OKLAHOMA GEOLOGICAL SURVEY

Robert H. Dott, Director

Mineral Report No. 16

GEOLOGY AND CHEMICAL COMPOSITION OF THE ST. CLAIR LIMESTONE NEAR MARBLE CITY, OKLAHOMA

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NORMAN

1943

(2nd Printing, 1980)

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INTRODUCTION

High-calcium limestone, produced from the St. Clair formation near Marble City, has been used for several years in making quicklime and for agricultural stone. Formerly dimension stone was produced in the area and used in the construction of buildings in Oklahoma City, Houston, Texas, and elsewhere. The present investigation was undertaken to obtain more detailed information on the extent of the deposits and their chemical composition, and to evaluate the possibilities of the district. The results of field and laboratory studies show that both high-calcium and dolomitic limestone of high purity are present in abundance, and that the district is unquestionably able to furnish much more stone than is being quarried at the present time. Furthermore, new uses are indicated for the dolomitic (magnesian) stone, which as yet has not been extensively quarried for chemical purposes.

The field work consisted of mapping and sampling. Dott and Oakes each spent one week in the field, and Ham spent two weeks. Lemberg staining tests for dolomite and other mineralogical examinations were made by Ham. Chemical analyses were made in the laboratory of the Oklahoma Geological Survey by W. L. Howard and J. F. Eberle under the direction of Burwell. H. C. Davis, geologist for the Lone Star Steel Company, Daingerfield, Texas, assisted for two days in the preliminary sampling. The cordial cooperation of the quarry operators and the Industrial Development Department of the Kansas City Southern Railroad is gratefully acknowledged.

Location. The outcrops of the St. Clair limestone discussed in this report form a rather sinuous belt across parts of seven sections in the northeast part of T. 13 N., R. 23 E., 1 to 3 miles northwest of Marble City, Sequoyah County. Sallisaw, county seat of Sequoyah County, is about 12 miles south and a good graveled road connects the two towns. The region is served by the main line of the Kansas City Southern Railroad, which enters Oklahoma near Watts and continues southward through Marble City, Sallisaw, and Poteau. East-west connections are available on the Missouri Pacific Railroad at Sallisaw.

Geography. Marble City lies on the southwest border of the Ozark uplift at the southern limit of a region known as the Cookson Hills. The topography consists of rugged, forested hills separated by deep, stream-cut valleys. The region is not densely populated, and farming and stock raising are the principal occupations. Sallisaw Creek, a perennial stream fed by many intermittent tributaries and springs, is the master stream of the area. Sallisaw Creek at Marble City has an elevation of approximately 600 feet, and the top of Quarry Mountain, on the sides of which the St. Clair limestone is exposed, is slightly more than 1400 feet above sea level. The maximum topographic relief thus is 800 feet.

Previous investigations. The geology of the area was first described in 1897 by Drake 1/, who prepared a sketch map of the area. A more detailed study was made by Taff 2/ in 1905, and little change has since been made in his mapping and broader concepts. Both identified the limestone under consideration as equivalent to the St. Clair limestone as previously defined in Arkansas 3/. Because of its coarsely crystalline texture, resembling "marble" of the building trade, they called it the St. Clair marble.

Subsequent articles on the geology of the general area include those by Snider 4/, Cram 5/, and two measured sections in the Marble City area by Laudon 6/. The

article by Cram is available at the Oklahoma Geological Survey.

In 1903, a private report on the economic possibility of the St. Clair marble was made by Major G. D. Fitzhugh. This report was kindly loaned to the Oklahoma Geological Survey by A. N. Reece, Assistant to the President, Kansas City Southern Railroad, in March 1943.

In 1922 Oakes sampled the dimension stone quarry and the sample was analysed by A. C. Shead in the laboratory of the Oklahoma Geological Survey. Results of this analysis are given in Bulletin 14 7/. In 1936 crews of the State Mineral Survey* obtained preliminary samples from several quarries of the area.

STRATIGRAPHY

The sedimentary rocks of the Marble City district range in age from Silurian through Pennsylvanian, and consist of limestone, dolomitic limestone, cherty limestone, shale, and sandstone. Several important unconformities are present in the stratigraphic section.

St. Clair limestone. The oldest formation exposed is the St. Clair, a massive-bedded, coarsely crystalline, white to pink limestone, some beds of which are dolomitic. A large part of the rock contains abundant crinoid fragments. Other fossils, including well-preserved brachiopods, trilobites, and cephalopods, indicate a Middle Silurian (Niagaran) age 8/. The total thickness is unknown, as the base is not exposed; the maximum measured thickness, however, is 165 feet, and Taff 9/ states that prospect drills penetrated an additional 100 feet without reaching the bottom of the formation.

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* WPA Project 65-65-538, sponsored by the Oklahoma Geological Survey.

An unconformity of considerable magnitude is present at the top of the formation. Schuchert 10/ describes from a quarry near Marble City a bed of white coquina-like limestone, 5 to 8 feet thick, which Taff had originally included with the St. Clair. According to Dunbar (cited by Schuchert) it occurs with an erosional unconformity above the St. Clair limestone, and contains fossils of Lower Devonian (Upper Oriskanian) age. Cram 11/ correlates this bed with the Frisco limestone of the Arbuckle Mountains.

The writers have observed in several places at the top of the St. Clair, in the position normally occupied by the Frisco, a zone of dense blue-gray limestone, ranging in thickness from 5 to 12 feet, that locally contains abundant fossils, chert nodules, or dolomite. No paleontological work was done to determine whether this bed is Frisco. It has a clearly observable gradational contact with the typical pink crinoidal phase of the upper St. Clair in two localities, but the gradational contact indicates that at least in these places it probably is a part of the St. Clair. This stratigraphic problem has no bearing on economic utilization of either stone, and for the purpose of this report the blue-gray limestone is considered a part of the St. Clair.

About 8 miles north of Marble City, near Bunch, the St. Clair is unconformably overlain by Boone chert (Mississippian-Osage), and similar stratigraphic relations were mapped by Taff in secs. 1, 2, and 12, T. 14 N., R. 23 E.

Part of the St. Clair limestone in the Marble City district undoubtedly has been cut out by erosion at the top of the formation, but any such erosion has not affected the chemical composition or quarrying possibilities of the stone that is still present.

Younger formations. In the Marble City district a sandstone lies above the Frisco limestone and below the Chattanooga shale. Taff considered it to be the equivalent of the Sylamore of Arkansas and assigned it a Devonian age. Later Schuchert found early Middle Devonian fossils in it at one locality near Marble City. Cram 12/, however, believes that the true Sylamore-Chattanooga sequence is Mississippian in age and proposed the name Sallisaw for the sandstone at Marble City that contains Middle Devonian fossils. According to Cram's interpretation the Sallisaw-Chattanooga contact is unconformable, and some weight is given this interpretation by an erosional unconformity between them observed by Taff in sec. 36, T. 14 N., R. 23 E. In the northern part of the Tahlequah Quadrangle the Sylamore is present and has a gradational contact with the overlying Chattanooga. Insufficient work was done in the course of this investigation to distinguish the Sallisaw from the Sylamore in the Marble City district, and for the present purpose the combined sandstones are considered a unit.

The sandstone is composed principally of frosted sand grains, locally cemented with calcite and containing large boulders of chert. The thickness is given by Taff at 20 to 30 feet. It is probably thick enough and sufficiently compact to make a good roof for underground mining in the St. Clair limestone.

The following table shows the lithology and thickness of the sedimentary beds lying above the Sallisaw-Sylamore sandstone on the south side of Quarry Mountain. They are arranged in stratigraphic order, oldest at the bottom. The data were compiled from a plane table survey made by the State Mineral Survey.

Formation	Thickness in feet
Winslow sandstone and shale (includes Atoka and probably some McAlester)......	183
Morrow limestone, shale, and sandstone....	152
Pitkin argillaceous blue limestone........	44
Fayetteville argillaceous limestone and shale............................	45
Boone chert............................	36
Chattanooga black shale.................	32

STRUCTURE

The St. Clair is exposed in six localities within a 10-mile radius of Marble City. The largest area of outcrop, near Marble City, which covers 600 acres, is described in this report. The other areas are less accessible, smaller in size, and do not offer such good opportunities for successful quarrying. All exposures of the St. Clair are dependent principally on two factors: uplift by faulting and erosion. Uplift along faults has locally displaced the sedimentary beds at least 500 feet vertically; and as a consequence older beds which normally lie at depths of several hundred feet have been brought to or near the surface on the upthrow sides of the faults. Later erosion by streams flowing across these uplifted areas has worn away the overlying strata and exposed the St. Clair.

The regional structure is related to that of the Ozark Dome, where the rocks dip in general southwestward. This regional dip is interrupted and modified by a system of nearly parallel faults and folds that trend approximately N. 45° E. The outcrops of St. Clair limestone near Marble City lie on the SE side of a large structural horst, an upthrown block bounded by two of the above faults.

In the vicinity of Marble City the St. Clair limestone is bounded by two faults, instead of one as mapped by Taff. They intersect at the big bend of Sallisaw Creek 1 mile north of Marble City and are connected by a small cross fault (see map). The cross fault cuts only the St. Clair; it separates strata at the top of the formation on the downthrow (SE) side from older beds that are at least 100 feet lower stratigraphically.

The larger of the two main faults trends N. 10° E. and extends from the big bend of Sallisaw Creek to a point about 7 miles northeast of Bunch. In the NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 13, T. 13 N., R. 23 E., the St. Clair is faulted against Morrow limestone with a throw of about 300 feet. The second fault trends approximately N. 75° E. Along

this fault in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 23 of the same township, the St. Clair is brought against Atoka sandstone and a throw of at least 500 feet is indicated. The limestone itself is exposed for a distance of approximately 3 miles along the faults.

The local structure of the St. Clair limestone in the vicinity of Marble City is that of a faulted anticline whose structurally high point is near the Talley quarry at the N$\frac{1}{4}$ cor. sec. 23, T. 13 N., R. 23 E., where it is cut by one of the major faults. The axis of this anticline plunges northeastward, parallel to and about 0.25 mile west of the other major fault (see map). It carries the St. Clair under cover of younger rocks near the center of the W$\frac{1}{2}$ of sec. 12. Because this fold passes through the east end of Quarry Mountain, it is here designated the Quarry Mountain anticline.

This folding, although associated with major faults, is apparently not a drag fold, for in the vicinity of the Talley quarry the dips are away from, rather than toward, the fault. It is concluded that the Quarry Mountain anticlinal axis was formed in pre-Mississippian time and later was broken by faulting during the Pennsylvanian period of structural movements that deformed the region.

Dips on the St. Clair limestone in the Marble City district are relatively low, ranging from 2 to 12 degrees, and the average is about 4 degrees. Over most of the district the dip is to the northwest; dips with eastward components occur only in the extreme eastern part of the outcrop area on the faulted, short east limb of the Quarry Mountain anticline.

The flatness of the dip makes for ease of quarrying operations, and produces a comparatively large area over which the St. Clair is accessible for quarrying. The flat dip also will be an important factor in underground mining, should this method of operation be instituted.

LITHOLOGY

Samples. For preliminary sampling, more than 100 hand specimens were collected in quarries and other selected areas throughout the district. A few of these were analyzed to determine the general chemical character of the rocks, and all were tested mineralogically for dolomite by Lemberg stain. The Lemberg stain has as its active ingredient an organic dye, extract of logwood, which selectively stains calcite a purple color whereas dolomite is only slightly affected, and its color remains unchanged 13/. From a polished surface of limestone or dolomitic limestone that has been stained, it is possible to estimate quantitatively the amount of dolomite present, and from this the probable magnesium carbonate content of the rock can be determined. By use of the staining method on the preliminary hand specimens in the field, it was possible to divide the formation into zones that were reasonably constant in the ratio of $MgCO_3$ to $CaCO_3$ and this zoning aided considerably in the later detailed sampling for chemical analysis.

The procedure of sampling for chemical analysis calls for taking chips from each inch of the exposed strata along a line perpendicular to the plane of the dip of the beds, breaking the sample every 5 feet or where there is a marked change in the lithology. This method ordinarily yields about 2 pounds of stone per foot. The beds are thus sampled as completely as possible, but it is recognized that the lithology and chemical character of the beds may change either along the strike or down dip, and the sample is intended to represent only the stone at the place sampled. The 18 samples analyzed, however, are adequate to indicate in a general way the probable chemical composition of most of the stone in the district.

Lithologic zones. The St. Clair formation exposed in the Marble City district, as shown by chemical analyses and mineralogical examination, consists chiefly of limestone and dolomitic limestone -- no true dolomites

have been observed. The following lithologic zones can be recognized in the exposed rocks:

(1) At the top, there is a blue-gray, dense, and uniformly crystalline limestone that ranges from 5 to 12 feet thick. Locally it contains abundant fossil remains and chert nodules. This zone is well exposed in an abandoned quarry near the NW cor. sec. 24, T. 13 N., R. 23 E. In two localities the MgO content is low (samples 7 and 11), but in the abandoned quarry in SE¼ SW¼ sec. 14, T. 13 N., R. 23 E., it contains 11.61 percent MgO, indicating that slightly more than half of the bed is composed of dolomite.

(2) A middle zone, ranging from 55 to about 100 feet thick, a high-calcium limestone comparatively free from dolomite, is composed largely of crinoid fragments. The texture in general is coarse and is determined by the size of the crinoid stems. This limestone is pale pink to white, locally mottled and streaked with very thin seams of asphalt. On the whole, the color has a very pleasing, mottled appearance; and this, together with the coarse texture, gives a stone that answers for marble of the building trade. A common feature of the zone is the presence of vugs and open cavities that are lined with small, perfectly-formed rhombohedrons of calcite. Some of the vugs have yielded small amounts of a light, straw-colored petroleum which undoubtedly is the source of the asphalt mentioned above. Stylolites of beautiful perfection may be seen in many of the quarries.

(3) The lowest exposed zone is a light gray dolomitic limestone containing as a general rule from 30 to 50 percent dolomite. It differs also from the overlying pink crinoidal phase in color and texture, but there is good reason to believe that the differences are due to dolomitization and that originally the two rocks were very similar. This zone contains a few coarse crinoid fragments, partly replaced by dolomite, set in a dense, uniformly crystalline matrix of dolomite and calcite. The texture is rather distinctive but not an infallible

guide to the recognition of dolomitic limestone. The dolomitic beds are well exposed in only two areas: in the vicinity of the Talley quarry and near the abandoned dimension stone quarry. At the latter the top beds are eroded and only about 30 feet is exposed in the quarry. The dolomitic limestone has been exposed in these two localities as a result of higher structural uplift and deeper erosion, and it is believed that this zone is present throughout the district at unknown depths below the surface.

Besides dolomite and calcite there are very few other minerals present in the St. Clair. A little pyrite has been noted in a few exposures; chert, quartz crystals in vugs, sphalerite, and clay minerals are of sporadic and rare occurrence.

Origin of the formation. Much of the exposed rock is composed of marine fossils, principally crinoid stems, but including also brachiopods, trilobites, and cephalopods. These testify to the abundant marine life that lived in the St. Clair sea. From this profusion of fossils, which fluorish only in quiet water, it is inferred that the sea was not frequently disturbed by storms. Some of the fossil fragments themselves have been broken and abraded slightly by weak currents that probably were of local origin, but there were no strong currents to sweep in quartz grains or other detrital constituents from other sources. These factors probably account for the exceptional purity of the limestone.

The dolomite is undoubtedly of secondary origin. The rhombohedral crystal form of the dolomite grains and their partial replacement of fossil fragments indicate introduction after the limestone was deposited, and this concept coincides with the conclusions of many earlier workers on the origin of dolomite. An important question to be answered, however, is the time of dolomitization, for it has economic as well as scientific significance. If the dolomite was introduced along the major faults by circulating ground water or by hot water of deep-seated origin, it should be present in

most of the beds near faults and diminish away from them. The magnesia content would probably be erratic, and the quarry operator could not depend upon a constant chemical composition. On the other hand, if dolomitization occurred on the sea floor, during or shortly after limestone deposition, it is to be expected that dolomite will occur in beds or in zones closely associated with stratigraphic beds. Sedimentary dolomites in other parts of Oklahoma and elsewhere are persistent over wide areas without much change in composition, and may be quarried safely. Although beds that are completely dolomitized are generally more persistent than those only partly dolomitized, in some places dolomitic limestone may be interbedded with thick zones of limestone that are essentially dolomite-free; and it is possible, by selective quarrying, to obtain beds which are either high or low in magnesia, depending upon the desired use.

The following field relations are cited as evidence that dolomitization took place during or shortly after deposition of the limestone:

1. Thin beds, 1 to 3 feet thick, of partly dolomitized limestone are found in a few places interbedded with dolomite-free limestone above and below. They have the aspect of sedimentary beds.

2. There is a sharp contact of the dolomitic limestone exposed in the Talley quarry with the underlying limestone. The dolomitic section continues upward for 60 feet, and there grades through about 10 feet of slightly dolomitic stone into pink crinoidal limestone above. Such contacts are characteristic of sedimentary deposition.

3. The pink crinoidal limestone, which contains only a small amount of dolomite throughout the district, has the same composition at the fault contacts. It has not been unduly dolomitized by proximity to faults, and this shows that the dolomite is not related to faulting.

It is concluded from the above facts that dolomitization was practically contemporaneous with deposition of the limestone, and took place on the sea floor while covered with marine water. The source of the magnesia was the marine water itself. The extent of dolomite replacement in a given bed depended chiefly upon the concentration of magnesium in the water; beds with abundant dolomite were deposited from more concentrated solutions than beds with less dolomite. Dolomitic and non-dolomitic zones probably are more or less uniformly persistent throughout the district.

CHEMICAL COMPOSITION

As pointed out in the section on lithology, the St. Clair throughout its exposures in the Marble City district is composed of thick beds of limestone or dolomitic limestone. In general, limestones are defined as carbonate rocks that consist essentially of calcium carbonate; dolomites contain carbonates of calcium and magnesium in comparatively definite proportions; and dolomitic limestone, a mixed rock of variable composition, is composed of mixtures of the mineral dolomite with calcite. The following table shows the theoretical composition of pure calcite, the principal mineral in limestones, and of the mineral dolomite, which is the chief constituent in dolomite rock.

THEORETICAL CHEMICAL COMPOSITION, CALCITE AND DOLOMITE

	CALCITE percent	DOLOMITE percent
CHEMICAL FORMULA	$CaCO_3$	$CaMg(CO_3)_2$
$CaCO_3$ (calcium carbonate)	100.00	54.27
$MgCO_3$ (magnesium carbonate)	0.00	45.73
CaO (calcium oxide; quicklime)	56.03	30.41
CO_2 (carbon dioxide)	43.97	47.73

Because it is a mixed rock, no constant composition can be given for dolomitic limestone. In it the magnesia (MgO) ranges between about 5 and 18 percent, and in some places the MgO-CaO ratio may change rapidly from place to place in the same bed.

Nearly all limestones, dolomites, and dolomitic limestones throughout the world contain one or more of the following impurities: silica, alumina, phosphorous, iron, and sulfur. Most stones carry excessive amounts of one or more of the above impurities, thus rendering them unfit for many chemical purposes. Although no limestone or dolomite ever reaches its theoretical composition as given in the above table, a few may approach it rather closely, and these may be of chemical grade.

Chemical analyses show that the St. Clair formation is characterized by a silica content that is very satisfactorily low. The average SiO_2 of 17 analyzed samples is 0.143 percent, and ranges from a maximum of 0.36 to a minimum of 0.039 percent. Sample No. 15 contains 0.82 percent insoluble residue, but the true silica is probably lower. The extremely low silica is a highly desirable factor, and makes the St. Clair one of the best chemical stones in the world in this respect.

The alumina, iron, sulfur, and phosphorous in the samples are given in the Table of Analyses. None of these is excessive in any of the samples analyzed.

The St. Clair formation can be divided into three chemical zones which correspond to the three lithologic zones given on pages 8-10. In zone 1, at the top, the thickness of the analyzed samples ranges from 9 to 12 feet, and the MgO ranges from 0.50 percent in sample No. 7 to 11.61 percent in sample No. 14. The composition of the rock in this zone obviously changes from limestone to dolomitic limestone in different places throughout the district.

Zone 2, in the middle of the formation, is composed of high-calcium limestone whose thickness ranges from about 55 feet up to 70 feet or more. In all samples, $CaCO_3$ and $MgCO_3$ make up more than 99 percent of the total, of which $MgCO_3$ constitutes 0.44 to 5.25 percent. The producing quarries in the district operate chiefly in this zone.

Zone 3 contains the oldest sedimentary beds exposed in the district and is dolomitic limestone. Its maximum measured thickness is 74 feet. One 14-foot bed (sample No. 15, Talley quarry) contains 13.63 percent MgO and 0.82 percent insoluble residue; this is overlain by 60 feet of stone (sample No. 16) that contains 6.95 percent MgO and 0.076 percent SiO_2. Samples No. 17 and 18 contain 8.37 and 5.86 percent MgO, respectively.

The dolomitic limestone of zone 3 has a rather uncommon ratio of MgO to CaO, and in addition is very low in silica. Steidtmann 14/ compiled the analyses of 1148 limestones and dolomites from the United States and concluded "... nearly pure limestones and dolomites are much more common than mixtures of the two, and the mixed beds average higher in insoluble constituents than the pure limestones and dolomites". Stout in investigating the limestones and dolomites of western Ohio, found that most of the carbonate rock sampled "... was either a true dolomite or a limestone bearing only a few percent of magnesium carbonate" 15/. According to these conclusions, therefore, dolomitic limestones are rarer and more impure than either of the end members. The rock in zone 3 thus appears to be a comparatively rare type and offers possibilities for certain specialized uses which very few stones could satisfy. For example, this stone has an ideal composition for a flux in blast furnace iron smelting where a high-magnesia slag is desired.

The chemical composition of the St. Clair formation from various quarry faces and outcrop sections near Marble City is shown in the following Table of Analyses, pages 16-19, inclusive.

PHYSICAL PROPERTIES

In most exposures of this district the St. Clair is compact and medium- to coarsely-crystalline, and the operators are able to quarry and ship it without excessive loss in fines. The compressive strength on four samples as determined by the Watertown Arsenal in 1930 16/ ranged from 12,340 to 14,270 pounds per square inch; and a block of the dolomitic limestone from the dimension stone quarry "... subjected to pressure tests six months after it was removed from the quarry showed a crushing strength of 12,000 pounds to the square inch. When just removed from the quarry, however, it crushed at 8,000 pounds" 17/. This compares favorable with the well-known Bedford oolite, whose compressive strength in pounds per square inch ranges from 2,720 to 17,700 and averages about 7,000 18/. The compressive strength of the St. Clair limestone, therefore, is high enough for most purposes. It is suitable for building stone and also would be strong enough to support the charge in a blast furnace.

TONNAGE

The outcrop of the St. Clair limestone near Marble City covers an area of approximately 600 acres. Throughout the district the stone is exposed along the sides of rather steep hills, in stream valleys, and on terrace-like benches that occur in a few places. Most of the quarries are located on hillsides, or on shoulders that project from them, where the slopes are rather gentle and where there is little overburden; on steep slopes a prohibitive overburden is quickly encountered. On the slopes at least 65 feet of high-calcium limestone is exposed above ground in three quarries (St. Clair Lime Company, Independent Gravel Company, and the abandoned quarry in SE¼ SE¼ SW¼ sec. 14, T. 13 N., R. 23 E.), and a similar thickness is exposed in reasonably accessible locations that are not now being quarried. The volume of high-calcium limestone in sight at the active quarries and other accessible locations must

TABLE OF ANALYSES OF ST. CLAIR LIMESTONE

Sample number	1	2	3	4	5	6	7	8	9
Lab. number	9196	9190	9191	9192	9193	9194	9195	9199	9200
Location	NE$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 13				NE$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 13			SE$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 22	
Operator	St. Clair Lime Company, Sallisaw,				Oklahoma			Independent Gravel Co Marble City, Oklahoma	
Thickness, feet	8	14	5	19	6	7	6	9	6
Stratigraphic position	Pit in quarry floor. Base not exposed.	Above quarry floor.	Above sample No. 2.	Above sample No. 3.	Above sample No. 4.	Above sample No. 5.	3' below top of St. Clair.	Floor of quarry. Base not exposed.	Top of quarry. Above sample No. 8.
Lithologic zone	2(Middle)	2(Middle)	2(Middle)	2(Middle)	2(Middle)	2(Middle)	1(Upper)	2(Middle)	2(Middle)
Lithology	Gray, coarse limestone	Gray-pink coarse limestone	Gray-pink coarse limestone	Gray-pink coarse limestone	Pink coarse limestone	Pink coarse limestone	Blue-gray dense limestone	Gray coarse limestone	Gray coarse limestone
$CaCO_3$ (a)	97.20	96.18	97.84	94.88	98.52	98.81	98.50	96.72	97.59
$MgCO_3$ (b)	2.93	3.60	1.92	5.25	0.56	0.44	1.05	2.87	2.07
CaO	54.46	53.89	54.82	53.16	55.20	55.36	55.19	54.19	54.70
MgO	1.40	1.72	0.92	2.51	0.27	0.21	0.50	1.31	0.99
SiO_2	0.058	0.07	0.06	0.238	0.182	0.166	0.296	0.039	0.04
R_2O_3	0.091	1.00	0.09	0.191	0.168	0.140	0.248	0.137	0.30
Fe_2O_3	0.042	0.044	0.05	0.084	0.081	0.041	0.077	0.068	0.04
Al_2O_3, et al (c)	0.049	0.056	0.04	0.107	0.087	0.009	0.171	0.069	0.24
S (d)	0.022	0.037	0.049	0.057	0.075	0.052	0.030	0.000	0.006
P (e)	0.001	0.002	0.001	0.004	0.001	0.001	0.004	trace	0.009
L.O.I. (f)	43.88	43.91	43.96	43.92	43.77	43.87	43.41	43.87	43.99
CO_2 (g)	44.11	44.05	44.02	44.24	43.74	43.82	44.04	44.12	43.96
CO_2 (h)	44.27	44.17	44.02	44.46	43.61	43.67	43.86	43.96	43.95

(a) Calculated from CaO
(b) Calculated from MgO
(c) By difference, R_2O_3 minus Fe_2O_3
(d) Determined from 50 gram sample
(e) Determined from 20 to 50 gram sample
(f) Ignited at 950-1000° C.
(g) Using Knorr alkalimeter
(h) Computed from CaO-MgO

TABLE OF ANALYSES OF ST. CLAIR LIMESTONE, continued

Sample number	10	11	12	13	14	15	16	17	18
Lab. number	composite 9201-9207	9208	composite 9219-9226	composite 9227-9230	9231	9176	composite 9209-9218	composite 9232-9238	Okla.Geol. Surv.Bull. 14, p. 88, 1929.
Location	SE¼ NE¼ NE¼ sec.22		SE¼ SE¼ SW¼		sec. 14	SE¼SW¼SE¼ sec. 14	NE¼SW¼SE¼ sec. 14	SW¼SW¼SE¼ sec. 14	SW¼NW¼SW¼ sec. 13
Operator	Independent Gravel Co., Marble City		Abandoned		quarry	Talley: abandoned	Not quarried	Not quarried	Southern Stone Co., abandoned
Thickness, feet	40	11	43	26	12	14	60	45	Top 25' of quarry
Stratigraphic position	Above sample No. 9	Top of St. Clair	Base of exposed section	Above sample No. 12 11' in quarry.	Top of St. Clair	25' above exposed base of St. Clair	55' below top of St. Clair. Overlies sample No. 15.	Stratigraphically above sample No. 15. 56' below top St. Clair.	About 100' below top of St. Clair. Top eroded.
Lithologic zone	2(Middle)	1(Upper)	2(Middle)	2(Middle)	1(Upper)	3(Lower)	3(Lower)	3(Lower)	3(Lower)
Lithology	Pink coarse limestone	Blue-gray dense limestone	Gray, slightly dolomitic limestone	Pink coarse limestone	Blue-gray dolomitic limestone	Gray, med. crystalline dolomitic limestone	Gray, med. crystalline dolomitic limestone	Gray, med. crystalline dolomitic limestone	Gray, med. crystalline dolomitic limestone
$CaCO_3$ (a)	97.65	96.47	95.38	97.74	74.41	70.50	85.13	81.83	87.80
$MgCO_3$ (b)	1.58	2.78	3.95	1.42	24.28	28.51	14.54	17.51	12.26
CaO	54.79	54.13	53.44	54.76	41.69	39.50	47.70	45.85	49.19
MgO	0.72	1.22	1.89	0.68	11.61	13.63	6.95	8.37	5.86
SiO_2	0.08	0.42	0.227	0.143	0.273	0.82*	0.076	0.36	0.075
R_2O_3	0.136	0.35	0.103	0.248	0.438		0.228	0.24	
Fe_2O_3	0.043	0.06	0.040	0.074	0.183		0.082	0.07	0.065
Al_2O_3, et al (c)	0.093	0.23	0.063	0.174	0.255		0.146	0.15	0.00
S (d)	0.004	0.006	sl.tr.	0.011	0.006		sl. tr.	0.007	
P (e)	0.003	0.028	0.004	0.003	0.004		0.011	0.009	0.003
L.O.I. (f)	43.94	44.18	44.03	43.94	45.63		44.62	44.92	
CO_2 (g)	44.02	43.88	43.97	43.82	45.50		44.85	45.26	44.99
CO_2 (h)	43.79	43.74	44.00	43.71	45.39		45.02	45.11	

* Insol. in HCl.

be measured in tens of millions of tons, 50,000,000 tons being a conservative estimate. Farther up the stream valleys the outcrop is narrower, the overburden increases, the thickness of the limestone above ground is less, and there are no good open-cut quarry sites. No underground mining has been attempted but apparently this practice would be feasible, and the above figure is to be increased many times if underground mining is considered.

Owing to scarcity of exposures, estimates of dolomitic limestone are more difficult to make. In the Talley quarry a bed 14 feet thick contains 13.63 percent MgO, and above it there is 60 feet that contains 6.95 percent MgO. The lower 14-foot bed is not exposed elsewhere in the district. The equivalent of the 60-foot zone was found in the abandoned dimension stone quarry, and scattered outcrops between the two quarries indicate the zone is probably continuous in that area. Any prospecting for dolomitic limestone should begin in the area just mentioned, and subsurface samples should be obtained by drilling in order to insure a complete understanding of its thickness, distribution, and uniformity.

DEVELOPMENT

First utilization of the St. Clair limestone dates back to early territorial days, when stone was quarried for building purposes, and possibly for the production of quicklime. An old quarry, probably operated during that period, is located in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 14, T. 13 N., R. 23 E. Drake 19/ mentions a quarry in his report published in 1896. Fitzhugh 20/ reported visiting several old quarries during his investigation in 1903, in one of which "... rock has been quarried quite extensively near 8 years ago." Taff, who surveyed the area in 1901, made no mention of any development in his report.

The best authenticated records of any development

of that early period concern the production of dimension stone from a quarry located in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 13. This plant was well equipped for quarrying and sawing, and furnished stone for the Pioneer Telephone Company building in Oklahoma City, buildings for Rice Institute, Houston, Texas, and other public buildings elsewhere. These operations were abandoned in 1914.

During 1933-1937, considerable stone was produced for road material for WPA projects, and stone from the Talley quarry is reported to have been shipped to a glass plant in the state. In 1937, at the suggestion of the Oklahoma Geological Survey, the Dunlap Company of Oklahoma City selected the area as a source of stone suitable for the company's lime kiln at Oklahoma City, and shortly thereafter reorganized as the St. Clair Lime Company. Later the company constructed a second, larger lime plant at Sallisaw. About the same time the Independent Gravel Company, of Joplin, Missouri, began producing aggregate and agricultural stone, first utilizing the spalls and fines derived from quarrying for the lime kiln, and later opening a separate quarry. Agricultural stone is ground in a small plant at Marble City. Present total output of crude stone from the district for all purposes is in excess of 500 tons per day.

The stone is hauled by trucks over improved roads from the quarries to the Kansas City Southern Railroad at Marble City, a distance of 2 to 2.5 miles. Sallisaw Creek, which is subject to flash floods, offers a slight operating problem by overflowing the road crossing at Marble City, thereby closing the road for short periods. This difficulty has been solved by stockpiling at the railroad and could be eliminated by construction of an automobile bridge at another location, or the building of a railroad bridge and spur into the quarry area.

SUMMARY AND CONCLUSIONS

The St. Clair formation in the Marble City district consists of three zones of carbonate rock, all exceptionally low in silica and other objectionable impurities. Most important commercially is the middle zone, about 65 feet thick, which is a high-calcium limestone. It has been actively quarried since 1937 and used for agricultural stone, concrete aggregate, in making quicklime, and as a flux in aluminum reduction at Bauxite, Arkansas.

The upper zone has a maximum thickness of 12 feet and grades from a high-calcium limestone into dolomitic limestone at different places. One company quarries a small amount of its output from this zone.

The lower zone is dolomitic limestone, in which the magnesia content averages about 7 percent; it has a maximum exposed thickness of about 75 feet. Dimension stone and stone for the glass trade formerly were quarried from the zone.

All of the above stone is suitable for concrete aggregate, road metal, dimension stone, and as a flux in certain metallurgical operations in which low silica is a necessary consideration. The dolomitic limestone is especially low in silica for a rock of its composition, and it could fulfill some specialized uses which very few other stones could satisfy.

A large volume of high-calcium limestone is still available in undeveloped quarry sites where there is little to moderate overburden. If underground mining should be considered, the reserves in the district would be several hundred million tons. The future of the district seems to be assured, for the high quality of the limestone makes it desirable for many chemical process industries; and the deposits enjoy a local geographic trade advantage because little or no stone of such good quality is found in the region embracing southeastern Oklahoma, southwestern Arkansas, northern Louisiana, and northeastern Texas.

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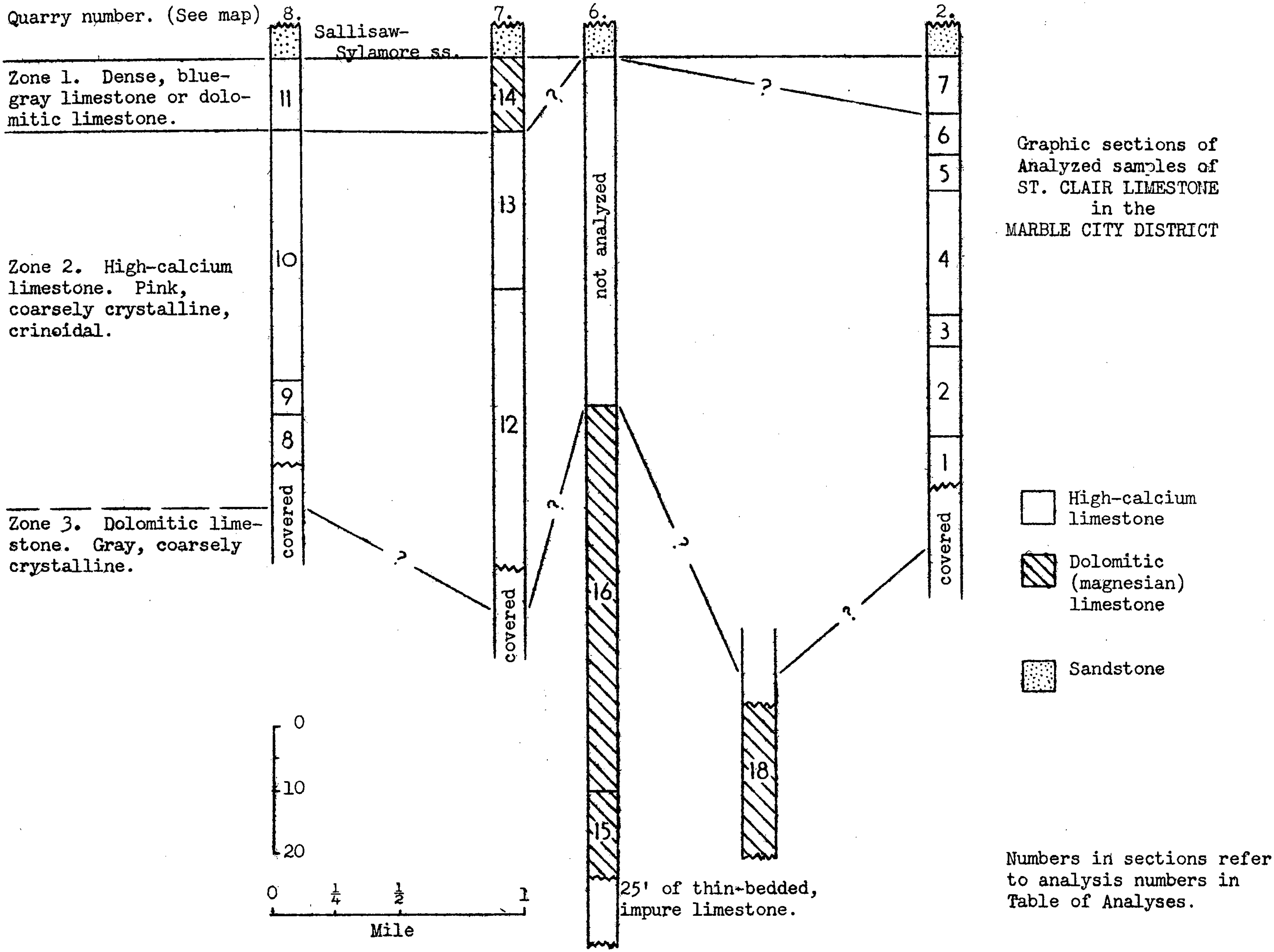
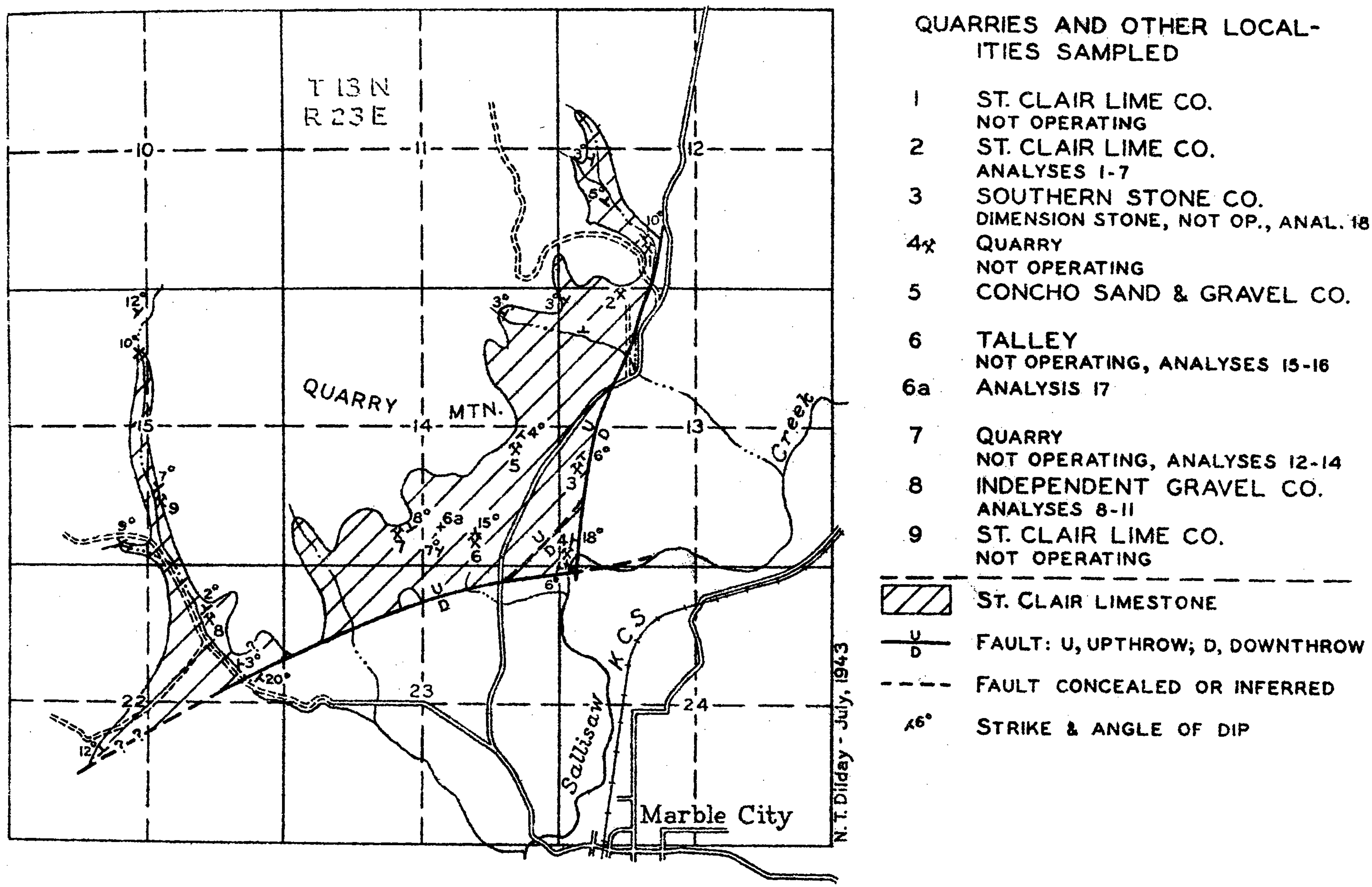


Graphic sections of Analyzed samples of ST. CLAIR LIMESTONE in the MARBLE CITY DISTRICT

Numbers in sections refer to analysis numbers in Table of Analyses.



ST. CLAIR LIMESTONE IN MARBLE CITY DISTRICT
BY
W. E. HAM, M. C. OAKES, AND R. H. DOTT
1943

ERATTA

P. 16 - Sample number 2, lab. number 9190, R_2O_3 should read 0.10

P. 17 - Sample number 6, lab. number 9194, Al_2O_3 should read 0.099

MAP - Angle of dip at quarry number 6 (SE¼, Sec. 14) should read 5° instead of 15°.