magnesium carbonates, and 1.55 percent silica.

Through about 10 square miles in the central part of the area anhydrite lies under the gypsum at an average depth of 44.4 feet and has an average thickness of 21.8 feet. The estimated reserve is 523 million tons, and the average composition is 87.25 percent anhydrite, 4.30 percent gypsum, 7.17 percent calcium and magnesium carbonates, and 1.05 percent silica.

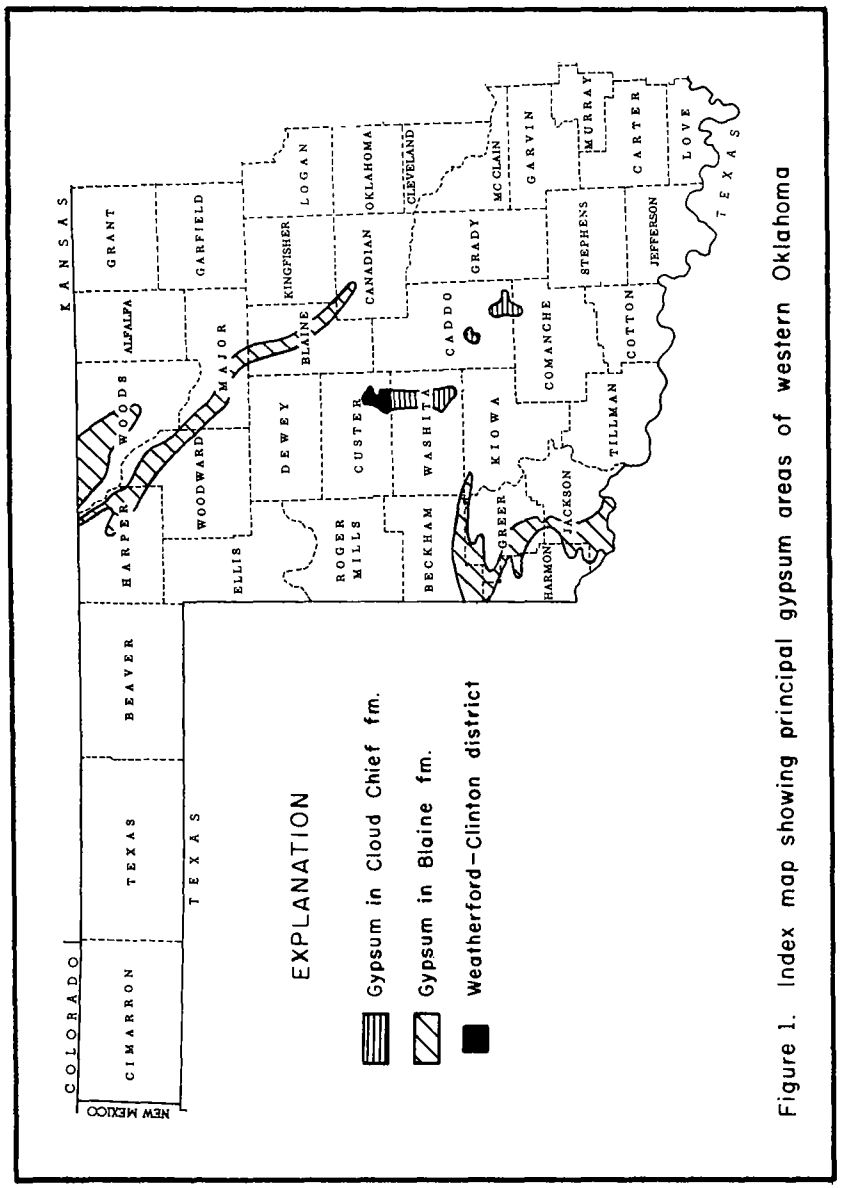


Figure 1. Index map showing principal gypsum areas of western Oklahoma

INTRODUCTION

Western Oklahoma is well known for its extensive outcrops and vast reserves of gypsum in the Blaine and Cloud Chief formations. The gypsum beds are Leonardian and Guadalupean (Middle and possibly Upper Permian) in age and they crop out over three principal regions in parts of 15 counties (Figure 1).

Locally in southwestern Oklahoma the Blaine formation contains as much as 150 feet of gypsum, divided into four main beds separated by shale, but the thickest single bed now known in Oklahoma is in the Cloud Chief formation near Weatherford and Clinton. Information from water well drilling and from earlier geological reports had indicated 100 feet of gypsum to be present in this area. Drilling conducted for the present investigation confirms the general order of thickness, as 92 feet of gypsum was found at one locality, and an even greater total thickness of gypsum and anhydrite is indicated elsewhere in the Weatherford-Clinton district.

This thick deposit of nearly flat-lying gypsum, available to transportation routes and to large supplies of natural gas, is shown to be a major source of gypsum for ordinary commercial uses. It is one of the largest readily accessible deposits in Oklahoma and one of the major deposits in the United States.

Approximately 59 square miles in the southeastern part of Custer County has been investigated (Plate I). The area lies between the towns of Weatherford and Clinton in central western Oklahoma, about 75 airline miles west of Oklahoma City. Major transportation facilities available for exploitation of the deposits are the Chicago, Rock Island, and Pacific Railroad; the Atchison, Topeka, and Santa Fe Railroad; the St. Louis and San Francisco Railroad; and U. S. Highways 66 and 183. Two of these transportation routes, the Rock Island R.R. and U.S. Highway 66, pass directly through the gypsum district.

The collaboration and support of many individuals and organizations have made possible this investigation. The Chambers of Commerce at Weatherford and Clinton showed special enthusiasm and support for the project by paying all costs of drilling and coring, as a result of which a great amount of detailed information was made available. Thanks are due Mr. O. C. Roof of the Roof Drilling Company at Weatherford, who as contract driller obtained nearly perfect recovery of gypsum and anhydrite cores, at times under adverse field conditions. Chemical analyses of 59 samples representing 957 feet of cores and cuttings were made in the geochemical laboratory of the Oklahoma Geological Survey by Mr. John A. Schleicher assisted by Ralph Slate and John Bland. The plates and text figures for the final report were made by Mr. Roy D. Davis and Mrs. Marion Clark of the Geological Survey.

Gypsum and Anhydrite in the Cloud Chief Formation

GENERAL GEOLOGY

The Cloud Chief formation is a widely distributed stratigraphic unit in the central part of western Oklahoma. It was originally named the Cloud Chief gypsum by Gould,[1] and stated by him to be as much as 115 feet thick. Later work by Green[2] and by others has shown that gypsum occurs as thick and thin lenses within a sequence of sandstone and shale 250 to 300 feet thick, and this gypsiferous unit is now known as the Cloud Chief formation. In the lower part of the formation, at or slightly above the base, the thickest gypsum is locally developed on a broad scale. It has a thickness of approximately 100 feet in southeastern Washita County near Cloud Chief, the type locality, and nearly the same thickness in southeastern Custer County. Westward from Cloud Chief and northwestward from Weatherford it grades largely into clastic sediments, but the thick gypsum lens is reasonably constant in the 25-mile distance between them, and it extends in the form of scattered outliers southeastward for 40 miles, into southern Caddo County and northeastern Comanche County. Some of these outliers cover as much as 20 square miles.

It is with the northern part of the thick gypsum lens in the lower part of the Cloud Chief formation that the present report is concerned. This northern segment is in the Weatherford-Clinton district, through which passes the only railroad to cross the gypsum outcrop in eastern Washita and southeastern Custer Counties. Availability to railroad transportation is a major consideration in working bulky industrial minerals such as gypsum. The Rock Island R.R. extends through the central part of the mapped area and connects with two other railroads at Clinton, making the gypsum accessible for large-scale mining.

THICKNESS AND STRATIGRAPHIC RELATIONS

Within the limits of the mapped area the outcrop distribution, character, and stratigraphic relations of the gypsum were obtained by geologic mapping, supplemented by information from the drilling program. Gypsum and anhydrite together make up the evaporite sequence. Gypsum alone crops out on the surface, but in subsurface the basal part of the evaporite body is massive coarse-grained anhydrite as much as 40 feet thick. The two rocks ordinarily are separated at a sharply defined contact, although

[1]Gould, C. N., 1924. A new classification of the Permian red beds of southwestern Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 8, p. 322-341.

[2]Green, D. A., 1936. Permian and Pennsylvanian sediments exposed in central and west-central Oklahoma: Amer Assoc. Petroleum Geologists, Bull., vol. 21, p. 1454-1475.

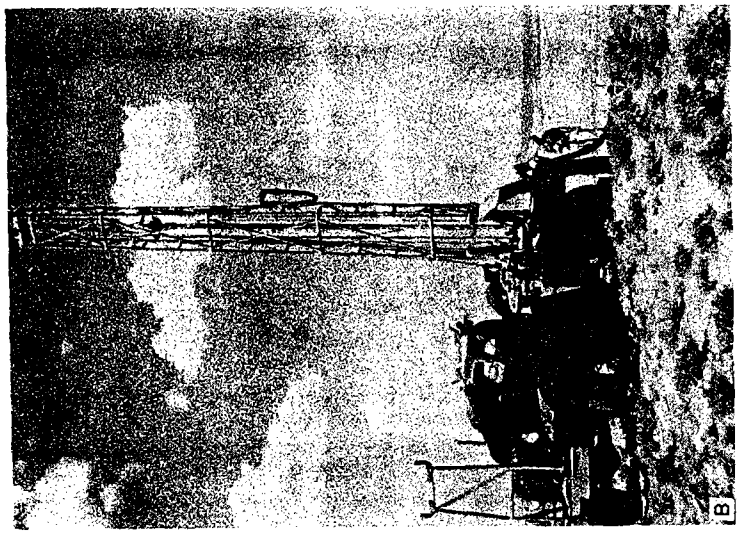
it is clear when considered regionally that the boundary between them is gradational, that anhydrite is the original evaporite sediment, and that gypsum has been derived from it by hydration under favorable topographic conditions which have permitted penetration of surface water. As shown by drilling, anhydrite is restricted mainly to the east-central and northernmost parts of the area, principally where thick shale overburden has retarded the hydration process.

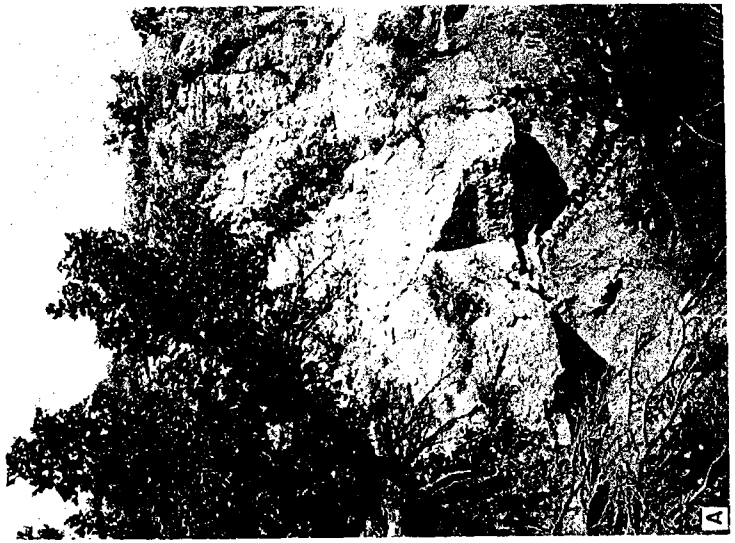
Total thickness of the evaporite unit is greatest in the eastern part of the area, diminishing both westward down the dip and northwestward along the strike. Ninety-two feet of gypsum is present in the N½ NE¼ sec. 1, T. 12 N., R. 15 W. and the S½ SW¼ sec. 31, T. 13 N., R. 14 W., where 5 feet of gypsum is exposed above test hole number 22 and the base of the evaporites was cut at 87 feet. As the top is eroded, the full thickness is even greater. At this locality all the rock is gypsum. A thickness of 118 feet is measured from drilling and elevation control at test hole number 10, SW¼ sec. 15 and NW¼ sec. 22, T. 12 N., R. 15 W. Here the basal 41 feet of the unit is anhydrite which contains in its lower part two beds of shale. From similar control a thickness of 98 feet is measured in the SW¼ SE¼ sec. 34, T. 12N., R. 15 W., where the lower 30 feet is anhydrite, together with some shale, and the upper 68 feet is massive gypsum. The maximum thickness thus ranges approximately between 100 and 120 feet.

Along the western edge of gypsum outcrop the evaporite thickness, measured at four localities where control is available, is approximately 60 feet. At test hole number 3, SW¼ SE¼ SW¼ sec. 31, T. 12 N., R. 15 W., the thickness is 61 feet, of which the basal 14 feet is anhydrite. At Gypsum School, test hole 12, S¼ cor. sec. 8, T. 12 N., R. 15 W., the unit is 59 feet thick and is composed of massive gypsum except for a 1-foot bed of anhydrite in the lower part. In the SE cor. sec. 33, T. 13 N., R. 15 W., test hole 29, the sequence is massive gypsum 62 feet thick. In the SW¼ sec. 17 and the NW¼ sec. 20, T. 12 N., R. 15 W., outcrop observations in deep gullies supplemented by data from drill hole 11 indicate a gypsum thickness of 58 feet and plainly show westward downdip gradation of gypsum into orange-red silty shale. Although the base of the unit is stratigraphically constant, a shale bed in the lower part of the gypsum increases in thickness from 13 feet to 26 feet along a 2,500-foot horizontal distance in the S½ SW¼ sec. 17. Projection of this westward gradation of gypsum into clastic sediments throughout the area would indicate that the gypsum disappears a short distance down dip from the upper gypsum boundary as mapped on the surface.

Virtually the entire evaporite body likewise grades into shale and sandstone along strike just beyond the northwestern corner of the mapped area. In secs. 16 and 21, T. 13 N., R. 15 W., the gypsum splits into westward-tapering tongues separated by fine-grained clastic sediments; and northwestward along the strike to Custer City only thin lenses of gypsum are present in the Cloud Chief formation.

In the Weatherford-Clinton district the base of the massive gypsum-anhydrite sequence normally is about 20 feet above the base of the Cloud Chief formation. Reddish-brown or orange-red shale extends below the sequence to the base of the formation, which is marked on the outcrop by





A. Contact of Cloud Chief gypsum with underlying shale, NE¼ NW¼ sec. 5, T. 11 N., R. 15 W.
B. Drill rig cutting cores at hole 8, NE¼ NW¼ NE¼ sec. 33, T. 12 N., R. 15 W. Note hare-rock knoll of gypsum in foreground and undulating topography of eroded gypsum surface in background.

the 1-foot bed of Weatherford dolomite in the area south of Weatherford, and by a gypsum bed 4 feet thick in the area north of Weatherford. In none of the holes drilled for this investigation was a bed of dolomite encountered, although the thin gypsum bed probably marking the base of the Cloud Chief was cut at a depth of 105 feet in hole number 9, at 74 feet in hole number 7, and at 79 feet in hole number 17. The thickness of shale separating this bed from the base of the main evaporite sequence in subsurface ranges from 5 to 25 feet. The base of the gypsum-anhydrite unit shown on the geologic sections (Plate II) is believed to be stratigraphically constant, whereas the thin bed supposedly marking the base of the Cloud Chief formation in subsurface probably is inconstant in terms of thickness, stratigraphic interval, and continuity.

OCCURRENCE OF PROBERTITE

The borate mineral probertite, not hitherto found in Oklahoma, was discovered in cores from some of the holes drilled for gypsum.[1] It is hydrous sodium-calcium borate, $NaCaB_5O_9.5H_2O$, and occurs as white compact nodules sparingly distributed in the massive gypsum, mostly along crudely defined bedding planes. The nodules are generally spheroidal and ¼ to ½ inch in diameter.

Both the nodular form of probertite and its localization along bedding planes show that the mineral has grown as secondary concretions, deriving boron, sodium, and calcium from the surrounding gypsum. Moreover, the restriction of probertite to the lower part of the gypsum (see Plate II) indicates that it has originated through the concentrating action of downward-moving ground waters.

Examination of all the cores drilled in the Cloud Chief gypsum shows that probertite occurs in seven holes at depths ranging from 34.0 to 70.65 feet. Core holes 3, 8, 9, 10, 19, 28, and 29 contain probertite. They are chiefly in a belt that trends northward through the central part of T. 12 N., R. 15 W. In two holes only one or two nodules were noted, but in the remaining five holes probertite occurs through as much as 14 feet of gypsum. It invariably occurs in the lower part of the gypsum, and generally it is restricted to the basal 10 feet.

EXPLORATORY DRILLING

Following the completion of geologic mapping, a selected number of test sites were chosen for exploratory drilling. To obtain a fair measure of random sampling, most of the locations were made one to two miles apart along section line roads, the resulting pattern being a partial rectangular grid. A preliminary program of rotary drilling and examination of drill cuttings from 27 sites was followed by coring at 16 sites.

For all drilling a Mayhew "1000" rotary drill rig was used. With a Hawthorne bit a 5⅝-inch hole was cut to 20 feet and a 4¾-inch hole to greater depths. The Hawthorne bit was satisfactory for drilling gypsum,

[1]Ham, W. E., Curtis, N. M., Jr., and Schleicher, J. A., 1958. A new occurrence of probertite in Oklahoma: Okla. Geology Notes, vol 18, no. 2, p. 24-27.

but the tough compact anhydrite was cut with a rock bit. The change from gypsum to anhydrite was immediately noted by the driller, as drilling time dropped sharply on penetrating the massive crystalline-textured anhydrite. The sharpness of this contact, repeatedly observed in the early phases of drilling, was later confirmed by examination of cores.

A 15-foot core barrel with black diamond bit was used to cut 2¼-inch cores at each location judged to be of importance for regional control and evaluation. The core hole in most instances was a twin spaced 3 to 10 feet away from the earlier-drilled sounding hole. The locations of all sounding holes and core holes are shown on Plate I.

In the preliminary drilling, 1,626 feet of rock strata and overburden was cut, and an additional 394 feet was drilled and lost through inabiilty to circulate cuttings back to the surface. Caves and other solution cavities in the soluble gypsum resulted in water loss at 15 to 25 feet and abandonment of the first or second test at about half the locations drilled. Of the total preliminary footage, 817 feet was drilled in gypsum and the remainder in shale, sandstone, anhydrite, and overburden of several types.

Nearly complete recovery of 2¼-inch cores was obtained from the 16 core holes. Beginning at 14 to 16 feet below the surface in each hole, to allow clearance for the core barrel, a total of 671 feet was cut with the following footage distribution: gypsum, 520 feet; anhydrite, 117 feet; and sandstone and shale, 34 feet. These cores are filed in the office of the Oklahoma Geological Survey where they may be examined by interested parties.

Economic Geology

GYPSUM

Outcrop character and distribution. Most of the gypsum in the Cloud Chief formation in the Weatherford-Clinton district is grayish pink, medium granular, and massive. Probably the best exposures of the gypsum are in the walls along an unnamed south-flowing intermittent stream just south of the mapped area, in the E½ NW¼ sec. 5, T. 11 N., R. 15 W. This locality, on the Harms farm, is well known locally for the so-called bat caves (also known as the Corn caves) present in the massive Cloud Chief gypsum. Solution phenomena here are abundantly and clearly shown in the form of large irregular caves, sinuous underground channels, sinks, and one beautifully formed small natural bridge. A minimum charge is made by the Harms family for visiting the caves.

The magnificent exposures give a clear insight into the character and thickness of the gypsum within the immediate area. Completely exposed in the sheer bluff faces is the lower 55 feet of the gypsum body. It is decidedly pink, massive, cleanly cut by close-spaced vertical joints, and almost completely devoid of bedding. The rock is medium granular to fine granular. Neither shale beds nor anhydrite were observed. The base of the gypsum is well exposed locally, and beneath it at a sharp contact is orange-pink shale cut by numerous veins of satin spar gypsum. From these exposures alone it was evident that workable gypsum doubtless was present over a wide area in the Weatherford-Clinton district.

The massive character of the gypsum, and the lack of interbedded shale and anhydrite, likewise is shown at the Weatherford cave, SE¼ SE¼ sec. 25, T. 13 N., R. 15 W., 3 miles northwest of Weatherford, but here not more than 30 feet of gypsum is observable and the base is not exposed. The main entrance to the cave is in a collapsed sink. Several small chimneys or narrow open cavities extend from the underground room through the gypsum to the ground surface, and elsewhere on the surface nearby there are soil-filled depressions that plainly indicate the collapsed portions of this cave or others similar to it.

As the gypsum is thick and the dip of the rocks over most of the area is toward the west or southwest at the low rate of 50 to 75 feet per mile, the gypsum crops out over a wide area in the Weatherford-Clinton district (Plate I). In the southern half of the district the outcrop has a gross width of 5 to 6 miles, and gypsum is present in nearly all the southern two-thirds of T. 12 N., R. 15 W. The outcrop itself is divided into eastern and western areas by shale which lies over the gypsum and extends as a low ridge through parts of secs. 9, 15, 16, 22, 23, 26, and 35, T. 12 N., R. 15 W. Streams flowing westward from this topographic divide enter Bear Creek, and those flowing eastward from it enter Little Deep Creek.

In the northern part of this district, in general terms that portion north of U.S. Highway 66, the gypsum outcrop is a single curving band about 1 to 2 miles wide. The greatest width is mostly in secs. 1, 2, and 3, T. 12 N., R. 15 W. and in adjoining sections to the north. Here the gypsum forms a ridge as much as 70 feet high. Northward from this ridge the gypsum outcrop narrows to about one-half mile at the northwestern corner of the map area, and in a short distance beyond this boundary the gypsum grades into shale.

Except at the Harms property and at Weatherford cave, good exposures of the gypsum are uncommon. The gypsum surface mostly is eroded into low hills or small hummocks, and much of the surface is covered by soil thick enough to cultivate for the planting of wheat. Where the gypsum outcrop is extensive and soil is essentially lacking, the land is used for pasturing beef cattle. Part of the soil is derived from thin remnants of terrace deposits, as scattered pebbles of quartzite and petrified wood are found in soils throughout the district.

Owing to its high solubility in ground waters, the gypsum is easily dissolved along joints and other planes of separation, with the result that its weathered upper surface in most places is uneven and quite irregular. Judging from exposures in road cuts and from experience gained in drilling, it is believed that the irregular surface normally extends downward 3 to 10 feet. Locally the entire gypsum body, 30 to 45 feet thick, is removed either in the process of cave formation or by stream channeling, as shown in holes 1, 5, 20, and 21 drilled for this investigation.

Mineralogic and chemical composition. The normal evaporite rock of the district is grayish-pink medium-granular massive gypsum, made up of anhedral grains 0.25 to 0.50 mm in diameter. In texture the rock is even granular. Although well-defined bedding planes are lacking, the direction of bedding is locally shown by planar openings that are partly filled with small euhedral or subhedral crystals of selenite. The medium-granular gypsum grades imperceptibly into fine-granular gypsum, in which the grains

are 0.06 to 0.25 mm in diameter, and into coarse-granular gypsum, in which the anhedral grains are 0.5 to 1.0 mm in diameter. Very coarse selenitic grains 1 to 2 mm in diameter locally are present as clusters or thin layers both on the outcrop and in subsurface.

Associated with the medium-granular gypsum is pinkish-gray alabaster, a compact very fine-grained variety that is more translucent than the coarser-granular types. Although rare in outcropping strata, alabaster is widely distributed throughout the district, as it is conspicuously present in 10 of the 16 core holes drilled. That alabaster has preceded granular gypsum in crystallization is clearly shown on polished sections of the cores, the alabaster being transected by numerous veins of the granular gypsum. All stages of this change in texture may be observed, and in the final stage only small residual patches of alabaster remain. Within the transitional sequence the rock has a mottled appearance.

Gypsum is the predominant mineral in the rock. The carbonate minerals calcite, dolomite, and magnesite are sparingly present, generally as disseminated grains, as small irregular clusters, or a thin anastomosing veins. Quite commonly these carbonate minerals are associated with an exceedingly fine-grained slightly argillaceous gypsum. Clay and silt-sized quartz sand grains are randomly distributed, generally in minute quantities. The mineral anhydrite ordinarily is not detectable as grains in the massive gypsum rock, but where present it occurs as distinct beds sharply separated from the gypsum. Nevertheless, chemical analyses of even the purest gypsum cores fail to show enough combined water for theoretical gypsum, and the assumption is made that anhydrite actually is present as minute particles disseminated within the gypsum grains of the rock.

Chemical analyses were made by John A. Schleicher and assistants in the geochemical laboratory of the Oklahoma Geological Survey. The results are given with the well logs in Table 4 and are summarized in Table 1. Forty-eight analyses from 17 holes, representing 718 feet of gypsum from all depths and from all parts of the district, show the average weighted composition to be 91.28 percent gypsum, 1.38 percent anhydrite, 5.34 percent calcium and magnesium carbonates, and 1.55 percent silica. The range of gypsum content by individual holes is from 93.36 to 86.13 percent, and the purest sample analyzed contained 97.04 percent. Residual anhydrite in the holes analyzed has a maximum value of 2.52 percent, too low to have appreciable effect on commercial use.

The principal impurities are carbonates and silica. Carbonate minerals range from 7.56 percent in hole number 26 to 3.24 percent in hole number 27. Dolomite and calcite thus detract most from the value of the gypsum, although for many industrial uses they are considered merely as inert constituents. Silica also is an inert material, and its maximum value for an individual hole is 4.62 percent, far above the average of 1.55 percent.

In Figure 2 the data on chemical purity are summarized. All the holes analyzed for gypsum are shown, as well as the gross thickness of the analyzed samples in each hole. When plotted in this manner a distribution pattern is evident, showing that gypsum of purity greater than 92 percent is restricted to two areas of nearly equal size. The southern area is in the southeastern portion of the district and covers parts of secs. 24, 25, 26, 33, 34, 35, and 36, T. 12 N., R. 15 W. The northern area lies

POLISHED SURFACES OF GYPSUM AND ANHYDRITE CORES. SCALE IN INCHES.

A. Alabaster variety of gypsum, hole 29, depth 48.5 feet.
B. Medium-granular gypsum, hole 9, depth 27.5 feet.
C. Mottled alabaster and medium-granular gypsum, hole 22, depth 22 feet.
D. Massive anhydrite, hole 15, depth 49.5 feet.
E, F, G. Probertite (white nodules) in gypsum, respectively in hole 19, depth 38.1 feet; hole 9, depth 42.2 feet; and hole 3, depth 47.9 feet.
H. Selenite crystals along bedding opening of alabaster, hole 25, depth 56 feet.

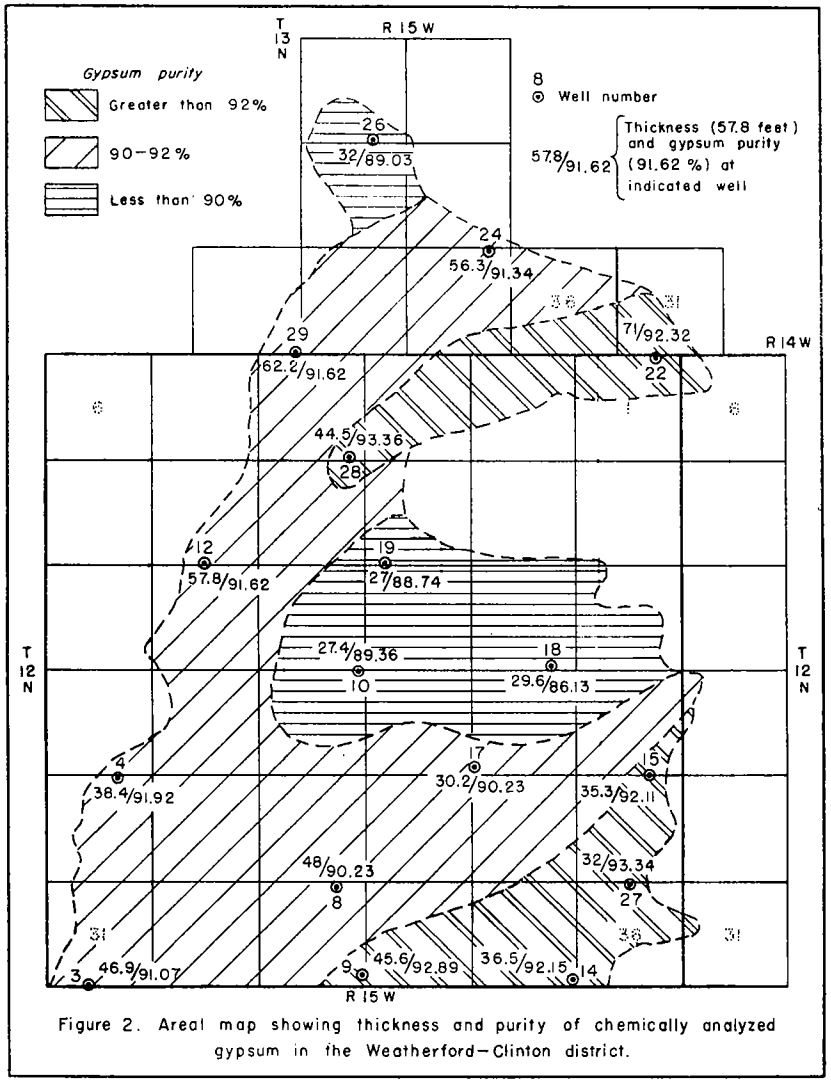


Figure 2. Areal map showing thickness and purity of chemically analyzed gypsum in the Weatherford–Clinton district.

Table I. Summary of thickness and character of chemically analyzed gypsum in the Weatherford-Clinton district.

Well No.	Overburden thickness, feet	Gypsum thickness, feet	Gypsum $CaSO_4.2H_2O$	Anhydrite $CaSO_4$	Carbonates $CaCO_3$ $Mg\ CO_3$	Silica SiO_2	Total
3	5	46.9	91.07	1.61	6.22	1.48	100.38
4	0	38.4	91.92	1.68	5.65	0.75	100.00
8	0	48.0	90.23	1.37	7.12	1.19	99.91
9	5	45.6	92.89	0.46	4.51	1.69	99.55
10	14	24.7	89.36	2.21	6.39	1.98	99.94
12	0	57.8	91.62	1.55	6.03	0.90	100.10
14	0	36.5	92.15	0.70	4.66	2.42	99.93
15	0	35.3	92.11	1.88	4.70	0.59	99.28
17	10	30.2	90.23	1.03	5.60	1.91	98.77
18	5	29.6	86.13	2.52	5.26	4.62	98.53
19	18	27.0	88.74	2.08	6.83	2.21	99.86
22	16	71.0	92.32	1.11	4.14	1.77	99.34
24	0	56.3	91.34	1.77	4.53	1.53	99.17
26	12	32.0	89.03	1.26	7.56	1.76	99.61
27	0	32.0	93.34	0.63	3.24	1.43	98.64
28	3	44.5	93.36	1.05	4.04	1.06	99.51
29	18	62.2	91.62	1.24	5.67	0.84	99.37
Total thickness analyzed		718.0					
Weighted average composition of all gypsum analyzed			91.28	1.38	5.34	1.55	99.55

Summary of all analyzed samples containing more than 94 percent gypsum

Well number	Depth, feet	Thickness, feet	Laboratory number	Percent gypsum
15	0-15	15	10238	97.04
28	18-35	17	10283	96.34
4	15-34.8	19.8	10231	94.65
29	55.1-64.7	9.6	10228	94.03
29	65.8-81.3	15.5	10229	94.60
27	15-32	17	10276	94.38
24	33.7-56.3	32.6	10250	94.19

north of Weatherford, chiefly in secs. 1, 2, 3, and 4, T. 12 N., R. 15 W., parts of secs. 35 and 36, T. 13 N., R. 15W., and in the southwestern part of sec. 31, T. 13 N., R. 14 W. In this northern area the gypsum is exceptionally thick, locally as much as 71 feet.

In a much larger area the gypsum has a purity of 90 to 92 percent. It is distributed mostly along the western edge of gypsum outcrop, but in the east-central part of T. 12 N., R. 15 W. it curves around and encloses an area containing gypsum of approximately 88 percent purity. A second locality of low-purity gypsum is centered around hole number 26, at the northern edge of the map area.

Reserves. The principal basis for estimating gypsum reserves of the Cloud Chief formation in the Weatherford-Clinton district consists of 9 east-west geologic profiles or sections drawn through the exploratory drill holes along section line roads one mile apart (Plate II). These profiles cover the area from the southern edge of the district to the northern limit of gypsum outcrop.

Elevations of drill holes and significant points of topography were obtained by use of carefully controlled altimeter surveys, based mainly on bench marks established by the U. S. Geological Survey. Geologic contacts, outcrops of gypsum, and observations on character and probable thickness of overburden were noted and recorded for construction of the profiles.

The essential information measured from these profiles is summarized in Table 2, which shows that the weighted average thickness of workable gypsum from all the geologic profiles is 36.17 feet, and that the weighted average thickness of overburden on the workable gypsum is 7.03 feet. These figures may be taken as the average for the entire mapped district, and have been used in arriving at the final estimate of reserves. No gypsum has been considered workable if it is overlain by more than 25 feet of overburden, but it is realized that overburden of this magnitude can be economically moved under special circumstances.

Table 2. Summary of gypsum and overburden thicknesses obtained from the geologic profiles (Plate II).

Geologic profile	Weighted average thickness, feet		Length of profile, feet
	Workable gypsum	Overburden	
A-A′	40.1	6.7	26,000
B-B′	32.9	4.7	21,000
C-C′	37.6	6.3	20,600
D-D′	35.5	7.0	25,900
E-E′	32.4	7.2	20,600
F-F′	29.5	6.8	4,400
G-G′	45.6	10.4	17,000
H-H′	32.0	7.2	14,000
I-I′	28.0	9.3	4,900
			154,400
Weighted average for the 9 profiles	36.17	7.03	

The conservative unit of 125 pounds per cubic foot has been used for the weight of gypsum in the ground, allowing for crevices, other small cavities, adsorbed water, and wastage in quarrying. This unit yields a figure of 2,500 short tons of gypsum per acre-foot or 1.5 million tons of gypsum per mile-foot.

The probable area of workable gypsum shown on Plate I is approximately 24 square miles. Using the weighted average thickness as 36 feet, the reserve of workable gypsum in the Weatherford-Clinton district is calculated to be 1,296,000,000 or approximately 1.3 billion short tons.

Inexpensive open-pit quarying methods can be used for working the gypsum. After removal of the thin soil overburden, the deposits would be workable either in benches or as a single high face. At many localities quarries could be opened on the sides of hills, so that natural drainage could be maintained as the face is driven forward. This type of quarrying is one of the cheapest forms of mining.

ANHYDRITE

Anhydrite underlies the gypsum of the Cloud Chief formation in a broad belt trending northward through the central part of the Weatherford-Clinton district. At no place within the district does it crop out, but 10 feet or more of anhydrite was drilled in 10 holes; and from the geologic profiles of Plate II it is estimated that anhydrite covers a subsurface area of approximately 10 square miles. It occurs beneath the gypsum at depths ranging from 33 to 68 feet and averaging 44.4 feet. In thickness it ranges from 11 to 39.5 feet and averages 21.8 feet (Table 3). Anhydrite thickness varies inversely with gypsum thickness, the evaporite body as a whole remaining constant.

The anhydrite, like the gypsum above it, is not of exceptionally high purity. Its weighted average composition is 87.25 percent theoretical anhydrite. Carbonate minerals, chiefly dolomite and magnesite, average 7.17 percent and thus contribute most of the mineral impurities. Silica averages 1.05 percent and gypsum averages 4.30 percent. Both gypsum and the carbonate minerals occur as disseminated grains and granular clusters, and as veinlets cutting the rock. Where anhydrite is present it normally is at the base of the Cloud Chief evaporite body, and to the writers it appears clear that all or nearly all of the gypsum in the district has been derived from anhydrite by hydration under favorable conditions of surface weathering.

Doubtless the anhydrite has been recrystallized, probably during diagenesis, for the characteristic texture is medium crystalline or coarse crystalline. The rock is grayish purple, translucent, compact, tough, and massive. It is both harder and tougher than gypsum, and it is instantly recognized in subsurface when encountered by the driller.

Based on an assumed weight of 175 pounds per cubic foot or 2.4 million tons per mile-foot, and an average thickness of 21.8 feet over 10 square miles, the reserves of anhydrite in the Weatherford-Clinton district are calculated to be 523 million short tons.

Table 3. Summary of potentially workable anhydrite in the Weatherford-Clinton district.

Well number	Depth to anhydrite, feet	Anhydrite thickness, feet*	Principal constituents, weighted average: Anhydrite $CaSO_4$	Gypsum $CaSO_4.2H_2O$	Carbonates $CaCO_3$ & $MgCO_3$	Silica SiO_2	Total
3	51.9	14.1	88.53	3.39	7.27	0.62	99.81
8	49	11	88.49	4.54	6.37	0.89	100.29
10	40.7	19.3	85.55	3.63	9.45	0.91	99.54
13	33	13	—	—	—	—	—
14	36.5	22.5	88.49	3.44	6.94	1.14	100.01
15	35.3	36.1	88.47	4.07	6.79	0.56	99.89
16	68	13+	—	—	—	—	—
17	40	34	86.11	5.93	6.22	1.36	99.62
18	34.6	19.4	81.01	10.89	5.50	1.51	98.91
19	43	39.5	89.80	1.05	8.01	1.14	100.00
24	56.3	17.5	86.54	4.11	7.91	1.25	99.81
Range	33-68	11-39.5	81.01-89.80	1.05-10.89	5.50-9.45	0.56-1.51	
Average or weighted average for the 11 holes	44.4	21.8	87.25	4.30	7.17	1.05	99.77

*Only holes penetrating 10 feet or more of anhydrite are included.

USES OF GYPSUM AND ANHYDRITE

Gypsum is one of the most widely used nonmetallic mineral commodities, and in 1957 slightly more than 13.3 million tons was produced domestically and imported for consumption or processing in the United States.[1] Of this total, 9.03 million tons was mined in the United States and 4.3 million tons was imported. Domestic production was 10 percent below that of 1956 and 11 percent below the record production of 10.7 million tons in 1955.

In Oklahoma gypsum is currently produced at three plants in central and northern Blaine County and at one plant in Caddo County. The deposits in Blaine County are in the Blaine formation, whereas the deposits worked near Cement in Caddo County are in gypsum of the Cloud Chief formation. According to the State Department of Chief Mine Inspector,[2] gypsum production in Oklahoma reached a record 468,269 tons in 1956. Average value of crude gypsum produced in Oklahoma in 1956 was $2.93 per ton,[3] compared with a national average of $3.30 per ton.

About 77 percent of the total gypsum produced domestically and imported in 1957 was calcined to make industrial and building plasters, lath and wallboard, and special cements. Approximately three-fourths of the remaining 23 percent was used as a retarder in the manufacture of portland cement, and the rest was used as a soil conditioner or for fillers. The principal uses of calcined gypsum are for the manufacture of wallboard, lath, and sheathing, and for plate-glass, pottery, dental, industrial, and base-coat plasters.

Chemical quality of commercial gypsum deposits ranges widely throughout the world, and no strict specifications are available. Gypsum with a purity of 99 percent or more is most desirable but is virtually unobtainable, as all deposits contain some mineral constituents other than gypsum. For a soil conditioner, earthy gypsite containing no more than 70 percent gypsum is acceptable locally; gypsum board products may be made from deposits containing only 80 percent gypsum; and portland cement retarder has been used from deposits of 90 percent purity. In general, however, deposits containing 90 percent or more gypsum are most sought after, and deposits are considered to be of high purity if they contain 95 or more percent gypsum.

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[1]Larson, L. P., and Jensen, N. C., 1958. Gypsum and gypsum products, 1957, annual summary: U. S. Bur. Mines, Quart. Gypsum Report no. 112, March 12, 1958, 4 p.

[2]Forty-ninth annual report of mines and mining in Oklahoma: Department of Chief Mine Inspector, Oklahoma City, Okla., 1958, p. 18.

[3]Grandone, P., and Ham, W. E., 1958. The mineral industries of Oklahoma in 1956 and 1957: Okla. Geological Survey, Mineral Report 34, p. 6.

For anhydrite no specifications are available and there is no large established market in the United States. In California it is used in small tonnage for soil conditioner and for retarder in manufacturing portland cement. Probably the greatest potential use of anhydrite is for chemical raw material. In England it is heated with coke, clay, and siliceous material to make sulfuric acid and portland cement clinker. This process is not used at present in the United States, apparently because most of the sulfuric acid made here utilizes native sulfur produced from salt domes in the Gulf Coast region of Texas and Louisiana.

Under favorable economic conditions an integrated sulfuric acid-portland cement industry might be established in the Weatherford-Clinton district. Shale for the silica-alumina additive for making portland cement overlies the gypsum and would be available at low cost.

Another chemical for which anhydrite is used as raw material is ammonium sulfate, a common fertilizer. In both England and Germany ammonium sulfate is made by reacting ammonia and carbon dioxide with an aqueous suspension of anhydrite. New methods of using anhydrite or gypsum for producing (1) quicklime and hydrogen sulfide by reduction with natural gas, and (2) for producing a fertilizer consisting of ammonium sulfate and calcium carbonate, have been described by Burwell.[1] His experiments were performed on gypsum from Oklahoma deposits.

The enormous volume of both gypsum and anhydrite in the Weatherford-Clinton district is available for manufacturing on the largest industrial scale. The calculated gypsum reserve of 1.3 billion tons is almost exactly equal to 100 years' supply for the entire United States at the 1957 consumption rate of 13.3 million tons. As this gypsum has an average purity of 91.35 percent, it could be converted into 715 million tons of 95 percent sulfuric acid. The 523 million tons of anhydrite is equivalent to 350 million tons of acid, and thus in terms of chemical use the gypsum and anhydrite together would make more than 1 billion tons of commercial sulfuric acid.

Gypsum is the primary commodity of value in the district at the present time. Although the typical color of the gypsum is slightly pink, it is doubtless suitable for the manufacture of wallboard, lath, and many industrial plasters.

[1]Burwell, A. L., 1955. An investigation of industrial possibilities of Oklahoma gypsum and anhydrite: Okla. Geol. Survey, Mineral Report 29, 21 p.

TABLE 4
WELL LOGS AND CHEMICAL ANALYSES
Profile A-A'. Well Numbers 3, 1, 9, and 14

Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 \cdot 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
Well Number 3. On road 0.35 mile east of SW cor. sec. 31, T. 12 N., R. 15 W. Elevation 1617 feet.																	
0–5	Cuttings	Soil containing quartzite pebbles.															
5–16	"	Gypsum, pale red, medium – granular.	10286	2.65	0.55	0.15	31.66	1.71	41.76	3.42	18.52	0.02	100.35	88.55	2.04	3.53	3.58
16–22.7	Core	Alabaster gypsum, pale red, containing patches of medium – crystalline selenite.	10287	1.61	0.51	0.10	31.82	1.71	42.60	3.34	18.91	0.02	100.62	90.37	1.24	3.34	3.58
22.7–43.9	"	Mottled alabaster and medium – granular gypsum, grayish-pink.	10288	1.19	0.15	0.08	32.09	1.46	43.30	2.76	19.23	0.02	100.38	91.90	1.63	2.66	3.05
43.9–51.9	"	Alabaster to 47.7, then grayish-pink fine – and medium – granular gypsum. Nodules of praberrite occur at 47.9–50.0 feet.	10289	0.53	0.28	0.03	32.56	1.27	43.64	2.76	19.45	0.02	100.54	92.95	1.29	3.12	2.66
51.9–66.0	"	Anhydrite, medium gray to dusky red, coarse – crystalline.	10290	0.62	0.14	0.09	39.97	1.43	54.06	3.44	0.71	0.02	100.48	3.39	88.53	4.28	2.99
66.0–67.5 T.D.	–	Red shale. Core not recovered.															
		Summary: gypsum thickness, 46.9 feet; weighted average gypsum content, 91.07%.															
Well Number 1. SE cor. sec. 32, T. 12 N., R. 15 W. Elevation 1635 feet.																	
0–38	Cuttings	Dark-colored soil and alluvium, evidently a filled sink.															
38–39	"	Gypsum and red sandstone.															
39–57 T.D.	"	Clay shale, reddish-brown.															
		Summary: gypsum mostly dissolved at a collapsed sink.															

TABLE 4 (continued)
Profile A-A'. (continued)

Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
	Well Number 9.	On road 500 feet north of SE cor. sec. 33, T. 12 N., R. 15 W. Elevation 1670 feet.															
0-5	Cuttings	Soil															
5-17	"	Gypsum, medium - and coarse - granular, mottled grayish pink and pale red.	10223	2.38	0.48	0.14	31.10	1.01	43.60	1.87	19.32	0.03	99.93	92.31	1.75	1.75	2.11
17-34	Core	Same, contains dolomite as fine-grained light brown irregular patches and anastomosing veinlets. Reddish-brown shale bed at 23.2-24.7.	10224	2.05	0.04	0.20	32.07	0.75	43.21	2.05	19.42	0.03	99.82	92.79	-	2.80	1.57
			(Shale excluded from analysis)														
34-50.6	"	Same. White nodules of probertite at 41.9-47.0 feet.	10225	0.83	0.43	0.17	32.32	0.80	43.43	2.39	19.55	0.06	99.98	93.41	-	3.45	1.67
50.6-56.5	"	Anhydrite, medium-gray to dusky red, coarse - crystalline. Contains veinlets of dolomite.															
56.5-58.0	"	Sandstone, reddish-brown, very fine-grained.															
58-63	Cuttings	Shale, alternating reddish-brown and grayish-green layers.															
63-68	"	Anhydrite as above.															
68-72	"	Shale, reddish-brown.															
72-75	"	Anhydrite as above.															
75-80	"	Sandstone, reddish-brown, fine-grained.															
80-105	"	Sandstone and silty shale.															
105-114	"	Anhydrite as above.															
114-120 T.D.	"	Shale, reddish-brown.															
		Summary: gypsum thickness, 45.6 feet; weighted average gypsum content, 92.89%.															
	Well Number 14.	On road 100 feet north of SE cor. sec. 35, T. 12 N., R. 15 W. Elevation 1723 feet.															
0-15.5	Cuttings	Gypsum, grayish-pink and pale red, medium-granular, calcitic.	10277	3.41	0.68	0.16	32.15	0.29	42.22	2.57	18.87	0.02	100.36	90.17	-	5.12	0.61
15.5-36.5	Core	Gypsum as above. Alabaster layers at 17.2-19.0 and 35.7-36.3.	10278	1.68	0.36	0.12	31.74	1.21	43.83	1.91	19.59	0.02	100.45	93.62	1.21	1.34	2.53
36.5-59	Cuttings	Anhydrite, light gray to dusky red, coarse - crystalline, translucent, dolomitic.	10279	1.14	0.23	0.10	39.75	1.46	54.02	3.30	0.72	0.01	100.73	3.44	88.49	3.89	3.05
59-65	"	Gypsum, white, soft and pasty. Red shale about 0.5 foot thick at top.															
65-74	"	Shale, alternating reddish-brown and grayish-green layers.															
74-77	"	Gypsum, white, pasty.															
77-80 T.D.	"	Sandstone, reddish-brown, fine-grained.															
		Summary: gypsum thickness, 36.5 feet; weighted average gypsum content, 92.15%.															

Profile B-B'. Well Numbers 2, 8, 13, and 27

Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
	Well Number 2.	On road 0.3 mile east of SW cor. sec. 29, T. 12 N., R. 15 W. Elevation 1679 feet.															
0-41	Cuttings	Gypsum, grayish-pink, medium-granular. Cave at 26-29.															
41-46	"	Anhydrite, light gray to dusky red, coarse-crystalline, containing veinlets and irregular patches of dolomite.															
46-48	"	Gypsum, fine - to medium - granular, pale green at base.															
48-60 T.D.	"	Shale, reddish-brown.															
		Summary: gypsum thickness, 41 feet.															
	Well Number 8.	On bare-rock gypsum knoll 0.3 mile west and 165 feet south of NE cor. sec. 33, T. 12 N., R. 15 W. Elevation 1700 feet.															
0-15	Cuttings	Gypsum, pale red, medium - and fine - granular, containing light brown veinlets and clusters of dolomite. Small selenite crystals scattered throughout.	10303	1.64	0.37	0.09	31.77	2.12	41.64	4.42	18.15	0.02	100.22	86.73	2.01	4.80	4.43
15-32	Core	Gypsum as above.	10304	1.02	0.29	0.07	32.01	1.68	43.05	3.39	19.03	0.02	100.56	90.94	0.97	3.55	3.51
32-48	"	Gypsum as above to 36.6. At 36.6-41.1 is grayish-orange-pink fine-granular alabaster-like gypsum. At 41.1-48.0 is pale red medium-granular gypsum cut by veinlets of very fine-grained dolomite. Probertite nodules at 46.25.	10305	0.96	0.28	0.06	32.14	1.26	43.95	2.51	19.41	0.01	100.57	92.76	1.19	2.57	2.64
48-60	Top 6' Core Lower 6' Cuttings	Anhydrite, medium-gray to grayish-red-purple, medium-crystalline, cut by veinlets of dolomite.	10306	0.89	0.10	0.06	39.59	1.63	54.13	3.08	0.95	0.02	100.45	4.54	88.49	2.96	3.41
60-61 T.D.	Cuttings	Shale, reddish-brown															
		Summary: gypsum thickness, 48 feet; weighted average gypsum content, 90.23%.															
	Well Number 13.	On section line road 0.5 mile east of NW cor. sec. 35, T. 12 N., R. 15 W. Elevation 1740 feet.															
0-12	Cuttings	Red shale and very fine-grained sandstone.															
12-33	"	Gypsum, grayish-pink, medium - to fine - granular.															
33-46	"	Anhydrite, gray to reddish-purple, fine - to medium - crystalline, dolomitic.															
46-48	"	Red and green shale.															
48-56	"	Gypsum, white, pasty.															
56-60	"	Red shale and very fine-grained sandstone.															
60-65	"	Gypsum, white, pasty.															
65-75 T.D.	"	Sandstone, reddish-brown, fine-grained.															
		Summary: gypsum thickness, 21 feet.															
	Well Number 27.	On road 0.5 mile west of NE co. sec. 36, T. 12 N., R. 15 W. Elevation 1760 feet.															
0-15	Cuttings	Gypsum, grayish-pink, medium-granular, grading into light gray alabaster.	10275	1.52	0.25	0.10	32.45	0.61	43.88	2.10	19.41	0.02	100.34	92.16	1.02	2.25	1.28
15-32	Core	Gypsum as above, mottled with grayish-pink alabaster. Contains veinlets of fine-grained dolomite.	10276	1.36	0.24	0.10	31.84	0.60	44.84	1.42	19.75	0.014	100.17	94.38	0.29	1.75	1.25
32-37.8 T.D.	"	Anhydrite, grayish-red-purple, medium-crystalline, dolomitic.															
		Summary: gypsum thickness, 32 feet; weighted average gypsum content, 93.34%.															

TABLE 4 (continued)

Profile C-C'. Well Numbers 4, 6, 5, 7, 17, 16, and 15

Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
	Well Number 4.	On road 0.35 mile west of NE cor. sec. 6, T. 12 N., R. 15 W. Elevation 1670 feet.															
0-15	Cuttings	Gypsum, grayish-pink, medium - granular.	10230	1.30	0.15	0.09	32.54	1.31	42.59	3.50	18.63	0.05	100.16	89.01	2.21	4.71	2.74
15-34.8	Core	Gypsum, grayish-pink, medium - granular, intergrown with compact alabaster.	10231	0.29	0.08	0.10	32.26	1.18	44.35	2.17	19.81	0.04	100.28	94.65	0.75	2.00	2.47
34.8-38.4	"	Gypsum, grayish-red, coarse - granular.	10232	0.98	0.50	0.11	31.81	1.50	44.13	2.35	18.64	0.06	100.08	89.08	4.59	1.61	3.14
38.4-42	"	Sandstone, pale reddish-brown, fine-grained.															
42-50 T.D.	Cuttings	Shale, alternating reddish-brown and grayish-green layers.															
		Summary: Gypsum thickness, 38.4 feet; weighted average gypsum content, 91.92%.															
	Well Number 6.	On road 0.3 mile west of NE cor. sec. 29, T. 12 N., R. 15 W. Elevation 1685 feet.															
0-10	Cuttings	Gypsum, pinkish-gray and light gray, medium - granular.															
10-18	-	Mud-filled cavity, not sampled.															
18-36	"	Gypsum as above.															
36-40	"	Red shale and sandstone.															
		Summary: gypsum thickness, 36 feet.															
	Well Number 5.	On road 50 feet east of NW cor. sec. 28, T. 12 N., R. 15 W. Elevation 1686 feet.															
0-30	Cuttings	Dark gray alluvial clay.															
30-32	"	Red shale.															
32-35	"	Gypsum, grayish-pink, medium - granular.															
35-50 T.D.	"	Red shale and sandstone.															
		Summary: gypsum mostly eroded in former channel of stream.															
	Well Number 7.	On road 100 feet east of SW cor. sec. 22, T. 12 N., R. 15 W. Elevation 1741 feet.															
0-15	Cuttings	Mud-filled crevice containing fragments of gypsum.															
15-46	"	Gypsum, pinkish-gray, medium - granular.															
46-52	"	Anhydrite, gray and pink, medium - crystalline, translucent.															
52-64	"	Red shale and sandstone.															
64-69	"	Gypsum, grayish-pink, compact and tough.															
69-74	"	Red shale and sandstone.															
74-77	"	Gypsum, grayish-pink, compact and tough.															
77-95 T. D.	"	Red shale and sandstone.															
		Summary: gypsum thickness, 31 feet.															
	Well Number 17.	On road 50 feet north of SW cor. sec. 23, T. 12 N., R. 15 W. Elevation 1760 feet.															
0-10	Cuttings	Red clay.															
10-15.5	"	Gypsum, pinkish-gray, fine - granular.	10220	2.82	0.37	0.19	31.84	1.18	41.96	3.28	18.31	0.04	99.99	87.48	1.92	4.57	2.45
15.5-32.7	Core	Gypsum, pinkish-gray, fine - granular, containing about 15% alabaster as irregular small patches. Fine network of grayish-pink dolomite cuts the rock.	10221	2.07	0.57	0.12	31.00	1.47	43.07	2.73	19.08	0.03	100.14	91.16	-	2.57	3.07
32.7-40.2	"	Gypsum, alabaster variety, grayish-pink, slightly mottled, with 10% fine - granular gypsum chiefly along numerous bedding seams. Dolomite in small veins and patches.	10222	0.88	0.34	0.12	32.16	1.67	43.54	3.13	18.86	0.04	100.74	90.13	2.74	1.98	2.49
40.2-74	Cuttings	Anhydrite, grayish-red, coarse - grained, grains mostly 0.5-1.0 mm. in diameter, containing irregular bedding seams of fine-grained moderate pink dolomite.	10310	1.36	0.29	0.09	38.81	1.77	53.73	3.04	1.24	0.01	100.34	5.93	86.11	2.52	3.70
74-79	"	Sandstone, fine-grained, brownish-red and grayish-green, interbedded with red shale.															
79-81 T.D.	"	Anhydrite as above.															
		Summary: gypsum thickness, 30.2 feet; weighted average gypsum content, 90.23%.															
	Well Number 16.	On road 0.5 mile west of SE cor. sec. 24, T. 12 N., R. 15 W. Elevation 1793 feet.															
0-25	Cuttings	Red clay, probably terrace deposit.															
25-40	"	Gypsum, grayish-pink, medium - and fine - granular.															
40-68	"	Gypsum, grayish-pink, fine-grained and compact like alabaster.															
68-81 T.D.	"	Anhydrite, gray and reddish-gray-purple, medium - crystalline, translucent. Lost circulation while adding a section of drill pipe and could not re-establish return flow of cuttings.															
		Summary: gypsum thickness, 43 feet.															
	Well Number 15.	On road 0.25 mile west of NE cor. sec. 25, T. 12 N., R. 15 W. Elevation 1781 feet.															
0-15	Cuttings	Gypsum, light gray and grayish-pink, fine - to medium - granular, mostly like alabaster.	10238	0.14	0.22	0.03	32.80	0.29	46.02	0.66	20.31	0.02	100.49	97.04	1.04	0.77	0.61
15-26.3	Core	Alabaster - like gypsum, grayish-orange-pink, containing patches of medium-granular grayish-pink gypsum, cut by veinlets of dolomite and calcite.	10239	0.98	0.39	0.07	33.21	0.49	42.84	3.21	18.86	0.02	100.07	90.11	1.07	6.10	1.02
26.3-35.3	"	Gypsum as above.	10240	0.85	0.34	0.07	31.01	2.92	43.15	4.05	18.07	0.02	100.48	86.35	4.32	1.96	5.21
35.3-56.8	"	Anhydrite, grayish-purple, medium - and coarse - granular, containing pale red stringers and irregular masses of extremely fine-grained dolomite and gypsum.	10241	0.52	0.16	0.04	39.55	1.85	54.90	3.16	0.63	0.07	100.88	3.01	90.11	2.59	3.87
56.8-67.2	"	Anhydrite as above, with less stringers.	10242	0.61	0.25	0.06	39.87	1.63	53.99	3.60	0.20	0.05	100.26	0.96	90.40	4.14	3.41
67.2-71.4	"	Anhydrite containing disseminated gypsum.	10243	0.62	0.24	0.06	38.94	1.20	52.99	3.15	3.59	0.04	100.78	17.16	75.28	4.18	2.51
71.4-74.1	"	Sandstone, moderate brown, fine-grained.															
74.1-75.5 T.D.	"	Silty shale, light brown.															
		Summary: gypsum thickness, 35.3 feet; weighted average gypsum content, 92.11%.															

TABLE 4 (continued)

Profile D-D'. Well Numbers 11, 10, and 18

Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
		Well Number 11. On knoll in field 0.2 mile east and 600 feet south of NW cor. sec. 20, T. 12 N., R. 15 W. Elevation 1715 feet.															
0-8	Cuttings	Soil															
8-40	"	Gypsum, grayish-pink, medium-granular.															
40-50 T. D.	-	No samples. Lost effective circulation. Drilling time indicates base of gypsum on red shale is at 50 feet. Summary: gypsum thickness, approximately 42 feet.															
		Well Number 10. On road 100 feet west of NE cor. sec. 21, T. 12 N., R. 15 W. Elevation 1736 feet.															
0-14	Cuttings	Soil.															
14-16	"	No sample (gypsum).															
16-40.7	Core	Gypsum, pale red and grayish-pink, medium - and fine - granular, containing stringers of very fine-grained dolomite. Probertite at 34 and 38.5 feet.	10280	1.98	0.40	0.12	31.70	1.62	43.25	3.09	18.70	0.02	100.88	89.36	2.21	3.00	3.39
40.7-60	Cuttings	Anhydrite, dusky red, medium-crystalline, translucent. Contains dolomite stringers.	10281	0.91	0.22	0.11	39.57	1.83	52.63	4.47	0.76	0.02	100.52	3.63	85.55	5.62	3.83
60-69	"	Shale, reddish-brown.															
69-76	"	Anhydrite as above.															
76-79	"	Shale, reddish-brown.															
79-82	"	Gypsum, light gray, very fine-grained.															
82-117	"	Red shale and fine-grained sandstone.															
117-126	"	Gypsum, light gray, very fine-grained.															
126-130 T.D.	"	Sandstone, reddish-brown, fine-grained. Summary: gypsum thickness, 24.7 feet; weighted average gypsum content, 89.36%.															
		Well Number 18. On road 0.25 mile west of SE cor. sec. 14, T. 12 N., R. 15 W. Elevation 1770 feet.															
0-5	Cuttings	Soil.	10244	12.10	2.09	0.40	27.88	1.86	36.13	3.62	16.08	0.01	100.17	76.84	1.99	3.62	3.89
5-14.5	"	Gypsum, pale red, medium-granular.	10245	1.35	0.35	0.09	32.16	1.70	44.01	2.54	18.76	0.01	100.15	89.65	3.08	1.55	2.56
14.5-26.6	Core	Gypsum, pale red, medium - and coarse - granular, containing about 15% alabaster.	10246	0.70	0.19	0.05	32.16	0.96	44.90	2.07	19.22	trc	100.25	91.85	2.28	2.32	2.01
26.6-34.6	"	Alabaster gypsum, grayish-pink, very fine-grained, containing about 15% pale red medium-granular gypsum.	10247	1.51	0.27	0.07	39.84	0.14	53.73	2.44	2.28	0.01	100.29	10.89	81.01	5.21	0.29
34.6-54	Cuttings	Anhydrite, moderate red, medium-granular, calcitic.															
54-56	"	Red shale and fine-grained sandstone.															
56-59	"	Anhydrite, pale pink, translucent.															
59-63	"	Gypsum, light gray, compact.															
63-65	"	Shale, reddish-brown.															
65-67	"	Gypsum, light gray, compact to powdery.															
67-75 T.D.	"	Red shale and fine-grained sandstone. Summary: gypsum thickness, 29.6 feet; weighted average gypsum content, 86.13%.															

Profile E-E'. Well Numbers 12 and 19

Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
		Well Number 12. In yard of Gypsum school (abandoned), 0.45 mile west of SE cor. sec. 8, T. 12 N., R. 15 W. Elevation 1760 feet.															
0-16	Cuttings	Gypsum, grayish-pink, coarse-granular in upper 5 feet, grading downward into alabaster.	10217	1.57	0.20	0.13	32.00	1.48	42.24	3.41	18.81	0.05	99.89	89.87	1.09	4.07	3.10
16-44.7	Core	Gypsum, alabaster variety, grayish-pink, containing about 25% medium-granular gypsum as bedding seams and layers 1/4 - 1 inch thick. Thin dolomite stringers.	10218	0.85	0.33	0.09	30.97	1.29	44.08	2.77	19.29	0.03	99.70	92.16	1.46	3.09	2.70
44.7-45.4	"	Anhydrite, medium-gray, medium - crystalline, dolomitic.															
45.4-58.5	"	Gypsum as above.	10219	0.20	0.13	0.06	32.51	1.28	44.67	2.49	19.37	0.04	100.75	92.55	2.35	2.48	2.68
58.5-59.0	"	Sandstone, dark reddish-brown, fine-grained, contains selenite.															
59.0-60.5 T.D.	"	Silty shale, dark reddish-brown, containing selenite crystals and satin spar veins. Summary: gypsum thickness, 58.5 feet; weighted average gypsum content, 91.62%.															
		Well Number 19. On north side of U.S. Hwy. 66, 0.23 mile east of SW cor. sec. 10. T. 12 N., R. 15 W. Elevation 1780 feet.															
0-16	Cuttings	Red clay.															
16-29	Core	Gypsum, mottled grayish-pink, fine-granular to medium-granular, slightly dolomitic.	10307	2.09	0.38	0.10	31.39	1.83	42.19	3.56	18.74	0.01	100.29	89.55	0.56	3.55	3.83
29-43	"	Gypsum as above, mostly fine-granular and alabaster-like. Small probertite nodules at 38.1, 39.0, and 40.6 feet.	10308	2.32	0.42	0.10	31.59	1.75	42.81	3.08	18.41	0.02	100.50	87.98	3.50	2.66	3.66
43-82.5	Cuttings	Anhydrite, light gray, medium-crystalline, dolomitic.	10309	1.14	0.26	0.10	39.53	1.95	53.37	3.86	0.22	0.02	100.45	1.05	89.80	3.93	4.08
82.5-85	Core	Sandstone, dark reddish-brown, fine-grained, cut by veins of satin spar.															
85-87 T.D.	"	Shale, reddish-brown, containing pale green spots and satin spar veins. Summary: gypsum thickness, 27 feet; weighted average gypsum content, 88.74%.															

TABLE 4 (continued)

Profile F-F'. Well Numbers 30, 28, and 20

Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
	Well Number 30.	On road 50 feet north of SW cor. sec. 4, T. 12 N., R. 15 W. Elevation 1738 feet.															
0-35	Cuttings	Dark gray clay, probably alluvial cave filling.															
35-40 T.D.	"	Gypsum, alabaster variety, pinkish-gray. Drilling discontinued as overburden has excessive thickness.															
	Well Number 28.	On road 0.1 mile west of SE cor. sec. 4, T. 12 N., R. 15 W. Elevation 1800 feet.															
0-3	Cuttings	Soil.															
3-15	"	Gypsum, grayish-pink, medium-granular, loosely coherent.	10282	1.21	0.25	0.09	32.37	1.21	43.12	3.14	18.73	0.02	100.14	89.51	2.16	4.14	2.53
15-18	Core	Core crumbled and not recovered.															
18-35	"	Gypsum, alabaster variety, grayish-pink, containing 30-50% medium-granular gypsum along open bedding planes and as anastomosing veinlets.	10283	0.80	0.11	0.03	32.40	0.16	45.66	0.82	20.16	0.03	100.19	96.34	0.46	1.48	0.33
35-47.5	"	Gypsum, moderate red, medium-granular, containing about 15% residual alabaster as small patches. Sparse cavity fillings of probertite at 46.0.	10284	1.27	0.32	0.07	31.79	1.17	43.82	2.18	19.47	0.01	100.15	93.04	0.80	2.05	2.45
47.5-55	"	Anhydrite, light gray, medium-crystalline, compact, translucent, cut by veinlets of light brown very fine-grained dolomitic gypsum.	10285	0.74	0.32	0.04	39.65	0.61	56.29	0.99	1.45	0.02	100.11	6.93	89.77	0.73	1.28
55-57.8	"	Gypsum, alabaster variety, grayish-pink; contains probertite at 56.5 feet. Four inches of red shale at 56.7 and two inches of shale at 57.2 feet.															
57.8-59	"	Anhydrite, pale red, medium-granular, gypsiferous.															
59-60	"	Gypsum, purplish-red, fine-granular. Contains small nodules of probertite.															
60-68 T.D.	"	Silty shale, pale reddish-brown.															
		Summary: gypsum thickness, 44.5 feet; weighted average gypsum content, 93.36%.															
	Well Number 20.	On road at NW cor. sec. 10, T. 12 N., R. 15 W. Elevation 1794 feet.															
0-40	Cuttings	Red clay shale, probably filling a collapsed sink. Lost circulation at 40 feet.															
40-50 T.D.	"	Red clay on bit at 50 feet. No sample return.															
		Summary: gypsum dissolved at a cave which has collapsed.															

Profile G-G'. Well Numbers 29, 21, and 22

Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
	Well Number 29.	On road 50 feet west of SE cor. sec. 33, T. 13 N., R. 15 W. Elevation 1768 feet.															
0-18	Cuttings	Silty shale, alternating reddish-brown and grayish-green layers															
18-32.5	Core	Gypsum, alabaster variety, grayish-pink, compact. Contains patches of light brown dolomite.	10226	1.67	0.57	0.11	31.44	1.58	42.38	3.30	18.67	0.03	99.75	89.20	0.92	3.59	3.30
32.5-55.1	"	Gypsum, grayish-pink to pale red, medium-granular, cut by a network of moderate reddish-brown dolomitic very fine-grained gypsum. Alabaster layer at 45.3-48.9 feet.	10227	0.62	0.14	0.09	32.33	1.32	44.25	2.85	18.86	0.03	100.49	90.13	2.84	3.21	2.76
55.1-64.7	"	Gypsum, alabaster variety, grayish-pink, compact and tough, containing bedding partings of medium-granular gypsum.	10228	0.47	0.47	0.13	31.25	1.50	44.23	2.49	19.68	0.03	100.25	94.03	-	1.93	3.14
64.7-65.8	"	Anhydrite, medium grayish-blue, medium-crystalline.															
65.8-81.3	"	Gypsum, grayish-pink, medium-granular, interlayered with and cutting alabaster. Probertite nodules at 70.65 feet.	10229	0.60	0.04	0.13	32.50	0.75	43.81	2.09	19.80	0.06	99.78	94.60	-	2.89	1.57
81.3-87 T.D.	"	Silty shale, reddish-brown, grading downward into interbedded shale and fine sandstone.															
		Summary: gypsum thickness, 63.3 feet; weighted average gypsum content, 91.62%.															
	Well Number 21.	On road 200 feet north of SE cor. sec. 35, T. 13 N., R. 15 W. Elevation 1744 feet.															
0-15	Cuttings	Red clay and clay-carbonate concretions.															
15-20	"	Concretions and gypsum fragments.															
20-30 T.D.	"	Red clay and gypsum fragments. Lost circulation at 25 feet.															
		Summary: gypsum boulders and clay in a filled sink.															
	Well Number 22.	On road 0.3 mile west of NE cor. sec. 1, T. 12 N., R. 15 W. Elevation 1814 feet.															
0-10	Cuttings	Red clay and clay-carbonate concretions.															
10-16	"	Red gypsum and clay-carbonate concretions.															
16-33.7	Core	Gypsum, alabaster variety, grayish-pink, irregularly mottled with medium-granular gypsum. Cut by irregular patches of pale reddish-brown compact gypsum.	10213	2.17	0.74	0.16	31.12	0.81	43.79	1.42	19.57	0.06	99.84	93.50	-	1.23	1.67
33.7-52.4	"	Gypsum, grayish-pink, medium-granular.	10214	2.93	0.26	0.18	31.80	0.80	43.46	1.96	19.49	0.06	100.44	90.73	2.09	2.48	1.67
52.4-75.6	"	Gypsum, pale red, even-grained, medium-granular, containing irregular patches of alabaster.	10215	0.93	0.40	0.08	32.06	1.19	43.38	2.65	19.26	0.05	100.00	92.02	1.04	3.01	2.49
75.6-87.0	"	Gypsum as above. Contains red-orange shale 0.25 and 0.4 feet thick between 76.1 and 78.3 feet.	10216 (Shale excluded from analysis)	1.01	0.47	0.06	32.49	0.36	44.79	1.51	19.60	0.05	100.34	93.65	1.36	2.55	0.75
87.0-87.5 T.D.	"	Sandstone, light brown, very fine-grained.															
		Summary: gypsum thickness, 71 feet; weighted average gypsum content, 92.32%.															

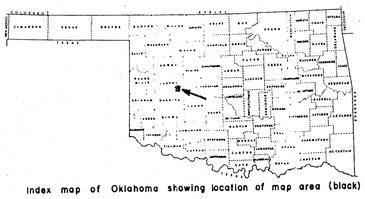
TABLE 4 (continued)

Profile H-H'. Well Numbers 25, 24, and 23

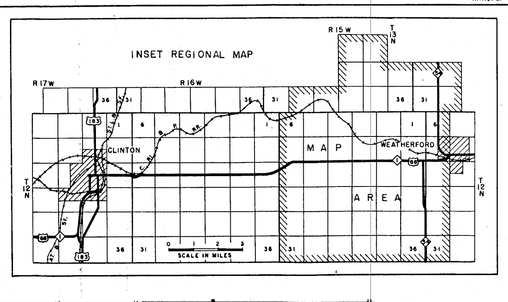
Depth, Feet	Type of Sample	Rock Description	Laboratory Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	NaCl	Total	Hypothetical Combinations: Gypsum $CaSO_4 2H_2O$	Anhydrite $CaSO_4$	$CaCO_3$	$MgCO_3$
		Well Number 25. On road 300 feet west of NE cor. sec. 34, T. 13 N., R. 15 W. Elevation 1774 feet.															
0-10	Cuttings	Cave filling; red clay and gypsum fragments.															
10-25	"	Gypsum, grayish-pink, medium-granular.															
25-34	"	Gypsum, alabaster variety, grayish-pink, compact.															
34-35 T.D.	"	Anhydrite, medium gray, coarse-crystalline.															
		Summary: gypsum thickness, 24 feet.															
		Well Number 24. On road 0.2 mile west of NE cor. sec. 35, T. 13 N., R. 15 W. Elevation 1787 feet.															
0-15	Cuttings	Gypsum, grayish-pink, medium-granular.	10248	1.20	0.17	0.07	32.36	1.17	43.31	3.35	18.37	trc	100.33	87.79	2.72	4.71	2.45
15-33.7	Core	Gypsum, variety alabaster, grayish-pink, mottled with pink medium-granular gypsum.	10249	2.19	0.45	0.12	31.77	0.74	43.93	1.78	18.99	trc	100.35	90.75	3.16	2.21	1.55
33.7-56.3	"	Gypsum as above.	10250	1.20	0.31	0.12	31.77	0.76	44.04	1.65	19.71	trc	99.56	94.19	-	1.86	1.59
56.3-74.0	"	Anhydrite, grayish-red-purple, medium-crystalline.	10251	1.25	0.30	0.06	39.35	1.77	53.03	3.78	0.86	0.04	100.44	4.11	86.54	4.21	3.70
74.0-75 T.D.	"	Shale, reddish-brown, slight salty taste. Contains bedding veins of satin spar.															
		Summary: gypsum thickness, 56.3 feet; weighted average gypsum content, 91.34%.															
		Well Number 23. On road 600 feet east of NW cor. sec. 31, T. 13 N., R. 14 W. Elevation 1789 feet.															
0-15	Cuttings	Gypsum, light gray and grayish-pink, medium-granular, mottled with patches of alabaster. Small amount of cave-filling clay in upper part.															
15-40.5	"	Gypsum as above.															
40.5-42 T.D.	"	Anhydrite, grayish-pink and reddish-purple, medium-crystalline, translucent.															
		Summary: gypsum thickness, 40.5 feet.															

Profile I-I'. Well Number 26

		Well Number 26. On road 0.32 mile west of SE cor. sec. 22, T. 13 N., R. 15 W. Elevation 1788 feet.															
0-12	Cuttings	Red shale and cave filling.															
12-44	"	Gypsum, grayish-pink, medium-granular, grading into alabaster at 42 feet. Dolomite stringers throughout.	10311	1.76	0.14	0.11	31.75	1.71	42.63	3.62	18.63	0.03	100.38	89.03	1.26	3.98	3.58
44-45 T.D.	"	Anhydrite, medium gray, coarse-crystalline, translucent.															
		Summary: gypsum thickness, 32 feet; weighted average gypsum content, 89.03%.															



Index map of Oklahoma showing location of map area (black)



EXPLANATION

- Pgy — Shales and sandstones younger than gypsum bed
- Pcg — Outcrop boundary of Cloud Chief gypsum (Permian)
- Pgo — Shales and sandstones older than gypsum bed
- Approximate area of workable gypsum
- ●7 — Exploratory drill hole
- ◉ — Gypsum cores
- 3/21 — Overburden - gypsum ratio (Overburden 3 feet thick underlain by gypsum 21 feet thick)
- ☆ — Chemical analyses of gypsum
- ☆ — Chemical analyses of gypsum and anhydrite

GEOLOGIC MAP OF CLOUD CHIEF GYPSUM IN THE WEATHERFORD - CLINTON DISTRICT CUSTER COUNTY, OKLAHOMA

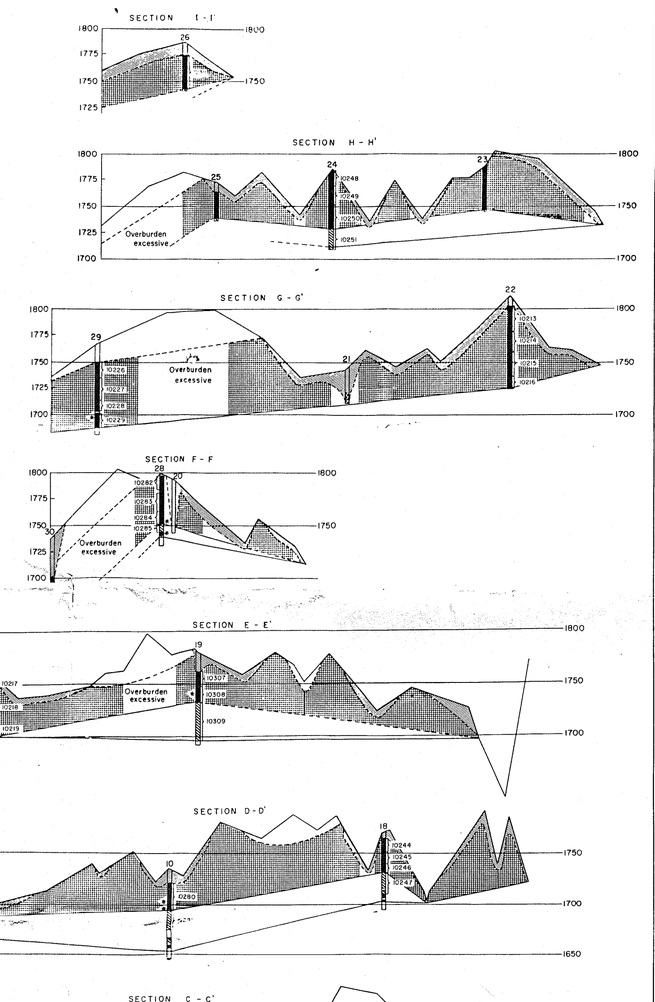
by
W. E. Ham and N. M. Curtis, Jr.
1958

Scale in miles

For lines of profile A-A' through I-I' see Plate II

EXPLANATION of drill hole data

- 13 — Drill hole number
- Soil, alluvium, or cave filling
- Gypsum
- Anhydrite
- Shale and sandstone
- Probertite nodules
- 10282 — Laboratory number of analyzed sample
- Workable gypsum, indicated



GEOLOGIC SECTIONS THROUGH HOLES DRILLED FOR GYPSUM IN WEATHERFORD - CLINTON DISTRICT

by
W. E. Ham
1958

Horizontal scale in miles

For lines of sections see Plate I