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GEOLOGY AND ORE DEPOSITS OF THE SHAFTER MINING DISTRICT PRESIDIO COUNTY, TEXAS

BY
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GEOLOGY AND ORE DEPOSITS OF THE SHAFTER MINING DISTRICT, PRESIDIO COUNTY, TEXAS

By CLYDE P. ROSS

ABSTRACT

The Shafter mining district is principally notable for the Presidio mine, which has been in almost continuous operation since 1880 and has yielded over $18,000,000, mainly in silver. The other mines in the district have not yet produced much.

Permian limestone, with some shale and other sedimentary rocks, constitutes the oldest exposed rock unit in the area and contains the principal ore bodies. Its thickness within the district is over 1,000 feet. Above this are the Presidio formation, about 450 feet thick, and the Shafter limestone, over 1,000 feet thick, both of Trinity age. Younger Cretaceous sedimentary rocks crop out in the outskirts of the district. On the borders of the district there is a thick sequence of lava and other volcanic strata. Intrusive masses of several kinds, mainly andesite, basalt, and diorite, occur in and near the district. Most of them are old enough to have been subjected to the effects of mineralization.

The strata in the region appear to form part of a broad dome, broken by faults and masked by volcanic and alluvial deposits. Some of the numerous faults, mostly of normal displacement, result from readjustments subsequent to the doming. At the Presidio mine there is a complex of faults related, in some way not entirely understood, to the block of Permian limestone that contains the ore bodies. These faults help to control location and shape of the ore bodies. No similar set of faults is yet known in any part of the surrounding region. If such a set should be discovered, either in Permian rocks or in overlying beds, search for ore bodies similar to those of the Presidio mine would be warranted, other conditions being favorable.

The ore occurs mainly as replacement deposits controlled by bedding planes and to some extent by fault fissures in the Permian limestone. A few are formed along thrust planes, and related low-angle shear zones have had an influence in localizing others. There are numerous steep veins and some replacement deposits in the Cretaceous beds. These are genetically related to the replacement deposits in the Permian beds but so far have nowhere been shown to have much commercial value, except insofar as they may be useful as indications of ore at depth. The ore deposition comprised (1) a limited amount of dolomitization, (2) silicification, (3) deposition of calcite and such metallic minerals as galena, sphalerite, and probably argentite, and (4) supergene alteration. Silver is the principal valuable component of nearly all of the ore with lead as a byproduct.

INTRODUCTION

LOCATION AND EXTENT OF THE DISTRICT

Of the silver and associated metals so far produced in Texas, much the greater part has come from the Shafter mining district, principally from the Presidio mine. The district is in south-central Presidio County, in the western part of the Big Bend region of

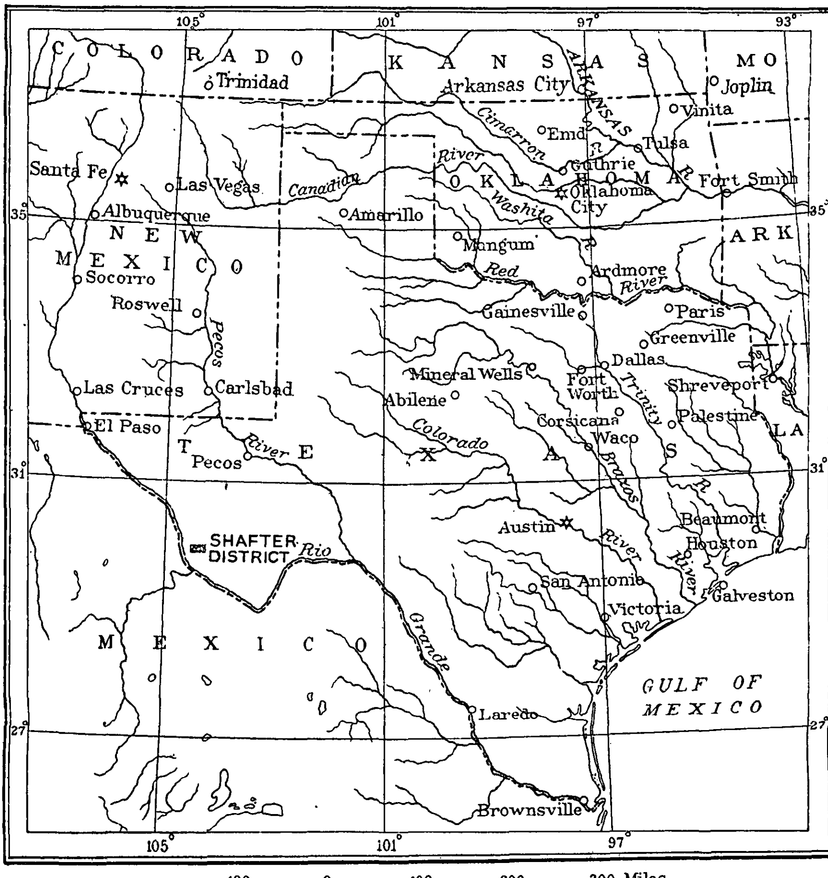

FIGURE 3.—Sketch map of Texas showing the location of the Shafter mining district.

southwestern Texas (see fig. 3). Shafter, a settlement of nearly 1,000 people, at the eastern border of the district, is 44 miles by highway (U. S. 67, State 17) south of Marfa, on the Southern Pacific Railroad, and 21 miles by the same highway from the Rio Grande at Presidio, which has long been a port of entry from Mexico. The property of the Presidio mine of the American Metal Co. of Texas extends as much as 2 miles west of Shafter. The rest of the district contained no residents at the time of the visit, although some of the mines were being operated on a small scale by people who resided at Shafter.

The district is not crossed by any railroad, but the Kansas City Mexico & Orient Railway, a subsidiary of the Atchison, Topeka & Santa Fe system, runs 16 miles east of Shafter, through Alpine and Presidio into Mexico. Presidio is the nearest point of this railroad that is accessible by highway from Shafter.

The limits of the district are indefinite, but all the prospects in it are within a rectangle that extends 6 miles east and west and 3 miles north and south. Shafter lies just northeast of the middle of the eastern boundary. As thus defined, the district includes most of block 8, Houston & Texas Central Railway Co.,[1] the eastern part of block 7, originally allotted to the same railroad, and certain sections between and south of these two blocks (see pl. 6). Shafter lies in section 327 of the "A. B. and M." block.

The developed mines in the Shafter district include the Presidio mine, with several score miles of underground workings; the Perry and Cibolo mines, more recently opened; the Montezuma, Chinati, Ross, and Last Chance mines. Each of the four properties last named contains a few score to a few hundred feet of workings.

SCOPE OF THE REPORT

Two months in the spring of 1934 were devoted by the writer, assisted by W. E. Cartwright and C. H. Coldwell, to the study of the Shafter mining district. The work was done under allotment from the Public Works Administration. Each of the mines enumerated above was visited by the writer. The underground workings of the Perry, Chinati, and Montezuma mines, and the area in the southwestern part of the Presidio mine where mining was in progress were geologically mapped. Other mine workings in the district were either inaccessible, or, because of the limitations of time, were inspected without being mapped. In the course of visits to the different mines by the writer and of rapid traverses by Cartwright and Coldwell general information concerning the geology of the district and neighboring areas was obtained. These data are roughly generalized on plate 6. The base for this map is the Shafter topographic map of the Geological Survey, which, however, is old and so inaccurate in many details that it is not well adapted to geologic work. For this reason and because the geologic features are too complex to be adequately understood after mere reconnaissance, no

[1] In the subdivision of the public lands of Texas the larger units are blocks, numbered in various ways. In most instances each block corresponds to a grant of land originally made to some railroad. The blocks are subdivided into numbered sections, many of which comprise a square mile, with the sides parallel to the major compass directions. Sections, however, vary greatly in both size and orientation.

special features such as faults and small intrusive masses are shown. A detailed plane-table survey of about 3 square miles, which includes 5 of the 8 mines, is represented on plate 7. Inasmuch as future expansion of mining in the district depends largely on comprehension of the structure and stratigraphy, more attention was given to these matters than to the details of the known ore deposits, particularly as the principal mines are in the hands of competent engineers. Stratigraphic studies, mainly by Cartwright, were carried some distance beyond the borders of the Shafter district.

A preliminary report outlining the principal results of the study as they appeared at the conclusion of the field work has already been published.[2] The present paper gives in greater detail the data obtained in the field and presents conclusions based on both field and office studies.

ACKNOWLEDGMENTS

Without exception the people of the district and the officers and engineers of the different mining properties were cordial and helpful in every way. Their whole-hearted cooperation greatly facilitated the work. They have made available all data in their possession, and many of the concepts here summarized were developed in consultation with them. Mention should be made especially of Charles E. Stott, general superintendent of the Presidio mine, of C. E. Wheelock, C. R. Amis, and Vincent Burnhardt of the engineering staff of that mine, and of Dunham Perry, the operator of one of the other properties in the district. E. M. Gleim, a former superintendent of the Presidio mine, very kindly made available statistical data for the years 1883 to 1924 and furnished other information.

The foundation for the study of the geology of the region was laid by Udden,[3] whose stratigraphic work has been very helpful in the present examination. The type sections of most of the formations distinguished by Udden were visited by Cartwright and the strata at each compared with those in the vicinity of the mines.

The detailed geologic map of the area in the vicinity of the Presidio mine by A. W. Frolli was made available through the courtesy of the officers of the American Metal Co., and was most valuable in connection with the mapping of this and adjacent ground (pl. 7).

The principal publication regarding the geology of the ore deposits of the district is that by Howbert and Bosustow.[4] This and other

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[2] Ross, C. P., and Cartwright, W. E., Preliminary report on the Shafter mining district, Presidio County, Tex.: Texas Bur. Econ. Geology. Texas Univ. Bull. 3401, pp. 573–608, 1935.

[3] Udden, J. A., The geology of the Shafter silver mine district, Presidio County, Tex.: Texas Univ. Min. Survey Bull. 8 (Texas Univ. Bull. 24), 1904.

[4] Howbert, Van Dyne, and Bosustow, Richard, Mining methods and costs at Presidio mine of the American Metal Co. of Texas: Am. Inst. Min. Met. Eng. Trans., 1931, gen. vol., pp. 38–43, 1931.

short papers cited in subsequent pages have been freely used in preparing the present report.

HISTORY OF THE DISTRICT [5]

Indications of the presence of metalliferous deposits in the Shafter district were discovered in 1880 or 1881 by John Spencer, of Presidio, or by Mexicans employed by him. Certain trenches close to the present Perry mine are reported to be older than Spencer's work and may record prospecting by the early Spaniards.

Spencer interested a group of Army officers stationed at Fort Davis in his discoveries. One of these was Capt. (later Gen.) William R. Shafter, for whom the town and district were named. These officers and others organized the Cibolo Creek Mill & Mining Co. and the Presidio Mining Co., which were soon consolidated under the name of the Presidio Mining Co.

Search for ore met with so little success during the first few years that the enterprise is reported to have been on the point of being abandoned when the Mina Grande ore body (fig. 3) was found. Production is reported to have begun in 1883, but the operation was not put on a profitable basis until 1888. From that time through 1913 ore continued to be mined and treated in the company's 50-ton pan-amalgamation mill at Shafter.[6] For nearly half this time the ore averaged about 30 ounces of silver to the ton. Even though the average decreased somewhat in later years operations were profitable for most of the period. Losses were recorded in 1906, 1907, 1909, and 1910, when the grade of the ore dropped to about 20 ounces of silver to the ton. From 1898 to 1913 the annual mine output averaged about 20,000 tons. Late in 1913 a 200-ton cyanide mill was built, the site and part of the equipment of the old mill being used. From 1913 until 1926 the mine output increased to more than 84,000 tons a year, but the grade of the ore dropped to about 10 ounces of silver to the ton. In 1926 the property passed into the hands of the American Metal Co. of Texas. Under the new management annual production from 1927 to 1929 decreased to roughly 50,000 tons, but the grade of the ore mined increased to more than 20 ounces of silver a ton, so that operations were profitable until decrease in the price of silver caused a temporary shutdown in July 1930. Operations were resumed in January 1934, and the mill was restarted in April 1934.

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[5] Howbert, Van Dyne and Bosustow, Richard, idem., p. 38. Howbert, Van Dyne and Gray, F. E., Milling methods and costs at Presidio mine of the American Metal Co. of Texas; Am. Inst. Min. Met. Eng. Trans., vol. 112, pp. 704–721, 1934. Kirt, M. E., The Presidio silver mines, Shafter, Tex.: Eng. and Min. Jour., vol. 88, pp. 818–819, 1909. Annual volumes of Mineral resources of the United States. Also oral discussions with mining men familiar with the district.

[6] This and following statements are based mainly on an analysis of the tables below.

Shortly thereafter the monthly output was about 4,700 tons of ore. An average grade of nearly 20 ounces of silver to the ton was maintained at first, but the grade has declined with increase in the tonnage mined. In 1940, the last year for which records are available, the ore milled averaged only 10.7 ounces of silver to the ton. The tables below, which show the operations at the Presidio mine from 1883 to 1940, show a recorded output of 2,020,375.92 tons with a content of 30,972,286.15 ounces of silver. The gross value of the output of the mine exceeds $18,000,000, of which roughly 10 percent has been operating profit.

From time to time a number of smaller mines have been opened in the Shafter district. The Ross mine was started about 1890 and was worked a little over a year. Some lead-silver ore was mined, but little, if any, was shipped. The Chinati mine was opened in 1890, and one car of lead-silver ore shipped from it. Some mining was also done here in 1891. In 1901 and 1902 this and the adjoining Montezuma mine were worked. At that time the Chinati had a small smelting plant at Shafter from which 10 cars of lead bars are reported to have been shipped.

From this time until the World War there appears to have been little activity in the small mines of the district. In 1915 and 1916, when the World War caused high prices for zinc, zinc carbonate ore was shipped from the Chinati and Montezuma mines. In 1910, 1915, and 1916 small shipments of lead-silver ore were made from the Last Chance.

In 1926 the Last Chance was reopened by Harry Young. It was worked for about a year, and 3 cars of lead-silver ore are reported to have been shipped. About the same time new development was undertaken at the Gleim and Stauber mines, but part of the work here, especially at the Gleim, is old.

In 1932 Dunham Perry began development at a new prospect east of the Chinati mine. Prior to the time of the visit several small shipments of ore had been made, mostly for test purposes, and other ore was piled near the mine in anticipation of the erection of a mill. In 1934 the Shafter Mining Co. was chartered for the purpose of operating the property. In 1935 some production was recorded from the Chinati and another mine in the vicinity of Shafter.[7] From that date through 1940 the Presidio mine has continued to be operated but little has been done at the other properties in the district.

[7] Henderson, C. W., and Martin, A. J., Gold, silver, copper, lead, and zinc in Texas: Minerals Yearbook, 1936, p. 339, 1936.

Record of operations at the Presidio mine, 1927–40

[Furnished by American Metal Co. of Texas through 1935. Records of later years from D. E. Stem (Milling methods and costs of the Presidio mine: Min. Jour., vol. 24, No. 22, pp. 3-5, 39-40, Apr. 15, 1941), supplemented by data from annual volumes of the Minerals Yearbook]

Year	Ore milled (tons)	Assay content of mill heads			Total recovery		Total production		
		Silver (ounces per ton)	Lead (percent)	Total silver (ounces)	Silver (percent)	Lead (percent)	Gold (ounces)	Silver (ounces)	Lead (pounds)
1927	48, 190	22. 8	2. 07	1, 097, 500. 0	91. 4	26. 0	396. 3	1, 003, 069	517, 705
1928	57, 475	23. 1	2. 15	1, 327, 479. 6	91. 0	27. 6	489. 3	1, 208, 238. 3	681, 821. 0
1929	54, 644	19. 74	2. 50	1, 078, 759. 1	90. 3	34. 3	1, 278. 7	974, 048. 6	936, 004. 4
1930	24, 984	16. 28	2. 17	401, 926. 3	88. 8	36. 7	176. 5	356, 854. 5	398, 337. 0
1934	46, 653	19. 56	2. 07	912, 722. 1	91. 0	40. 3	328. 1	830, 684. 4	776, 808. 4
1935	70. 166. 2	15. 87	1. 83	1, 113, 686. 7	87. 85	39. 3	486. 7	978, 302. 7	1, 009, 786
1936	98, 499	14. 41	1. 26	1, 419, 371	87. 50	38. 7	600. 6	1, 241, 604. 5	961, 224
1937	110, 220	12. 76	1. 08	1, 406, 825	86. 79	33. 4	557. 2	1, 220, 920. 6	795, 037
1938	127, 574	12. 76	. 896	1, 627, 844	85. 43	34. 1	438. 9	1, 375, 805. 3	709, 356
1939	138, 934	11. 35	. 623	1, 561, 618	83. 50	27. 2	322. 9	1, 303, 747. 7	470, 652
1940	144, 558	10. 70	. 566	1, 525, 087	85. 07	25. 7	330. 9	1, 315, 893. 2	421, 319
	921, 897. 2	16. 33	1. 51	13, 472, 818. 80	88. 15	33. 03	5, 406. 10	11, 809, 168. 80	7, 678, 049. 80

SEDIMENTARY ROCKS

GENERAL RELATIONS

The sedimentary rocks were mapped in detail in the eastern part of the Shafter mining district. In addition, reconnaissance mapping was done, and significant sections, of the beds were examined in parts of the surrounding region. These sections include the type localities of the Permian formations here described. These formations are of special interest, as most of the productive mines are in Permian limestone. Data on the stratigraphy of the Cretaceous strata, however, also have much value, as these rocks mask the Permian strata over extensive areas and are themselves mineralized in numerous places. Some problems of the stratigraphy of both the Permian and the Cretaceous rocks can be cleared up only by extending the detailed mapping over a much larger area than that already covered. The Paleozoic rocks crop out only in isolated areas, and the Cretaceous strata are covered in many places by Tertiary and later deposits, so that direct correlation is hindered.

The following section shows the sedimentary units, other than alluvium present in the general vicinity of Shafter. The dominantly calcareous beds in the lower part of the sequence are mainly of Permain age, although on the basis of recent work, the lower part of them may be Pennsylvanian.

The Trinity group (Cretaceous) is extensively exposed and has been somewhat mineralized within the mining district. Rocks of the Fredericksburg and Washita groups are present south of the area studied in detail. One of the results of the present study is to show that beds of the approximate age of the Walnut formation, grouped with the Shafter formation by Udden,[8] can be distinguished in the field. Udden noted that Edwards limestone crops out south of Shafter and included with it beds of probable Comanche Peak age below and Georgetown age above. Inspection of some of the exposures of these beds indicates that such a grouping is desirable in this locality, as the differences between the beds seem insufficient for consistent mapping. The beds thus grouped are here called the Devils River limestone, as they appear to correspond essentially to the formation to which Udden [9] applied that name, mainly limestone of Edwards age but with strata of other ages included.

Udden also noted that still farther south there are beds that resemble the Del Rio clay and Buda limestone. This locality was not examined, and the Del Rio and Buda are consequently not further discussed in the present paper.

[8] Udden, J. A., op. cit., pp. 38–40.
[9] Udden, J. A., Report on a geological survey of the lands belonging to the New York and Texas Land Co., Ltd., in the upper Rio Grande Embayment in Texas: Augustana Library Pub. No. 6, p. 56, 1907.

Stratigraphic section in the Shafter region

Age	Group	Formation
Lower Cretaceous.	Washita group.	Buda limestone (?). Del Rio clay (?)
	Fredericksburg group.	Devils River limestone (equivalent to Edwards and probably Georgetown and Comanche Peak limestones). Walnut (?) formation.
	Trinity group.	Shafter limestone. Presidio formation.
Unconformity——		
Permian.		Cibolo formation. Alta formation. Cieneguita beds of Udden.

PERMIAN ROCKS

SUBDIVISIONS

Udden[10] divided the Permian rocks in the general vicinity of Shafter into three formations, which he named the Cieneguita, Alta, and Cibolo, after localities in and just north of the northeast part of the area shown on plate 6. He subdivided these into a total of eight members, as shown in the table below. This table also outlines the correlations proposed by Baker[11] from information obtained by him in the basin at the head of Cibolo Creek. The thicknesses of certain units not given in his original publication have been kindly supplied by Mr. Baker. The exposures north of Shafter on which Udden based his subdivision of the Permian rocks were visited by Cartwright during the present investigation, and the lithologic descriptions in the table are based mainly on his observations.

As will be seen from the table and from the descriptions of the exposures in the Shafter mining district that follow, there are so many differences in the details of lithology and thickness in the scattered outcrops of Permian rocks in this region that precise correlations based on present data are unwarranted. In a broad way there can be no doubt that the beds containing Permian fossils all belong to the same sequence. Those in the area mapped in detail on plate 7 are in the upper part of this sequence.

[10] Udden, J. A., op. cit. (Tex. Univ. Min. Survey Bull. 8), pp. 11–13.

[11] Baker, C. L., Note on the Permian Chinati series of west Texas: Texas Univ. Bull. 2701, pp. 77–79, 1929.

Permian formations in or near the Shafter district

Formation	Subdivision	Udden's type section	Thickness (feet)	Type locality	Baker's upper Cibolo Basin section	Thickness (feet)
	8. Yellow limestone.	Fine- to medium-grained hard yellow dolomitie limestone; thin to medium beds in lower portion; middle and upper portion massive, with local brecciation; chert nodules throughout.	650		Absent.	
	7. Thin-bedded zone.	Thin-bedded brown, gray, and black mostly fine-grained limestone, with numerous thin beds, lenses, and concretions of chert and some thin-bedded yellow to brown sandstone. At 0.9 mile southeast of crest of Sierra Alta sandstone is more abundant.	470		Dark-brown to gray coarse-grained and coarsely laminated cherty shale. Rusty-colored thin-bedded micaceous sandstone, interbedded with some shale.	500
Cibolo formation.	6. Zone of sponge spicules.	Gray, tan, and brown siliceous limestone, with a few thin layers of sandstone. Yellow, brown, and grayish-black thin-bedded limestone and yellow to brown thin-bedded sandstone. Sponge spicules locally abundant, especially in the siliceous and cherty beds; scarce or absent in other beds.	85	East bluff of Sierra Alta Creek, just above confluence with Cibolo Creek, 0.5 mile east of the Cibolo ranch.	Hard, dense siliceous limestone, composed mainly of sponge spicules.	1
	5. Lower brecciated zone.	Essentially a collapse breccia, composed of grayish-white to brown limestone boulders of various sizes, some as large as 6 feet in diameter.	133		Platy brown argillaceous beds at top only. Varicolored chert, occurring in irregular beds, lenses, and concretions, interbeeddd with a few thin layers of limestone.	385
	4. Transition beds.	Principally gray marl and clay, with some thin to moderately thick beds of sandstone and a few beds of limestone.	100		Absent.	

Alta formation.	3. Yellow sandstone.	Yellow to brown soft sandstone, with numerous thin to medium beds of hard gray to brown sandstone and a few beds of yellow to brown sandy shale. The hard sandstone beds are relatively abundant in the middle and upper parts of the unit.	1,500	Arroyo just south-southwest of the crest of Sierra Alta and 3.1 miles north-northeast of Cibolo ranch.	Medium-bedded quartzites, weathering rusty brown; upper part contains thin layers of grit.	100
					Platy argillaceous sandstone.	
					Green muscovitic and arenaceous sandstones and mudstones.	
	2. Dark shales.	Grayish-black to black paper shale, with yellow to brown hard thin-bedded sandstone intercalated at short intervals.	2,000		Absent.	
Cieneguita beds of Udden.	1. Basal deposits.	Consists essentially of dark almost black shales, with some thin beds of chert and medium to thick beds of limestone and conglomerate.	1,000	South of Ojo Bonito and 3 miles north of Cibolo ranch.	Absent.	

LOCAL DETAILS

Beds of the Permian series crop out in several localities in the Shafter mining district. They have been studied in detail in the isolated exposure at the Presidio mine and especially in the hills just north of the Perry mine. Beds that evidently belong to the series are exposed in and near section 4, block 8, Houston & Texas Central Ry., and also in and near the eastern part of block 7, of the same railway, but these have been examined less carefully. At both of these localities most of the Permian beds are stratigraphically lower than those in the two localities which were studied in detail.

BEDS AT THE PRESIDIO MINE

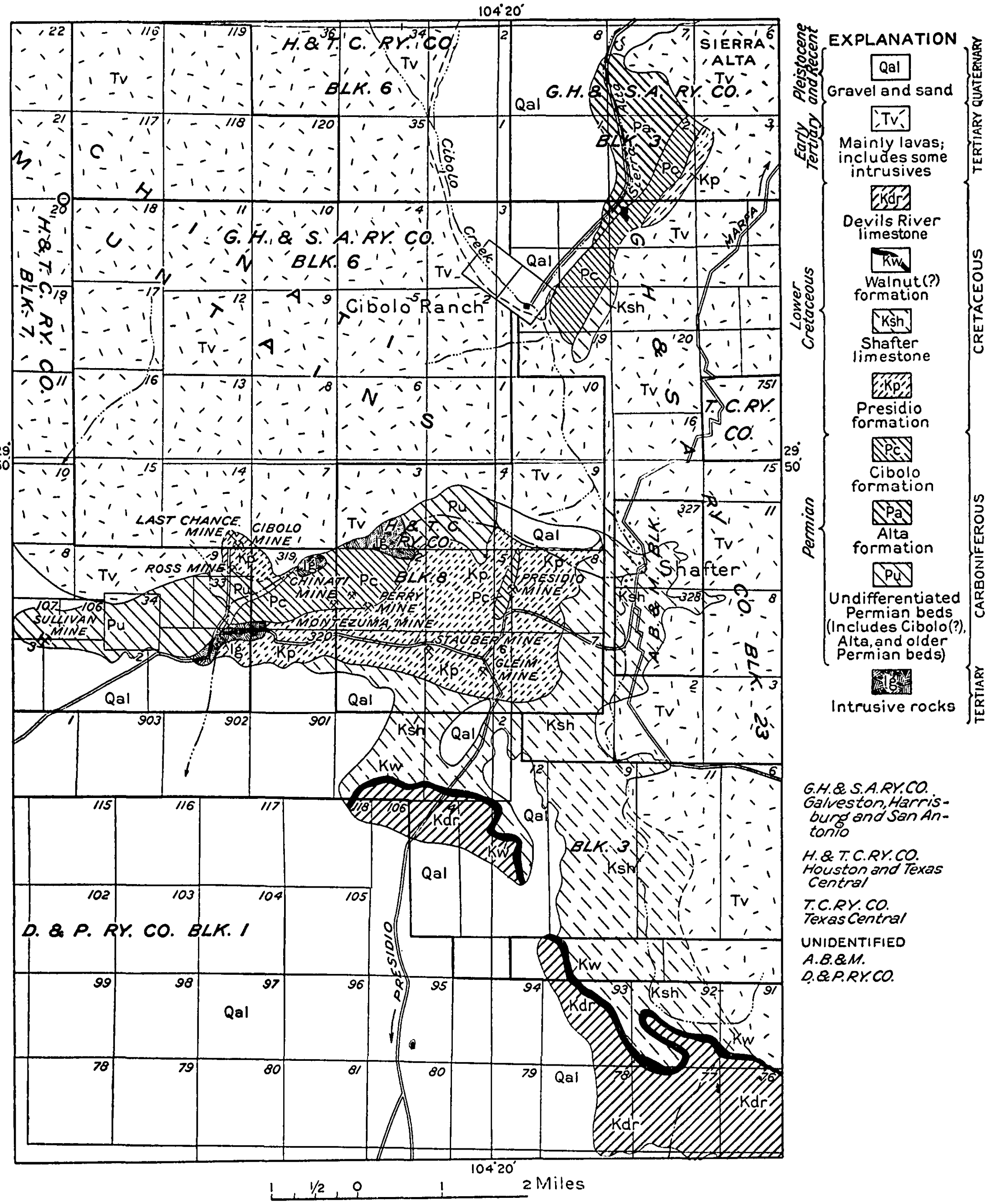
The Permian beds at the Presidio mine are overlain unconformably by the basal beds of the Presidio formation. Largely for this reason they are locally believed to belong to the Cibolo formation, a correlation which agrees with Udden's conclusions.[12] He further suggests that they belong to the "yellow limestone," the uppermost member of the Cibolo formation, which in most places was removed by erosion before the Cretaceous strata were laid down; but unlike the yellow limestone at its type locality, most of the unmineralized limestone at the Presidio mine is not dolomitic.

Most of the upper part of the supposed Cibolo strata in the vicinity of the Presido mine is a massive dark-gray limestone. In several localities the gray rock has brownish-yellow mottlings, which have no relation to the mineralization that has affected much of the limestone in the vicinity, as is shown by the presence of similar mottlings within pebbles included in Cretaceous conglomerate. Commonly, although the pattern of the mottling may resemble that of a breccia, the brown areas merge into the gray. The brown or brownish-yellow material is more magnesian than the gray and may correspond to the yellow dolomitic limestone of the type locality near the Cibolo ranch. A mottled limestone of similar appearance has been described by Wallace[13] as the result of "pseudobrecciation" brought about by partial dolomitization. Of several possible explanations, he favors the concept that dolomitization was practically contemporaneous with the deposition of the limestone and was effected only in the limestone immediately surrounding decomposing algae, which contained sufficient magnesium to make this possible.

Thin shaly lenses occur in a few outcrops of the limestone, such as those near the northwest corner of section 8, block 8. Layers of gray, laminated clay shale a few inches to about 4 feet thick are exposed in several places underground, notably in the roof of 404 stope and in

[12] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), pp. 23, 54.

[13] Wallace, R. C., Pseudobrecciation in Ordovician limestones in Manitoba: Jour. Geology, vol. 21, pp. 402–421, 1913.



RECONNAISSANCE GEOLOGIC MAP OF THE REGION AROUND SHAFTER, PRESIDIO, COUNTY, TEX.
By C. P. Ross, W. E. Cartwright, and C. H. Coldwell.

workings to the southwest (pl. 10). The laminations are persistent and even, although in places only faintly visible. The finer laminations are about 0.2 millimeter thick, but some of the shale shows slightly gritty layers 1 to 2 millimeters thick. The shale is moderately hard, and much of it cleaves readily, parallel to the bedding.

The analyses below show that the clay, which is the principal component of this shale, has a somewhat unusual composition. One of the analyses is from a sample of typical shale, the other from gouge composed in part of ground-up shale, which came from the roof of an ore body. The conspicuous features of these analyses are the complete absence of soda and the high content of potash, especially in the clay shale. The lower content of potash in the gouge may be accounted for by the fact that it contains impurities, whereas the shale is almost exclusively clay. This composition, considered with the optical properties of the clay, suggests that it belongs to a distinct group of potassium-bearing clay minerals, which have been briefly described by Ross and Kerr [14] but as yet unnamed. According to them: "Clays of this type probably form a small portion of many soils and possibly shales, but the only widespread beds of this type of material are the Ordovician meta-bentonites that have been recognized in Missouri, Minnesota, Wisconsin, Kentucky, Tennessee, Alabama," and other States. As the potash-rich clay is found in close association with ore deposits and the shale containing it shows no indication of derivation from volcanic rocks, it is possible that the clay was one of the products of mineralization; however, recent work in the Guadaloupe Mountains has shown that shaly beds there are composed in part of volcanic ash.[15] Those beds are interbedded in sandstone that lies a few hundred feet beneath the Capitan limestone and are therefore, according to King, of about the same age as the Cibolo formation. Two analyses of the clay shale from the Guadaloupe Mountains, by E. T. Erickson, show that it contains less than 1 percent of soda and 5 to 9 percent of potash. Microscopic examination by C. S. Ross shows that parts of this clay are clearly derived from volcanic ash but that other parts of it now bear no evidence of such an origin. The parts showing no evidence of volcanic origin are very similar in appearance to the shale in the Presidio mine. Thus, it is possible that the Permian shale in the Shafter district, like the Ordovician shales of similar composition in other regions, may be of bentonitic origin.

In the mine workings, the massive limestone grades rather abruptly downward into distinctly thin-bedded, locally somewhat shaly limestone. The massive unit is fully 200 feet thick, and the thin-

[14] Ross, C. S., and Kerr, P. F., The clay minerals and their identity: Jour. Sedimentary Petrology, vol. 1, No. 1, pp. 59, 63, 1931.

[15] King, Philip, personal communication.

bedded unit must be almost as thick, as the base has not yet been reached in mining.[16]

Analyses of clays from the Presidio mine, Shafter, Tex.

[Charles Milton, analyst]

	Clay shale from west end of 404 stope	Gouge clay from north-west part of 404 stope
Sio_2	62. 67	74. 4
Al_2O_3	18. 47	[1] 13. 76
Fe_2O_3	1. 78	1. 43
MgO	1. 94	. 93
CaO	1. 17	. 25
Na_2O	0	. 13
K_2O	5. 50	1. 32
H_2O—	. 90	6. 93
H_2O+	5. 48	
TiO_2	1. 31	. 69
CO_2	. 79	----------
P_2O_5	. 16	----------
BaO	. 05	----------
Total	100. 22	99. 88

[1] Includes about 0.3 P_2O_5.

BEDS NEAR THE PERRY MINE

In the hills north of the Perry mine, the Permian beds are tilted at about 20°, so that a thickness of more than 1,000 feet may be examined—much more than is visible in or near the Presidio mine. These beds lie unconformably beneath the basal beds of the Presidio formation. Because of lithologic changes, laterally, it is difficult to correlate the subdivisions of the Permian, but it is probable that all of the beds exposed along this section correspond broadly to Udden's Cibolo beds.

A section of the strata near the Perry mine is presented in tabular form below to permit comparison with Udden's and Baker's sections in the table on pages 54–55. Most of the beds are thin. They are exposed along the gulch that emerges from the hills at the Perry mine and northward to the body of intrusive rock shown on the general map (pl. 6). Data from nearby outcrops, however, have been used to supplement the information obtained along the line of section. Most of the thicknesses given are believed to be correct within about 10 percent, but certain units, notably those above the red shale, exhibit marked variations in thickness within short distances. The breccia in the fourth unit from the top in the table consists of angular pieces of dark-gray limestone and yellow dolomite in a softer, somewhat earthy, light-colored calcareous matrix. The

[16] Howbert, Van Dyne, and Bosustow, Richard, Mining methods and costs at Presidio mine of the American Metal Co. of Texas: Am. Inst. Min. Met. Eng., Trans., 1931, gen. vol., p. 39, 1931.

more massive limestones continue westward past the Chinati and Montezuma mines. Near the Montezuma some exposures show rounded fragments of yellow dolomite, about an inch in diameter, in dark gray, somewhat brecciated limestone. This material differs from the mottled limestone previously described in that it is a distinct breccia in which the brown and gray components do not show any tendency to merge.

On the map (pl. 7) the Permian rocks near the Perry Mine are not subdivided into as many units as are listed in the table. The uppermost unit in the table corresponds to the massive limestone on plate 7. The thin-bedded limestone separated into two divisions in the table by the upper andesite sill is given a single designation on the map. The five dominantly shaly units between the thin-bedded limestone and the lower sill are included in the red shale unit on the map, but two distinctive limestone beds within the shales are shown separately. The upper one of these consists of a mosaic of limestone blocks, highly irregular in size and shape and now thoroughly recemented. The other thin limestone unit mapped is sufficiently resistant to form low bluffs, and most of it is crowded with Foraminifera. Below the lower sill there are distinctly dark-colored calcareous shale and limestone beds, which are mapped as a unit.

Section of the Permian rocks in the area north of the Perry mine

	Feet
Dark-gray massive, rather pure limestone; contains concretions of chert; thin-bedded near the base (fossil collection 7735)	100+
Thin-bedded limestone similar to that below the underlying sill	95
Tertiary andesite sill	45
Dark-gray to black thin-bedded limestone, locally brecciated and with some thin beds of sandstone and shale in the lower portion (fossil collections 7733a, 7734)	185
Dark-red paper-thin shale (fossil collection 7733)	70
Thin beds of reddish-pink to reddish-brown siliceous limestone, with intercalated red shale; numerous sponge spicules	15
Dark-red paper-thin shale	40
Brecciated limestone (fossil collection 7732)	10
Dark-red paper-thin shale (fossil collection 7730)	150
Moderately thick beds of limestone, with red shale partings; some of the limestone beds contain numerous Foraminifera, possibly *Schwagerina* (fossil collection 7731)	10−
Dark-red paper-thin shale	150
Tertiary calcic andesite sill	100
Dark thin-bedded shale, with numerous beds of black limestone	150+
	1, 120±

The massive and the thin-bedded limestones can be traced eastward to a point within a short distance of the Presidio mine, except for a short stretch occupied by intrusive rock, and undoubtedly are equivalent to the two units exposed there. As indicated in the description of the beds at the Presidio mine, it seems likely that the massive and the thin-bedded limestones together may correspond to Udden's yellow limestone. Some of the limestone north of the Perry mine, especially in the thin-bedded portion, weathers yellow, but the massive limestone weathers gray to brown, with local reddish and yellowish-brown magnesian mottlings. On the other hand, it is equally probable that only the massive limestone is to be so correlated and that the thinner beds correspond to part or all of Udden's "thin-bedded zone." In view of Baker's correlations farther north (see p. 53), it is possible that at least part of the red shale north of the Perry mine may correspond to Udden's thin-bedded zone and that the rest of the red and black shales and the intercalated limestone beds correspond in a general way to the lower part of the Cibolo formation.

BEDS IN SECTION 4, BLOCK 8

In and close to section 4, block 8, Houston & Texas Central Ry., there are extensive exposures of the Permian rocks, most of which have been viewed only on reconnaissance trips. A southerly prong of the Permian mass extends into section 5, part of the area mapped in detail on plate 7. This part belongs to the upper massive limestone unit and is similar in all respects to that unit as exposed near the Presidio mine (pp. 56–58). Stratigraphically and topographically below the massive limestone there is a thick sequence of thin-bedded limestone, shaly limestone, and shale, with massive limestone reefs in places. The lowest exposed beds are massive conglomerates, which underlie shale that contains scattered pebbles. Conglomerate is recorded by Udden[17] only in his Cieneguita beds, the lowest formation in his Chinati series.

BEDS IN THE WESTERN PART OF THE DISTRICT

Beds that evidently belong to the Permian are extensively exposed in the eastern part of block 7, Houston & Texas Central Ry. This area is in the extreme western part of the Shafter mining district, and the only available data on it are those obtained in brief examinations of the prospects.

The undifferentiated Permian beds in this area are overlain by the upper massive limestone unit of the Cibolo formation, which continues eastward without break past the Perry mine. Similar massive

[17] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), pp. 13, 14.

limestone, which may well belong to the same unit, is widespread in the vicinity of the old Sullivan mine, the most westerly in the Shafter district. There are, however, beds of limestone conglomerate here that are not seen in any of the exposures of the massive limestone unit farther east, and the bedding throughout is somewhat better marked than is characteristic of that unit.

East of the Sullivan mine there are red hills composed largely of iron-stained and altered quartzite intruded by porphyritic rocks. The stratigraphic relations of the quartzitic beds have not been determined, but they appear to lie well below the massive limestone unit of the Cibolo formation. Lithologically they accord best with the Alta beds described by Udden and Baker.

South of the old Ross mine there are, in upward succession, beds of black limestone crowded with Foraminifera, black fissile shale with limestone ribs, and, finally, dark limestone. This succession is separated from the western extension of the massive limestone unit of the Cibolo formation by an intrusive mass, but there seems no question that it underlies the massive unit.

AGE

Udden [18] suggested that his Cieneguita and Alta beds were of upper Pennsylvanian age and that the Cibolo was probably Permian. Böse,[19] from a study of Udden's collection, concluded that the Cibolo formation is of Permian age.

On the basis of field studies at and north of the localities studied by Udden and of fossils collected from these localities, Baker [20] concluded that the entire sequence of Carboniferous rocks in this region is Permian and correlated the Cibolo formation with the Word formation of the Glass Mountain region.

Sellards [21] correlated Udden's Cieneguita with the Wolfcamp formation of the Glass Mountain region and the Alta formation with the Leonard formation of the same region, and he agreed with Baker that the Cibolo formation is equivalent to the Word formation of the Glass Mountain region. Sellards' correlation is accepted by King.[22] G. H. Girty examined 15 collections made by Cartwright during the present study, with the results listed below. He reported that the only ones that possess distinguishing features are lots 7730, 7733a, 7734,

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[18] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), pp. 23–25.

[19] Böse, Emil, Contributions to the knowledge of *Richtofenia* in the Permian of west Texas: Texas Univ. Bull. 55, pp. 17–18, 1916.

[20] Baker, C. L., Note on the Permian Chinati series of west Texas: Texas Univ. Bull. 2701, pp. 76–79, 1929.

[21] Sellards, E. H., The pre-Paleozoic and Paleozoic systems in Texas: Texas Univ. Bull. 3232, pt. 1, p. 146, 1932 [1933].

[22] King, P. B., Permian stratigraphy of trans-Pecos Texas: Geol. Soc. America Bull., vol. 45, p. 783, pl. 107, 1934.

7737, 7739, 7740, and 7741. Girty stated that these are all Permian and of the Guadalupian type (Leonard or younger). There is nothing in the other collections incompatible with a similar age assignment. In the following tables the generic term *Fusulina* is used by Girty in its broad sense. More precise designations for some of the fusulinids are given by Henbest. The collection numbers given are those of the Geological Survey's permanent collection of Carboniferous fossils. The first 7 collections in the faunal lists given below, which includes 3 of those reported to be of distinctive character, are from the measured section north of the Perry mine. Their location in the section is given in the table on page 59. All but one of the others are from the type localities of the Alta and Cibolo beds as described by Udden (see table on pp. 54–55).[23] Collection No. 7739 is from a point 2.9 miles north-northeast of the Cibolo ranch and 1.3 miles south-southeast of the top of Sierra Alta (pl. 6). The different subdivisions of these two formations from which collections were made are indicated in the table. The names of the subdivisions are those assigned by Udden. It will be noted that all the collections except No. 7736, which has no diagnostic features, came from beds supposed to belong to the Cibolo formation.

The Foraminifera in 8 of the collections were studied by L. G. Henbest, and his determinations are appended to the accompanying lists. Of those examined by Henbest, 4 are from the measured section close to the Perry mine. One of these (No. 7733) came from the highest unit recognized, at a point immediately above the Perry mine, and another (No. 7735) came from the top of the same unit, at a point somewhat farther east, more nearly along the line on which most of the measurements were taken. Collections Nos. 7730 and 7731, as shown in the section on page 59 are from lower beds. The other 4 collections studied by Henbest are all from outcrops of different units in the Cibolo formation as defined by Udden in the vicinity of Sierra Alta.

Henbest's conclusion is that all but two of the collections studied by him represent beds of Bone Spring or younger age. These collections would then suggest that the beds they come from belong to either division B or division C of the Permian according to King,[24] mostly the former. These divisions are regarded as equivalent to the Leonard and Word formations of the Glass Mountains, respectively; hence the character of the Foraminifera found agrees broadly with Sellard's opinion, cited on page 61, that most of the Permian beds in the general vicinity of Shafter are equivalent to the Word and Leonard. Two collections (Nos. 7737 and 7743) are regarded by Henbest as indicating a Wolfcamp age. Both these collections come

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[23] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), pp. 11–13.
[24] King, P. B., op. cit., pp. 791–792, pl. 107.

from Udden's type localities. Collection 7737 came from an outcrop believed to represent the brecciated zone of Udden in the lower part of the Cibolo formation. Collection 7743 came from the thin-bedded zone of Udden near the top of the Cibolo formation. Explanation of the discrepancies between the various fusulinid collections and between the collections of fusulinids and larger fossils will have to await more detailed areal and paleontologic work.

Field and paleontologic investigations have been made subsequent to the preparation of this report by W. E. Cartwright, John Skinner, A. K. Muller, and others. Their results, which have not yet been published, may require modification of some of the present tentative correlations.

Fauna from measured section north of Perry mine. See table on page 59

Collection 7730

Determinations by G. H. Girty:

Fusulina sp.
Sponge spicules.
Lophophyllum sp.
Fistulipora? sp.
Enteletes dumblei Girty.
Chonetes sp.
Productus walcottianus Girty.
Productus dartoni King.
Productus waagenianus Girty?
Productus sp.
Productus wordensis King.
Richthofenia permiana Shumard.
Pugnoides? sp.
Spirifer pseudocameratus of King.
Hustedia meekana Shumard.
Aviculipecten sp.
Euphemites carbonarius Cox?

Henbest states: The specimens are very poorly preserved in this small collection. A few exfoliated specimens show definite septal traces characteristic of cuniculae, thus indicating that the genus is either *Parafusulina* or *Polydiexodina*. On the basis of shape and size of the species, an identification as genus *Parafusulina* seems most likely correct. The age is definitely Permian, most likely middle Permian.

Collection 7731

Determination by G. H. Girty: Fusulina sp.

Henbest reports: This collection contains *Schwagerina setum* Dunbar and Skinner and *Parafusulina maleyi* Dunbar and Skinner. According to present reports the first species indicates a position similar to the Bone Spring formation of the Delaware and Guadalupe Mountains, and the second species the lower or middle formations of the Delaware Mountain group. The specimens of *Schwagerina setum* are slightly more advanced in anatomical development than the Bone Spring variety, because a few of the fused septal plications have developed cuniculae. For this reason, the evidence seems to agree in indicating middle or lower Delaware Mountain age.

Collection 7732

Fusulina sp.
Lophophyllum sp.
Fistulipara sp.
Tabulipara? sp.
Productus dartoni King.
Spirifier sp.

Collection 7733

Determination by G. H. Girty: Sponge spicules (mostly monaxons, according to Henbest).

Henbest reports: This very small collection of sandy limestone containing a great abundance of siliceous sponge spicules contains also a few broken or eroded specimens of *Parafusulina.* The species cannot be identified with assurance, because of the small amount of material, but seems to be close to *P. fountaini* Dunbar and Skinner. According to the known range of similar species *of Parafusulina,* the age of this collection is Bone Spring to middle Delaware Mountain.

Collection 7733a

Determinations by G. H. Girty:

Striatopora sp.
Domopora? sp.
Hustedia meekana Shumard?
Ammonites indet.

Collection 7734

Determinations by G. H. Girty:

Fusulina sp.
Echinocrinus sp.
Fistulipora sp.
Productus popei Shumard.
Productus signatus of King.
Camarophoria sp.
Composita sp.
Myoconcha costulata Girty.

Collection 7735

Determinations by G. H. Girty:

Fusulina sp.
Lophophyllum? sp.
Fistulipora sp.
Batostomella? sp.

Henbest reports: The small chip submitted contains specimens of *Schwagerina,* apparently *Schwagerina setum* Dunbar and Skinner or perhaps *S. franklinensis* Dunbar and Skinner. More material is needed for definite identification. Insofar as the specimens are identifiable they appear to be either Hueco or Bone Spring age.

Fauna from the vicinity of Sierra Alta

Collection 7736

[From the dark shaly unit in the Alta formation]

Determinations by G. H. Girty: Tracks or burrows.

Collection 7737

[From brecciated zone, near base of Cibolo formation]

Determinations by G. H. Girty:

Fusulina sp.
Lophophyllum? sp.
Crinoid columnals (large).
Fistulipora sp.
Enteletes sp.
Productus wordensis King.
Richtofenia? sp.
Spirifer marcoui var. S. infraplica King?

Henbest notes that the collection contains a few specimens of *Schwagerina campacta* (White). He says that the age indicated is Wolfcamp. His conclusion, therefore, differs from that of Girty, who regarded collection 7737 as definitely of Leonard age or younger.

Collection 7738

[From zone of sponge spicules near middle of Cibolo formation]

Determinations by G. H. Girty:

Sponge spicules.

Rhombopora sp.

Collection 7739

[From the zone of sponge spicules in middle of Cibolo formation]

Determinations by G. H. Girty:

Sponge spicules.
Sponge fragments, 2 genera.
Chonetes sp.
Pustula sp.
Aulosteges magnicostatus Girty.
Parallelodon? sp.
Astartella? sp.
Plagioglypta? sp.
Euphemites? sp.
Solenospira? sp.
Holopea? sp.
Naticopsis? sp.
Aclisina sp.
Perrinites vidriensis Böse?
Griffithides? sp.
Paraparchites sp.

Collection 7740

[From thin-bedded zone, near top of Cibolo formation]

Determinations by G. H. Girty:

Acanthocladia sp.
Rhombopora sp.
Schizophoria? sp.
Chonetes quadratus King.
Chonetes subliratus Girty.
Productus leonardensis King?
Productus sp.
Pustula pileola Shumard?
Camarophoria venusta Girty.
Pugnoides texanus Shumard.
Spirifer sp.
Squamularia perplexa McChesney?
Ambocoelia arcuata Girty.
Hustedia sp.
Parallelodon politus Girty.
Parallelodon multistriatus Girty.
Parallelodon aff. P. sangamonensis Worthen.
Parallelodon sp.
Streblopteria sp.
Lima retifera Shumard.
Modiola? sp.
Schizodus aff. S. rossicus de Verneuil.
Astartella nasuta Girty.
Plagioglypta sp.
Bellerophon aff. B. crassus var. wewokanus Girty.
Pleurotomaria alamillana Girty?
Pleurotomaria sp.
Zygopleura n. sp.
Turbo? sp.
Soleniscus? sp.
Holopea n. sp.

Fauna from the east side of Sierra Alta Creek at its confluence with Cibolo Creek

Collection 7741

[From the transition zone at base of Cibolo formation]

Determinations by G. H. Girty:

Fusulina sp.
Chaetetes n. sp.
Lophophyllum sp.
Productus geniculatus Girty.
Productus wordensis King.
Productus waagenianus Girty?
Spirifer pseudocameratus of King.
Squamularia guadalupensis Shumard var.
Composita sp.
Hustedia sp.

Henbest states: The pieces of cherty limestone submitted contain *Schwagerina* and *Parafusulina.* Among these I find specimens of *Schwagerina setum* Dunbar and Skinner and *Parafusulina fountaini* (?) Dunbar and Skinner. The age indicated is Bone Spring.

Collection 7742

[From the zone of sponge spicules, near middle of Cibolo formation]

Determinations by G. H. Girty:

Rhombopora sp.	Productus sp.
Rhipidomella sp.	Spirifer sp.

Henbest states: This collection contains limestone of two lithologic varieties. One is composed largely of shells or fragments of brachiopods, bryozoans, crinoids, and other invertebrates but few if any Foraminifera; the other is a light grayish, pink, partly silicified limestone that contains numerous *Climacammina* and *Parafusulina?*. As classified at present the species of *Climacammina* are rather long-ranging. The one (or more?) fusulinid species is hard to determine as to genus because of its transitional anatomy between *Schwagerina* and *Parafusulina.* On the basis of its relationship to known species I would suppose that its age is most likely Bone Spring to middle Delaware Mountain.

Collection 7743

[From the thin-bedded zone, near top of Cibolo formation]

Determinations by G. H. Girty:

Crinoid columnals.	Spirifer sp.
Enteletes sp.	

Henbest reports: One of the two very small pieces of limestone submitted contains an abundance of calcareous algaloid pellets. Included also is an abundance of smaller Foraminifera, particularly climacamminids, *Hemigordius?*, and porcellaneous shelled sessile foraminifers. A few eroded shells of *Schwagerina compacta* (White) that are smaller than usual for this species are present. The age indicated is Wolfcamp. This species was originally described by White on the basis of specimens from an ant hill that were supposed to have come from the Gaptank formation, but later work shows that the original age determination was an error.

LOWER CRETACEOUS ROCKS

PRESIDIO FORMATION

CHARACTER

The lowest of the Cretaceous formations in this region was named the Presidio formation by Udden,[25] because the principal known exposures are near and southwest of the Presidio mine. Many of these exposures are included in the area mapped in detail during the present investigation. The broader characteristics of the formation are such that five subdivisions can be recognized and mapped throughout the area shown on the detailed map (pl. 7). There is, however, considerable lateral variation in both the lithology and the thickness

[25] Udden, J. A., The geology of the Shafter silver mine district, Presidio County, Tex.: Texas Univ. Min. Survey Bull. 8 (Texas Univ. Bull. 24) p. 25, 1904.

of the different subdivisions, and in places certain of the basal beds are absent.

The basal unit of the Presidio formation, which is 50 to 90 feet thick, consists principally of soft marl, clay, thin-bedded arenaceous limestone, calcareous sandstone, and shell breccia. In some localities a part of these beds is missing; in others all are absent. The distinguishing features of the unit include the softness of the rock and the fact that most beds are mixtures of clayey, sandy, and calcareous material. The overlying unit, which is 90 to a little more than 120 feet thick, contains more sandy limestone and calcareous sandstone and in addition conglomerate and several beds of marl and shale. This unit is distinguished by its greater content of conglomerate and by the fact that some of the sandy beds are rather bright yellow and red. It may be termed the conglomerate unit.

The unit next above consists of three parts and hence may be termed the tripartite unit. It consists of medium-bedded to massive limestone, calcareous sandstone, thin-bedded limestone, in part arenaceous, thin beds of shell breccia composed mainly of *Ostrea* sp. and a fairly massive sandstone, in part calcareous. It is 75 feet or more in maximum thickness. In the lower part, dark-brown calcareous sandstone and medium-bedded to massive sandy limestone predominate. The principal component of the middle part is a thick yellow to gray limestone with numerous veins of calcite, weathering yellow to yellowish gray, but there are several thinner, in part argillaceous, limestone beds, and the beds of shell breccia are composed mainly of *Ostrea* sp. Above this is sandy limestone, which grades upward into white sandstone, in part calcareous, which ranges from 5 feet to more than 20 feet in thickness. The massive yellow limestone near the middle and white sandstone at the top of the tripartite unit make it one of the most easily recognizable subdivisions of the formation. Its upper part contains *Orbitulina* sp. and is the lowest stratigraphic horizon at which this foraminifer was found. The lowest part of the unit is less definitely recognizable than the other two. It is more massive and resistant to erosion than the beds below but locally interfingers with them.

Overlying the beds of the tripartite unit is a group of strata that ranges from 110 to more than 165 feet in thickness. It is composed mostly of soft sandstone, interbedded with numerous thin layers of arenaceous limestone, hard calcareous sandstone, marl, shale, and two rather thick shell breccias. As the breccias constitute the conspicuous and characteristic part of these beds, the name shell-breccia unit is appropriate.

The uppermost part of the Presidio formation consists of rather massive beds of hard arenaceous to fairly pure limestone, with some beds of calcareous sandstone. This unit is resistant to erosion and caps many of the hills in the vicinity of the Presidio mine; hence it is here called the cap rock unit. It is 25 to more than 50 feet thick.

The Presidio formation was studied in detail by Cartwright on the east flank of the butte near the middle of the north border of section 5, block 8, close to the intersection of coordinates 1200 W. and 4800 N. shown on plate 7, with the results listed below. He distinguishes 90 subdivisions. The lower 18 of these, totaling 56.6 feet, belong to the basal unit as defined above. Subdivisions 19 to 48, aggregating 121.2 feet, belong to the conglomerate unit. Subdivisions 49 to 57, totaling 64 feet, belong to the tripartite unit. Subdivisions 58 to 89, composing the shell-breccia unit, total 167.1 feet. In this section the shell breccias are thinner and less conspicuous than in most other localities. The cap-rock unit is here 27.3 feet thick, with the upper part eroded off. The total thickness of the Presidio formation here is thus 436 feet, but the missing part of the cap-rock unit would raise the total to at least 450 feet.

At the time that he measured the section of the Presidio formation tabulated below, Cartwright made incidental notes regarding conspicuous fossils. As these notes constitute the only record of some of these fossils, they are retained in the table. The fossil collections that he made have been studied by J. B. Reeside, Jr., and his determinations (distinguished by serial numbers) have been inserted in the table. Udden[26] cites two detailed sections of the formation. In one section, measured in the hill between the north and east shafts of the Presidio mine, 27 rock units are distinguished, and the aggregate thickness is 415 feet. The second section is in the east shaft, only a little more than 800 feet east of the crest of the hill in which the first was measured. The thicknesses here are based on data obtained by the company's engineers during the sinking of the shaft. Udden distinguishes 18 rock units, totaling 442 feet. The upper part of the cap-rock unit is not included in either of these sections. The table on page 76 summarizes Udden's description of the two sections and gives a tentative correlation with the five members of the Presidio formation distinguished in mapping during the present study. The marked differences in detail betwen these two sections in neighboring localities and between them and the section described above emphasize the amount of lateral variation in the formation. The broader characteristics, however, are sufficiently uniform to permit one, after a little practice, to distinguish such subdivisions as those shown on plate 7 with confidence.

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[26] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), pp. 27–39.

Section of the Presidio formation on slope above intersection of coordinates 1,200 W. and 4,800 N., plate 7

	Feet
Cap-rock unit:	
90. Principally gray to grayish-brown massive hard arenaceous limestone, with some grayish-brown calcareous sandstone and fairly pure limestone. Cartwright reported that the limestone contains fragments of a rudistid, probably *Toucasia*, and concretions of grayish-tan to brown chert	27. 3
Shell-breccia unit:	
89. Largely covered but consisting chiefly of soft calcareous gray to brown sandstone	22. 8
88. Alternating beds of rather massive calcareous sandstone and grayish-brown arenaceous limestone, the sandstone predominating	9. 5
87. Partly covered but essentially soft thin-bedded grayish-brown calcareous sandstone, with a few beds of gray to brown arenaceous limestone	8. 3
86. Covered, probably sandstone	10. 3
85. Yellowish-brown marl	4. 4
84. Grayish-black medium-grained limestone; weathers light gray	. 8
83. Finely laminated grayish-brown nonfossiliferous marl	1. 4
82. Gray sandy marl; weathers grayish tan. Cartwright distinguished *Orbitulina* sp. and *Ostrea* sp., but Reeside (fossil collection 16887) reported only undetermined pelecypods in the material sent to him	2. 2
81. Medium-grained thin-bedded grayish black limestone; weathers light gray. Cartwright noted *Orbitulina* sp	2. 0
80. Gray arsenaceous nonfossiliferous marl. Contains *Luna* sp. and *Camptonectis* sp. (fossil collection 16886)	1. 7
79. Grayish-tan medium-grained limestone; weathers brown to grayish brown, and also weathers into more or less rounded nodules. Cartwright noted *Orbitulina* sp. and *Ostrea*, of which only the former were reported by Reeside (fossil collection 16885)	2. 0
78. Dark steel-gray medium-grained thin-bedded limestone, in part arenaceous; weathers brownish gray	4. 8
77. Impure medium-grained dark-gray limestone; weathers dirty brown. Cartwright and Reeside noted *Orbitulina* sp., and Reeside reported *Ostrea* sp. from either unit 77 or 78 (fossil collections 16883 and 16884)	. 4
76. Steel-gray thin-bedded medium-gray limestone; weathers rusty gray. Cartwright and Reeside noted *Orbitulina* sp. (fossil collection 16882)	4. 0

Section of the Presidio formation on slope above intersection of coordinates 1,200 W. and 4,800 N., plate 7—Continued

	Feet
Shell-breccia unit—Continued.	
75. Covered	15. 8
74. Grayish-tan nonfossiliferous marly shale	4. 1
73. Covered	6. 2
72. Medium-grained gray limestone; weathers into rounded nodules. Cartwright reported *Orbitulina* sp., and Reeside (fossil collection 16881) noted *Camptonectis* sp	1. 0
71. Covered, probably sandstone and marl	7. 4
70. Steel-gray medium-grained limestone, with streaks of tan; weathers grayish-tan. Cartwright noted *Orbitulina* sp	. 7
69. Gray to grayish-tan moderately thin-bedded sandy marl	3. 0
68. Gray arenaceous moderately fine-grained limestone; weathers light brown with splotches of yellow. Cartwright noted fragments of *Ostrea* sp	. 6
67. Calcareous and argillaceous yellowish-tan sandstone	1. 4
66. Dark-gray medium-grained limestone; weathers light gray. Cartwright noted *Ostrea* sp	. 4
65. Soft argillaceous light-tan sandstone; weathers grayish brown	2. 5
64. Dark-gray limestone; weathers gray with a tinge of brown	. 3
63. Shell breccia, made up mostly of *Ostrea* sp., according to Cartwright; matrix consists of soft argillaceous yellow to grayish-tan limestone	7. 6
Fossil collection 16878:	
Cliona sp. borings.	
Membranipora sp.	
Ostrea sp., large elongate form.	
Neithea aff. N. texana (Roemer).	
Fossil collection 16877:	
Serpula sp.	
Ostrea sp.	
Pecten sp., coarse simple ribs.	
Cyprimerial? sp.	
Tylostoma? sp.	
Trochus? sp.	
62. Grayish-brown fine to moderately fine-grained thin-bedded limestone; weathers dirty gray to brownish gray	7. 0
Fossil collection 16876:	
Ostrea sp., fragments.	
Pecten sp.	
Artica (Cyprina) sp.	

Section of the Presidio formation on slope above intersection of coordinates 1,200 W. and 4,800 N., plate 7—Continued

	Feet
Shell-breccia unit—Continued.	
61. Shell breccia consisting, according to Cartwright, chiefly of broken shells of *Ostrea* but containing several other fossils, including *Orbitulina* sp.; matrix consists of soft yellow or tan to grayish brown somewhat sandy marl	8. 2
Fossil collection 16875:	
Ostrea sp., elongate form.	
Pecten sp., distant coarse ribs.	
Artica (Cyprina) sp.	
60. Medium-grained light-gray to grayish-black limestone; weathers gray to steel gray; contains, according to Cartwright, *Tylostoma* sp. and *Orbitlina* sp	6. 8
Fossil collection 16874:	
Orbitulina sp.	
Ostrea sp.	
Lunatia pedernalis Roemer.	
59. Grayish-tan to yellowish-brown calcareous medium-bedded to massive sandstone; weathers tan to brown. Cartwright found *Orbitulina* sp., and Reeside reported fragments of *Ostrea* sp. (fossil collection 16873)	7. 1
58. Medium-grained dark steel-gray thin-bedded limestone; weathers gray to grayish brown. Both Cartwright and Reeside (fossil collection 16872) reported numerous *Orbitulina* sp	12. 4
Tripartite unit:	
57. Principally arenaceous limestone below and gray to yellowish-white sandstone, in part calcareous, above; the sandstone weathers grayish tan to a glaring white and is one of the most easily recognizable beds in the Presidio formation. Cartwright reported *Orbitulina* sp. and fragments of *Ostrea*	6. 1
56. Grayish-black medium-grained rather flaky arenaceous limestone; weathers gray; Cartwright noted *Orbitulina* sp. Reeside found *Orbitulina* sp., *Ostrea* sp. (fragments), and *Artica* (*Cyprina*) sp.? (fossil collection 16871, representative of units 55 and 56)	2. 0
55. Dark grayish-black medium-grained somewhat argillaceous limestone; weathers gray to steel gray. Cartwright noted abundant *Orbitulina* sp	4. 2
54. Shell breccia, made up principally of broken *Ostrea* shells; matrix is a yellow to brownish-gray marl. Yielded *Serpula* sp. and a large elongate species of *Ostrea* (fossil collection 16870)	5. 4
53. Dark grayish-black flinty limestone; weathers dark gray to grayish black	3. 0

Section of the Presidio formation on slope above intersection of coordinates 1,200 W. and 4,800 N., plate 7—Continued

	Feet
Tripartite unit—Continued.	
52. Fine-grained grayish-brown to dark-gray argillaceous limestone; weathers dark gray and into more or less rounded nodules	2. 0
51. Gray to yellow medium- to fine-grained limestone, veined with calcite and in some parts slightly brecciated; usually weathers a pale to a distinct yellow but sometimes gray; beds massive, with a thin bed here and there; fossils scarce or absent	26. 5
50. Grayish-brown to steel-gray medium-grained limestone, gray arenaceous limestone, and yellowish-brown calcareous sandstone, the limestone predominating; occurs in medium to massive beds	11. 8
49. Medium to moderately fine-grained yellowish-brown to grayish-black thin-bedded limestone; contains a few fragments of *Ostrea*	3. 0
Conglomerate unit:	
48. Alternating beds of tan to brown calcareous sandstone and fine-grained gray argillaceous limestone. Contains "worm" borings (fossil collection 16869, which represents units 47 and 48)	6. 0
47. Alternating beds of grayish-brown arenaceous limestone, dark-gray limestone, and rusty calcareous sandstone; occurs in thin to medium beds	18. 0
46. Conglomerate containing angular to rounded pebbles of limestone and quartz; matrix consists of medium to coarse sand grains	8. 0
45. Alternating beds of gray to steel-gray medium-grained limestone, in part arenaceous, and soft brown to tan calcareous sandstone containing fucoids. Contains "worm" trails and borings (fossil collection 16868)	8. 0
44. Coarse grayish-brown nonfossiliferous limestone; weathers yellowish-tan	1. 1
43. Light-tan shale, thinly laminated	1. 5
42. Medium-grained grayish-black limestone; weathers grayish brown	. 7
41. Brown shale	1. 0
40. Dark-gray medium-grained limestone; weathers gray with tinge of tan	1. 1
39. Calcareous grayish-brown sandstone; weathers yellowish gray	. 2
38. Brown shale	1. 0
37. Brown to black marl, thinly laminated; contains some bituminous matter	. 6
36. Tan to brown nonfossiliferous marl	4. 3
35. Dark-gray medium-grained impure limestone; weathers grayish brown; contains fragments of *Ostrea*	. 6

Section of the Presidio formation on slope above intersection of coordinates 1,200 W. and 4,800 N., plate 7—Continued

Conglomerate unit—Continued.	Feet
34. Dark-gray shale	2. 9
33. Brownish-gray moderately fine-grained limestone; weather yellowish brown	. 3
32. Gray marl	. 8
31. Medium-grained thin-bedded grayish-brown limestone. Cartwright noted a few fragments of *Ostrea*, and Reeside (fossil collection 16866, representative of units 28–31) reported *Orbitulina* sp	4. 0
30. Argillaceous and calcareous grayish-brown sandstone; weathers tan to brown	2. 4
29. Fine-grained gray argillaceous limestone; weathers light gray	1. 6
28. Soft brownish-tan thin-bedded argillaceous sandstone; weathers light brown	3. 0
27. Reddish-brown to tan moderately fine-grained to fine-grained limestone; weathers reddish brown to rusty brown; in part veined with calcite	7. 0
26. Gray arenaceous medium-grained limestone; weathers light gray	3. 3
25. Soft calcareous tan to brown sandstone; contains some medium-sized pebbles of quartz and worn limestone	3. 0
24. Covered, probably sandstone	3. 0
23. Light-brown calcareous sandstone; weathers light tan. Contains *Orbitulina* sp. (fossil collection 16865, which represents units 22 and 23)	2. 0
22. Fine-grained gray limestone; weathers dark gray	3. 3
21. Alternating beds of rusty calcareous sandstone and grayish-brown arenaceous limestone medium to fairly thick bedded	8. 3
20. Light-tan to brown calcareous sandstone in thin to medium beds; some of the beds are slightly conglomeratic. Contains *Exogyra texana Roemer* (fossil collection 16863)	12. 5
19. Very fossiliferous grayish-brown moderately coarse-grained limestone in thin to medium beds; contains numerous small pelecypods	11. 7

Fossil collection 16862 (represents units 18 and 19):

Ostrea sp., elongate form.
Exogyra texana Conrad.
Cucullaea sp.
Trigonia? sp.
Pecten sp.
Cardita? sp.
Corbis? sp.
Fasciolaria? sp.

Section of the Presidio formation on slope above intersection of coordinates 1,200 W. and 4,800 N., plate 7—Continued

	Feet
Basal unit:	
18. Dark-gray moderately fine-grained limestone; contains an abundance of fine impurities	0.3
17. Shell breccia, made up mostly of *Ostrea;* according to Cartwright, matrix yellow to brown marl. Reeside found (fossil collections 16860, 16861) *Ostrea* sp. (elongate form), *Serpula* sp., *Trigonia* cf. T. *emoryi Conrad,* and fragments of a *Naticoid* gastropod	7.2
16. Brown calcareous sandstone; weathers grayish tan. Contains *Ostrea* (*Alectryonia*) cf. *O. subovata* (Shumard), *Ostrea* sp., elongate form, and a fragment of a *Pinna* sp. (fossil collection 16859, representative of units 15 and 16)	2.8
15. Medium-grained grayish-black arenaceous limestone; weathers steel gray	3.2
14. Grayish-black rather coarse-grained very fossiliferous limestone. Contains *Ostrea*? sp., *Exogyra texana Conrad, Pecten* sp., and *Trigonia*? sp (fossil collection 16858, which represents units 11-14)	1.7
13. Medium-grained gray limestone; weathers light grayish brown	2.3
12. Grayish-brown medium-grained arenaceous limestone	.5
11. Light-gray thin-bedded limestone; weathers steel gray	.7
10. Dark-gray moderately fine-grained arenaceous limestone	1.1
Fossil collection 16857 (represents units 5-10 inclusive): Serpula sp. Ostrea sp., elongate form. Ostrea (Alectryonia) cf. O. subovata (Shumard). Exogyra texana Conrad. Trigonia cf. T. emoryi. Anomia sp. Lucina? sp. Corbis? sp. Cyprimeria sp. Corbula? sp. Turritella cf. T. seriatim-granulata Roemer. Fasciolaria? sp.	
9. Light-gray calcareous sandstone; weathers grayish-brown	1.2

Section of the Presidio formation on slope above intersection of coordinates 1,200 W. and 4,800 N., plate 7—Continued

	Feet
Basal unit—Continued.	
8. Gray fossiliferous calcareous sandstone, in part almost a shell breccia; contains a few disklike concretions and an abundance of small pelecypods	0. 8
7. Gray nearly pure fairly coarse-grained nonfossilliferous limestone, weathers brown	. 4
6. Grayish-brown sandstone; weathers tan to grayish brown; contains myriads of small pelecypods	1. 7
5. Alternating beds of brown calcareous sandstone and gray limestone, in part arenaceous; the sandstone contains a few rounded concretions; both the limestone and the sandstone contain numerous fossils	5. 2
4. Moderately fine-grained gray limestone; weathers into somewhat rounded nodules; fossils scarce or absent	8. 3
3. Grayish-tan medium-grained arenaceous limestone; weathers tan to light brown	2. 8
Fossil collection 16856:	
Sepula sp.	
Ostrea sp., elongated form.	
Ostrea (Alectryonia cf. O. subovata (Shumard).	
Exogyra sp.	
Cucullaea sp.	
Small pelecypods, undetermined.	
Ammonite fragment, possibly Hamites.	
2. Brown clay slightly calcareous	4. 0
1. Covered, but essentially gray to brown clay and marl	12. 4
	436. 2

Angular unconformity.
Permian: Yellow limestone (Cibolo formation).

Approximate correlation of Udden's sections of the Presidio formation with map units of the present report

Present report	Udden's sections	
	Hill between north and east shafts of Presidio mine	East shaft of Presidio mine
Cap-rock unit.	Hard arenaceous limestone. 30 feet.	Hard arenaceous limestone. 34 feet.
Shell-breccia unit.	Poorly exposed, mostly soft, arenaceous and argillaceous limestone, with a brecciated ledge below. 82 feet.	Gray sandstone. 17 feet.
	Sandy shell breccia. Fragments are small. 3 feet.	Yellowish gray calcareous sandstone. 21 feet.
	Dark-gray limestone with imbedded sandy coarse shell breccia in upper part. 29 feet.	Dark shell breccia. 72 feet.
	Dark gray impure sandy limetsone. 12 feet.	
Tripartite unit.	Light-gray moderately coarse sandstone. 15 feet.	Fine-grained arenaceous limestone. 28 feet.
	Gray limestone. 12 feet.	Gray sandstone, with sparse calcareous cement. 34 feet.
	Gray limestone, in part brecciated. 28 feet.	Fine-grained dark-gray limestone, with scattered quartz grains. 11 feet.
	Thin-bedded soft marl. 10 feet.	
	Grayish-white sandy limestone. grading upward into a sandstone. 29 feet.	Yellow limestone. 14 feet.
		Gray sandy limestone. 28 feet.
Conglomerate unit.	Hard gray calcareous sandstone. 7 feet	Yellow marl, with scattered chert pebbles. 14 feet.
	Sandy conglomerate, locally coarse-bedded. 14 feet.	Conglomerate. 40 feet.
	Gray fine-grained slightly arenaceous limestone. 4 feet.	Gray arenaceous limestone. 14 feet.
	Sandy marl, with a conglomerate bed; in upper part beds of yellow and red brecciated limestone. 26 feet.	Gray calcareous sandstone. 14 feet.
		Dark shell breccia. 25 feet.
		Brownish-gray sandstone. 2 feet.
	Dark concretionary limestone. 26 feet.	
Basal unit.	Fine-grained gray sandstone. 1 foot.	Dark-gray sandy limestone. 42 feet.
	Gray sandy shell breccia. 14 feet.	
	Light-gray marl, with yellow sand laminae. 6 feet.	
	Gray laminated shale, with narrow sandy and calcareous bands. 7 feet.	
	Gray calcareous sandstone, with layers of sandstone and shell breccia. 14 feet.	Dark-gray sandstone, with calcareous cement. 6 feet.
	Gray marl. 8 feet.	
	Gray sandy limestone, with some conglomerate. 2 feet.	
	Gray marl. 9 feet.	
	Hard dark limestone. 2 feet.	
	Gray marl, with sandy shell breccias above. 2 feet.	
	Gray marl with concretions. 6 feet.	Gray clayey limestone, 26 feet.
	Bluish gray clay. 17 feet.	

AGE

Udden[27] states that "lithologically the Presidio beds are identical with R. T. Hill's Travis Peak formation of the Grand Prairie region, and the two are analogous in position." Because there are faunal differences he assigned to them the local name "Presidio beds."

Cartwright, on the basis of his field examination, agrees that lithologically and probably also paleontologically there is close resemblance between the Presidio and Travis Peak formations. The absence of *Dufrenoza* in the Presidio is the main paleontologic difference he noted between that formation and the Travis Peak. Reeside's work on the fossils collected by Cartwright (pp. 67–76), however, leads him to think that the paleontologic resemblance is not very close. He says that certain forms, such as *Lunatia pedernalis* Roemer, supposed to be of Glen Rose age, are present in the Presidio formation. He is, however, satisfied that the Presidio formation falls within the age range of the Trinity group. T. W. Stanton, who has been so kind as to look over the fossil collections, agrees with Reeside that the Presidio formation contains fossils regarded as indicative of Glen Rose age.

From the standpoint of their revelation of the age of the rocks, the most important fossil collections made during the present investigation are those from the measured section of the formation. The fossil determinations are listed with the lithologic description of the section given above. In addition 4 other collections from the Presidio formation were studied by Reeside, with the determinations listed below:

No. 16912:
- Orbitulina sp.
- Tylostoma tumida Shumard.
- Tylostoma regina (Cragin).

No. 16913: Exogyra cf. E. quitmanensis Cragin.

No. 16914: Trigonia taffi Cragin.

No. 16917:
- Large shell of an ostreid pelecypod with borings of the sponge *Cliona*. May be *Exogyra walkeri* White.
- Echinoid spines.
- Fragments of thick fibrous shell, probably Inoceramus.
- Fragments of shell that may represent an ammonite.

Reeside regarded all but No. 16917 as definitely of Trinity age and thought that Nos. 16912 and 16914 were probably of Glen Rose age. These and also No. 16913 are from the shell breccia unit of the Presidio formation from outcrops close to the road to Presidio, in the southeast part of the area shown on plate 7. Collection 16917 is from an isolated outcrop of limestone resembling the capping unit of the Presidio formation close to the shaft of the Cibolo Mining

[27] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), p. 30.

Co. Reeside says it is definitely Cretaceous but that he cannot determine it more closely.

SHAFTER LIMESTONE (RESTRICTED)

CHARACTER

The rocks here designated "Shafter limestone" are exposed in and around the town of Shafter and on the banks of Cibolo Creek south of Shafter and form part of a prominent range of hills about 3.2 miles southeast of Shafter and the valley north of the range. They appear to rest unconformably on the Presidio formation.

The Shafter formation as defined by Udden[28] contains rocks of both Trinity and Fredericksburg age. As the Walnut (?) and other younger rocks are susceptible of being mapped separately and are not present close to Shafter, it is here proposed to restrict the name "Shafter" to beds of upper Trinity age.

A section of the Shafter limestone, as here restricted, was measured at a locality 3 to 3.6 miles southwest of Shafter and about 0.2 mile south of the Stauber prospect. Its measurement is estimated to be correct within 15 percent. This section, presented in detail on pages 79–83, is about 1,085 feet thick. As in the section of the Presidio formation, palentologic notes by Cartwright are cited, and more complete data, distinguished by the serial numbers of the Geological Survey permanent collections, are added by Reeside. Udden,[29] on the basis of several partial sections, reported a total of about 700 feet of the Shafter limestone, including 80 to 120 feet of strata approximately of Walnut age, not here included in the formation. The following generalized description applies particularly to the formation as seen in the neighborhood of the Stauber mine.

The lower 200 feet of the Shafter consists of limestone beds separated by local thin beds of marl. The next 100 feet consists mostly of limestone, with several sandstone beds, and a few more marl beds than were present in the lower beds. The next 175 feet is almost entirely limestone, with numerous thin marl partings in the lower part and only a few marl partings near the top. Above this are about 150 feet of alternating beds of limestone and marl, the limestone predominating. Overlying these are about 125 feet of alternating beds of limestone, marl, and sandstone in which the limestone predominates, but the marl beds are thicker and more numerous than below. The next 75 feet consists largely of marl and limestone but contains one bed of clay and one of sandstone. The next 200 feet contains slightly more marl than limestone, and the sandstone beds are also more numerous. The uppermost 65 feet consists of alternating beds of limestone and marl, with one thin bed of sandstone near the top.

[28] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8, pp. 30–39.

[29] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), pp. 31–38.

The lithologic character of the Shafter shows less lateral variation than that of the Presidio formation, but several of the sandstone beds thin abruptly and are replaced by limestones.

Section of the Shafter limestone, 3 to 3.6 miles southwest of Shafter

	Feet
Walnut (?) formation	80–120
Shafter limestone:	
51. Thin- to thick-bedded steel-gray limestone; weathers light gray to grayish brown; massive beds are hard and contain fragments of *Exogyra texana*	20
50. Pink to reddish-brown rather coarse-grained limestone	7
49. Massive grayish-brown to gray limestone; weathers yellowish gray to grayish brown. Cartwright noted fragments of *Exogyra texana.* Reeside (fossil collection 16906) noted these and *Nerinea* sp., probably unnamed	11
48. Alternating beds of grayish-white limestone and gray to whitish-gray marl. Part of the limestone is crowded with *Exogyra texana*	15
47. White or pink to tan medium- to thick-bedded sandstone	11
46. Dioritic sill	13
45. Alternating beds of gray to steel-gray thin-bedded limestone and thin gray to grayish-white marl; slightly more limestone than marl; contains *Exogyra texana, Porocystis globularis,* and other fossils	28
44. Light steel-gray moderately fine-grained limestone, with a few thin partings of gray marl; the limestone ranges from thin beds below to massive beds in the upper part; contains fragments of *Exogyra texana*	27
43. Gray to grayish-white marl	12
42. Soft thin- to medium-bedded white or yellowish-white to pink fairly coarse-grained sandstone; weathers yellowish white to rusty brown	9
41. Alternating beds of thin- to medium-bedded gray to grayish-brown limestone, which weathers light gray, and white to gray marl. The limestone contains, according to Cartwright, *Exogyra texana* and *Orbitulina* sp.	24

Fossil collection 16905:

Orbitulina.
Echinoid spines.
Cucullaea sp. mold.
Exogyra texana Conrad.
Neithea cf. N. subalpinis Böse.
Artica sp., large mold.
Lucina? sp.
Lunatia pedernalis (Roemer).
Tylostoma? sp., fragment.

Section of the Shafter limestone, 3 to 3.6 miles southwest of Shafter—Continued

	Feet
Shafter limestone—Continued.	
40. Reddish-brown hard limestone, internally grayish-brown. Reeside (fossil collection 16904) noted *Ostreid* fragments, suggestive of *Exogyra texana Conrad*	3
39. Yellowish-red to brick-red coarse-grained sandstone; weathers rusty brown to pinkish red	17
38. White to greenish-gray marl	7
37. Alternating beds of thin-bedded gray limestone, with streaks of yellow and whitish-gray marl, and one thin sandstone bed. The limestone contains *Porocystis globularis* and *Exogyra texana*	41
36. Yellowish-brown or pink to brick-red fairly coarse- to medium-grained sandstone	12
35. Grayish-brown marl	5
34. Thin- to medium-bedded moderately fine-grained light-gray to grayish-tan limestone; weathers into flat to rounded nodules; Cartwright noted fragments of what appears to be *Exogyra texana*	13
Fossil collection 16903:	
Orbitulina sp.	
Cidarid echinoid, abraded.	
Holaster sp. fragment.	
Exogyra texana Conrad.	
Neithea cf. N. subalpinis Böse.	
Homomva cf. H. bravoensis Böse.	
33. Gray to brown shale containing several thin beds of grayish-brown to reddish-brown limestone	8
32. Partly covered, but essentially thin-bedded gray limestone interbedded with grayish-white marl. The limestone contains *Orbitulina texana*	31
31. Gray fine-grained limestone; weathers light gray. Cartwright and Reeside noted a few fragments of *Ostrea* (fossil collection 16902)	5
30. Pink or reddish-pink to yellow-brown sandstone in medium to thick beds; weathers yellowish tan to reddish brown	19
Fossil collection 16901:	
Ostrea sp., fragments.	
Neithea occidentalis Conrad.	
Arctica (Cyprina) sp.	
Cardium sp.	
29. Tan to brown soft marl containing one bed of grayish-brown limestone and a gray medium-grained limestone, in which Cartwright noted *Orbitulina* sp	11
Fossil collection 16900:	
Orbitulina sp.	
Ostrea sp.	
Pecten occidentalis Conrad?	
Trigonia emoryi Cragin?	
Arctica (Cyprina) sp.	

Section of the Shafter limestone, 3 to 3.6 miles southwest of Shafter—Continued

Shafter limestone—Continued.	*Feet*
28. Gray to grayish-tan medium-grained limestone containing *Orbitulina texana*	9
27. Whitish-yellow and reddish-brown to rusty-brown thin-bedded sandstone	7
26. Partly covered but consisting essentially of gray to steel-gray thin-bedded limestone, with numerous gray marl partings; the limestone contains *Orbitulina texana*	36
25. Gray to grayish-tan limestone and gray marl. The limestone, according to Cartwright, contains *Porocystis globularis, Tylostoma,* sp., *Orbitulina* in abundance, and several unidentified echinoids	19
Fossil collection 16899: Porocystis globularis (Giebel). Orbitulina sp. Heteraster sp. Ostrea sp. Neithea occidentalis Conrad. Cardium sp. Arctica (Cyprina)? sp. Lunatia pedernalis (Roemer). Tylostoma.	
24. Yellowish-red soft sandstone	2
23. Gray thin-bedded hard limestone; weathers gray, with splotches of yellow	7
22. Thin- to medium-bedded gray to light-gray limestone; weathers light gray to whitish gray. Cartwright noted fragments of a rudistid, probably *Toucasia*, and *Orbitulina* sp. Reeside reported (fossil collection 16898) *Orbitulina* sp. and a coral? fragment	18
21. Steel-gray thin-bedded limestone separated by several thin beds of gray marl. The limestone contains *Orbitulina* sp	15
20. Gray to steel-gray thin- to medium-bedded moderately fine-grained limestone; weathers light gray. Cartwright noted *Porocystis globularis* and *Orbitulina* sp	34
Fossil collection 16897: Orbitulina sp. Heteraster sp. Arctica (Cyprina) sp. Lucina? sp. Homomya? sp. Lunatia pedernalis (Roemer).	
19. Whitish-gray to gray thin-bedded limestone, in part slightly argillaceous. According to Cartwright some of the beds contain numerous *Orbitulina* sp. Reeside (fossil collection 16896) noted these and *Ostrea* sp	48

Section of the Shafter limestone, 3 to 3.6 miles southwest of Shafter—Continued

	Feet
Shafter limestone—Continued.	
18. Gray to grayish-tan thin- to medium thich-bedded limestone; weathers grayish brown	36
17. Steel-gray fine-grained limestone; medium-bedded in the upper part thin-bedded below	14
16. Thin-bedded gray to brownish-gray limestone and gray marl; the limestone is moderately fine-grained, weathers grayish brown to light gray, and according to Cartwright contains a few *Porocystis globularis*. Reeside (fossil collection 16895) noted these and some rudistid fragments	24
15. White to gray marl, with a few thin beds of light-grey limestone	10
14. Grayish-brown to steel-gray fine- to medium-grained limestone; weathers gray or brownish gray to light brown; thin-bedded below, medium-bedded in the middle, and thick-bedded, with a few thin beds, in the upper part. Cartwright noted that some of the beds contain *Orbitulina* sp. in profusion, and a rudistid, probably *Toucasia* occurs in several of the harder beds. Reeside found (fossil collection 16894) *Orbitulina* sp., an undetermined fragment of a coral, and some other undertermined organism	110
13. Thin-bedded steel-gray limestone, separated by a few marl partings. Cartwright noted that the limestone contains numerous *Orbitulina* sp. and a few *Porocystis globularis*. Reeside reported (fossil collection 16893) *Orbitulina* sp., *Arctica* (*Cyprina*) sp., and *Ostrea* sp	63
12. Dark-gray moderately fine-grained medium- to thick-bedded limestone; contains *Orbitulina* sp. Reeside reported (fossil collection 16892) *Orbitulina* sp., *Salenia*? sp., and *Exogyra*? sp	15
11. Fine-grained gray thin-bedded limestone; weathers light gray; contains *Orbitulina* sp	16
10. Yellowish-white fairly hard coarse-grained sandstone; weathers reddish brown to rusty brown	15
9. Principally thin-bedded gray limestone, separated by a few occasional thin partings of gray to grayish-tan marl. Cartwright noted that the limestone contains *Orbitulina* sp. and *Porocystis globularis* in abundance, as well as several other fossils	41
Fossil collection 16890: Porocystis globularis (Giebel). Orbitulina sp. Ostrea sp., juvenile individuals. Arctica (Cyprina) sp. mold. Lunatia pedernalis (Roemer). Tylostoma sp. Turritella? sp., section. Actaeonella? sp., section.	

Section of the Shafter limestone, 3 to 3.6 miles southwest of Shafter—Continued

	Feet
Shafter limestone—Continued.	
8. Yellowish-red fairly coarse-grained sandstone; weathers yellowish red to brick red	20
7. Mostly thin-bedded fossiliferous steel-gray limestone, with a few marl partings. Cartwright noted that *Porocystis globularis* and *Orbitulina* sp. are abundant and other fossils are numerous	60
Fossil collection 16889:	
Porocystis globularis (Giebel).	
Orbitulina sp.	
Cardium? sp.	
Lunatia pedernalis Roemer.	
6. Gray to grayish-black medium-grained limestone in thin to medium beds; weathers light gray; some of the thin layers are hard and contain a rudistid, identified by Reeside (fossil collection 16888) as *Toucasia texana* Roemer	21
5. Thinly laminated nonfossiliferous gray marl	12
4. Alternating thin-bedded steel-gray fine-grained limestone and grayish-brown marl. The limestone weathers grayish brown	36
3. Grayish-brown to gray marl	6
2. Gray thin-bedded limestone, with a few marl partings	23
1. Medium-bedded hard-gray limestone; contains some brown chert	19
	1, 085

AGE

The Shafter limestone, as restricted in this paper, is lithologically similar to the Glen Rose limestone and contains a similar faunal assemblage. Such forms as *Porocystis globularis* (Giebel) are considered distinctive of Glen Rose age and among the collections made during the present investigations were found only in material from the measured sections of Shafter strata. On the other hand, *Douvilleiceras* and other ammonities of Glen Rose age appear to be absent, and some fossils generally regarded as indicative of Glen Rose age range downward into the Presidio formation. Thus, while the Shafter limestone is probably of about the same age as the Glen Rose limestone, precise equivalence has not yet been established. Of the collections listed above, Stanton notes that Nos. 16889 to 16900 contain a Glen Rose fauna and Nos. 16901 to 16906 are probably of that age, but the fossil assemblage is not complete.

WALNUT (?) FORMATION

As indicated above, it is here proposed to separate beds of Walnut age from the Shafter limestone. Udden[30] long ago suggested that beds of this age were probably present in the vicinity of Shafter.

[30] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), p. 38.

The formation is from 80 to 120 feet thick in the region south of Shafter. It is distinguishable from the underlying Shafter limestone (restricted) by a greater proportion of marl and clay and correspondingly less limestone. In the localities visited, sandstone is not present in the Walnut (?) formation. The marls and clays are generally thicker and lighter than those of the Shafter, and the limestones are characteristically softer. Thin shell breccias made up mainly of *Exogyra texana* with a calcareous matrix, are locally present.

AGE

Cartwright, on the basis of his field study of the fossils in this formation regards it as of Walnut age. Among the fossils collected are *Exogyra texana*, which is abundant, *Gryphaea marcoui*, *Holectypus planatus*, *Pseudodiadema? texana*, and an ammonite, not well preserved but belonging to the *Engonoceratidae*.

Two collections of fossils from the beds assigned to the Walnut (?) in this area were examined by Reeside, with the determinations listed below. He regards both collections as of Fredericksburg age but makes no closer designation.

Collection 16908. From the entire thickness of the supposed Walnut formation on top of the measured sections of Shafter limestone described on pp. 79–83:

Holaster? sp., small corroded specimen.
Gryphaea marcoui Hill and Vaughan.
Exogyra texana Conrad.
Artica? sp., mold.

Collection 16909. From 5.3 miles south of Shafter and 0.7 mile west of the lower end of the Canyon of Cibolo Creek:

Echnoid, undetermined.
Gryphaea mucronata Hill and Vaughan.
Exogyra texana Conrad.
Neithea occidentalis Conrad.
Lunatia pedernalis (Roemer).
Aporrhais? sp.
Turritella? sp.
Egonoceras sp., fragment.

Stanton finds nothing in the available faunal evidence incompatible with the concept that the beds are of Walnut age, but questions whether precise equivalence can be established. Present purposes may be served by terming the beds the Walnut (?) formation.

DEVILS RIVER LIMESTONE

The beds that overlie the Walnut (?) formation south of Shafter are part of a thick succession of rather massive limestones that is widespread in the region included in the Big Bend of the Rio Grande. These beds have affinities with the Georgetown and Edwards limestones as mapped in other parts of Texas, but no basis for consistent mapping of subdivisions is known; consequently the entire sequence has been designated the Devils River limestone.[31] This is a general term originally applied by Udden to broadly similar beds without mappable subdivisions in Val Verde County, Tex.[32] The lower and middle parts of the beds of this formation exposed near Shafter were hurriedly examined by Cartwright at several locations, all some distance south of the area studied in detail. The best exposures seen are those at the north end of Cibolo Canyon, about 6 miles south of Shafter, and those that cap a range of hills about 3 miles southwest of Shafter. Udden [33] estimated the total thickness of the formation to be not less than 350 feet, which suggests that only a part of the Devils River limestone is here exposed. The formation in the Terlingua region is estimated to be over 1,500 feet thick.

At the localities visited, the Devils River strata consists of white to gray generally crystaline limestones. The beds become progressively more massive upward. In the lower 30 to 50 feet of beds *Exogyra texana* is present, but rudistid forms and flint nodules are absent, observations that lend support to the concept, advanced by Udden, that the lower part of the formation is of Comanche Peak age.

The overlying beds are very similar, except that they contain abundant lenses and concretions of grayish-brown and tan flint. Some of the lenses are more than a foot thick. These beds, thought to be of Edwards age, are at least 150 to 200 feet thick.

Rudistids, of which *Toncasia* and *Monoplena* were recognized in the field, are present at several horizons. Other fossils are rare. Collection 16910, from the canyon of Cibolo Creek, 6.2 miles south-southeast of Shafter, is reported by Reeside to contain *Neithea duplicosta* (Roemer), *Toucasia patagiata* (White), and *Caprinula* sp., and to be of Edwards age.

QUATERNARY DEPOSITS

ALLUVIUM

Valley floors and some of the slopess above them are covered more or less completely by alluvial deposits. As plate 6 shows, such deposits are widespread on parts of the rolling intermontane lowlands and on the gentle slopes between the Chinati Mountains and the Rio Grande. The alluvium consists of gravel, sand, and silt. The more

[31] Ross, C. P., and Cartwright, W. E., Preliminary report on the Shafter mining district, Presidio County, Tex., Texas Univ. Bull. 3401, p. 596, 1935. Ross, C. P., The quicksilver deposits of the Terlinqua region, Texas: Econ. Geology, vol. 36, No. 2, pp. 120–123, 1941.

[32] Udden, J. A., Report on a geological survey of the lands belonging to the New York, and Texas Land Co., Ltd., in the Upper Rio Grande Embayment in Texas: Augustana Library Pub. No. 6, p. 56, 1907.

[33] Udden, J. A., The geology of the Shafter silver mine district, Presidio County, Tex.: Texas Univ. Min. Survey Bull. 8 (Texas Univ. Bull. 24), p. 39, 1904.

recent deposits are unconsolidated, but the older ones are compacted and contain some calcium carbonate. Differences of this sort, coupled with the fact that some of the alluvium has been deformed, particularly on the steeper slopes, show that alluvial deposits of more than one age exist. The deposits in present stream channels are obviously recent, and all of the unconsolidated alluvium is presumably of Quaternary age. No evidence in regard to the age of the tilted and partly consolidated deposits was obtained, but it is not probable that they are older than Pliocene.

IGNEOUS ROCKS

EFFUSIVE ROCKS

In the central part of the Chinati Mountains and in the plateau area east and north of Shafter extensive masses of effusive rocks of probable Tertiary age are exposed. Marginal parts of these masses are shown on plate 6, but the rocks were not studied during the present investigation. The broadly similar volcanic rocks along the eastern margin of the plateau east of Shafter [34] include trachyte, soda trachyte, rhyolite, andesite, and tuff. In that region Upper Cretaceous beds locally contain enough glass shards and other fragmental volcanic material to prove that volcanism began during that period, but the strata in which lava flows predominate seem clearly to be of Tertiary age. In places in the Terlingua region there is an angular unconformity between dominantly sedimentary beds of Upper Cretaceous age and the Tertiary volcanic strata, but in other parts of that region the two are conformable. The lava flows and tuffs near Shafter seem, on the basis of reconnaissance examination, to be essentially coextensive with those of the Terlingua region. Hence it is probable that the lavas and associated beds near Shafter are of early Tertiary age. The younger Cretaceous beds so abundant near Terlingua are absent near Shafter. The volcanic rocks rest unconformably on earlier Cretaceous and probably locally on Permian strata. They are faulted and warped but have not been as sharply deformed as the Cretaceous and older strata.

INTRUSIVE ROCKS

The intrusive rocks near Shafter include dark, much-altered mica andesite, fresher buff mica andesite, hornblende-augite andesite, and some basalt and gabbro. The dark mica andesite and the basalt form narrow dikes in and near the Presidio mine. As they cannot be distinguished from each other in the deeply weathered exposures, they

[34] Ross, C. P., The quicksilver deposits of the Terlingua region, Texas: Econ. Geology, vol. 36, No. 2, pp. 122–123, 1941.

are grouped together on plate 7. All the buff andesite bodies may be sills, although exposures are not everywhere adequate to prove this. The more irregular and in part larger masses of hornblende-augite andesite are also somewhat sill-like. Only one mass of gabbro has been recognized; this is close to the road, in section 1, block 8, but is too small to show on plate 6, and is outside of the area mapped in detail on plate 7.

DARK MICA ANDESITE

At least 12 narrow dikes of dark intrusive rock crop out close to the Presidio mine. Some of these and others that have not been recognized at the surface are exposed in the mine workings. Small sills are also reported to be exposed in the workings.[35] Many of the dikes are dark mica andesite.

In most of these dikes a large part of the rock consists of feathery laths of altered feldspar, whose length varies in different dikes from 0.05 to 0.20 millimeter. The phenocrysts include altered feldspar and mica and are as much as 2 millimeters in length. They make up as much as 15 percent of some of the dikes. The feldspar is kaolinized and locally has been partly replaced by calcite and fine quartz aggregates with some sulfides and their alteration products. This extensive alteration, coupled with the fact that twinning lamellae are rare and poorly defined, prohibits precise determination, but the indices of refraction indicate that the feldspar has approximately the composition of oligoclase. The mica, now bleached and chloritized, is believed to have been originally biotite. Some apatite, magnetite, and titanite are present.

Wherever exposed, the dark mica andesite is deeply weathered. Commonly the only indication of the presence of the dikes is that given by parallel-walled trenches, which look somewhat like narrow roads sunk a foot or more below the ground level. The floor of the trench consists of soil mingled with chips of kaolinized dike rock. Plate 11, *B* illustrates a typical dike depression. Partial analyses of two of the altered dike rocks are given below. These show a rather high content of alumina and a small content of alkalies. As the amount of silica present is not far from that to be expected in a fresh andesitic rock, it appears that these rocks have been altered by the formation of clay minerals, with the corresponding removal of the alkalies.

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[35] Howbert, Van Dyne and Bosustow, Richard, Mining methods and costs at Presidio mine of the American Metal Co. of Texas: Am. Inst. Min. Met. Eng. Trans., 1931, gen. vol., p. 39, 1931.

Partial analyses of altered dike rocks from the Shafter district, Texas

[R. E. Stevens, analyst]

	ST 3	ST 5
Silica (SiO_2)	51. 84	53. 07
Alumina (Al_2O_3)	18. 60	23. 65
Iron oxide (Fe_2O_3)	4. 12	9. 36
Titanium oxide (TiO_2)	1. 14	1. 56
Soda (Na_2O)	. 35	. 48
Potash (K_2O)	. 46	. 44
Carbon dioxide (CO_2)	6. 82	(1)

[1] Not determined.

Localities (see fig. 3):
ST 3, 3750 N., 1180 E.
ST 5, 3850 N., 1400 E.

BUFF MICA ANDESITE

A somewhat different variety of intrusive rock forms sill-like masses in sections 2 and 5, block 8. These are similar in original composition to the dark mica andesite, but differ in color, texture, and degree of alteration. They are gray-buff porphyries. The oligoclase of the ground mass forms a granular mosaic in which the grains average about 0.05 millimeter in diameter. The roughly lath-shaped phenocrysts attain a length of as much as 3 millimeters. Twinning is poorly developed in the feldspar grains in the groundmass and is rarely conspicuous even in the phenocrysts. The intrusive a mile west of the Montezuma mine has rare quartz phenocrysts. Apatite, magnetite, and a little titanite are generally present. Flakes of mica 2 millimeters in maximum length form as much as 10 percent of most of the rocks. In some specimens the apatite grains are as much as 0.5 millimeter in diameter. In most exposures replacement and veining of the rock by calcite has begun. The feldspar is in part filled with micaceous alteration products. Locally a little silicification has occurred. Pyrite is sparsely disseminated in some sills.

HORNBLENDE-AUGITE ANDESITE

Much of the intrusive material in the depression at the southeast base of the Chinati Mountains and a few intrusions in the foothill country differ from those above described in that ferromagnesian minerals are more abundant and diverse. Such rock may be termed horneblende-augite andesite. The intrusions in the depression are similar in general appearance and in part in composition to those described in the previous paragraph, but the most abundant rock here contains, in addition to the minerals mentioned above, a few percent of deeply pleochroic brown hornblende and rare phenocrysts of sodic augite. The rock of the sill near the north border of section 2, block 8, is black, but its essential constituents are the same as those of the hornblende-augite andesite.

Phenocrysts of brown hornblende and sodic augite in nearly equal proportions comprise about 15 percent of this sill. A little biotite was probably originally present, but it is now much altered. The feldspar is probably oligoclase. Most of it is in frayed laths with an average length of about 0.2 millimeter. Dark-brownish coloring matter is abundant throughout.

A few of the dikes in the Presidio mine are similar to the sill just described. In particular, the dike along drift No. 401 of the 400 level appears to be almost identical with this sill in both texture and composition. Although this dike is one of the freshest in the mine, it is too thoroughly altered for satisfactory determination of the proportions of the constituents or of the composition of the feldspar.

GABBRO AND BASALT

A small sill in section 1, block 8, is composed of gabbro, much less altered than the rock previously described. The labradorite laths in the groundmass are as much as half a millimeter in length. Some of the abundant labradorite phenocrysts are fully 3 millimeters long. Augite, in grains rarely over a millimeter long, composes roughly 20 percent of the rock. Some olivine appears to have been originally present, but, if so, it is now altered beyond positive recognition. Titanite, magnetite, chlorite, calcite, and micaceous alteration products are also present.

Some of the dark dikes in and close to the Presidio mine may be much-altered basalt. One specimen in particular, collected at coordinates 2198 N. and 167 W. on the 200 level, consists essentially of augite and greatly altered feldspar. There is a little chloritized mica, magnetite, and what appears to be much altered grains of olivine. The whole is obscured by micaceous alteration products and partly replaced by calcite and fine-grained quartz. It is striking that, although the rest of this rock is intensely altered, the augite is fresh.

AGE

Data accumulated during the present investigation suffice to show only that the intrusive rocks are younger than rocks of Trinity age and that most of them were present when mineralization took place. In and near the western part of block 8 intrusive and extrusive rocks are in contact. Mica andesite extends under the flows with a nearly horizontal upper contact. The exposures seen, however, did not permit decision as to whether this contact was intrusive. Analogy with conditions in the Terlingua region suggests that it is and that the intrusive rocks, or most of them, are of early Tertiary age.

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So little is known about conditions in northern Mexico that comparison with the diverse igneous rocks there is of little value in the present connection. As some of the ore deposits are similar to those of Shafter, it is probable that future studies will show that igneous rocks of similar age are present in the two regions. The oldest of the Mexican rocks that might be correlated with those near Shafter are products of the Laramide revolution and thus of much the same age as the volcanism in the Terlingua region. In Mexico, as in most parts of the United States, most of the Laramide rocks are more coarsely crystalline and more distinctly plutonic in aspect than those of either the Terlingua or Shafter areas, but smaller, finer-grained intrusions of Laramide age appear also to be present.

Such data as are available in regard to ore deposits in northern Mexico,[36] particularly those that resemble the lodes at Shafter, indicate that mineralization and related magmatic activity are later than the Upper Cretaceous. In those places where Upper Cretaceous strata are present they have been affected by one or both of these processes. Thus the inference seems justified that intrusive activity in the vicinity of Shafter did not precede the close of the Cretaceous and was at least in part essentially contemporaneous with the volcanism.

This general conclusion agrees with the opinions expressed by Udden and Baker, but the extent to which the intrusions may be older than the volcanism remains undetermined. Udden[37] favors the concept that the larger intrusions are older than the lava, but he mentions a dike that cuts lava and infers that others are of similar age. He regards even the larger intrusives as of Tertiary age. Baker[38] speaks of granite in the Quitman Mountains that "probably was intruded during the time of the rhyolitic eruptions." In the same paper he refers to intrusions in the Chinati Mountains, but makes no definite statement as to the relative age of these. In a later paper[39] he appears to favor, in general, the idea that the volcanic eruptions were later than the intrusions, yet shows that in places in the Chinati Mountains part of the effusive rocks, at least, may be older than the intrusions.

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[36] Spurr, J. E., The ore magmas; a series of essays on ore deposition, pp. 197–216, New York, McGraw-Hill Book Co., Inc. 1923. Prescott, Basil, The underlying principles of the limestone replacement deposits of the Mexican province: Eng. and Min. Jour., vol. 122, pp. 248–253, 289–296, 1926. Hayward, M. W., and Triplett, W. H., Occurrence of lead-zinc ores in dolomitic limestones in northern Mexico: Am. Inst. Min. Met. Eng. Tech. Pub. 442, pp. 5–28, 1931. Singewald, Quentin, Evolution of the Coahuila Peninsula, Mexico, part 5, Igneous phenomena and geologic structure near Mapini: Geol. Soc. America Bull., vol. 47, pp. 1153–1176, 1936.

[37] Udden, J. A., op. cit. (Texas Univ. Min. Survey Bull. 8), pp. 42–44, 59–60.

[38] Baker, C. L., Exploratory geology of a part of southwestern trans-Pecos Texas: Texas Univ. Bull. 2745, pp. 34–36, 1927.

[39] Baker, C. L., Note on the Permian Chinati series of west Texas: Texas Univ. Bull. 2901, pp. 73–74, 79–82, 1929.

STRUCTURE

BROAD FEATURES

Reconnaissance studies by Udden,[40] mainly in the eastern and southern parts of the region, and by Baker,[41] farther north and west, coupled with such general observations as were made during the present investigation, furnish a basis for inferences in regard to the structure of the region as a whole. These are strengthened by Baker's study [42] of a small area on the upper reaches of Cibolo Creek and the different detailed studies that have been made in the vicinity of Shafter, but much of the region remains inadequately known. The late Carboniferous and Cretaceous rocks are nearly, or quite, conformable to each other and have been folded much more sharply than any of the later rocks. They appear to form a broad anticline or dome, only the southeast quarter of which lies within the area shown in plate 6. This dome is probably modified by subsidiary domes in places. The uplift in a general way corresponds in position to the present Chinati Mountains. Both Udden and Baker have suggested that the doming may have been related to intrusion and have shown that, at least on upper Cibolo Creek, the beds tend to dip away from cores of igneous rock. Further facts are needed before the relation between intrusion and deformation can be evaluated. It seems probable that here, as in other parts of Texas and in northern Mexico, the folds in the Cretaceous and earlier rocks are among the products of the widespread Laramide revolution. Igneous activity accompanied this revolution, but much of the folding was independent of such activity. The folded beds are now visible only in scattered localities, such as the vicinity of Shafter, where erosion has cut through the cover of effusive rocks. In the vicinity of Shafter the volcanic strata form a slightly disturbed mantle, which rests on the much more highly disturbed pre-Tertiary rocks. The papers by Udden and Baker cited above indicate that similar relations exist over more distant parts of the Chinati Mountains. However, Baker [43] in a more recent paper states that in the Chinati Mountains beds that belong to the earliest of the post-Cretaceous volcanic rocks in west Texas are folded and faulted with the Cretaceous rocks. This suggests that here, as in the Terlingua region, the Tertiary volcanic beds may be conformable with the Cretaceus rocks in places and unconformable elsewhere.

Faults are plentiful in the region. Close to Shafter most of them are normal and have small displacements. These record minor re-

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[40] Udden, J. A., The geology of the Shafter silver mine district, Presidio County, Tex.: Texas Univ. Min. Survey Bull. 8 (Texas Univ. Bull. 24), 1904.

[41] Baker, C. L., op. cit. (Texas Univ. Bull. 2745), pp. 41–57.

[42] Baker, C. L. (Texas Univ. Bull. 2901), pp. 73–84.

[43] Baker, C. L., Overthrusting in trans-Pecos Texas: Pan-Am. Geologist, vol. 53, pp. 23–28, 1930.

adjustments during and subsequent to the folding. Some, however, have displacements of hundreds of feet. Northwest of the Chinati Mountains Baker[44] reports a fault with a displacement of about 2,000 feet. If, as seems probable, the block of the Shafter limestone in juxtaposition with the Cibolo formation east of the Cibolo ranch house owes its position to faulting, the displacement here may well be nearly 1,000 feet. The fact that limestone apparently belonging in the upper part of the Presidio formation lies in the depression in the vicinity of the Cibolo and Last Chance mines, with Permian beds to the south and Tertiary lava to the north, suggests faulting of considerable magnitude. This suggestion is strengthened by the brecciation evident in the Cretaceous strata here. More detailed work would be required to trace faults, as patches of alluvium and irregular intrusions obscure the relations. This part of plate 6 is much generalized. The maximum vertical displacement in the complex of faults near the Presidio mine, described in detail below, is somewhat more than 300 feet.

Farther northwest, in Hudspeth County, Baker[45] records the presence of intricate folds and major overthrusts, apparently of Tertiary age, allied with similar structures in Mexico. So far as present data go, the Chinati Mountains and their vicinity seem to have escaped this extreme deformation. However, some evidence of thrusting is known in and near the Presidio mine. This is so slight that it seems best interpreted as an incidental feature of the adjustments related to folding. Detailed studies in neighboring areas, however, may show that the minor thrusts near Shafter are results of a period of overthrusting more widespread than is now realized.

FOLDS NEAR THE PRESIDIO MINE

In the area studied in detail (pl. 7) the sedimentary rocks form a somewhat broken arc, concave to the northwest. The beds dip southeast and south. Almost the only dips in other directions are on the west side of the local anticlinal flexure that brings the massive Permian limestone to the surface in the northeast corner of section 5, block 8, and in local folds and crumples near the thrusts in the vicinities of the Chinati and Montezuma mines in section 2. Dips throughout the area shown on plate 7 range from zero to more than 30° and, on the east side of the local anticline just mentioned, up to 50°. The Permian limestone in the northeast corner of section 5, block 8, connects with the main body of the Permian rocks a short distance to the north, as indicated on plate 6. Near the boundary between sections 5 and 8, block 8, a third body of Permian beds crops out. This

[44] Baker, C. L., (Texas Univ. Bull. 2745) p. 43.
[45] Baker, C. L., (Pan-Am. Geologist) pp. 23–28.

mass, which is bounded on the west by a persistent fault, trends about N. 15° E. It is nearly a mile long and has a maximum exposed width of nearly 800 feet. The ore bodies of the Presidio mine lie within this body and the concealed Permian limestone west of it. The present position of the mass results in part from a terrace-like flexure on the flanks of the anticline and in part from faulting (section *C–C′* and *D—D′*, pl. 7). A fourth body of Permian rock comes close to the surface at the Stauber workings in the vicinity of coordinate 1,000 S., between coordinates 4,000 and 6,500 W. This results largely from faulting but in part from the flattening of the beds on the flank of the anticline.

NORMAL FAULTS NEAR THE PRESIDIO MINE

As plate 7 shows, the area in the vicinity of the Presidio mine contains numerous faults. In some parts of this area minor fractures are so numerous that some generalization in mapping was necessary. Throughout the area minor discontinuous and poorly exposed fractures were not mapped. Most of the faults thus omitted have vertical displacements of less than 2 feet. Study of the available data on the surface and in the mines shows that most of the faults belong to a small number of groups of fractures. The classification discussed below is based on trend and relationship to folding and to other faults. The different groups doubtless record fracturing at different times, but all are believed to be premineral. As shown by plate 7 and by the mine descriptions (pp. 112–124), faults belonging to each of the different groups are locally lined with the products of hypogene mineralization, mainly calcite. Faults thus lined are shown as veins on the map. Several of the faults of different trends have also served as channels for the introduction of dikes, which are silicified and in other ways show the effects of mineralization. This diversified evidence that the faults existed prior to mineralization outweighs the indications of postmineral movement that are locally visible. Attention has been called [46] to the presence of drag ore along certain of the faults. This proves, as is to be expected, that some postmineral disturbance has occurred along the old faults. In the places underground where conditions of this sort were seen during the recent study the displacements that had affected mineralized material appear to be small.

The fault complex in the area shown on plate 7 may be divided, somewhat arbitrarily, into 3 groups: (1) Faults roughly parallel to the strike of the Cretaceous strata, (2) faults parallel to the long axis of the exposed body of Permian limestone along the boundary

[46] Howbert, Van Dyne, and Bosustow, Richard, Mining methods and costs at Presidio mine of the American Metal Co. of Texas: Am. Inst. Min. Met. Eng. Trans., 1931, gen. vol., p. 39, 1931.

between sections 5 and 8, block 8, and (3) minor faults of diverse trends exposed at the surface. Faults that are exposed only underground and correspond in part to some of those exposed at the surface are most conveniently treated as a fourth group.

The first group includes the faults that tend to dominate the structure over most of the area studied in detail. They are irregular and have numerous interruptions, yet, on the whole, are comparatively persistent. These strike faults form a curved belt, which extends from coordinates 3,650 N. and 60 E. to at least 130 S. and 7,900 W. Some of them dip southeastward in the same general direction as the beds they cut (south and southwest), though at much steeper angles, but most of those with great displacement are either vertical or dip steeply northwestward. The principal effect of this faulting is the dropping of a group of narrow blocks to form a complex graben, as shown on plate 7, section D–D′.

The second group is represented mainly by the sinuous fault that passes through the Mina Grande open cut (pl. 7 and fig. 4) and is therefore known locally as the Mina Grande fault. This fault, which separates the Permian block from Cretaceous rocks, has an average trend of about N. 10° E. and cuts sharply across the trend of the Cretaceous strata. Along it the Cretaceous beds have dropped more than 200 feet. A little to the west one rather long fault and farther west several short faults, which lie between the faults of group 1, are essentially parallel to the Mina Grande fault; however, no comparable fault has been recognized along the eastern boundary of the Permian mass. The relation in attitude between the strike faults of the first group and the Cretaceous beds is so close as to suggest that these faults formed soon after the folding took place and earlier than the sharply discordant faults of the second group. This inference is strengthened by the fact that faults of the first group nowhere appear to cut those of the second group.

Most of the faults shown on plate 7 that are not included in the two groups already described are arranged en échelon in the Cretaceous rocks along the flanks of the elongate body of Permian limestone. Those on the east side strike southeast, whereas those on the west side strike southwest. Most faults of this group have small vertical displacements but appear to have marked horizontal shifts. Plate 7 shows plainly that faults of this group on the west side of the Permian block cut and hence are later than the Mina Grande fault.

A few of the faults mapped on plate 7 do not appear to belong to any of the three groups just described. These may reflect local irregularities of different kinds. Some may result from minor stresses conjugate to those that produced the larger faults.

Many more fracture planes are visible underground than on the surface. Most have very small vertical displacement. An intimate rela-

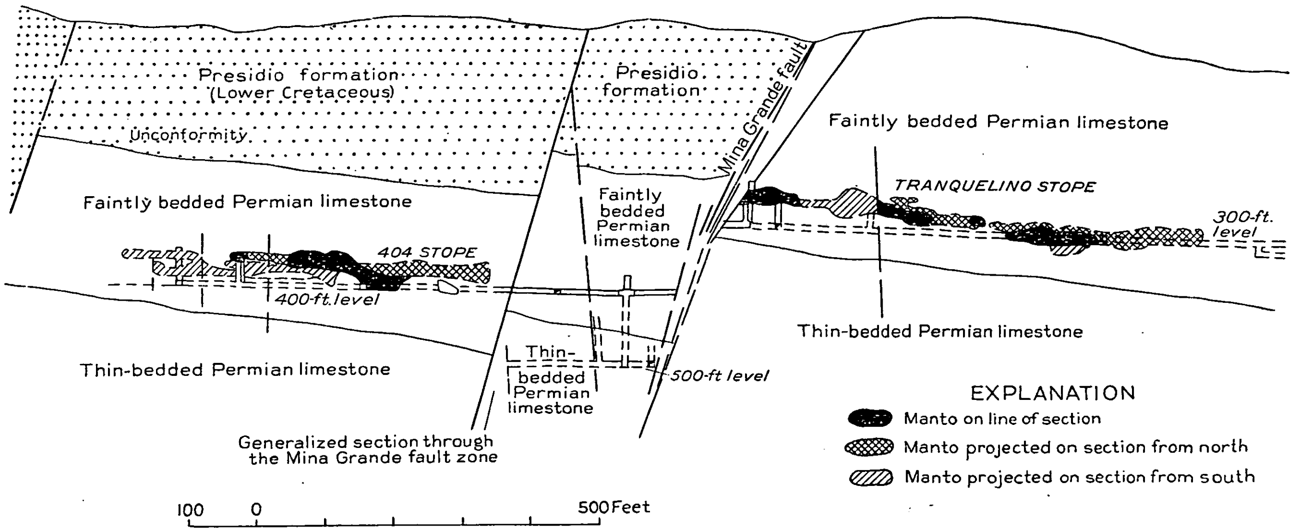

FIGURE 4.—Section through the Presidio mine illustrating the effect of the Mina Grande fault. Adapted from figure 2 of paper by Howbert and Bosustow (Am. Inst. Min. Met. Eng. Trans., p. 41, 1931). Data obtained during the present study have been added.

tion between faulting and ore occurrence is evident. (See pp. 110–111.) At least three faults of some magnitude that trend, on the average, a little east of north are exposed in the workings. In addition many of the stopes have long axes trending somewhat east of north (pl. 8), evidently because ore deposition was in some degree governed by fractures of this trend. In conformity with local usage such fissures and faults may be termed the Mina Grande system, as the largest of them is the Mina Grande fault. Another set of fractures trends N. 40°–60° W., and is locally called the Tranquelino system, because some of the most persistent faults of this trend are found in the Tranquelino stope in the southern part of the mine (pl. 8 and fig. 4). In places the stoped ore conforms in trend to this set also. The faults of the Tranquelino system obviously correspond in position and trend to the northwestward-trending set of faults at the surface grouped en échelon on the east side of the Mina Grande fault. Fractures corresponding to the western group are comparatively rare underground, as would be expected from the fact that most of the workings are east of the main faults of the Mina Grande system. The only strong fault exposed underground west of the main Mina Grande fault trends about N. 40° E. and hence corresponds to the group in comparable position on the surface west of the Mina Grande fault.

In and near the 404 stope (pl. 9) one set of fractures trends about N. 80° E. Another set of somewhat more numerous, shorter fractures, trends about N. 25° W. Neither of these seems to correspond to any of the sets of faults discussed above. A few relatively young fractures, which correspond essentially to the Mina Grande system, cross the stope between coordinates 1200 W. and 1300 W. Presumably the N. 80° E. and N. 25° W. faults resulted from the same forces that produced the faults conspicuous in the rest of the mine. The 404 stope is the only large one yet opened west of the main Mina Grande fault zone. Possibly further development here will disclose other faults of the same character.

The mode of origin of the complex fault system outlined above is only partly understood. At an early stage there appears to have been peripheral slumping within the part of the dome that has been mapped. It may be that the entire dome is bordered by curved strike faults, of which those in the first group described above constitute a small part. The block of Permian limestone that crops out at the Presidio mine, however, is sharply transverse to the downfaulted block formed by curved strike faults and calls for a different explanation. This block and the faults related to it set the Presidio mine apart structurally from the rest of the area mapped on plate 7. In some way, as yet unknown, the Permian mass along the Mina Grande fault appears to have been shoved in such a way as to break the Cretaceous strata along lines out of harmony with the regional structure. The Permian limestone is much more competent than the Cretaceous rocks, so that any set of stresses that tended to force it through the Cretaceous beds might easily be successful. The present relative positions of the different stratigraphic units involved show plainly that there was a large vertical component of movement. There must also have been a considerable horizontal component to the movement. The horizontal grooves visible on many fault surfaces, especially in underground exposures, show that in late stages, at least, approximately horizontal movements were conspicuous. Also the steep fractures arranged en échelon on both sides of the Permian mass appear to reflect the action of dominantly horizontal rather than vertical forces.

LOW-ANGLE SHEARS

Evidence of thrust faulting and of shearing akin thereto is present in several places in the Shafter area. The most conspicuous faults of this nature lie in a zone in and just west of section 2, block 8 (pl. 7). The thrust zone strikes nearly east, and the component fracture planes dip north at angles as high as 65°. One of the faults in this zone is explored by the workings of the Chinati mine (pp. 119–121) and one or more others by the scattered workings of the Montezuma mine. These faults served as channels for the introduction of the ore minerals. In a cut along an abandoned roadway, at the intersection of coordinates 9850 W. and 1780 N., massive Permian limestone is thrust over crumpled and broken Cretaceous strata along a nearly horizontal surface.

Thrust faults have not been proved to exist anywhere else in the Shafter district, but evidence of low-angle shearing has been observed in several places. In the stopes of the Presidio mine closely spaced planes essentially parallel to the bedding are visible nearly everywhere. In places such planes are filled with vein quartz. The limestone at the same stratigraphic horizons a few score feet away from mineralized areas is massive, with little or no visible parting along bedding planes. It is evident that the mineralized ground has been subjected to forces acting in such fashion as to open slightly the normally undetectable bedding planes in the massive, gently inclined limestone. A little greater force in the same direction would produce low-angle bedding-plane faults. Just above the ore in the 404 stope there is clayey material. Its character and relation to the surrounding limestone indicate with little doubt that the clayey bands represent beds intercalated in the limestone. However the clay is so crushed as to resemble gouge and contains extraneous material mixed with it during the crushing. (See pp. 56–57.) This implies that there has been appreciable movement approximately parallel to the gently inclined sedimentary beds.

Low-angle sheeting is exposed in a cut along the narrow-gauge railway between the south and east shafts of the Presidio mine at the intersection of coordinates 900 E. and 2230 N. Here beds belonging to the tripartite unit of the Presidio formation are crossed and somewhat displaced by a zone of sheeting that strikes N. 50° W. and dips 25° SW., approximately. The beds strike nearly parallel to the sheeting but dip in the opposite direction at angles of 35° and more. (See pl. 10.)

It will be noted that the attitude of the thrusting and sheeting at each of the three places described is different. Somewhat similar fracturing is present elsewhere within the area shown on plate 7 but is less conspicuous. The stresses that produced these effects may have been relatively minor components of the same sets of forces as those that produced the normal faults described above. Small as these effects may have been, they may have had much to do with ore deposition. Some of the larger fractures provided channels for the circulation of the ore-bearing solutions. An even more important effect may have been to open bedding planes and thus facilitate entrance into and replacement of the limestone. In both places where mineralized rock and low-angle shearing are associated the shearing is in the same general direction as the dip of the beds.

ORE DEPOSITS

The ore deposits of the Shafter mining district are valuable mainly for their silver but yield lead and locally zinc as by-products. A few shipments of ore mined primarily for its lead or zinc content have been made. Nearly all ore so far mined shows the effect of oxidization, and a large proportion of the silver content is in minerals of supergene origin, mainly argentite and cerargyrite. The known ore deposits of value occur in Permian limestone, mainly as replacement bodies that lie approximately along the bedding. The effects of mineralization extend into the overlying Cretaceous beds as veins and replacement bodies, which as yet have yielded little ore but may be valuable as indicators of the possible presence of ore bodies at depth.

The ore is believed to have been deposited far from its magmatic source and at a fairly shallow depth. Mineralization took place after the intrusion of dikes and sills of probable early Tertiary age. The localization of ore shoots was influenced by bedding planes and fractures (minor faults) that gave ore-forming solutions access to certain limestone beds and also by faults and dikes that cut Cretaceous rocks. Both faults and dikes are exceptionally numerous and closely spaced in the immediate vicinity of the Presidio mine and in part may account for the fact that the Presidio is the only large mine so far developed in or near the Shafter district.

The outstanding differences that serve to classify the ore deposits of the district are structural. Stratigraphic relations and mineralogic differences are of minor importance in this connection. Because of the value of stratigraphy in the study of structure and in prospecting, stratigraphic data have been presented in some detail on preceding pages, but such data have only secondary bearing on the characteristics of the ore deposits. The hypogene minerals in all the deposits are broadly similar, irrespective of stratigraphic or structural relations. For these reasons and because available data on mineralogy are incomplete in some respects, emphasis has been laid on structural features in the discussion of the ore deposits that follows. The types of lodes represented in the district include (1) manto deposits, roughly accordant with the bedding of enclosing rock, (2) deposits related to thrust faults, and (3) steep veins along normal faults. Known lodes of the first and second kinds are in Permian limestone, whereas most of those associated with normal faults are in the Cretaceous rocks.

ORE BODIES

MANTO AND RELATED ORE BODIES

In the Presidio mine and several of the others in the district the principal ore bodies lie roughly parallel with the bedding of the limestone. An ore deposit of this sort, common in Mexico, is generally given the Spanish name "manto." This term signifies a nearly horizontal lode,[47] which is not very thick. In practice ore bodies inclined 15° from the horizontal and even more are called mantos. All ore bodies so named [48] are roughly parallel with the bedding planes of the enclosing rock but clearly have been formed by replacement.

In the Presidio mine many of the stopes originally contained two or more such bodies, separated, especially near the margins of the mineralized mass, by limestone beds relatively little affected by the mineralization. Commonly, where a given ore body ends in the direction of dip another ore body is discovered at a slightly higher or lower horizon. All the different ore bodies are doubtless connected

[47] "Veta que se extiende horizontalmente hacia los lados, sin considerable inclinacion al centro de la tierra." Zerolo, Elias, and others, Diccionario enciclopedico de la lengua castellana, p. 259, Paris, Garmir Bros., 1895. "Capa de mineral, de poco espesor, que yace casi horizontalmente." Diccionario de la lengua española, 15th ed., p. 780, Madrid, Real Academia Española, 1925.

[48] Hayward, M. W., and Triplett, W. H., Occurrence of lead-zinc ores in dolomitic limestones in northern Mexico: Am. Inst. Min. Met. Eng. Tech. Pub. 442, pp. 5–28, 1931. Prescott, Basil, The underlying principles of the limestone replacement deposits of the Mexican province: Eng. and Min. Jour., vol. 122, pp. 248–253, 290–294, 1926.

with each other by channels of one kind or another along which the mineralizing solutions passed. In many ore bodies these channels are obscure, and successive ore bodies, even though close together, are hard to find. Plates 11, *A* and 12 are photographs taken in open cuts. They show spaces from which the individual ore bodies have been mined, separated by the limestone beds, which were left untouched because they were of too low grade to be mined profitably. Plate 12, *A*, especially shows that beds at several closely spaced horizons have been replaced by ore, a fact not well brought out in plans of the workings, such as plates 8 and 9. In the central part of the open cuts, as in most of the stopes, the whole mass was mined, mainly because replacement by ore was more complete. Where thin beds of slightly altered limestone were encountered in the central part of a stope they had to be taken out, but the rock in the Presidio mine stands so well that very little unprofitable material has to be moved, and the shapes of the stopes record closely the original shapes of masses of ore shoots. Here and there, even in the central parts of stopes, pillars have been left, as shown in plate 9. A few of these actually consist of ore that has been left to support the roof, but most of them represent lean masses within the ore bodies.

When the present company took over the mine they introduced careful, selective mining, so as to raise the average silver tenor of the material sent to the mill. As a result, it has been estimated [49] that about 75 percent of a mineralized body is broken as ore, the remainder being left in pillars and along the sides of the stopes. About 6 percent of the material broken is sorted out underground, and an additional 10 percent of the material hoisted is rejected as waste by the sorters at the shaft collar. The rejected material mainly represents lean spots within the ore bodies, which are individually too small to be left unbroken as pillars.

The ore bodies depart in many details from conformity with the bedding. Structure sections of some stopes would show that they diverge sharply from the bedding. As shown on plates 8 and 9, the stoped ore bodies are elongate in several different directions and have many irregularities. The major elongations correspond to one or another of the different sets of faults dominant in the area, as discussed on pp. 93–97. In many places the comparatively barren masses left as pillars in the stopes are bounded on one or more sides by fracture planes. The fact that the limits of many of the ore bodies coincide with the fracture systems shows that the fractures helped control ore deposition. The amount of displacement along many of these fractures is small, but most fractures are accompanied

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[49] Howbert, Van Dyne, and Bosustow, Richard, op. cit., p. 47.

by sufficient crushed material and clayey gouge to show that some movement has taken place.

There is abundant evidence throughout the mine that numerous fractures corresponding to the different fault systems are present and that the principal fractures in any particular part of a stope correspond to the long axis of this part of the stope. This is illustrated by plate 9, which records the writer's observations in the part of the mine most active at the time of the visit. In numerous places, both in this and in older parts of the mine, rather well-defined fracture planes limit the ore on one or both sides. In most places, however, the limits of the ore body are not sharp, as they would be if an ore body had been cut off by a post-mineral fault. Commonly the rock on the outer side of the fracture plane that bounds an ore body is itself somewhat mineralized. In some places blocks of relatively massive and unaltered limestone on one side of a fracture plane have been cut through in the course of mine development, and a new zone of fracture and mineralization has been found beyond. The fact that hypogene gangue minerals lie in fracture planes is additional evidence that fracturing and faulting preceded ore deposition and served to guide the mineralizing solutions. In some parts of the Presidio mine the ore bodies are tabular masses along steeply inclined fracture planes that cut across the bedding. The stopes above the 600 level contain good examples of these ore shoots, although here, as elsewhere, mantos also extend out along the bedding. In the Perry mine most of the minerals lie along steep fracture planes. In parts of the mine ore minerals extend out along bedding planes, but, where visible at the time of the visit, they appeared to be commercially negligible. In the prospects and small mines, both in the Permian and the Cretaceous limestones, in the western part of the district fractures are locally conspicuous, but mantos are certainly present. Further development may well show that mantos are present here to a greater extent than is now realized.

There are many irregularities in the shapes of the ore bodies, for many of which no adequate explanation is at hand. In the midst of most stopes there are relatively low-grade and even essentially barren blocks of limestone of various shapes and sizes, left as pillars in mining. The largest of these are shown on plate 8, and all pillars in 404 stope are shown on plate 9. Some such blocks may be relatively unbroken masses between zones of fractures. Some may have been protected from the attack of the mineralizing solutions by gouge on fault planes. In many places, both in the interior and on the borders of the ore bodies, no fissures or other definite boundaries are visible. The introduced minerals fade out into the surrounding limestone, and the limits of the stope are fixed by assay content.

It is noteworthy that the ore bodies show more closely spaced fractures than the unaltered limestone nearby. This is illustrated to some extent by plate 9, which shows all the more persistent fractures in the stopes and drifts in the southwest part of the Presidio mine. There are innumerable minor fractures, healed and open, that cannot be represented adequately on a map. Further, the mineralized limestone has the appearance of being thinner bedded than the limestone at corresponding horizons immediately outside of the ore bodies. This appearance results in part from closely spaced layers of vein quartz, parallel to the bedding, but is evident also in some places where the quartz layers are absent. Where replacement by ore minerals, especially those of supergene origin, has been thorough, all original features tend to be so obscured that the thin bedding referred to is particularly well shown only in the less completely replaced parts of the ore bodies. The effect is attributed largely to the opening by shearing forces of planes of weakness that had resulted from minor variations in original sedimentation. Such planes may have been inconspicuous from the first or may have been made so by the recrystallization which the limestone has undergone. The shear planes, once opened, were emphasized by the introduction of vein quartz. Where the quartz is absent the increased visibility of the minor differences in composition, porosity, and similar features may have resulted from the attack of solutions capable of dissolving the limestone to some slight degree. The process would be somewhat analogous to the etching of steel by means of which strain effects and other hidden features are made visible. That obscure bedding planes exist in the massive unit of the Cibolo formation is shown by the fact that stratification is much more plainly visible in weathered surface exposures than in the fresh rock in mine drifts.

LODES RELATED TO OVERTHRUSTS

The only ore bodies in the Shafter district known to be related to overthrusts are those along the zone of thrusting through the Chinati and Montezuma properties. They also are associated with deposits along bedding planes, and appear to differ little in origin from the deposits associated with the steeply dipping normal faults described above. This similarity is shown in the main Montezuma tunnel (fig. 7) and would probably be further revealed if development in this part of the area were more extensive.

In the Chinati mine all the stoping is on and close to the thrust plane, which dips 30° to 45° N. Below the stopes the vein matter leaves the thrust zone and bends sharply downward along a fracture that dips 75° N. (fig. 6). By itself, the steep lower part of the lode, as yet unexplored, could not be distinguished from steep, mineralized fractures, such as are common in the Presidio mine. The Permian limestone in this vicinity is disturbed and locally has dips of as much as 45°. This condition may have some bearing on the apparent paucity of ore along bedding planes.

VEINS RELATED TO NORMAL FAULTS

Steep veins that contain essentially the same minerals as the mantos just described are plentiful in the eastern part of the Shafter mining district. Several of the smaller mines, such as the Perry, contain lodes of this kind, but the aggregate production to date has been small. Most of the veins plotted on plate 7 are of this sort, and are clearly shown to lie along normal faults of all the different fault groups recognized.

Many of the veins are nearly vertical, and very few depart more than 30° from the vertical. They range commonly from a few inches to nearly 5 feet in width. Many, especially the smaller ones, are fillings of clean-cut fissures with very little evidence of alteration of the wall rock. In many of these calcite is the principal constituent. A number of the larger veins include sheared and brecciated wall rock, and these are locally bordered by silicified and otherwise altered rock.

As noted on pages 97–98, some thrusting has evidently occurred in and near the Presidio mine, but the effect that thrusting may have had on the mineral deposits is not completely understood. One minor effect may be the sheeting that permitted quartz to penetrate hidden bedding planes. (See p. 102.) In general, the thrusts, like the normal faults, fractured the rock and produced openings that could be utilized by the mineralizing solutions.

MINERALOGY

Nearly all of the lodes in the Shafter district contain essentially the same mineral assemblages, irrespective of the structural features that serve to differentiate them. Such mineralogic differences as exist are mainly in the proportions of the minerals present and in details of the effects of oxidation. The hypogene minerals include dolomite, calcite, quartz, pyrite, sphalerite, galena, probably argentite, and perhaps chalcopyrite and tetrahedrite. Supergene minerals include iron and manganese oxides, plumbojarosite, argentite, cerargyrite, native silver, cerusite, anglesite, descloisite, and small amounts of covellite, chrysocolla, and probably other copper minerals. Some of the clay minerals in the dikes and argillaceous rocks close to the ore bodies, and locally along faults, are supergene, but others are of either hypogene or premineral origin.

Many mineralogic details remain undetermined. The lodes related to overthrusts and those along faults, especially in the Cretaceous rocks, have been so little developed that such factors as mineralogic changes either laterally or with depth cannot be adequately studied. The manto deposits in the Presidio mine have been opened up much more by mining, but the ore has been so completely removed from the older workings that it would be difficult to learn its character in detail. In the limited time available for underground studies during the present examination only cursory attention could be given to most of the older workings in this mine. A more thorough examination might reveal a number of things not now known.

HYPOGENE MINERALS

DOLOMITE

As noted on page 56, the Permian limestone locally contains a little dolomite, which crystallized during or soon after the deposition of the limestone. In addition some dolomite is intimately associated with the ore deposits. Areas of rather dark-brown to pinkish dolomite are visible here and there in the walls and pillars of the Mina Grande open cut and on the borders of stopes in several places in the Presidio and Perry mines. These dolomite areas are irregular and nowhere extend much more than a score of feet beyond the borders of the ore bodies. In many places in the Presidio mine no dolomite is discernable.

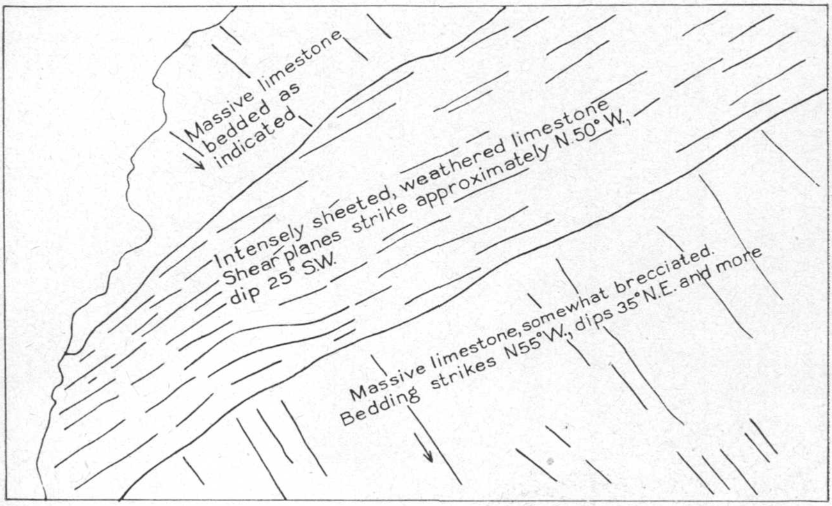
The dolomite near the ore bodies is thought to represent remnants of originally more extensive masses, which here, as in similar ore deposits in other regions,[50] may have been produced by the first wave of the mineralizing solutions. On this hypothesis, the products of later steps in mineralization have wiped out all record of dolomitization, except in marginal areas where dolomite extended into the limestone farther than the later minerals did.

QUARTZ

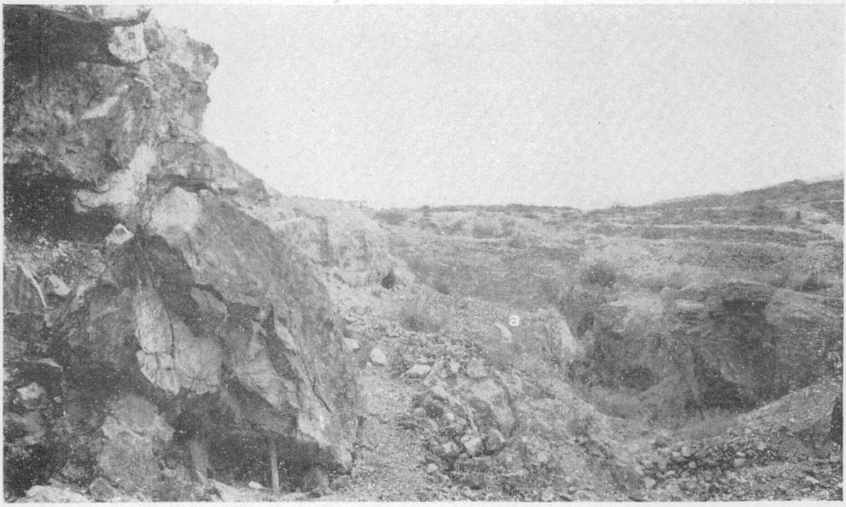
The ore bodies in all the mines contain much fine-grained quartz, formed mainly by replacement at an early stage but probably everywhere later than the dolomite. The quartz is distributed in varying proportions throughout the ore bodies and extends beyond their limits. Most of the limestone in low-grade pillars and on the margins of the stopes contains quartz. Part of the quartz is finely disseminated, part is in irregular masses, and part is in thin layers along bedding planes. These three modes of occurrence are present throughout the ore, although the abundant products of oxidation obscure the details. Available analyses indicate that the ore mined contains from 45 to 60 percent of silica. (See p. 116.) Some of this is

[50] Hewett, D. F., Dolomitization and ore deposition: Econ. Geology, vol. 28, No. 8, pp. 821–863, Dec. 1928.

A. SHEETED ROCK OF THE TRIPARTITE UNIT OF THE PRESIDIO FORMATION EXPOSED IN A RAILROAD CUT AT COORDINATES 850 E. AND 2225 N., LOOKING NORTHWEST.

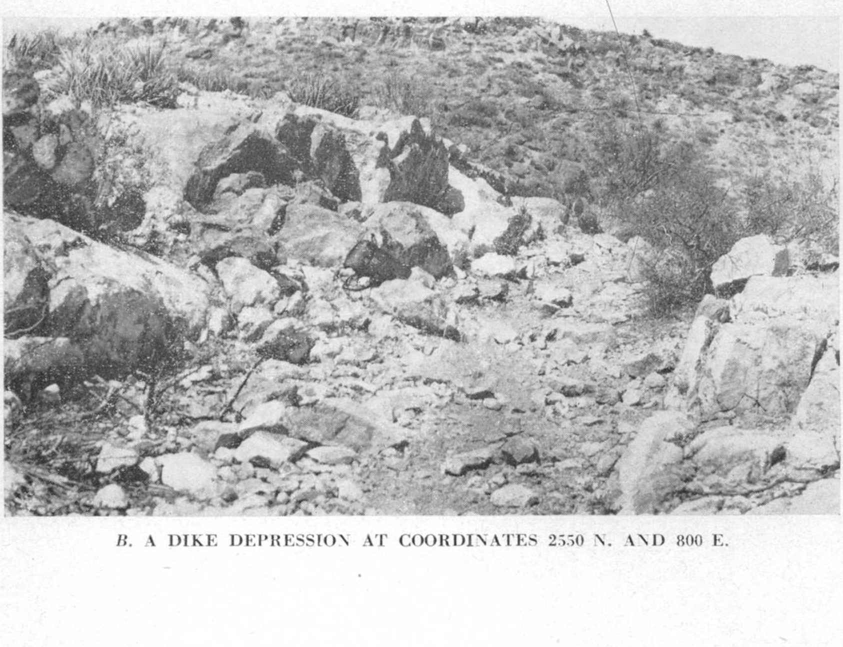


B. SKETCH OF THE OUTCROP SHOWN IN *A*.

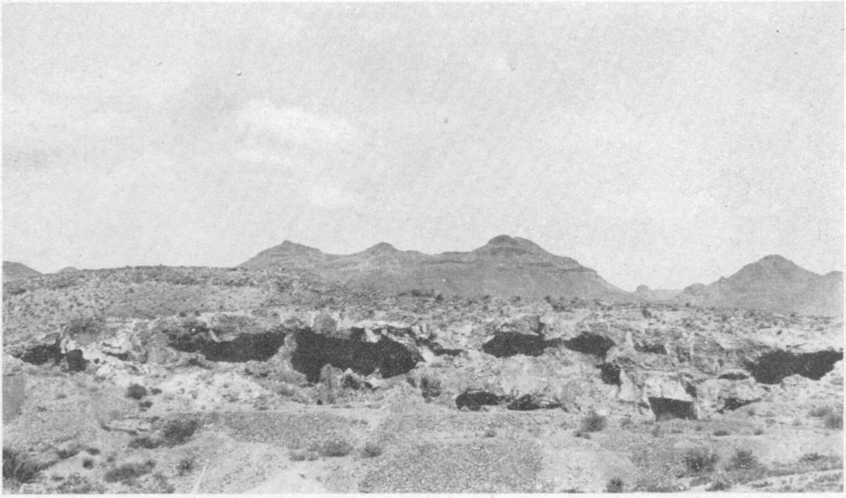


A. MINA GRANDE OPEN CUT, LOOKING SOUTH.

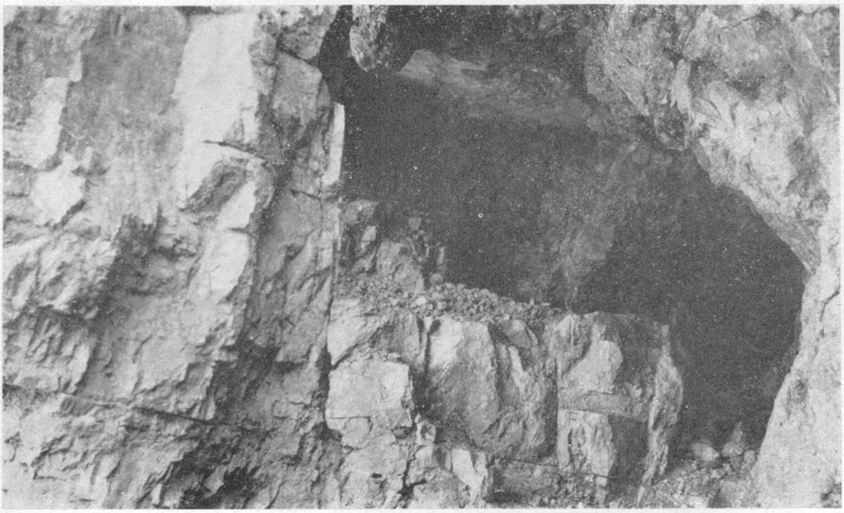
The letter a, near the southern end of the cut, marks the zone of sheeted rock along the main Mina Grande fault.



B. A DIKE DEPRESSION AT COORDINATES 2550 N. AND 800 E.



A. GENERAL VIEW OF THE EAST SIDE OF THE MINA GRANDE OPEN CUT SHOWING SEVERAL STOPED-OUT MANTO ORE BODIES.



B. A DETAIL IN THE WALL OF THE MINA GRANDE OPEN CUT SHOWING BEDDING IN THE MASSIVE UNIT OF THE PERMIAN LIMESTONE.

doubtless an original constituent of the limestone, but most was introduced by the mineralizing solutions. In much of the better ore, silicification appears to have been nearly complete. Quartz veins, such as result from the filling of fractures, appear to be entirely absent. Much of the ore appears to have been extensively brecciated and recemented by silica after the original limestone had been silicified.

Silicified rock is by no means confined to the limestone of the upper massive unit in the Cibolo formation. The dikes that traverse the Presidio mine are partly silicified. In surface exposures of several different units in the Presidio formation there has also been some silicification along fracture planes, in some of which there are dikes. The long vein near the northern border of section 2, block 8, is bordered at intervals by silicified rock. The effects of silicification are also evident in the prospect holes in the western part of the district, both in igneous rocks and in different units of the Permian strata.

CALCITE

Coarse-grained calcite is sporadically present in all of the ore bodies in the Permian limestone and is the principal constituent in the steep veins throughout the district. It varies greatly in color as a result of supergene changes (see p. 116), but all of that in the lodes appears to be a fairly pure calcite with a small manganese content. In the mantos it lines minor fractures and locally constitutes more or less bulbous masses several feet wide, which are essentially barren of metallic minerals. In places in, and close to, the mantos it forms conspicuous veins. In the steep veins at a distance from mantos, particularly in the Cretaceous rocks, calcite forms clean-cut tabular and locally lenticular bodies. In all its modes of occurrence most of the calcite encloses metallic minerals only locally and exceptionally, but it is everywhere in or closely associated with lodes that do contain them.

Calcite appears to be among the latest of the hypogene gangue minerals. Bodies formed of this mineral cut across and heal fractures in the silicified rock. In the mantos of the Presidio mine the coarse-grained calcite masses are not known to extend beyond the limits of the silicified rock that contains the ore. In the Cretaceous rocks, many of the calcite veins are not accompanied by silicified or otherwise altered wall rock, but such veins do not contain appreciable quantities of valuable metallic minerals. The observed relations suggest that calcite began to crystallize in the ore bodies while the metallic minerals were forming but continued to be deposited afterwards and spread rather widely into rock not reached by metallic minerals.

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METALLIC MINERALS

The character and mutual relations of the different hypogene metallic minerals are not completely understood, in part, because alteration has obliterated the evidence. Apparently some galena, sphalerite, and pyrite were present in all of the ore deposits. Although nowhere abundant, pyrite was more widely distributed than the other sulfides. It formed as small, sparsely disseminated crystals. The galena and sphalerite were originally in irregular, coarsely crystalline bunches enclosed in thoroughly silicified limestone and locally in masses of calcite. The detailed relation between these sulfides and the enclosing quartz or calcite is so intimate as to suggest that sulfide and gangue were deposited at about the same time.

Sphalerite, which is readily removed during oxidation, is not now recognizable in most of the ore but must originally have been widely distributed. Zinc has been recovered only from oxidized ore bodies in the Chinati and Montezuma mines. The mineralized material in the Perry mine is reported to contain 5 percent of zinc, and the few available analyses indicate that the ore from the Presidio mine contains from 2.5 to nearly 5 percent of zinc.

Galena and its oxidation products have been abundant in the Ross and Last Chance mines, which are in Cretaceous beds. They are also abundant in small masses in and near the Perry mine in limestone close to the top of the Cibolo formation. Some of the ore here is reported to contain as much as 15 percent of lead. Most of the galena is rather coarse grained, but this mine also contains seams of steel galena. Lead is present throughout the Presidio mine but nowhere constitutes a large percentage of the mineralized rock. Galena is conspicuous in small bodies on the 600 level and in several places in the stopes above the 400 level in the southwestern part of the mine. There appears to have been some increase in the average lead content of the ore as mining has progressed downward and to the southwest. An analysis published in 1909 records only 0.5 percent of lead, but analyses made in 1929 show an average content of 2.5 percent of lead. A composite analysis of ore mined in May 1934 showed only 1.87 percent of lead, but much of that mined in 1934 had a higher lead content. These figures accord with statements of the mine staff that the lead content of the ore is higher in the present stopes. They may indicate that lead and silver tend to separate during oxidation so that in the stopes relatively close to the surface mined in the early days the ore selected because of its high silver content ran comparatively low in lead.

Lead and perhaps zinc, appear to be more plentiful in proportion to silver in the outlying mines than they are in the Presidio mine. For example, assay data summarized in the mine descriptions (pp.

112–123) indicate that there are two or three times as many pounds of lead to each ounce of silver in the Perry ore bodies as in the ore so far obtained at the Presidio mine. The outlying mines are so scattered and so poorly developed that generalizations based on observations therein are hazardous. If future work should show that lead is consistently more abundant in a zone at a distance from the Presidio mine, it might be interpreted as an indication that the source of the mineralizing solutions is nearer to the Presidio than it is to the western part of the district. Such a zonal relation has been suggested for somewhat similar deposits elsewhere.[51]

The form in which the silver was originally deposited is a matter of some doubt. Most of the silver minerals now present in the ore of the Presidio mine are probably supergene. Copper minerals in the oxidized ore suggest the possibility that part of the silver was originally in tetrahedrite, but even in the few places where the green color of copper is conspicuous the amount is far too small to account for the silver content, especially as part of the copper may have come from chalcopyrite. Most of the ore shows no evidence of copper. Microscopic study of specimens of galena has failed to reveal any silver minerals, but it is reported that assays show that both galena and the other lead minerals are argentiferous. In the absence of any indication of the former presence of sulfarsenides or other complex silver minerals, the most probable assumption is that the principal hypogene silver mineral was argentite, perhaps in part in solid solution in the galena.

SUPERGENE MINERALS

Throughout the accessible parts of all mines and prospects in the Shafter district the effects of supergene changes are conspicuous. Much of the ore is a more or less porous aggregate of indefinite composition, which is stained with iron and, locally, manganese oxides. In some of the richer ore dark streaks of argentite are conspicuous, and it is probable that much of the silver is contained in this mineral. The table on page 116 indicates that 60 percent of the silver in ore mined in 1929 was in the form of sulfide; yet no silver mineral has been recognized among the residual aggregates of hypogene minerals. In the table the rest of the silver is recorded as "chloride." Part of this is actually cerargyrite, as this mineral is easily recognized in some specimens of rich ore. The cerargyrite is reported to contain some iodide but is mainly silver chloride. Probably a considerable part of the silver is in the aggregates of oxidation products, in which it would be difficult to recognize specific minerals.

[51] Hewett, D. F., Geology and ore deposits of the Goodsprings quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 162, p. 90, 1931.

Nearly everywhere some residual galena or other hypogene sulfides remain in the ore, but in many of the stopes visited in 1934 these are so inconspicuous that it is somewhat surprising to find half of the lead in the ore milled in 1929 recorded as sulfide, as is done in the table on page 116. At the time of the visit galena appeared to be preponderant over its oxidation products only in the Perry mine and in parts of the 404 stope and in places in stopes near the 600 level in the Presidio mine. Among the oxidized lead minerals, cerusite and anglesite are probably the most abundant, but plumbojarosite and descloisite are locally conspicuous. The zinc in the ore was doubtless originally present as sphalerite, and this mineral may remain in places, but the principal zinc mineral now recognizable is smithsonite. Even in the most thoroughly oxidized parts of the ore bodies silicified rock, masses of coarse calcite, or other hypogene minerals remain. Supergene processes changed the mineral character of the ore and redistributed some of the materials within the ore bodies. They do not appear to have carried metals in solution far outside the ground originally mineralized. In the Chinati mine smithsonite bodies extend short distances into otherwise little altered limestone in the walls of the thrust zone, but even here galena and some other hypogene minerals are plentiful in the broken limestone nearby.

Within the ore bodies, rendered permeable by fractures and by porosity produced by solution of materials during oxidation, some redistribution of the metallic constituents doubtless has taken place. This matter has not yet been studied in detail, but such data as are available suggest local rearrangement rather than development of any restricted zone of secondary enrichment. The history of mining at the Presidio mine shows that in the early days the ore averaged about 30 ounces of silver to the ton, whereas at the time of the visit the average was maintained at about 20 ounces to the ton, and there have been years in which the average grade dropped to little over 10 ounces to the ton. These figures doubtless reveal a somewhat higher silver content in the upper levels. They hardly indicate any zone of marked enrichment at those levels, especially when variations in methods of mining are considered. The low silver content recorded during the last part of the operation of the Presidio Mining Co. resulted in part from dilution with low-grade material in the attempt to increase the tonnage mined. (See table, p. 50.) Similarly, the high assay content of the ore that went to the mill in early years was doubtless in some measure due to more selective mining and perhaps also to more hand sorting than is now practiced. So far as known there is no significant difference between the supergene minerals found in the different parts of the mine.

The argentite in the supergene ore suggests that the original silver minerals, whatever they may have been, were oxidized and the silver dissolved and later redeposited as sulfide. This implies transportation of the silver, but the argentite is distributed throughout the Presidio mine without obvious relation to the surface.

In many places, especially in the Presidio mine, the calcite masses are partly or completely stained brown to black by manganese oxides. Commonly, a core of unaltered white calcite remains. The boundary between altered and unaltered material is irregular and wavey, but generally sharp. In a specimen from stope 404 of the Presidio mine, which was tested microscopically by W. T. Schaller, the white calcite has an ω index of refraction of 1.662 and the black calcite has an ω index of 1.660. These determinations are accurate within 0.002. The ω index of pure calcite is 1.658. These figures suggest that the manganese content of the original calcite was low and that oxidation has decreased it slightly.

As already noted, the dike rocks in the vicinity of the Presidio mine are extensively kaolinized, and some of them have clearly been subjected to the influence of hypogene solutions, with resulting deposition of calcite and sulfides. The clay minerals now in these dikes are presumably products of weathering. The thoroughness with which the feldspar of the original rock has been kaolinized suggests, however, that alteration by hypogene solutions may well have begun with the formation of sericite or similar material, which was later converted into kaolin by supergene solutions.

LOCALIZATION OF THE ORE

STRATIGRAPHIC CONTROL

It seems clear that the massive limestone at the top of the Cibolo formation is the most favorable to replacement by solutions of the sort that produced the ore of the Presidio mine. The stopes in that mine range in position from near the bottom of the unit to fully 200 feet above its base. In the Perry mine and workings, just west of it, ore lies at still higher horizons in the same unit. In Mexico it has been found that originally dolomitic beds are favorable to ore deposits of the general kind here considered.[52] In the Shafter district this generalization does not appear to hold. The unmineralized limestone in the general vicinity of the known ore deposits contains little dolomite. In contrast, what appears to be equivalent limestone in the vicinity of the Cibolo ranch is essentially dolomitic. No ore deposits are known in this dolomite, and there is no evidence that the partial early dolomitization near Shafter was any more intense in the ground that has been mineralized than it is elsewhere. Hayward and Triplett, in the paper just cited think that the greater brittleness

[52] Hayward, M. W., and Triplett, W. H., Occurrence of lead-zinc ores in dolomitic limestones in northern Mexico: Am. Inst. Min. Met. Eng. Tech. Pub. 442, pp. 3-5, Dec., 1931.

of dolomite as compared with limestone and the fact that much dolomite tends to be porous are among the principal reasons why dolomite is favorable to ore deposition. As dolomite produced early in the process of mineralization in the Shafter district is also brittle and porous, dolomitization may have been a factor in preparing the way for deposition of sulfides.

Although by far the greater part of the ore thus far produced has come from the upper member of the Cibolo formation, the effects of mineralization spread beyond this unit. The old Ross and Last Chance mines contained ore bodies of replacement type that may have differed little from the mantos of the Presidio mine. The limestone at both localities is thought to be Cretaceous. There are numerous veins in different members of the Cretaceous formations and in the intrusive rocks that are genetically related to the mantos, although differing in form. Thus, available data suggest that the best place to search for new ore bodies is the top member of the Cibolo formation, but there is also the possibility that valuable bodies exist at other horizons.

STRUCTURAL CONTROL

Within rocks of suitable character structural features are dominant both in determining the general localization of an ore-bearing area such as the Shafter district and in the control of the distribution of individual ore bodies. In the Shafter district sufficient development for adequate study has been attained only at the Presidio mine. The information gained here is applicable not only to further extension of its large stope system but to search for new ore bodies in other parts of the district, particularly where rocks unfavorable to replacement by ore minerals are exposed at the surface.

Three structural features in and near the Presidio mine stand out as probably determining the distribution of ore deposits: (1) The numerous steep faults, many of which do not accord in strike or dip with known faults in the surrounding region, (2) the presence of numerous narrow dikes in contrast to the sills in the region to the west, and (3) the relatively large amount of shattering in the mineralized rock.

The different fault systems recognizable around the Presidio mine are discussed on pages 93–96. It appears that the pattern produced by these fractures within the small area studied in detail are unique. It seems logical to expect that any similar ore deposit in the surrounding region would show similar relations. As these features are perceptible in the Cretaceous strata overlying the favorable Permian limestone, they offer a possible clue in searching for ore in place where this stratum is entirely covered by the Cretaceous rocks. Uncertainty exists as to the origin of the local fault pattern at the

Presidio mine, and numerous factors might affect the development of similar faults in another locality; hence any areas that exhibits relatively closely spaced faults that diverge from the regional structure would warrant further investigation. The essential thing is that faults of this character may provide channels for solutions from some distant source, which otherwise might be unable to travel freely enough to produce ore bodies.

The dikes at the Presidio mine may be related to ore deposition in several different ways. The presence of the narrow but widespread dikes suggests that an intrusive mass may underlie the area occupied by this mine. Such a buried mass may well have a genetic relation to the exceptionally complex fault pattern here. The fact that the dikes are themselves somewhat mineralized may have no significance beyond showing that they were present in the fissures at the time of mineralization.

The close spacing of openings is one of the outstanding features of the mineralized areas. These openings cut across and lie parallel to the gently inclined beds. The conditions that made such shattering possible within these limited areas may have been among the most potent factors in permitting the formation of commercially valuable ore bodies. One factor in producing these numerous openings within a restricted area may have been dolomitization early in the process of mineralization (see p. 104). Small quantities of a solution rising along fractures and spreading laterally in favorable limestone would affect local irregular parts of the limestone. During renewed movements, the brittle, dolomitized masses would tend to localize fracturing. If so, dolomite irregularly distributed in a limestone may be a useful clue in prospecting. The increase in abundance of minor fissures and of their sheet or platy structure along bedding is a clue that ordinarily will be of value only in development within a mine. In virgin territory these minor openings may lie so close to the ore body itself that iron stains, silicified rock, and other more readily recognized evidence of the effects of mineralization may usually be conspicuous in surface exposures.

DEPOSITION IN RELATION TO SOURCE

There is little in the Shafter district to indicate the source of the ore. Except for garnets reported to occur locally but not seen during the present examination, no lime silicates or other evidence of contact metamorphic action are known, a fact that distinguishes this district from a number of districts in Mexico. Insofar as this absence of contact-metamorphic minerals may indicate distance from the source from which the ore solutions were derived, it suggests that these solutions have traveled far along such faults or other channels as they happened to reach. This inference supports the idea that ore deposition of consequence may have occurred at more than one place in the district.

Neither in the Presidio mine nor in any of the other properties is there anything corresponding to the steep pipes that are regarded as the main channels of access of the solutions in many of the Mexican districts.[53] The absence of these also favors the possibility that the deposits in present workings are high above their source.

Whatever may have been the source of the mineralizing solutions, the narrow veins filled mainly with calcite probably mark the outer limits of the effects of mineralization. Products of the earlier stages of mineralization accompany the calcite veins only rarely and in small amounts. At the Presidio mine calcite veins are found over some of the ore bodies, but such silver as has been found in association with them is mainly in silicified rock. Dikes are present in each of the principal localities near the Presidio mine where silicified rock is conspicuous in the Cretaceous strata, near the intersections of coordinates 4,300 N. and 500 W. and 3,000 N. and 1,000 W., for example. This association is believed to indicate the zones most directly connected with the source of supply, and therefore most likely to contain ore deposits. Silicified and otherwise altered rock containing silver is associated with calcite veins in Cretaceous strata at the Stauber workings and south of the Perry mine. Dikes are absent here, but sills crop out so near that the association may be equally significant, although structural conditions are different. Several places where calcite veins are abundant but where dikes are absent show no evidence of silver in surface exposures but have not yet been tested underground. The area in the southwest corner of section 8, block 8, is an example.

MINE DESCRIPTIONS

PRESIDIO MINE

The property that includes the Presidio mine of the American Metal Co. of Texas comprises sections 5 and 8 of block 8, which extend westward from Shafter. This mine is the only one in the district that contains much developed ground or that has yielded a notable amount of ore. It has been in operation with few interruptions since about 1880. During this period it has produced over 2,000,000 tons of ore. About 99.5 percent of the value of the recovered metals is in silver, according to the table facing page 50.

The workings extend along a zone trending roughly N. 60° E. in which the stopes, although most irregular, are nearly continuous for

[53] Prescott, Basil, The underlying principles of the limestone replacement deposits of the Mexican province: Eng. and Min. Jour., vol. 122, pp. 246–253, 289–296, 1926.

more than 4,000 feet, with a maximum width in the central part of the zone of about 1,500 feet, measured at right angles to the general trend. Within this zone the individual stopes are elongate in diverse directions and at different inclinations in different parts of the mine. Ore was mined at the surface 300 feet west of the north shaft in the Mina Grande open cut, near the middle of the northwestern border of the developed zone, and also in the vicinity of the south shaft more than 600 feet farther south. Stoping extends down to the 600-foot level in the eastern part of the mine. A short drift has been driven on the 700-foot level of the east shaft, but ore has not been encountered in it. As already noted there was opportunity during the present investigation to study in detail only those parts of the mine under development at the time of the visit. The older workings were inspected in more cursory fashion.

Nearly all the ore bodies are confined to the thick-bedded to massive limestone in the upper part of the Cibolo formation (Permian). Much of the ore is in the lower part of this member, but there is considerable variation in this respect. Some of the ore in the northwestern part of the mine appears to have been mined at higher horizons than that now being explored. (See pl. 7, sections C–C′ and D–D′.) The ore bodies that were being worked in the western part of the mine at the time of the visit are low in the massive unit, probably not far above the top of the thin-bedded limestone member. In stope 404, in this part of the mine, the ore is overlain by discontinuous clay shale, along which there is reported to be evidence of movement. (See pl. 9.) Similar shale is associated with thin-bedded argillaceous limestone along drift 302A, just east of stope 407 (pl. 9.) There is so much faulting in this vicinity that the stratigraphic relations of the different beds are uncertain, but it is quite possible that the shale here is the approximate stratigraphic equivalent of that above stope 404. Similar shale 1 to 2.5 feet thick overlies a recently opened high-grade ore body north of stope 404.[54] This stratum is at about the same altitude as that above stope 404.

On the 600 level many of the drifts of southeasterly trend follow preexisting open fissures in the limestone. The fissures have steep, undulating walls, which at some places are in close contact, at others several feet apart. The height of the openings is locally several score feet. Parts of the walls show clearly defined nearly horizontal slickensides. Most of the walls are covered by botryoidal masses of calcite crystals. No evidence of the effect of ore solutions was seen in any of the open fissures. In the stopes just above the 600 level much of the ore lay along steep fissures that trend N. 50°–80° W., parallel to the open fissure described above. The height of such

[54] Stott, C. E., letter of Mar. 5, 1935.

ore bodies is much greater than their width. In addition there are masses of ore that conform essentially to the bedding, here almost flat.

The Presidio formation overlies the limestone of the Cibolo in normal position throughout the mine. In the vicinity of the east shaft the dip carries the base of the Presidio somewhat below the 400-foot level. In the southwestern part of the mine, near the 404 stope, Cretaceous beds again appear at this level because of faulting. The same fault zone should bring the Cretaceous beds close to the face of the 302A drift on the 2,300 level. At the time of the visit the face was at the intersection of coordinates 1,250 W. and 2,420 N. in black limestone, which may have belonged to one of the more massive units in the Presidio formation, but it showed no features that permitted definite correlation. Although no stopes of any consequence have been opened in Cretaceous beds anywhere on the Presidio property, there are numerous places where prospect holes disclose the effects of mineralization in this rock. One such place is directly over the most recently opened stope on the 300-level at the intersection of coordinates 1,150 W. and 2,450 N. On the surface at the intersection of coordinates 310 W. and 2,360 N. a short tunnel expands into what appears to have been a small stope in the mineralized strata belonging to the tripartite unit of the Presidio formation.

Fissures and faults are present in all parts of the mine. They are much more closely spaced in the mineralized rock than they are in the fresh limestone nearby. Although postmineral disturbance has certainly taken place along many of the fractures, most or all seem to have formed before or during hypogene mineralization, as products of this mineralization are found in numerous places along the fractures. There is great diversity in the trends of the fractures, especially the minor ones, but by far the greater part belong to fairly well defined systems discussed on pp. 93–97.

During the study here reported fractures were mapped in the southwestern part of the mine, where mining had recently been most active. Most of the then accessible parts of the rest of the mine were visited, and it is evident that conditions are broadly similar throughout the stoped area, except that different fracture systems are dominant in different parts of the mine. The big fault that passes through the Mina Grande open cut and other fractures in the same zone interrupt the continuity of the ore bodies more than any others so far encountered. This is illustrated by figure 4. The interruption is believed to be mainly a feature of original deposition. The influence of fractures of this trend on the shapes of the ore bodies is evident from plates 8 and 9. Stopes elongate parallel to the fault are especially conspicuous along the east side of the main Mina Grande fault zone. In addition to this general feature there are numerous places where calcite and other products of hypogene mineralization lie in or along the fracture planes of the Mina Grande zone. Small amounts of more or less broken ore are reported to have been found in the Mina Grande zone. Some of these are doubtless drag ore resulting from minor readjustments subsequent to ore deposition. Brecciation and slickensides show plainly that such movements have taken place.

Persistent, narrow dikes of an altered igneous rock are present in several places. Where comparatively fresh, they are nearly black. In most places the dike rock has been altered to a brown kaolinized material in which the igneous characteristics are almost or quite unrecognizable. Much of this alteration was effected during the oxidation of the ore, but part of it doubtless took pllace during hypogene mineralization. In several places the dikes are bordered by calcite veins or other hypogene minerals in such a way as to indicate that the dike rock was present when ore deposition took place.

The shapes of the ore shoots tend to be controlled in part by the bedding and in part by fractures. The complicated and not completely understood reasons for such control are discussed on pages 110–111. That such control exists is obvious in every stope and is illustrated in its broader features on plates 7 and 9.

Study of the mineralogy of the ore in the Presidio mine is complicated by the fact that oxidation is conspicuous throughout the developed area. Except for some of the dolomite, fine-grained quartz,, calcite, and locally a little galena and pyrite, the hypogene minerals have been destroyed or masked beyond recognition by supergene processes. The supergene minerals include cerargyrite, argentite, cerusite, anglesite, iron and manganese oxides, and locally small amounts of descloisite and other rare minerals. There has been some redistribution and recrystallization of calcite, but most of the coarse-grained calcite that is common in the ore bodies, especially in the western part of the mine, seems to be of hypogene origin. It has, however, been partly changed in appearance and composition by incorporation of iron and manganese oxides, presumably derived from supergene solutions. (See pp. 107–109.)

The analyses given below show the general character of the ore at different periods in the operation of the mine.

Analyses of ore from the Presidio mine

	Silver (ounces to the ton)			Gold (ounces to the ton)	Lead (percent)			Zinc (percent)	Iron (percent)	Lime (percent)	Carbon dioxide (percent)	Magnesia (percent)	Manganese (percent)	Water (percent)	Insoluble (percent)
	Total	Sulfide	Chloride		Total	Sulfide	Oxide								
Average content, 1909 [1]	[2] 21.64	------	------	------	0.5	------	------	2.5	4.5	12.0	13.2	2.4	------	------	[3] 62.0
Average mill heads, 1929 [4]	19.741	11.901	7.840	0.02	2.499	1.253	1.246	4.87	3.87	12.84	------	6.15	0.38	3.0	48.9
Composite sample, May 1934 [5]	21.11	------	------	.01	1.87	------	------	4.7	4.7	18.9	------	------	------	------	46.4

[1] Kirk, E. M., Eng. and Min. Jour., vol. 88, p. 819, 1909.
[2] From table, facing p. 50.
[3] Silica.
[4] Howlet, Van Dyne, and Gray, F. E., Milling methods and costs at Presidio mine of the American Metal Co. of Texas. Am. Inst. Min. Met. Eng. Trans., vol. 112, p. 705, 1934.
[5] Records of the American Metal Co. of Texas.

GLEIM MINE

In the northeastern part of section 6, block 8, close to the highway to Presidio, there are old workings controlled by E. M. Gleim. At the time of the visit no work had been done here for years, and the shaft was inaccessible, but the size of the dump indicated that there are several hundred feet of workings. The rocks at the surface belong to the upper units of the Presidio formation. Pits disclose a steep calcite vein trending east to N. 70 E. The wall rocks are brecciated, iron-stained, and locally silicified.

STAUBER MINE

In and near the northwestern part of section 6, block 8, there are two shafts and several pits in the tripartite and conglomerate units of the Presidio formation. The dumps show that several hundred feet have been worked. The shafts were not entered during the present study, but it is reported that the western one at least has been sunk into the limestone at the top of the Cibolo formation and that drifts have been driven from it to the east and west in the limestone. Surface exposures show considerable faulting. Several of the faults contain calcite veins that are locally accompanied by brecciated and silicified rock and are reported to contain some silver and lead.

PERRY MINE

The Perry mine, one of the few properties at which there has been recent development, is in the south-central part of section 2, block 8. When visited in June 1934, development compromised a shaft 120 feet deep and short drifts near the surface and at intervals of 40 feet down the shaft. (See fig. 5.) The work was done during 1932 and 1933 under the direction of Dunham Perry, of Shafter. Four carloads of ore, whose compositions are indicated in the table below, have been shipped to a smelter at El Paso, largely for test purposes, and much machinery has been gathered at the property in preparation for the building of a concentrating mill.

Analyses of ore from the Perry mine

Gold (ounces per ton)	Silver (ounces per ton)	Lead (percent)	Zinc (percent)	Iron (percent)	Lime (percent)	Insoluble (percent)	Silica (percent)	Sulfur (percent)
0.05	5.4	30.7						2.3
.05	7.2	25.4		5.1	18.3	26.2	25.4	
.06	4.6	15.2		5.8	9.2	47.2		
.05	5.5	18.3	5.6			42.6		1.1

The main lode is along a fracture zone in the massive limestone near the top of the Cibolo formation. It trends about N. 50° E. and dips steeply northwest. The ore consists of coarse-grained and partly

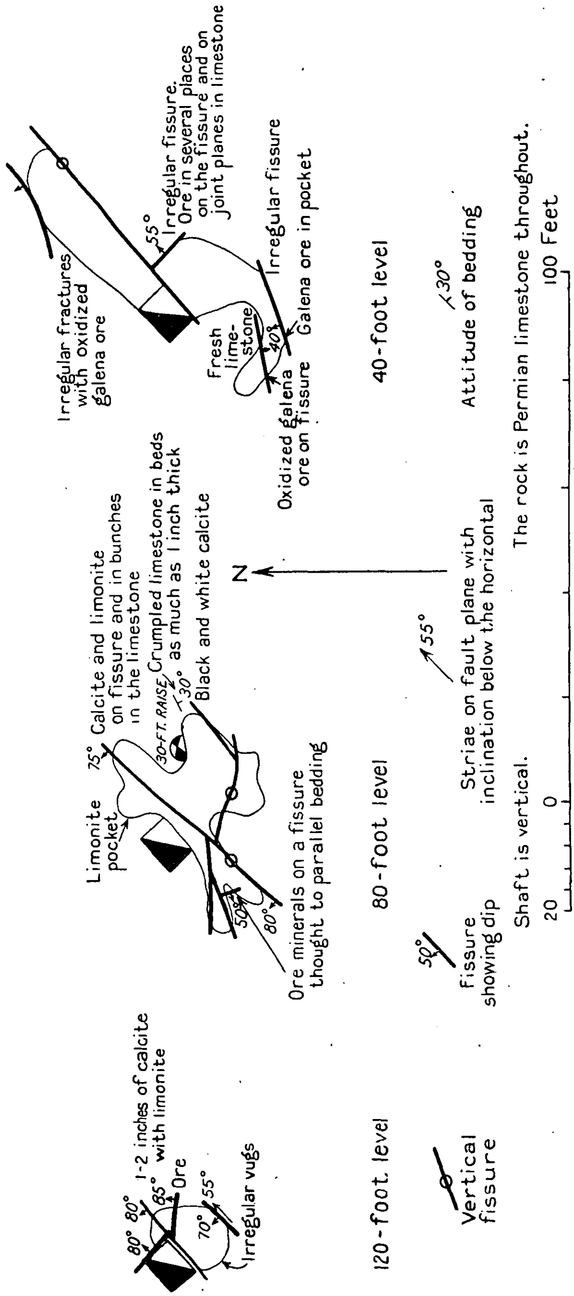

FIGURE 5.—Sketch map of the Perry mine.

oxidized galena with coarsely crystalline impure calcite in limestone that has been locally silicified and dolomitized. The ore minerals lie both in the main fracture zone and along nearby fractures and joint surfaces of various trends. Locally they have also formed along shear planes parallel to the bedding of the limestone, which strikes nearly east and dips south.

The oxidized minerals in the ore include hydrated iron oxides, jarosite, cerussite, anglesite, and probably also smithsonite.

Mr. Perry [55] writes that the average content of the ore as shown by all assays made in the course of development is about 15 percent lead, 5 percent zinc, 6 ounces of silver to the ton, and 0.05 ounce of gold to the ton.

There are a number of places in the general vicinity of the Perry shaft where galena and its oxidation products occur along fractures in silicified and altered Permian limestone. As yet these have been developed only by shallow pits, so that the extent and continuity remain undetermined.

CHINATI MINE

The Chinati mine lies just west of the Perry mine, in the same section. It is likewise under the control of Mr. Dunham Perry, although at the time of the visit he had not as yet undertaken any development there. This property was patented in 1901 and was operated for about a year-and-a-half shortly thereafter. Some oxidized zinc ore is reported to have been shipped from it during the first World War. According to the United States Bureau of Mines, 153 tons of lead-silver-gold ore was shipped from this mine in 1935.

Development consists of a shaft, inclined to the north at 30° to 45°, which attains a vertical depth of roughly 100 feet and from which drifts have been driven to either side at the bottom and at intervals from there to the collar. The principal stopes extend from the surface to a vertical depth of perhaps 45 feet on the west side of the shaft. There are small stopes on the east side and at lower levels.

The mine is in thick-bedded Permian limestone, which strikes N. 80° E. and dips 45° S. near the surface and N. 75° W. and 20° S. near the bottom of the shaft. Here the beds are distinctly thinner. The workings follow a somewhat winding fracture, which strikes about east on the average, and dips 30° and more to the north. (See fig. 6.) In the lower part of the mine the fracturing is decidedly more irregular and discontinuous than it is above. Some of the fractures curve and lose themselves along bedding planes. In the upper levels the fracture walls are well defined and

[55] Perry, Dunham, letter of Jan. 9, 1935.

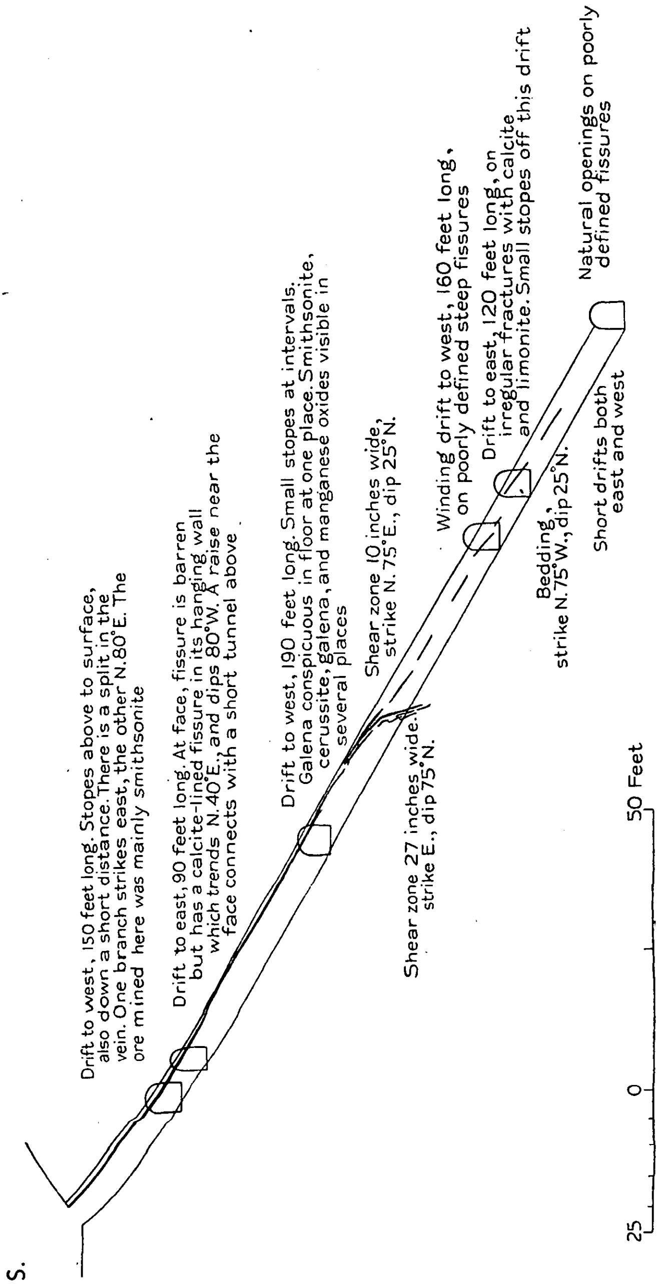

FIGURE 6.—Diagrammatic section along the shaft of the Chinati mine.

continuous. The vein matter along them ranges from several inches to, locally, several feet in thickness. Somewhat more than half way down the incline shaft the vein matter bends sharply downward without any suggestion of being broken and assumes a dip of 75° N., whereas the fracture that it follows above continues with a dip of 35° N. but without any vein matter; thus the lower workings are in the hangingwall of the lode and show little evidence of mineralization.

The ore consists of fine-grained quartz and altered limestone with hydrated iron and manganese oxides and the carbonates of lead and zinc. In several places there are bunches of almost unoxidized galena as well as seams of steel galena that extend out into the walls along branch fractures.

MONTEZUMA MINE

The Montezuma mine is immediately west of the Chinati mine, mainly in section 319. Like the Chinati it was operated about 1902 and again during the World War. The principal working is a tunnel trending N. 40° E. for about 220 feet. (See fig. 7.) It intersects two manto deposits in the massive limestone of the upper member of the Cibolo formation, on both of which there are small stopes. The ore has been followed on both sides of the tunnel near the portal. It lies approximately parallel with the bedding, which here dips 25° SW. Near the end of the tunnel a small stope on the southeast side exposes ore that dips only about 5° SW. There are several less extensive workings nearby, mainly between this tunnel and the contact between the Cibolo formation and Cretaceous beds in the gulch below. In all the workings the ore is oxidized, and the principal metallic minerals are cerussite and smithsonite. A small intrusion of an intensely altered, fine-grained igneous rock is exposed at one place along the Cretaceous contact.

ROSS MINE

The Ross mine is in the northern part of section 9, block 7, about 9 miles by road from Shafter. It was located some time prior to 1895 and has apparently not been operated for 30 or 40 years. According to report some good lead-silver ore was shipped from this property in the early days, but data as to quantity and grade are not available.

The accessible part of the mine includes irregular workings in the upper part of a mass of dark, moderately coarse-grained limestone, supposed to belong to the Presidio formation, which has been eroded and dissolved by surficial waters and the resulting openings filled by a roughly bedded deposit of caliche containing pebbles and boulders, mostly of limestone and chert. In mining, small caves filled with this soft material have been re-excavated. Winzes extend into the limestone below. They were not accessible at the time of the visit but apparently are not deep. Much of the limestone in the upper workings, including boulders in the caliche, has been mineralized and

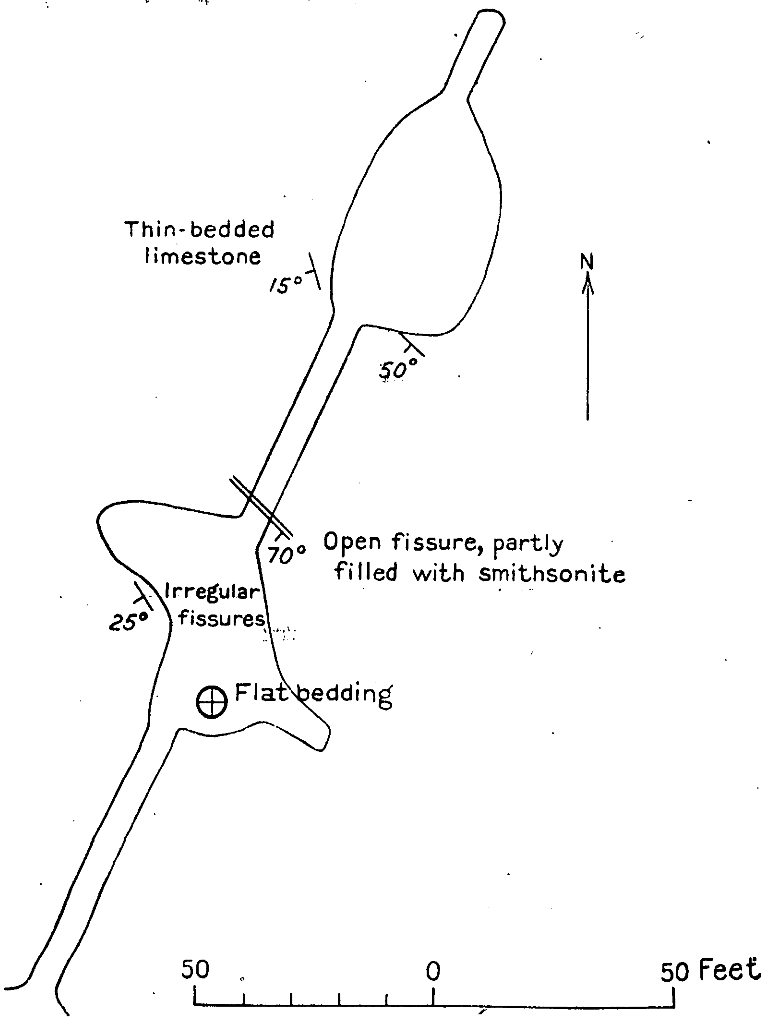

FIGURE 7.—Sketch map of the Montezuma mine.

subsequently oxidized. It is partly silicified, honey-combed, and extensively iron-stained. There is some cerussite, cerargyrite, and probably also argentite in places in the caliche.

LAST CHANCE MINE

The Last Chance mine, near the southern boundary of section 14, block 6 of the Galveston, Houston and San Antonio Railroad, has not been operated for many years, and at the time of the visit was not safely accessible. It includes a nearly vertical shaft on an irregular fracture zone in a massive limestone that appears to belong to the upper part of the Presidio formation. Solution openings along the fractures have been filled with debris, which consists in part of water-worn boulders. The mine is supposed to be at least 75 feet deep and to have produced a small amount of lead-silver ore, some of which was treated in a small concentrator on the property, now removed. It would appear from descriptions by those who knew the mine when it was in operation that part of the ore consisted of mere boulders in the crevice filling.

CIBOLO MINING CO.

The property of the Cibolo Mining Co. consists of 8 claims near the southern border of section 14, block 6, between the old Last Chance and Ross mines. Development here commenced in the spring of 1934. When visited early in June 1934, the shaft was down about 60 feet in soft, caliche-cemented material. Limestone similar to that in the old mines nearby crops out in the gulch below and the shaft was being sunk in search of it. When water was encountered in the shaft, late in June 1934, the mine was shut down.

MINOR PROSPECTS

At several places south and southwest of the old Ross mine pits and shallow shafts reveal oxidized lead ore in limestone. About a mile southwest of the Ross mine, along the branch road leading to the mine, there are small hills of quartzite intruded by altered igneous rock. Both rocks are colored yellow and red by iron oxides. Pits here show the presence of quartz, specularite, and masses of brown chert.

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