Dolomite Deposit near Sloan Nevada

By CHARLES DEISS

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A study of the stratigraphy and geologic structure of Sloan Hill

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DOLOMITE DEPOSIT NEAR SLOAN, NEVADA

By Charles Deiss

ABSTRACT

The dolomite deposit near Sloan, Clark County, Nev., is 19 miles southwest of Las Vegas. The deposit and surrounding area were studied and mapped by the U. S. Geological Survey in 1943 and 1944 to obtain dependable information concerning the stratigraphy and geologic structure of Sloan Hill, to make an accurate map on which the position of drill holes could be located, and to determine the grade and tonnage of the dolomite deposit.

Six rock units are exposed in the map area. The oldest, the Valentine dolomite, and the overlying Crystal Pass limestone are members of the Sultan limestone of Devonian age as described in the Goodsprings quadrangle. The Crystal Pass limestone member is 190 feet thick near Sloan. The Mississippian Monte Cristo dolomite, composed of the Dawn, Anchor, and Bullion members, overlies the Sultan. Dolomite of the Dawn member, which is 175 feet thick, was used by the Bureau of Mines in the pilot plant at Boulder City, Nev. The Anchor member, 75 feet thick, rests on the Dawn and contains 15 to 20 percent chert. The Bullion member overlies the Anchor and is 445 feet thick. The Bird Spring formation of Pennsylvanian age rests on the Monte Cristo dolomite northwest of Sloan Hill. A remnant of a flow of olivine basalt is the only igneous rock within the map area.

Sloan Hill is a fault block (horst) tilted gently to the north between two graben and bounded on three sides by high-angle normal faults that dip away from the hill. Two periods of deformation are indicated, an early period of compression when overthrusts and underthrusts were produced and a later period of tension when normal faults occurred. The normal faults can be grouped into two systems. The first system strikes N. 25°-48° W., subparallel or slightly oblique to the axis of Sloan Hill. The second system consists of short normal faults that strike approximately west. The faults in both systems dip 70°-88° to the southwest or northeast and are marked by conspicuous breccia zones 2 to 65 feet thick.

The dolomite in Sloan Hill is probably a replacement deposit formed early in Tertiary time when deep-seated igneous rocks were intruded in southern Nevada. The dolomites were originally limestones and magnesian limestones replaced by ascending magmatic solutions that derived part of their magnesia from the magma and part from the Goodsprings dolomite of Upper Cambrian to Devonian (?) age.

The Bullion member of the Monte Cristo dolomite in the upper part of Sloan Hill is readily accessible for mining by open-pit methods. At least 45,000,000

tons of high-grade dolomite is indicated. North and south of the block of indicated ore are two additional blocks of the Bullion that contain 22,000,000 tons of inferred ore. Thus the total indicated and inferred ore in the Bullion available to open-pit mining is 67,000,000 tons, to which 3,000,000 tons of Dawn member may be added, giving a grand total of 70,000,000 tons. Analysis of diamond-drill cores would be necessary to establish accurately the quality of the dolomite at depth.

The Anchor member, although a high-grade dolomite in Sloan Hill, contains so much chert that the rock is worthless as a commercial source of magnesium. The presence of the Anchor will prevent large-scale open-pit mining of the underlying Dawn member.

From 1929 to 1943, inclusive, the United States Lime Products Corp. mined approximately 1,693,340 tons of rock, of which the Crystal Pass limestone member of the Sultan limestone constituted 93 percent and the Dawn member of the Monte Cristo dolomite 7 percent. The Bullion member of the Monte Cristo has not been mined at Sloan Hill.

INTRODUCTION

LOCATION OF DEPOSIT

The dolomite deposit described in this report constitutes the upper part of the nearby isolated hill, herein called Sloan Hill, that rises approximately 900 feet above the railroad at Sloan, Nev. (fig. 14). Sloan, a small industrial town on the Los Angeles & Salt Lake Railroad (Union Pacific), is 19.2 miles by rail southwest of Las Vegas and 21.8 miles from the plant of Basic Magnesium, Inc. Sloan is also served by a graveled road 1½ miles long that joins paved U. S. Highway 91 approximately 17 miles southwest of Las Vegas. An unimproved

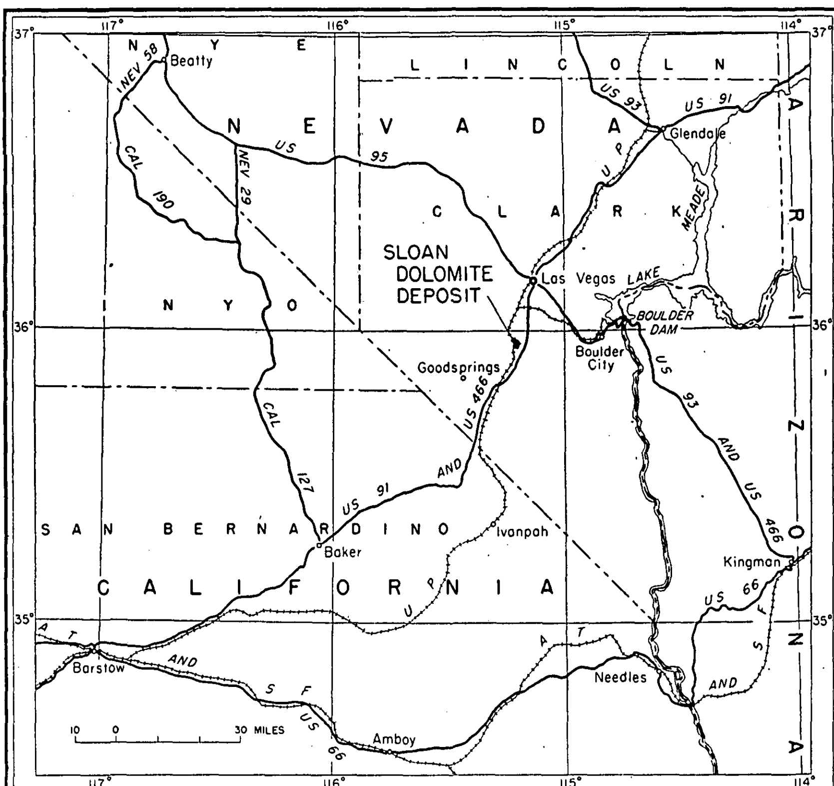


FIGURE 14.—Index map showing the location of the dolomite deposit near Sloan, Nev.

desert road connects the highway with the low pass on the east side of Sloan Hill.

The dolomite deposit is in the southwestern part of Clark County, Nev., and in the northeastern part of the Ivanpah quadrangle; it lies in the eastern part of the Mohave Desert. The principal part of the deposit is 3,200 to 3,700 feet above sea level, in the NE¼ sec. 13, T. 23 S., R. 60 E. The area mapped (pl. 13) is in the S½SE¼ sec. 12 and the NE¼ sec. 13, T. 23 S., R. 60 E., and in the SW¼SW¼ sec. 7, the W½ and NW¼NW¼ sec. 18, and the N½NW¼NW¼ sec. 19, T. 23 S., R. 61 E., Mount Diablo meridian.

PURPOSE OF INVESTIGATION

The deposit near Sloan was studied intensively by the U. S. Geological Survey because preliminary examination indicated a large reserve of seemingly high-grade dolomite that might be mined and converted into magnesium oxide (MgO) for plant feed at Basic Magnesium, Inc. The objectives of the study were to obtain accurate data relating to the geologic structure, stratigraphy, and geologic history of the Sloan area in order to make an accurate map on which the position of drill holes could be located; to obtain dependable information concerning the boundaries of the most promising block of dolomite on Sloan Hill for commercial development; to determine the lithologic characteristics and chemical composition of the dolomite; and to assemble data that might suggest the origin of the dolomite. All this information was needed to obtain reliable estimates of the grade and tonnage of the deposit.

FIELD WORK

The dolomite and limestone near Sloan were examined briefly by B. N. Moore (Hewett et al., 1936, pp. 163–164) as part of the exploratory survey of the mineral resources of the region around Boulder Dam. The deposit was examined, also, by J. Gordon Cole and R. G. Greene (1941, pp. 1–2) for the Union Pacific Railroad Co. in 1941 and by the Bureau of Mines (Weitz, 1942, p. 73) in 1942. The dolomites in the Sloan district were examined by the writer early in March 1943 as part of a reconnaissance examination of the dolomite deposits of southern Nevada that might be used as magnesium ore. At that time the Sloan deposit was chosen as the most favorable one in the southwestern part of the United States for additional study and development. The deposit and the contiguous upper part of Sloan Hill were mapped during the period April 5 to May 25, 1943, on a scale of 1:2,400 and with a contour interval of 20 feet. The region between Sloan Hill and the railroad was mapped during the period February 7 to April 22, 1944.

ACKNOWLEDGMENTS

R. H. Black and G. E. Ericksen assisted the writer in mapping in 1943. Ericksen assisted, also, with the preliminary field examination in March 1943 and in making chemical tests on the samples after the field work was completed. He was the field assistant in 1944 and also drafted the index map (fig. 14), the geologic map (pl. 13), and the structure sections (pl. 14). R. E. Tremoureux, President, United States Lime Products Corp., made available the information concerning production, history of development, and products manufactured at Sloan. L. N. Grindell, superintendent of the corporation's Sloan plant, made available its map of the property and the assays made for the company. Grindell also furnished the powder and the services of two men to obtain a 300-pound sample of dolomite (Bullion) and gave his time during the field work. H. C. Lee, Assistant Superintendent, Technical Service Department, Basic Magnesium, Inc., arranged for the preparation and analysis of the 300-pound sample of dolomite and made a number of useful suggestions. R. G. Greene and J. G. Cole, geologists of the Union Pacific Railroad Co., assisted the writer in the field during the preliminary examination in 1943 and furnished copies of their reports on the deposit. J. P. Mack, Engineer, Maintenance of Way, Union Pacific Railroad Co., furnished a map and profile section of the railroad near Sloan. Eugene Callaghan made a number of useful suggestions in the field and in connection with the report. To these persons and others the writer offers his thanks.

STRATIGRAPHY

GENERAL FEATURES

The sedimentary rocks near Sloan, as indicated on the geologic map (pl. 13), are Devonian and Carboniferous in age and were named and described by Hewett (1931) for their occurrence in the Goodsprings quadrangle, 20 miles west of Sloan. Hewett divided the Sultan limestone (Devonian) into three members; they are, from oldest to youngest, the Ironside dolomite, Valentine limestone, and Crystal Pass limestone members. The Ironside dolomite member is not exposed near Sloan, but is indicated in several of the structure sections (pl. 14). Hewett (1931, pp. 17–21) divided the Monte Cristo limestone (Mississippian) of the Goodsprings quadrangle into five members: the Dawn limestone, Anchor limestone, Bullion dolomite, Arrowhead limestone, and Yellowpine limestone members. The Arrowhead and Yellowpine limestone members are not lithologically separable from the Bullion member in the Sloan district because all are dolomitized. The name "Bullion" is therefore retained for the unit, and the name "Dawn member" is used in this area for the equivalent of Hewett's (1931, pp. 17–21) Dawn limestone member. The Bird Spring (Pennsylvanian) is the youngest formation near Sloan (Hewett, 1931, pp. 21–30).

Most of the dolomites were probably deposited as limestone and magnesian limestone. Dolomitization obscured and in places obliterated the boundaries of the original formations. Consequently, the cartographic units on the map (pl. 13) may partly represent replaced areas instead of original stratigraphic formations. All the rocks mapped as the Crystal Pass limestone member of the Sultan limestone (pl. 15) may not be Devonian in age and may not be precise time equivalents of the rocks assigned by Hewett (1931, p. 15) to the Crystal Pass limestone member in the Goodsprings quadrangle.

DESCRIPTION OF FORMATIONS

SULTAN LIMESTONE

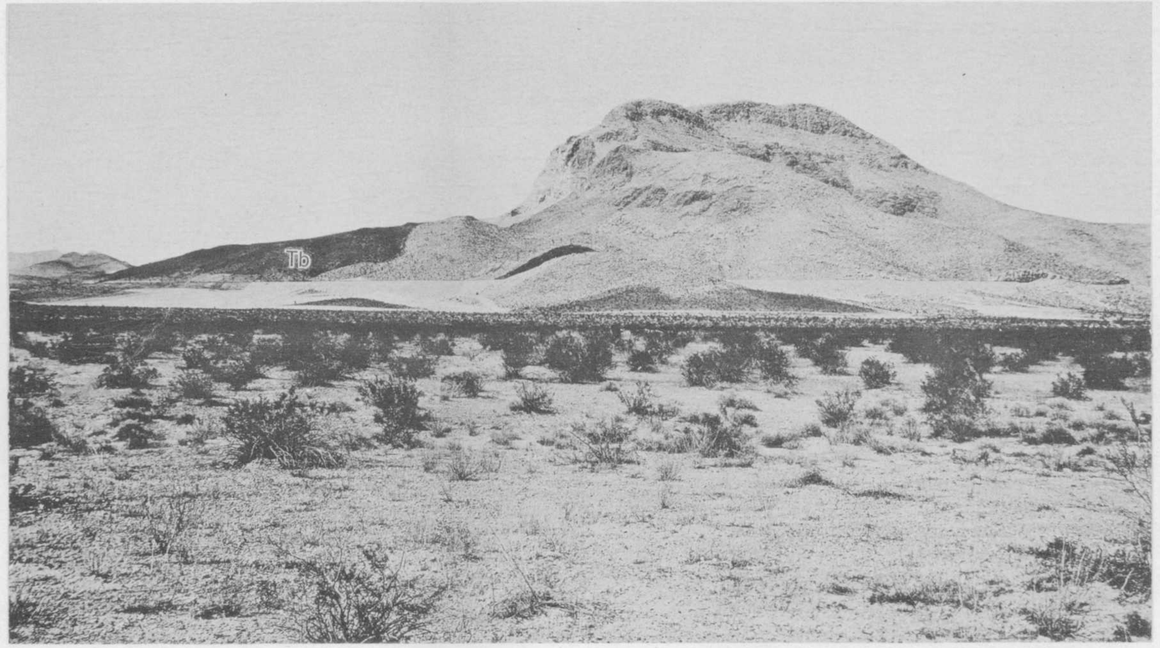
VALENTINE DOLOMITE MEMBER

The oldest rocks exposed in the Sloan map area (pl. 13) are dull-gray, finely to medium crystalline, thick- and thin-bedded, unfossiliferous dolomites and limestones that weather reddish tan. These rocks, the Valentine dolomite member, are equivalent to the Valentine limestone member of the Sultan limestone (Hewett, 1931, pp. 14–15) in the Goodsprings quadrangle. The Valentine member is exposed along the southwest side of Sloan Hill (pl. 15*A*), where it is overlain by the Crystal Pass limestone member. Much of the Valentine in the Sloan map area is dolomite, but part of the formation is pale-gray, nearly lithographic limestone that contains irregular thin bands, spots, and stringers of reddish-weathering dolomite. Some of the upper beds contain lenses of calcareous sandstone and arenaceous limestone. Pale-green, medium-grained sandstone interbedded with 1-inch beds of green and maroon fissile shale and thicker beds of calcareous mudstone also are present locally. The lithologic characteristics of the part of the Valentine exposed in the Sloan area are described in the stratigraphic section (pp. 125–127).

When the stratigraphic section of the Valentine member was measured, 11 rock specimens were collected, one from each lithologic type of carbonate rock. The 11 rock specimens were combined to form one sample, which was analyzed by Esther Claffy in the Chemical Laboratory of the Geological Survey in Washington, D. C. $CaCO_3$ was calculated, and $MgCO_3$ was obtained by difference. The results of the analysis are:

	Percent
Insoluble	4.42
R_2O_3	.51
CaO	29.46
$CaCO_3$	52.59
$MgCO_3$	42.48

A. SOUTHWEST SIDE.



B. SOUTH END.

C. WEST SIDE.

QUARRIES AT SLOAN HILL, NEVADA.

Showing the Bullion (Cmb), Anchor (Cma), and Dawn (Cmd) members of the Monte Cristo dolomite; the Crystal Pass limestone (Dsc) and Valentine dolomite (Dsv) members of the Sultan limestone; and Tertiary olivine basalt (Tb). 1-7, Quarries; 8, primary crusher; 9, secondary crusher; 10, lime plant; 11, powder house; 12, Sloan station.

CRYSTAL PASS LIMESTONE MEMBER

The Crystal Pass limestone member of the Sultan limestone is best exposed along the southwest and west sides of the hill (pls. 15*A*, 15*C*), where it is being quarried by the United States Lime Products Corp. The member is 160 to 190 feet thick in the map area and is composed of pale blue-gray, thick- and thin-bedded, generally lithographic or finely crystalline limestone. The upper beds are separated by 1- to 10-millimeter laminae of calcareous shale. A unit 1 to 10 feet thick of pale-green and maroon shale interbedded with lenticular beds of limestone and dolomitic mudstone is well exposed in two of the quarry faces, 10 to 30 feet below the top of the member. Two other shale units, 8 to 14 inches thick, occur in the upper middle part of the member. The limestone weathers pale gray in contrast to the buff tan of the overlying Dawn member of the Monte Cristo dolomite and the reddish tan of the underlying Valentine dolomite member of the Sultan.

The Crystal Pass limestone member contains less dolomite than any other unit in the Sloan district. The contact of the Crystal Pass and Valentine members is not well exposed. The contact of the Monte Cristo and Sultan formations, however, is well exposed in the quarry walls but is irregular because of irregular dolomitization. The pale-gray color, the purity of the limestone, and the extreme fineness of grain readily distinguish the Crystal Pass from the other units in the Sloan district. The stratigraphic section of the Crystal Pass measured south of quarry 1 (pl. 15*A*) is given on pages 124–125.

The chemical composition of the undolomitized part of the Crystal Pass limestone member of the Sultan limestone at Sloan is indicated by the following analysis, taken from the report of Tremoureux (1932, p. 3):

	Percent
SiO_2	0.72
R_2O_3	.45
$CaCO_3$	97.11
$MgCO_3$	1.72

Concerning the chemical composition of the Crystal Pass, Tremoureux says: "Variations in the impurities do not exceed 10 percent plus or minus the above percentages."

The composition of the crushed limestone delivered to the lime plant is indicated by the following analyses made by William Watkins at the Sloan plant of the United States Lime Products Corp. Analyses 1 to 4 and 5 to 7 are of limestone mined in 1940 and 1941, respectively.

Analysis No.	Ignition loss (pct.)	Insoluble (pct.)	R_2O_3 (pct.)	CaO (pct.)	MgO (pct.)
1	43.20	0.58	0.43	55.56	0.33
2	43.20	.78	.46	54.58	.20
3	43.50	.62	.37	55.06	.24
4	43.40	.60	.24	55.00	.27
5	43.40	.70	.38	54.36	1.15
6	43.52	.76	.46	55.08	.29
7	43.40	.72	.57	55.28	.22

MONTE CRISTO DOLOMITE

DAWN MEMBER

The rock unit overlying the Crystal Pass limestone member of the Sultan limestone in the Sloan district is readily recognizable (pls. 15*A*, 15*C*) and is considered to be the stratigraphic equivalent of the Dawn limestone member of the Monte Cristo limestone (Mississippian) in the Goodsprings quadrangle, where it is reported by Hewett (1931, p. 17) to be 60 to 400 feet thick. In the Sloan district the Dawn member is approximately 175 feet thick and consists of two lithologic units. The lower unit, which comprises four-fifths of the formation, is dull faint chocolate gray, tan gray, light gray, or white; it consists of a medium to coarsely crystalline, thick-bedded dolomite that contains irregular solution cavities 1 to 10 millimeters and occasionally as much as 35 millimeters in diameter. The cavities are lined with white amorphous calcite. The few cherty nodules that weather tan gray in the Dawn member are confined to several feet of thickness 60 feet below the top of the lower unit. The upper unit consists of thinner-bedded (2 to 18 inches), tan-buff, medium crystalline dolomite, which in many places forms a small bench above the cliffs of the lower unit. The upper unit is so similar in composition to the dolomite in the overlying Anchor member that the contact of the Anchor and Dawn was drawn arbitrarily at the base of the lowest bed containing chert. The Dawn member weathers drab tan buff in contrast to the pale buff of the Bullion member. Weathered surfaces of the Dawn, like those of the Bullion, exhibit many pits and sharp points (pl. 16*B*).

Detailed lithologic descriptions of the Dawn member are given in the stratigraphic section (p. 123). The only dolomite quarried by the United States Lime Products Corp. at Sloan is from the Dawn. It was also used by the Bureau of Mines to make 96-percent magnesium oxide in the pilot plant at Boulder City, Nev.

H. W. St. Clair, Assistant Regional Engineer, Bureau of Mines, furnished analysis 1 and stated in a personal communication on February 3, 1943: "This assay represents the 15-year average of analyses of Sloan dolomite." L. N. Grindell, Superintendent, Sloan Works, United States

Lime Products Corp., furnished analysis 2, made by G. E. Troxell on January 16, 1942. Analysis 3 is of a chip sample taken by J. G. Cole (1942, p. 3) from the Dawn member of the Monte Cristo dolomite on the hill east of Sloan Hill and was made by the California Testing Laboratories, Inc., Los Angeles, Calif.

Analysis No.	Ignition loss (pct.)	Insoluble (pct.)	R_2O_3 (pct.)	CaO (pct.)	MgO (pct.)
1	47.10	0.14	0.37	31.44	20.40
2	46.80	.10	[1].29	31.50	21.40
3	45.95	.85	.28	31.74	21.54

[1] Al_2O_3 only.

ANCHOR MEMBER

In the mapped area the 65 to 75 feet of rock above the Dawn member is assigned to the Anchor member of the Monte Cristo dolomite (pl. 15*C*). It is composed of a dense, hard, finely and medium crystalline dolomite that is generally thin-bedded (2 to 18 inches), buff and pale gray in color, and characterized by flattened ovoid nodules of gray and tan chert arranged in irregular layers. The nodules range in length from half an inch to 7 inches and average 4 inches in thickness. The chert constitutes 40 to 60 percent of some beds and possibly 15 to 20 percent of the formation. Lenticular beds and irregular masses of limestone as much as 35 feet thick are present in some places (pl. 13). The Anchor member forms prominent steep slopes between the Bullion and Dawn members (pl. 16*A*) and contains a few poorly preserved specimens of *Spirifer* sp., fenestrellinid bryozoans, and zaphrentid corals. The Anchor member near Sloan resembles the Anchor limestone member of the Goodsprings quadrangle in the presence of abundant chert nodules, similar stratigraphic position, and similarity of the fossils. The Anchor near Sloan, however, is predominantly dolomitized. (See pp. 122–123.)

The following analyses were made of three chip samples taken from the dolomite matrix of the Anchor member of the Monte Cristo dolomite, exclusive of the chert and limestone. The chips were taken 4 to 7 feet stratigraphically apart across the entire thickness of the Anchor on the southwest side of Sloan Hill. The traverse lines along which the chips were collected were approximately 500 feet from one another. The analyses were made by Esther Claffy in the Chemical Laboratory of the U. S. Geological Survey, Washington, D. C.

Analysis No.	Insoluble (pct.)	R_2O_3 (pct.)	CaO (pct.)	$CaCO_3$ (pct.)	$MgCO_3$ (pct.)
1	0.86	0.32	30.56	54.55	44.27
2	1.63	.61	30.09	53.71	44.05
3	.97	.42	30.59	54.59	44.02

The excessive amount of chert in the Anchor member makes the rock useless as a commercial source of magnesium, and the presence of this member will prevent large-scale quarrying of the underlying Dawn member by open-pit methods.

BULLION MEMBER

The youngest Mississippian rocks in the Sloan district lie between the Anchor member of the Monte Cristo dolomite and the Pennsylvanian Bird Spring formation and are included with the Bullion member of the Monte Cristo dolomite (pls. 13, 15*C*). The upper part of this unit in Sloan Hill is thought to be equivalent to the Arrowhead and Yellowpine limestone members of the Monte Cristo limestone in the Goodsprings quadrangle because of the presence in one horizon of individuals of a large zaphrentid coral associated with large gastropods. The Arrowhead and Yellowpine limestone members, however, because of dolomitization are not lithologically recognizable and are therefore included with the Bullion. Moreover, most of these rocks near Sloan are probably correlative with Hewett's (1931, p. 18) Bullion dolomite member of the Monte Cristo limestone.

The Bullion member in Sloan Hill is 445 feet thick (pp. 121–122), is almost completely exposed (pls. 15*A*, 15*C*), and contains the most promising dolomite in southern Nevada for mining by open-pit methods. The dolomite in the Bullion member is also the only dolomite near Sloan exposed in a large enough block to be mined on a large scale by power shovels (pls. 15*A*, 15*C*).

The lower 325 to 350 feet of the Bullion member on Sloan Hill consists of coarsely crystalline, thick-bedded, massive dolomite that is pale gray, cream gray, and white and contains many irregular solution cavities 1 to 5 millimeters in diameter. Several irregular zones are stained pink or pink gray. The dolomite is much jointed and weathers to angular tan-buff blocks (pl. 16*A*) whose surfaces consist of irregular sharp points and pits (pl. 15*B*). Finely banded secondary dolomite and calcite were deposited in some of the joint fissures. Chert is rare or absent except in the basal 3 to 10 feet of the formation, where irregular nodules and masses of tan and gray chert are present. The basal cherty bed of the Bullion is useless as a commercial source of magnesium and was mapped with the underlying Anchor member (pl. 13).

The upper 75 to 100 feet of the Bullion member is generally thinner-bedded and contains more numerous veins of secondary calcite along joint surfaces and bedding planes. A number of lenticular beds of gray, siliceous, dolomitic limestone are irregularly intercalated with the dolomite. The siliceous beds are covered with desert varnish (Laudermilk, 1931, pp. 51–66) on weathered surfaces. (See analyses 8, 9.) Silicified specimens of *Zaphrentis* sp. and *Lithostrotion* sp. occur locally in the lower part of the upper unit. A few lenticular masses of limestone are present in the upper part of the Bullion on the north and northeast sides of the hill (pl.13). The lithologic units in the Bullion are described in the stratigraphic section (pp. 121–122).

The following chemical analyses of samples from the Sloan deposit indicate that the dolomite in the lower 325 to 350 feet of the Bullion member of the Monte Cristo dolomite is uniformly high-grade. The upper quarter of the Bullion contains many irregular lenticular beds of siliceous dolomite (analyses 8, 9), which reduce the over-all grade of this part of the member. The uniformly high-grade dolomite in the Bullion is indicated by analyses 1 to 7 and 10 to 14.

Analysis No.	Ignition loss (pct.)	Insoluble (pct.)	R_2O_3 (pct.)	CaO (pct.)	$CaCO_3$ (pct.)	MgO (pct.)	$MgCO_3$ (pct.)	Total (pct.)
1	47.1	0.45	0.27	30.4	....	21.8	....	[1]100.056
2	....	.35	.45	30.7	54.80	....	44.4	100.00
3	....	.24	.12	30.36	54.19	....	45.45	100.00
4	....	.30	.27	30.41	54.28	....	45.15	100.00
5	....	.97	.49	36.43	65.03	....	33.51	100.00
6	....	.28	.43	30.77	54.94	....	44.35	100.00
7	....	.34	.12	31.00	55.34	....	44.20	100.00
8	....	23.56	.23	23.32	41.62	....	34.59	100.00
9	....	67.21	.75	10.54	18.81	....	13.23	100.00
10	45.29	.50	.40	32.52	....	21.63	....	100.34
11	46.00	.26	.32	31.96	....	21.53	....	100.07
12	45.90	.29	.32	32.56	....	21.03	....	100.10
13	45.68	.50	.30	32.90	....	20.83	....	100.21
14	45.95	.35	.22	32.26	....	21.26	....	100.04

[1] Includes S, 0.003; P_2O_5, 0.007; and Mn, 0.026.

1. Three-hundred-pound sample from four holes blasted in lower 350 feet of member. Analyst, H. P. House, Basic Magnesium, Inc.
2. Chip sample taken from beds 5 to 15 feet stratigraphically across lower 300 feet of member. Analyst, Esther Claffy, U. S. Geological Survey.
3. Composite sample of 14 specimens from lower three-quarters of member in section measured across hill above northern quarry. Analyst, Cyrus Feldman, U. S. Geological Survey.
4. Sample of combined specimens 4414 and 4416 from measured section (pp. 122). Analyst, Esther Claffy, U. S. Geological Survey.
5. Specimen 4415 from 5-inch vein of banded dolomite and calcite in measured section. Analyst, Esther Claffy, U. S. Geological Survey.
6. Specimen 4418, salmon-red and gray dolomite, from measured section. Analyst, Esther Claffy, U. S. Geological Survey.
7. Specimen 4420, light-gray siliceous (?) dolomite, from measured section. Analyst, Esther Claffy, U. S. Geological Survey.
8. Specimen 4422, brown-weathering siliceous dolomite, from measured section. Analyst, Esther Claffy, U. S. Geological Survey.
9. Siliceous dolomite coated with desert varnish, taken near crest of Sloan Hill. Analyst, J. E. Husted, U. S. Geological Survey.

10 to 14. Samples of dolomite from Bullion member on hill east of Sloan Hill, taken by R. G. Green and J. G. Cole (1942, p. 4), geologists, Union Pacific Railroad Co. Analyst, California Testing Laboratories, Inc.

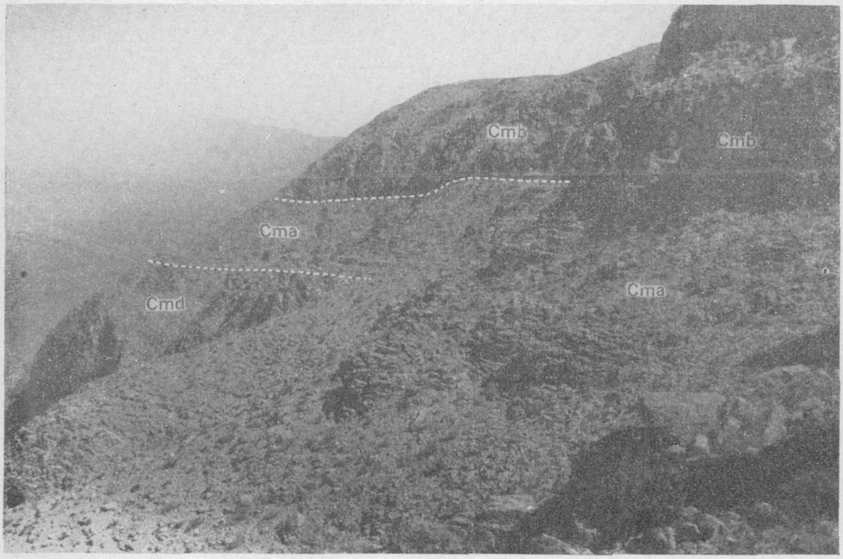
BIRD SPRING FORMATION

The youngest indurated sedimentary rocks in the Sloan map area are interbedded limestones, dolomites, shales, and sandstones that are the stratigraphic equivalent of the Bird Spring formation in the Goodsprings quadrangle (Hewett, 1931, pp. 21–23). Only the lower 100 to 125 feet of the formation was mapped in the Sloan district, but the lower 350 feet of the formation was measured (pp. 119–120). Hewett (1931, p. 21) states that the Bird Spring formation is 2,500 feet thick in the Goodsprings quadrangle. Near Sloan the lower part of the Bird Spring formation consists of bright-buff limestone in some places, dull-gray, finely crystalline, thick- and thin-bedded limestone in others, and maroon, dolomitic, arenaceous mudstone or shale in still other places. The contact with the underlying Bullion member of the Monte Cristo dolomite is irregular and poorly defined because the basal limestone of the Bird Spring formation is locally dolomitized. The stratigraphy is complicated further by isolated undolomitized limestone masses in the upper part of the Bullion member of the Monte Cristo dolomite and by dolomite breccia along its contact with the overlying Bird Spring formation.

The most striking characteristic of the Bird Spring formation in the Sloan area is its prominent banded appearance in cliffs (pl. 17*A*), in which it is usually darker-colored than the underlying Bullion member of the Monte Cristo dolomite. The beds are alternately dark gray and tan; gray is dominant. The characteristic banded appearance readily distinguishes the Bird Spring formation from the underlying unbanded Mississippian rocks, which are uniformly buff in color. The Bird Spring formation covers the Bullion member of the Monte Cristo dolomite only in the hills northwest of the Sloan deposit (pl. 17*A*) and therefore will not affect the mining of the dolomite (pl. 13).

STRATIGRAPHIC SECTION OF FORMATIONS EXPOSED ON SLOAN HILL

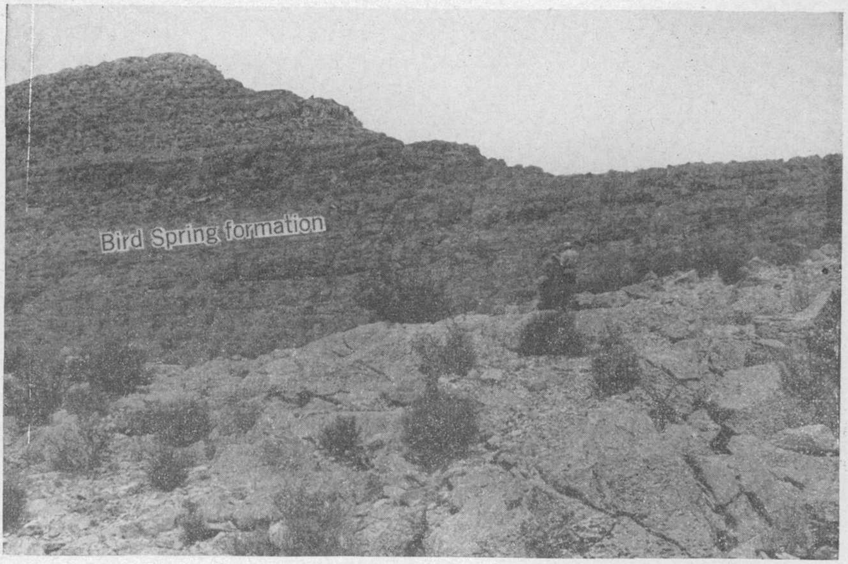
The following stratigraphic section was measured in three parts. The Valentine dolomite and Crystal Pass limestone members of the Sultan limestone were measured south of quarry 1 (pls. 13, 15*A*), the Dawn and Anchor members of the Monte Cristo dolomite above quarry 7 (pl. 15*C*), and the Bullion member of the Monte Cristo dolomite and the Bird Spring formation northwest of quarry 7 (pl. 15*C*) and along the crest of the hill (pl. 17*A*). The three parts of the section were tied in by tracing the contacts between the Dawn and the Crystal Pass and between the Anchor and the Bullion. Because these contacts may vary as much as 15 feet stratigraphically between the traverse lines of the measured section, some error may be present in the total thickness. The location of the traverse line of each part of the measured section is given in the text.



A. BENCH OF ANCHOR MEMBER ON THE WEST SIDE OF THE HILL.
Above the quarries. The Bullion (Cmb), Anchor (Cma), and Dawn (Cmd) members of the Monte Cristo dolomite are shown. See also plate 15.

B. POINTS AND PITS ON THE WEATHERED SURFACE OF THE BULLION MEMBER OF THE MONTE CRISTO DOLOMITE.
The flat part of the steel tape is 6 inches long.

SLOAN HILL, NEVADA.



A. LOWER PART OF THE BIRD SPRING FORMATION.
The northwestern part of the hill is shown. In the foreground is the Bullion member of the Monte Cristo dolomite.

B. PART OF A FAULT BRECCIA ZONE IN THE BULLION MEMBER OF THE MONTE CRISTO DOLOMITE.
The notebook at the top measures 8⅜ by 5¼ inches.

SLOAN HILL, NEVADA.

The first part of the section, including the Bullion member of the Monte Cristo dolomite and the lower part of the Bird Spring formation, was measured from an altitude of 3,180 feet upward on the southwest side of Sloan Hill (pl. 15*C*) to the crest of the main northwest ridge, thence northwest along the ridge to the top of the highest peak (altitude, 3,370 feet) of the Bird Spring formation (pl. 17*A*). The section traverse line is in the E½SW¼ sec. 12.

Stratigraphic section of formations exposed on Sloan Hill: Part I, Bullion member of Monte Cristo dolomite and lower part of Bird Spring formation

	Feet
Pennsylvanian:	
Bird Spring formation:	
48. Shale and limestone: Red arenaceous shale and thin interbedded limestones that contain siliceous nodules. Unit much covered. May contain much nodular-bedded arenaceous limestone	22
47. Dolomite: As in unit 46, but contains brown siliceous nodules and is even more sugary	56
46. Dolomite: White to white-gray, finely crystalline, sugary, thick- and thin-bedded siliceous dolomite; weathers buff and white gray; contains some angular chert nodules in lower and middle parts	32
45. Dolomite, limestone, and chert: Tan-buff, finely crystalline siliceous dolomite in thick beds; weathers bright buff tan; contains many chert nodules and, in lower part, a few beds of limestone. Upper 5 feet contains rounded, lenslike masses of siliceous oolites that weather in relief and take on dark-brown varnish	38
44. Limestone and chert: Dull-gray, lithographic, thin-bedded limestone and tan-brown chert; weathers gray and brown and forms strongly banded slopes	35
43. Limestone, dolomite, and chert: Dark-gray, medium and finely crystalline limestone, thick- and thin-bedded limestone, and interbedded, tan-weathering dolomite in lower half. Tan-gray, coarsely crystalline, thick-bedded, bright-tan-weathering dolomite in upper half. A few 1-foot shale beds in middle of unit. Most of limestone and all of dolomite contain many angular nodules and rounded masses of brown, tan, and gray chert that constitutes 15 to 25 percent of many beds. Unit weathers buff tan and gray; banded. Strong Liesegang rings in some larger chert nodules	62

	Feet
Pennsylvanian—Continued	
Bird Spring formation—Continued	
42. Limestone and shale: Dull-gray, medium crystalline siliceous limestone, overlain by shaly-bedded limestone, and shale (?), which forms prominent bench. Limestone grades laterally into bright buff-tan dolomite	17
41. Limestone: Dull-gray, medium crystalline limestone in beds 1 to 3 feet thick; weathers dull gray and forms cliff; contains many brachiopods, bryozoans, and a few shark teeth. Upper beds contain brown siliceous nodules	12
40. Limestone: Tan-gray limestone, stained maroon in spots; weathers white gray and to angular fragments; forms marker bed and bench	2-3
39. Limestone: Alternating series of dull-gray, coarsely crystalline, thick-bedded limestone; pale-gray, slightly lithographic, platy-bedded limestone; and white- to gray-weathering, lithographic, thick- and irregular-bedded limestone. Unit strongly bedded in contrast to limestone and dolomite in Bullion member of Monte Cristo dolomite. Some beds contain brown siliceous nodules. Upper 6 to 8 feet weathers red tan	48
38. Shale and limestone: Brick-red, soft, chunky, finely sandy shale interbedded with two 6- to 13-inch beds of gray, coarsely crystalline limestone stained red; contains rounded vitreous pebbles of bright hematite (?) 1 to 2 millimeters in diameter	11
37. Limestone: Pale tan-gray, finely crystalline, thick-bedded, massive limestone; breaks with conchoidal fracture; contains blebs, veins, and stringers of crystalline dolomite that weathers tan and limonite nodules one-quarter inch to 2 inches in diameter. Limestone weathers to dull-gray, rounded, rough surfaces. Many 1/8- to 1/4-inch crystals of limonite pseudomorphs after pyrite in upper beds of unit. This limestone may be unaltered Bullion instead of Bird Spring formation; the contact between the Bird Spring and Bullion is obscure here, and the base of the Bird Spring was arbitrarily taken at the base of the continuous limestone above the highest identifiable Bullion	15
Total measured thickness of Bird Spring formation	350

	Feet
Mississippian:	
Monte Cristo dolomite:	
Bullion member:	
36. Dolomite and limestone: Pale-gray, coarsely crystalline, thick- and thin-bedded, buff- to tan-weathering dolomite, interbedded with dull-gray, finely crystalline, thick- and thin-bedded, nearly pure limestone that contains isolated stringers and masses of coarsely crystalline dolomite. Upper 3 to 8 feet faintly brecciated	12
35. Dolomite: Pale- to white-gray dolomite with local areas of salmon red; coarsely crystalline, finely vesicular, marked with thin tan bands or streaks. Several beds of medium crystalline, gray-weathering dolomite. Twenty-two feet below top of unit is a 2- to 3-foot bed of siliceous gray dolomite covered with brown desert varnish. Siliceous dolomite weathers brown. Rock specimen 4422 of brown-weathering siliceous bed taken 22 feet below top of unit	61
34. Dolomite: Pale- and white-gray, generally finely to medium crystalline, thick- and thin-bedded dolomite; lower half contains three or four siliceous beds. Middle zone contains compound corals with small, isolated, round corallites, a large (4 to 5 inches) simple coral, and occasional *Syringopora* sp. Cephalopods absent in this locality but present at this horizon on east side of Sloan Hill. Several 8- to 15-inch beds of dolomite weather light gray in contrast to buff tan to which most of Bullion weathers. Rock specimen 4420 of light-gray siliceoue (?) dolomite taken 21 feet above base	67
33. Dolomite: Pale-gray, medium and coarsely crystalline, thick-bedded dolomite; weathers much lighter tan than in unit. Lower 10 feet contains siliceous zones that weather pale to dark brown depending on amount of silica. Another siliceous zone occurs a quarter of way down unit	64
32. Dolomite: Pale-gray, coarsely crystalline dolomite with much maroon; weathers banded maroon tan in contrast with underlying units; contains thin breccias along joint planes and many veins 1 to 5 inches thick of secondary calcite and dolomite. One 3- to 4-foot mass of dolomite contains irregular dark-red hematite nodules. Rock specimen 4418 of salmon-red and gray dolomite taken a third of way down unit	68

	Feet
Mississippian—Continued	
Monte Cristo dolomite—Continued	
Bullion member—Continued	
31. Dolomite: As in unit 29, but smoother-bedded; contains thick, finely banded veins as in unit 30. Rock specimen 4416 from middle of unit combined with specimen 4414 in analysis 4 (p. 117)	48
30. Dolomite: Light-gray dolomite, some beds marked with areas of faint tan gray and salmon gray; contains wavy-banded veins 2 to 6 inches thick of brown-gray, impure secondary dolomite and white calcite. Rock specimen 4415 from vein 5 feet below top of unit	64
29. Dolomite: Light cream-gray, coarsely crystalline, thick-bedded, massive pure dolomite, dull gray in lower part; weathers tan and to sharp points and round depressions (pl. 16*A*); contains many 1- to 3-millimeter cavities and a few simple corals. Lower 5 feet similar to finely crystalline dolomite of upper 5 feet of Anchor member; contains large, irregular lenses of chert and calcite. Rock specimen 4414 taken 1 foot above base of unit	61
Total thickness of Bullion member	445

The second part of the section, including the Anchor and Dawn members of the Monte Cristo dolomite, was measured from the top of the Sultan limestone above quarry 7 (pl. 15*C*), from an altitude of 3,220 feet up the hill northeastward to an altitude of 3,460 feet at the base of the Bullion member of the Monte Cristo dolomite. This part of the section was measured in the N½SW¼NE¼ and the S½NW¼NE¼ sec. 13 (pl. 13).

Stratigraphic section of formations exposed on Sloan Hill: Part 2, Anchor and Dawn members of Monte Cristo dolomite

	Feet
Mississippian:	
Monte Cristo dolomite:	
Anchor member:	
28. Dolomite and chert: As in unit 27, but dolomite is thicker-bedded and probably contains a little less chert. See analyses of chip samples of Anchor (p. 116)	24
27. Dolomite and chert: Pale- and dark-gray, finely to medium crystalline dolomite in 2- to 18-inch beds and tan and pale-gray chert in bands of irregular ovoid nodules half an inch to 7 inches thick and 12 to 36 inches long. Chert forms 10 to 20 percent of this unit	51
Total thickness of Anchor member	75

	Feet
Mississippian—Continued	
Monte Cristo dolomite—Continued	
Dawn member:	
26. Dolomite: Faint tan-gray to light-gray dolomite, stained pink locally, finely to coarsely crystalline, in 2- to 18-inch beds; weathers tan buff; contains thin partings of calcareous and dolomitic shale	14
25. Dolomite: White-gray, medium to coarsely crystalline dolomite; forms upper part of cliff here	12
24. Dolomite: Dull-gray to faint chocolate-gray dolomite, stained red locally; medium to coarsely crystalline, thick-bedded, dense, hard; forms buff-tan weathered cliff	27
23. Dolomite: Pale-gray, medium crystalline, thick-bedded dolomite; contains flatly coiled gastropods and an occasional irregular siliceous nodule 6 to 8 inches in diameter	27
22. Dolomite: In lower three-quarters of unit, tan-gray, coarsely crystalline, thick-bedded dolomite containing 1- to 20-millimeter cavities, some of which contain calcite. Upper quarter lighter tan-gray, with some pale chocolate-gray, medium crystalline dolomite. Rock weathers drab buff tan and to sharp points and to cavities (pl. 16*B*); forms slope composed of broken ridges	55
21. Dolomite: Irregularly mottled, dull-tan and light-gray, coarsely crystalline, finely vesicular dolomite in beds 1½ to 4 feet thick; weathers drab buff and to points and cavities irregularly arranged in bands	40
Total thickness of Dawn member	175

The third part of the section, including the Valentine dolomite and Crystal Pass limestone members of the Sultan limestone, was measured southeast of quarry 1 (pl. 15*A*), on the southeast side of Sloan Hill in the N½SE¼SE¼ and the S½NE¼SE¼ sec. 13 (pl. 13). The line of the section traverse extends north from the lowest exposed beds of the Valentine, at an altitude of 2,900 feet in the small gully near the end of the railroad spur, up the hill to the contact of the Dawn and Crystal Pass near the upper edge of the quarry wall at an altitude of 3,260 feet. The strata in the section are broken by several small normal faults, but as the rocks are well exposed and the same beds can be recognized on both sides of the fault planes, probably no parts of the section are omitted or duplicated.

Stratigraphic section of formations exposed on Sloan Hill: Part 3, Valentine dolomite and Crystal Pass limestone members of the Sultan limestone

	Feet
Devonian:	
Sultan limestone:	
Crystal Pass limestone member:	
20. Limestone: Most of unit dull-gray, lithographic, thick-bedded limestone partly replaced with irregular stringers of coarsely crystalline, tan-weathering dolomite. Stringers parallel with bedding in upper 4 feet. Beds much jointed, some irregularly marked with maroon. Lower part dark gray; contains pseudomorphs of limonite or hematite 8 to 15 millimeters square. Contact of Dawn and Crystal Pass irregular here as a result of dolomitization	15
19. Mudstone: Tan-green, brown, and maroon mudstone, nearly unbedded; weathers red buff and forms bench here. This unit appears green and tan brown in quarry walls	10
18. Limestone and shale: Gray and black-gray, finely crystalline limestone in 1- to 3-foot beds, interbedded with 6- to 18-inch units of gray and green-gray shale. This 22-foot unit appears to be all limestone in quarry wall just west of here	22
17. Limestone: Alternating 3- to 5-foot beds of light-gray, finely to medium crystalline and dark-gray, finely crystalline, nodular-bedded limestone; weathers light and dark gray	20
16. Limestone and shale: Basal and upper parts nodular-bedded limestone and shale partings, separated by 6 or 7 feet of dark-gray, finely crystalline, finely banded limestone that weathers dull gray. Unit forms bench	15
15. Limestone and shale: Dull- and light-gray, lithographic and finely crystalline limestone in beds 1 to 48 inches thick, separated by thin partings of green and red shale. Two 6- to 14-inch units of tan and green shale occur 35 feet stratigraphically apart. Limestone weathers dull gray, stained maroon, and to sharp points and depressions. Upper bed 2½ feet thick; weathers tan buff. Quarry wall shows cavities, as much as 18 inches long, filled with green and maroon hematitic clay, and many joint partings filled with white calcite veins	55

	Feet
Devonian—Continued	
Sultan limestone—Continued	
Crystal Pass limestone member—Continued	
14. Limestone and shale: Finely crystalline, nodular-bedded limestone interbedded with pale-green shale. Unit not well exposed; forms bench	2½-3
13. Limestone and dolomite: Pale-gray, lithographic, thick- and thin-bedded limestone partly replaced with tan-gray, finely to medium crystalline dolomite that weathers tan. Limestone weathers gray and forms cliff. Contact of Crystal Pass and Valentine members here not a boundary between natural stratigraphic units, but upper limit of dolomitization of original Valentine member. Contact in Sloan map area also irregular, extending through beds 15 to 20 feet thick within short horizontal distances	50
Total thickness of Crystal Pass limestone member	190
Valentine dolomite member:	
12. Dolomite: Dark- and light-tan dolomite, finely crystalline in lower part and medium crystalline in upper part; weathers brown and to sharp points and cavities. Lower quarter contains ferrous, siliceous layers and nodules, as much as 18 inches thick, that weather dark rusty brown and in relief. Upper quarter lighter in color and more coarsely crystalline. Rock specimen 4413 taken 10 feet below top of unit; rock specimen 4412 taken 1 foot above base of unit. (See discussion of analysis of Valentine dolomite member on p. 112.)	26
11. Dolomite: Dull tan-gray and dark tan-gray, finely to medium crystalline, thick-bedded, hard, slightly vitreous dolomite; weathers tan brown and to sharp points and pits; contains flakes, veins, and nodules of impure hematite. Some beds finely wavy-banded on weathered surfaces. Dolomite strongly siliceous in upper quarter of unit. Rock specimen 4411 from middle of unit. (See p. 112.)	43
10. Dolomite: Tan-gray, finely crystalline, thin-bedded dolomite; weathers brown, strongly stained red; contains much impure hematite in veins and, in upper part of unit, nodules and parting laminae of dolomitic sandstone. Units 8 to 10 form bench and smooth slope above cliffs formed by dolomite in unit 7	4-4½

Devonian—Continued | *Feet*
Sultan limestone—Continued
Valentine dolomite member—Continued

9. Mudstone, shale, and limestone: Pale-gray and pale-green, calcareous, arenaceous mudstone that grades laterally into arenaceous, siliceous dolomite. Mudstone contains an intercalated 1-inch bed of bright-green, slightly fissile shale and, in upper part, 1- to 2-inch lenses of impure, argillaceous limestone or dolomite 4
8. Sandstone: Tan and dull-gray, fine-grained, soft, medium-bedded, slightly argillaceous sandstone; calcareous, becoming more so in upper 2 feet. Rock much jointed; in upper half contains dark-red hematite flakes and small nodules. This sandstone well exposed only in one small gully 14
7. Dolomite: Tan- and brown-gray dolomite, slightly vitreous in some beds; thick-bedded (1 to 5 feet); weathers brown and forms lowest prominent cliff in section here; contains veins and flakes of hematite calcite. Occasional beds slightly arenaceous but grade laterally into purer dolomite. Rock specimen 4408 from upper middle of unit. (See p. 112.) 47
6. Dolomite: Dark steel- to tan-gray, slightly vitreous, hard, thick- and irregular-bedded dolomite; weathers reddish chocolate brown and to sharp points and depressions; contains many ½- to 1-inch veins of amorphous white calcite. Rock specimen 4407 from middle of unit. (See p. 112.) 59
5. Dolomite: Dull blue-tan, medium crystalline, hard, thick-bedded dolomite, slightly vitreous on fresh fractures; weathers drab red brown and to rough surfaces; contains many 0.2- to 1.0-millimeter veins and flakes of hematite. Rock specimen 4406 from middle of unit 23
4. Dolomite: Dark brown-tan, finely crystalline, hard, thick- and thin-bedded dolomite, probably siliceous; weathers drab tan. Many beds finely wavy-banded; bands weather slightly in relief. Rock specimen 4405 taken 6 feet above base of unit 20
3. Dolomite: Pale tan-gray, finely crystalline, hard, thick- and thin-bedded, slightly arenaceous dolomite; weathers to smooth tan-gray surfaces. Near base is 3- to 4-foot unit of arenaceous limestone or calcarenite. Rock specimen 4404 taken 9 feet below top of unit; rock specimen 4403 from arenaceous lens 25

	Feet
Devonian—Continued	
Sultan limestone—Continued	
Valentine dolomite member—Continued	
2. Dolomite: Drab brown-gray dolomite in lower part grading to dull tan gray in upper part; finely crystalline to finely sugary; thick-bedded; softer and less dense than in unit 1, probably siliceous; weathers drab gray; contains irregular veins of secondary calcite one-eighth inch to 4 inches thick and, in lower part, several beds of fault breccia 1 to 2 feet thick. Rock specimen 4402 taken 8 feet below top of unit. (See p. 112.)	54
1. Limestone: Dull blue-gray, medium crystalline, hard, siliceous, dolomitic limestone in beds 13 to 24 inches thick; weathers dull gray and to irregular points and depressions; contains many 0.2- to 0.5-millimeter veins of hematite-stained calcite. Rock specimen 4401 taken 2 feet above base of unit. (See p. 112.)	6
Total exposed thickness of Valentine dolomite member (lower part covered with hill wash)	325

IGNEOUS ROCKS

The only igneous rock exposed in the Sloan map area is the erosional remnant of a basalt flow at the south end of the area (pl. 13; pl. 14, sections *E–E′*, *F–F′*, *H–H′*). The igneous mass, approximately 1,500 feet in diameter, is irregularly circular in outline and is eroded into a low rounded hill (pl. 15*B*). The basalt was extruded in middle or late Miocene time after Sloan Hill was maturely eroded and long after dolomitization was completed.

In the field, the flow appears to consist of several types of extrusive rocks that range from gray black to maroon in color and from basaltic to andesitic in composition. Much of the rock is finely crystalline and dense, but some local areas are porphyritic and others are scoriaceous. Thin sections of specimens taken from different parts of the flow, however, indicate that the rock is a fairly uniform olivine basalt, of which parts are strongly vesicular and other parts are much altered.

The following petrographic descriptions of specimens from four widely separated parts of the igneous mass are taken from an unpublished report by R. L. Smith, who studied the rocks in the laboratory of the U. S. Geological Survey in Washington, D. C. Specimen 1 was taken from the northern part of the mass at an altitude of 2,900 feet (pl. 13). Specimen 2, described in the field as "red scoria," was taken from the northeastern part of the mass at an altitude of 2,928 feet. Specimen

3 was collected in the railroad cut near the southwest edge of the igneous mass, and specimen 4 came from a small dikelike mass within and near the southeast corner of the flow at an altitude of 2,840 feet. Smith says:

Specimen no. 1 consists of olivine, pigeonite, and calcic-andesine, with small amounts of interstitial alkalic feldspar, biotite, and magnetite. The olivine and pigeonite occur both in phenocrysts and in the groundmass. It seems likely, however, that they represent only one generation, as the crystals of both the olivine and the pigeonite are gradational in size from the phenocrysts to the groundmass material. All of the olivine crystals are partially altered to iddingsite. Flow structure is pronounced.

Specimen no. 2 is a highly altered vesicular rock composed of phenocrysts of iddingsite after olivine in a groundmass of clino-pyroxene and calcic-plagioclase. The original composition of this rock was probably similar to no. 1. The secondary minerals include calcite and a clay mineral (possibly saponite), which occur as linings and fillings in the vesicles, and iron oxide, which impregnates the entire rock and has no doubt been derived by the oxidation of the ferromagnesian minerals.

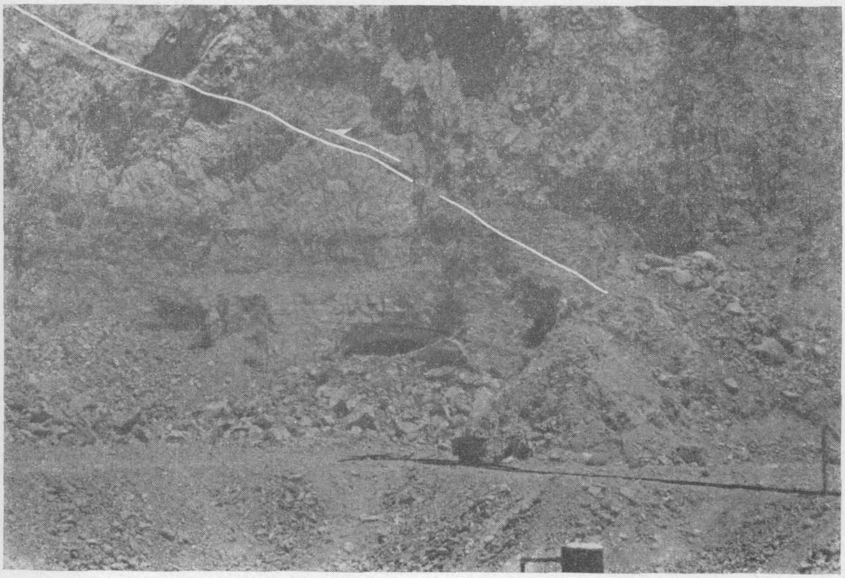
Specimen no. 3 is a very coarse-grained porphyritic rock containing large phenocrysts of zoned plagioclase (labradorite cores and calcic-andesine rims), augite, and iddingsite after olivine, in a coarsely crystalline groundmass of calcic-andesine and augite. Small amounts of magnetite and hornblende are also present in the groundmass. This rock contains a number of vesicles that are filled usually with calcite and sometimes with a clay mineral (possibly saponite) or with mixtures of both. In composition this rock could be an olivine basalt, and if it is truly a flow rock there seems no alternative but to call it an olivine basalt. It is extremely coarse-textured for a normal basaltic rock; even the groundmass material is unusually coarse for a normal basaltic texture.

Specimen no. 4 is composed of phenocrysts of olivine in a groundmass of olivine, pigeonite, and labradorite. The olivine phenocrysts all have a pronounced iddingsite rim with an unaltered olivine interior. The groundmass olivine has gone over entirely to iddingsite. This rock is quite similar in texture and general appearance to no. 1.

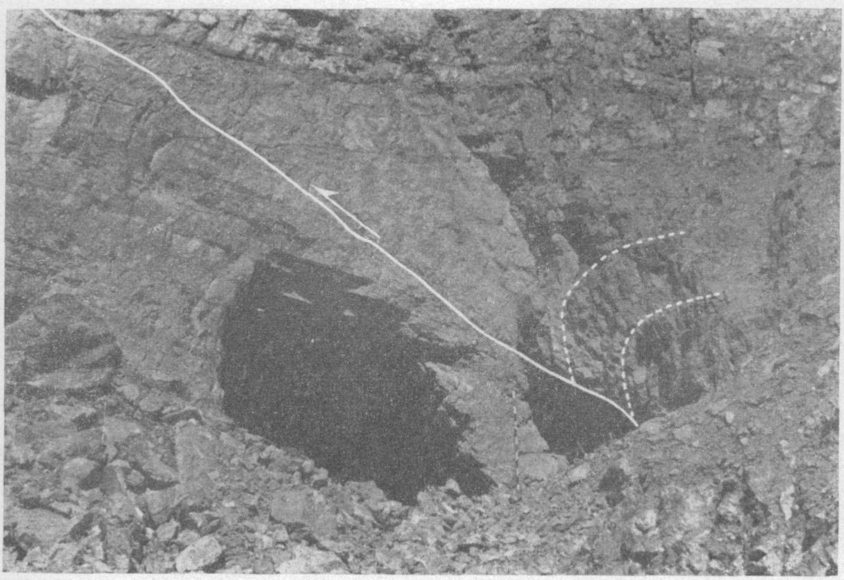
GEOLOGIC STRUCTURE

GENERAL FEATURES

Sloan Hill (pl. 15) is a fault block tilted gently to the north and bounded on the southwest, southeast, and northeast sides by high-angle faults that dip away from the hill (pl. 13). It therefore has the structure of a horst and probably lies between two graben. The beds exhibit a wide range of dip in many of the fault blocks on the sides of the hill; they dip 5°-33° N. in the northern crest of the hill, and they are approximately horizontal in the central part of the hill. Most of the faults are in the southwest, south, and southeast sides of the hill (pl. 14). The present relief of Sloan Hill is due to displacement on these faults. The rocks are most disturbed in the southern half of the map area, where the beds were broken and repeated by small thrust faults (pls. 18*A*, 18*B*).



A. SMALL OVERTHRUST IN THE CRYSTAL PASS LIMESTOME MEMBER OF THE SULTAN LIMESTONE.
Face of quarry 3. Note the mouths of the two tunnels.



B. DRAG FOLD ON A SMALL OVERTHRUST.
Above the south tunnel in quarry 3. Compare with *A.* The fold is at the left on the overthrust side of the fault. Stadia rod in foreground.

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Two periods of deformation are indicated by the faulting: an early period (Eocene?) of compression when the low-angle thrusts were produced and a later period (Miocene?) of tension when the normal faults developed. These two periods were probably contemporaneous with the formation of the overthrusts and the "early normal faults" (Hewett, 1931, pp. 54, 55, 60) in the Goodsprings quadrangle, but the geologic age of the faults in the Sloan area can only be inferred.

THRUST FAULTS

Nine overthrust faults were found in the southern and southeastern parts of Sloan Hill. The most conspicuous one is near the intersection of sections *E–E′* and *H–H′* on plate 13, near the south edge of the map area. A plate of the Bullion member of the Monte Cristo dolomite was thrust northwestward over the Anchor member along this thrust, which dips to the southwest and is nearly parallel with the bedding (pl. 14, middle part of section *F–F′*, left edge of section *H–H′*). Both members were intensely brecciated, and the thrust was broken by westward-dipping high-angle normal faults.

On the crest of the south end of the hill, 350 to 550 feet southeast of section *D–D′*, plate 13, the Anchor and Bullion members were thrust southward over the Bullion along an overthrust that dips to the northwest. The Dawn member was thrust eastward over the Anchor member along another fault that dips gently to the northwest, 20 to 280 feet southeast of section *D–D′*, plate 13, southeast of the hill crest. On the northeast side of the hill, 430 to 730 feet southeast of section *C–C′*, plate 13, the Dawn was thrust west over the Anchor along an eastward-dipping thrust fault.

The amount of movement on the overthrusts in the Sloan area is unknown but appears to have been as little as 10 and as much as 150 feet. The faults died out northward. The dolomite and limestone were dragged into folds (pl. 18*B*) but were much less brecciated by the overthrusts than by the normal faults (pl. 17*B*), the only large breccia zone on a thrust fault being the one on the low-angle thrust in the southern part of the map area (pl. 14, sections *E–E′*, *H–H′*).

In the faces of quarries 3 and 4, several thrusts are exposed. They die out rapidly or merge with the bedding planes. Because most of these thrusts are exposed only in steep cliffs (pl. 18*B*) and are within one formation, their displacement cannot be shown on the map (pl. 13).

NORMAL FAULTS

Normal faults are numerous and conspicuous in the Sloan area and, like the thrusts, are more numerous on the sides than in the upper part of Sloan Hill (pl. 13). In contrast with the thrusts, many of the normal faults are marked by conspicuous breccia zones 2 to 65 feet thick. The breccia zones are thickest and most numerous in the massive dolomites of the Bullion (pl. 17*B*) and the Dawn members of the Monte Cristo dolomite.

The normal faults are separable into two loosely defined systems. The first system contains all the largest and most conspicuous normal faults in the map area. They strike N. 25°–48° W., subparallel or oblique to the axis of Sloan Hill, and may be divided into two sets: those which dip to the southwest and those which dip to the northeast. The angle of dip in both sets is 70°–88°. Many of the faults are convex toward the upthrown side, the inside of the curve or bow being the downthrown block. The second system of normal faults consists of a few short, nearly vertical faults that strike approximately west.

The most noteworthy features of the normal faults are (1) their short length, (2) the abruptness with which they end, (3) their distribution around the sides of the hill, and (4) the strong brecciation of their hanging walls. The movement along the two sides of the horst block seemingly took place along a number of parallel distributive normal faults, which do not merge as wedges (pl. 14, east side of section *G–G′*). Many seem to resemble the faults in Cloos' experiments with wet clay (Balk, 1937, pp. 29–30, pls. 12–14) and dip into the graben from the two sides of the horst, thus "distributing the total displacement over wide areas." If this interpretation is correct, the traces of the major normal faults that bound the horst block between the graben on the northeast and southwest are probably covered with the wash in the valleys.

GEOLOGIC HISTORY OF SLOAN AREA

The geologic history of the Sloan area is typical of that of all southern Nevada but is less complex because all the events of the region are not recorded in the Sloan area. The sequence of events in the geologic history includes (1) a long period of marine sedimentation; (2) temporary elevation above sea level followed by renewed deposition; (3) a second, longer period of elevation followed by deposition and volcanism; (4) igneous intrusion, dolomitization, folding, faulting, and mountain building; (5) erosion; (6) reelevation accompanied by normal faulting and extrusion of igneous rocks; and (7) final uplift and erosion.

Chemical deposition of calcitic and dolomitic sediments in epicontinental seas, interrupted by deposition of sands and muds during the final stages, took place during the Devonian and Carboniferous. During this long period of time the Sultan, Monte Cristo, and Bird Spring formations were laid down.

The region was temporarily elevated above sea level early in the Permian but sank later in the period. The sandstones, shales, and gypsum of the Supai formation of Hewett (1931, p. 30) were deposited during the Permian. Many of these rocks were laid down on land by wind and in lakes and streams by fresh water. Toward the close of the period, when marine waters again covered southern Nevada, the limy sediments that formed the Kaibab limestone (Darton, 1910, pp. 21, 28, 32) were deposited in this sea.

Southern Nevada was reelevated for a longer time after the close of the Permian but sank again during the Triassic period, at which time a thick series of red sands, muds, thin limestones, and gravels was deposited. Some of these sediments were deposited in shallow, oscillating seas, and others were laid down on land and in lakes by wind and fresh water. During the early part of this cycle of deposition (Triassic and Jurassic?) explosive volcanoes northwest of Sloan ejected ash and tuff, some of which fell in the Goodsprings quadrangle (Hewett, 1931, p. 32) just west of the Sloan area.

Late in the Cretaceous period, and probably during much of the Eocene epoch, the rocks were folded and broken by thrust faults, and the region was elevated to mountainous heights. This period of deformation constitutes the first stage in the structural history of Sloan Hill. Igneous rocks were intruded at this time in southern Nevada, but the magmas did not reach the earth's surface in the Sloan area. Dolomitization of the original limestones probably started early in the period but may not have been completed until after this stage of mountain building was finished.

Erosion was active during the Oligocene epoch and the earlier part of the Miocene, following the period of deformation. The debris of the eroded Mesozoic and upper Paleozoic rocks was removed from Sloan Hill and transported to the surrounding basins, where the detritus accumulated. In the Sloan area these Oligocene and lower Miocene sediments are covered by post-Pliocene debris from Sloan Hill and the surrounding mountains.

The mountains were uplifted a second time in the Miocene, when most of the normal faults in Sloan Hill probably were produced (pl. 14, all sections). Fine- to medium-grained igneous rocks were extruded late in the Miocene after the normal faults were developed and while erosion of the then reelevated mountains was in progress. The olivine basalt (pl. 15*B*) in the southwestern part of the map area (pl. 13) is the erosional remnant of a large flow that was probably extruded at this time. In the Pliocene or the Pleistocene epoch Sloan Hill and the surrounding mountains were elevated to their present positions. Doubtless some movement on the faults occurred then, but no direct evidence of such movement was recognized in the field.

Erosion of Sloan Hill and the surrounding hills has continued since the Pliocene. The debris has been spread out as giant alluvial cones and fans on the valley floors, and today the hills are partly buried in their own erosional products.

DOLOMITE DEPOSIT

GENERAL FEATURES

The two main dolomite units at Sloan Hill are the Bullion and Dawn members of the Monte Cristo dolomite, separated by the economically worthless Anchor member. The dolomite of the Dawn member has been quarried by the United States Lime Products Corp. and was used by the U. S. Bureau of Mines in the pilot plant at Boulder City, Nev. The experimental work in the pilot plant demonstrated that in Sloan Hill this is an unusually high-grade dolomite that can be used commercially for producing 96-percent magnesium oxide (MgO). The presence of the chert in the Anchor member was not known, and the Bullion had not been sampled, when the experimental work was done.

The exposed part of the Dawn member is of little commercial value, however, and the only rock unit that contains a large exposure of high-grade dolomite in Sloan Hill is the Bullion member; it is therefore the only one that could be mined on a large scale with power shovels. Analyses of surface samples (p. 117) indicate that the lower 350 feet of the Bullion probably is uniformly high-grade dolomite, but analysis of diamond-drill cores will be necessary to determine accurately the composition of the dolomite at depth. The lithologic characteristics of the Bullion are summarized on pages 116–117 and are given in the stratigraphic section on pages 121–122.

OWNERSHIP

The Dawn member of the Monte Cristo dolomite above the quarries on the southwest side of Sloan Hill and most of the Bullion member in the main deposit on the crest of the hill lie within mining claims controlled by the United States Lime Products Corp., 1840 East Twenty-fifth Street, Los Angeles 11, Calif. The Dawn above the quarries is in the Sloan claim; the Bullion most accessible for open-pit mining is in the Sloan, Sloan No. 3, Sloan No. 4, and Sloan No. 5 claims (pl. 13).

ORIGIN

The origin of the dolomite in the Dawn, Anchor, and Bullion members of the Monte Cristo dolomite in Sloan Hill is not known conclusively, but the evidence suggests replacement of an original limestone by upward diffusion of magnesia-bearing solutions. The Dawn and Bullion members are similar in composition to theoretical dolomite, containing 54.35 percent $CaCO_3$ and 45.65 percent $MgCO_3$, and except for local undolomitized limestone masses are exceptionally uniform lithologically.

The Dawn and Bullion members are so uniform vertically and horizontally that evidence is not available to indicate the relationship of the faults to the paths of the ascending magnesia-bearing solutions. However, most of the fault breccias consist of sharply demarcated dolomite fragments and matrix, implying that dolomitization preceded faulting.

Locally the Crystal Pass limestone member of the Sultan limestone, which underlies the Monte Cristo dolomite, is irregularly replaced by dolomite. The replacement was strongest along bedding and joint surfaces. Stringers of dolomite extend irregularly into the limestone. Isolated 1- to 15-millimeter masses of dolomite crystals occur in the limestone, decreasing in number away from the principal dolomitized areas. Although the position of the Crystal Pass Limestone member below the Dawn member of the Monte Cristo dolomite may imply that the Dawn and Bullion contained much original dolomite, this conclusion is not supported by evidence. More likely, the magnesia-bearing solutions were concentrated in the Mississippian limestones between the Crystal Pass limestone member and the Bird Spring formation.

The only igneous rock exposed close to the dolomite near Sloan is the remnant of a basalt flow (pl. 13) that was extruded long after dolomitization occurred. The Valentine dolomite member of the Sultan limestone is not replaced as much along its contact with the flow as in places where it is faulted against the Dawn member of the Monte Cristo. Limestone masses, unreplaced parts of the original rock, occur also above the Crystal Pass limestone member of the Sultan along the contact of the Anchor and Dawn members and in the upper part of the Bullion member of the Monte Cristo. Their significance, however, is not understood.

From the Goodsprings quadrangle, 20 miles west of Sloan, to Tassai Ridge, Ariz., 60 miles to the east, and to Pioche, Nev., 150 miles to the northwest, a rock sequence of Upper Cambrian to Devonian (?) age contains thick units of dolomite, which probably represent original deposition of the double carbonate $MgCO_3 . CaCO_3$. Many of the Upper Cambrian rocks in the southern part of the Cordilleran trough, throughout an area of 75,000 square miles, likewise consist of dolomite that was either an original sedimentary deposit or was limestone altered to dolomite shortly after deposition and while still covered with sea water. The Goodsprings dolomite, of Upper Cambrian to Devonian? age (Hewett, 1931, pp. 11–13), 2,000 to 2,500 feet thick, crops out east and west of Sloan and is probably present under the exposed rocks in the Sloan district (pl. 14). The vast amount of sedimentary dolomite in the early Paleozoic rocks of southern Nevada may have furnished some of the magnesia that replaced the limestones and formed the dolomite in the Sloan deposit.

Hewett (1931, pp. 57–67) made a comprehensive field and laboratory study of dolomitization in the Goodsprings quadrangle. In his summary of the problem he stated:

> In the present state of knowledge of the Goodsprings district, as well as some similar districts, it seems that although magmatic sources and underlying dolomitic limestones, such as those of the Goodsprings formation, may have been the source of some of the magnesia now present in the dolomitized limestone, a more productive source was the shallow masses of intrusive porphyry.

Much of the evidence he cites is observable, also, in the Sloan district; therefore the causes and methods of replacement and the source of magnesia probably were similar in the two adjacent regions.

Deductions concerning the origin of the dolomite can be briefly summarized as follows: The dolomites in the Dawn, Anchor, and Bullion members of the Monte Cristo dolomite represent replacement of original limestone or magnesian limestone, which was completed before normal faulting took place. Consequently, dolomitization occurred early in the Tertiary period. Apparently the magnesia was carried by ascending magmatic solutions. Intrusive magmas probably furnished some magnesia, but the solutions may have acquired more magnesia while passing through the Goodsprings dolomite. The shales in the Bird Spring formation, being more impervious than the underlying limestones, probably caused the solutions to be concentrated in the limestones. Maximum replacement, therefore, occurred in the Mississippian limestone that lay in the zone of maximum saturation below the Bird Spring formation. If this conclusion is correct, the Crystal Pass limestone and Valentine dolomite members of the Sultan limestone were relatively little replaced by dolomite because the ascending magnesia-bearing solutions merely passed through them, and the Mississippian limestones were not replaced until the pressure and saturation of the solutions increased below the impervious shales of the Bird Spring formation. The cavities, especially in the Dawn and Bullion members of the Monte Cristo dolomite, seem to represent much later solution by ground water of calcite deposited with the dolomite (Hewett, 1931, p. 63).

RESERVES

The Bullion member of the Monte Cristo dolomite contains all the dolomite in the deposit that can be quarried on a large scale by open-pit methods. The following estimates are based on nine geologic structure sections drawn from the map (pl. 13) and apply to the blocks of dolomite that are relatively free from faults, siliceous bands, and lenses of limestone. The Bullion member has not been core-drilled, so that the composition and quality of the dolomite below the surface are not known, but the deposit is assumed to be uniform throughout. The largest exposure of the Dawn member of the Monte Cristo accessible for quarrying is along the southwest side of Sloan Hill in and above the quarries of the United States Lime Products Corp. (pl. 15*A*).

Indicated ore.—The most favorable exposure of the Bullion member for open-pit mining is in the block bounded by the contact of the Bullion with the Anchor member of the Monte Cristo dolomite on the west and east, by section *C–C′* (pls. 13, 14) on the south, and by a line 600 feet to the northwest and parallel with section *B–B′* (pl. 13) on the north. If the interpretation of the geology shown in the structure sections (pl. 14) is correct, this block of the Bullion contains at least 45,000,000 tons. The block of accessible dolomite of the Dawn member is approximately 1,000 feet long, 175 feet thick, and 200 feet wide and contains a little less than 3,000,000 tons.

Inferred ore.—The Bullion member, from the block of indicated ore north to a line 200 feet south of the contact of the Bird Spring formation and the Bullion on the crest of Sloan Hill, and between sections *C–C′* and a line 500 feet to the northwest and parallel with section *D–D′* (pl. 18), contains at least 22,000,000 tons of additional ore. The dolomite north of the block of indicated ore contains numerous siliceous nodules and occasional lenses and irregular masses of limestone in the upper beds, and south of the block it is faulted and thin. The facts suggest that much of these two parts of the Bullion member may not be suitable for commercial development.

Total reserves.—If the 45,000,000 tons of indicated ore and the 22,000,000 additional tons of inferred ore in the Bullion member are added to the 3,000,000 tons of indicated ore in the Dawn member, the total indicated and inferred ore available for open-pit mining is 70,-000,000 tons.

DEVELOPMENT, PRODUCTION, AND MANUFACTURING AT SLOAN

The data presented in this brief summary of activities at Sloan were obtained from the publications cited, from R. E. Tremoureux, President, United States Lime Products Corp., San Francisco, Calif., and from L. N. Grindell, superintendent of the Sloan plant. The production figures were taken from the corporation's records, which were made available to the writer through the courtesy of Mr. Tremoureux.

HISTORY OF DEVELOPMENT

The limestone deposit in the hill east of Sloan was located in 1910, and the first rock was quarried shortly thereafter. In 1914, a total of 1,160 tons was sold (Couch and Carpenter, 1943, p. 31) and used in the cyanide treatment of the gold and silver ores of the Goldfield and Tonopah districts. The quarries were worked by the Nevada Lime and Rock Corp. from 1914 until 1927, when the name of the company was changed to the United States Lime Products Corp.

Dolomite was not mined commercially until 1928; at that time three vertical kilns were installed to supply the demand for dolomitic hydrated lime (Tremoureux, 1932, p. 2).

The limestone was quarried from the open face above the quarry floors from 1914 to 1945. During the years 1934 and 1935 the limestone near the southeast end of Sloan Hill was mined underground by the room-and-pillar method (R. E. Tremoureux, personal communication, May 20, 1944). Until 1837 all rock in the quarries and underground was mined by hand and trammed by gravity to the plant or to the railroad. In 1937 a power shovel was put into operation at the quarry, the old hand tram cars were replaced by gasoline motor trucks, and a 24- by 36-inch primary jaw crusher and a screening plant were installed. Since 1937 all the limestone and most of the dolomite have been moved from the quarries to the primary crusher, from the primary to the secondary crusher, and from the secondary crusher to the rotary kilns in standard types of automobile dump trucks. Only the dolomite feed for the vertical kilns is sized and loaded by hand at the quarry, and this dolomite also is trucked. Crushed limestone and dolomite are stockpiled, the amount being controlled by impending needs.

Much of the siliceous material in the limestone is eliminated in the fines. Other impurities, such as dolomite in a run of limestone, are handpicked from the conveyor belts at the primary crusher and discarded on the fines dump at the quarry.

SIZES OF ROCK PRODUCED

Limestone from the primary crusher is screened to three sizes: (1) plus 3½, minus 8 inches (sugar rock); (2) plus ¾, minus 3½ inches (spals feed for the secondary crusher); and (3) minus ¾ inch (fines, always wasted from the primary crusher).

Limestone from the secondary crusher is screened to four sizes: (1) plus ¾, minus 1½ inches; (2) plus ¼, minus 1 inch (rotary-kiln size); (3) plus ¼, minus ¾ inch; and (4) minus ¼ inch (fines).

Dolomite is hand-sized to plus 4, minus 12 inches (vertical-kiln feed) and also is crushed to four sizes in the two crushers: (1) plus 1, minus 3½ inches; (2) plus ¼, minus 1½ inches (rotary-kiln feed); (3) plus ⅛, minus ¾ inch (most of which goes to steel companies); and (4) minus ⅛ inch (fines from the secondary crushers).

Approximately 25 percent of the rock that entered the primary crusher and 15 percent of the rock that entered the secondary crusher, in 1943, was lost in fines. The total loss in fines of rock handled by the power shovel in the quarry in 1943 was about 29 percent (L. N. Grindell, personal communication, April 24, 1944).

PRODUCTION FIGURES

Limestone constitutes 93 percent and dolomite 7 percent of the rock mined annually at Sloan. All the limestone is mined from the Crystal Pass limestone member of the Sultan limestone, and the dolomite from the Dawn member of the Monte Cristo dolomite (pls. 13, 14). The Bullion member of the Monte Cristo at Sloan has not been mined.

The tonnage figures in the middle column of the following table are taken from the books of the company. The limestone and dolomite produced at Sloan are combined in each of the tonnage figures. If the 1943 ratio of fines to crushed rock (29 to 71) was constant for all the years, the figures in the right-hand column represent, approximately, the tonnage mined in each of those years. A record of annual production at Sloan is not available for the years 1915 to 1928.

Year	*Tons produced for sale*	*Tons mined*
1929	85,019	119,540
1930	65,795	92,700
1931	60,309	84,400
1932	50,142	70,500
1933	65,126	91,300
1934	68,540	96,400
1935	71,482	100,500
1936	72,942	102,500
1937	75,730	106,400
1938	62,331	87,500
1939	92,703	130,500
1940	91,850	129,260
1941	110,396	155,200
1942	111,851	157,200
1943	118,055	166,100
Total	1,202,271	1,690,000

These figures show that the smallest tonnage on record since the present company acquired the property was produced in 1932 and, also, that production increased steadily from 1940 to the peak year 1943, the last year of record, when 107,583 tons of limestone and 10,472 tons of dolomite were quarried.

The average monthly production of limestone in 1943 for the peak months June through September was 18,000 tons, and for the slack months of January and February the average was 4,000 to 5,000 tons. In the same year the production of dolomite ranged from 600 to 3,000 tons per month.

PRODUCTS MANUFACTURED

The United States Lime Products Corp. manufactures 24 different products, ranging from dolomite in size plus 4, minus 12 inches, to calcined limestone or dolomite in size 200 mesh. A large proportion of the limestone is sold to the beet-sugar companies in southern California and is shipped in size plus 3, minus 8 inches. Some limestone is sold to foundries, steel companies, and other manufacturing concerns, and a substantial tonnage goes to the rotary kilns for manufacture into various lime products. The dolomite is used principally for vertical-kiln feed at Sloan, but 6,000 to 7,000 tons per year is sold in size plus ⅛, minus ¾ inch, to the steel companies in southern California.

Products of five general types are manufactured from calcined limestone and dolomite: (1) lime flux, (2) high-calcium quicklime, (3) dolomitic quicklime, (4) hydrated high-calcium lime, and (5) hydrated dolomitic lime. The consumers of the lime flux are the steel manufacturing companies in California. The main consumers of the high-calcium quicklime are carbide manufacturers, chemical manufacturers, and the building industry. The dolomitic quicklime is used chiefly by the oil industry. The principal uses of hydrated high-calcium lime are in water treatment, manufacture of chloride of lime, manufacture of insecticides, and general chemical and construction-industry processes. The hydrated dolomitic lime is used chiefly in the construction industry in the manufacture of stucco and lime plaster.

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