Field Excursion Eastern Llano Region

BY VIRGIL E. BARNES

ANNUAL MEETING
Association of American State Geologists
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FIELD EXCURSION, EASTERN LLANO REGION

Virgil E. Barnes

INTRODUCTION

Central Texas combines range of geologic section, quality of natural exposures, diversity of mineral commodities, and climate difficult to duplicate in an equivalent area elsewhere in the United States. A few of the more interesting localities (fig. 1) in the eastern part of the Llano region, frequently visited by groups of geologists, are briefly described in the following pages.

The following listing of various geologic units recognized in the eastern part of the Llano region and the résumé were prepared so that each visitor can more readily integrate the geologic features seen at each locality into the geologic history of the region as a whole.

GEOLOGIC UNITS

- Cretaceous
  - Lower Cretaceous
    - Fredericksburg division
      - Edwards limestone
      - Comanche Peak limestone
      - Walnut clay
    - Trinity division
      - Upper Trinity (Shingle Hills formation)
        - Glen Rose limestone
        - Hensell sand
      - Middle Trinity
        - Cow Creek limestone
        - Hammett shale
      - Lower Trinity
        - Sycamore sand
- Pennsylvanian
  - Lower Pennsylvanian
    - Strawn group
    - Smithwick shale
    - Marble Falls limestone
    - Unnamed phosphorite

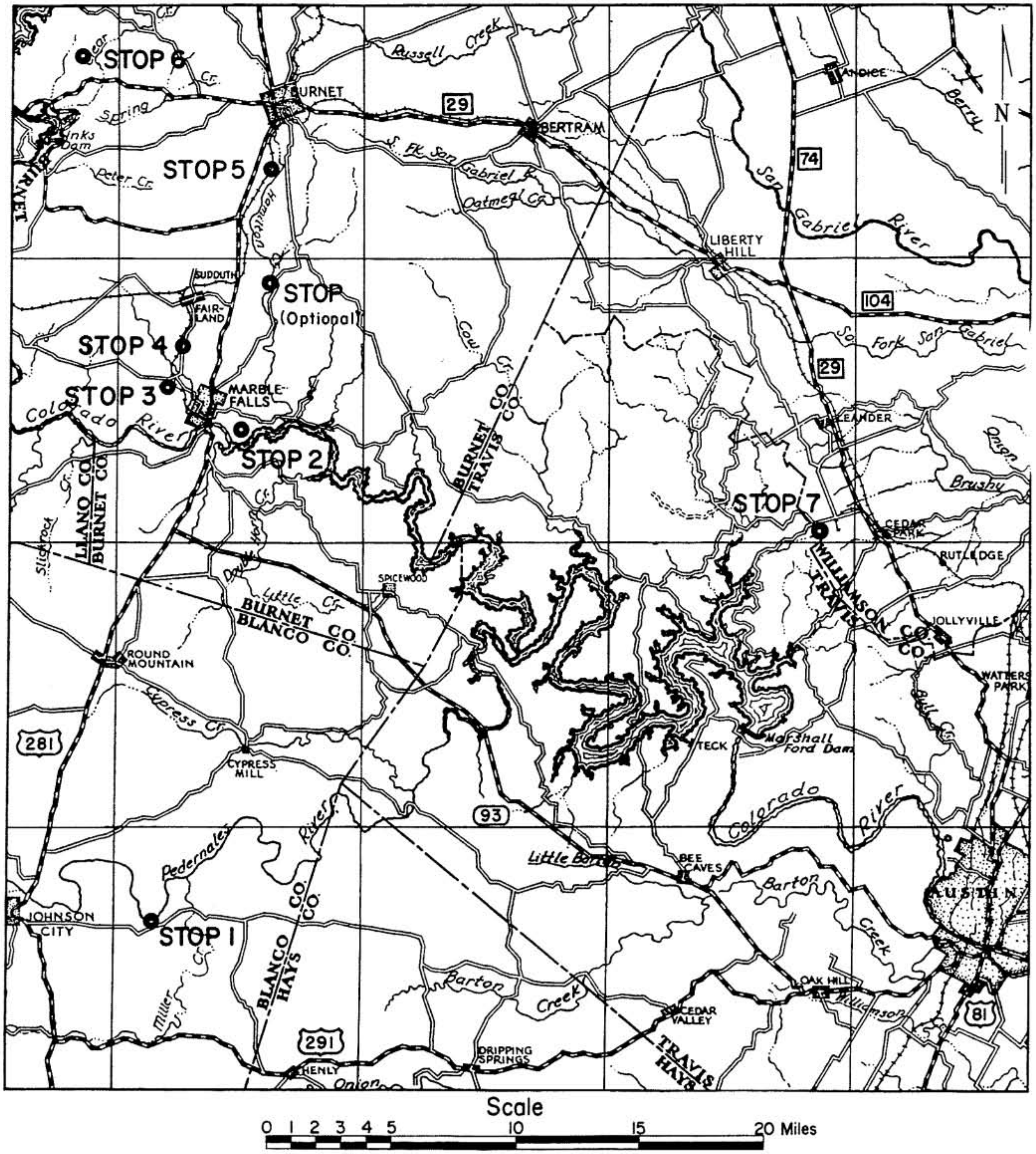


Figure 1. INDEX MAP SHOWING EXCURSION ROUTE AND LOCALITIES.

Mississippian
- Barnett formation
- Chappel limestone

Mississippian and Devonian
- Houy formation
  - Doublehorn shale
  - Ives breccia

Devonian
- Stribling formation
- Pillar Bluff limestone

Ordovician
- Upper Ordovician
  - Burnam limestone
- Lower Ordovician
  - Honeycut formation
  - Gorman formation
  - Tanyard formation
    - Staendebach member
    - Threadgill member

Cambrian
- Wilberns formation
  - San Saba member
  - Point Peak member
  - Morgan Creek limestone member
  - Welge sandstone member
- Riley formation
  - Lion Mountain sandstone member
  - Cap Mountain limestone member
  - Hickory sandstone member

Precambrian
- Town Mountain granite and other intrusive rocks
- Packsaddle schist
- Valley Spring gneiss

RÉSUMÉ

The Valley Spring gneiss, the oldest rock recognized in the Llano region, was originally probably a feldspathic and argillaceous sandstone which upon being metamorphosed changed to a pink feldspathic gneiss. The Packsaddle schist, also of sedimentary origin, was composed originally of shale or clay of several types (including some that were carbonaceous), limestone, perhaps dolomite, and some sandstone. During metamorphism these rocks changed to muscovite schist, biotite schist, graphite schist, hornblende schist, marble, including calcitic, dolomitic, and magnesitic varieties, and various other rock types.

Igneous rocks were emplaced about 800 to 900 million years ago during and following metamorphism of the sedimentary rocks. Those which were introduced early became gneissic, while other, mostly larger, masses (Town Mountain granite) either followed the structure of the country rock or were emplaced with little regard to the existing structure. These latter are batholithic, coarse-grained masses which mostly erode to low featureless areas. The finer grained, smaller masses resist erosion and today form monadnock-like hills much like those present at the start of Cambrian sedimentation.

Several miles of Precambrian rock were removed by erosion before the first Paleozoic sediments were deposited on the site of the Llano uplift. These sediments were probably of Middle Cambrian age, because several hundred feet of unfossiliferous Hickory sandstone are beneath the first fossils, which are transitional Middle to Upper Cambrian forms. The first sediments were eolian, as indicated by wind-abraded pebbles in many localities at the base of the Hickory sandstone, especially in the western part of the Llano region. The dividing horizon between rocks of eolian origin and those deposited in water has not been established. However, low in the Hickory, many beds with ice-crystal markings indicate that at least on some frosty Cambrian mornings, these beds were barely awash. About 1,400 feet of Cambrian rock, including limestone, sandstone, siltstone, and some shale, accumulated in a broad, bay-like, northwestward-extending arm of the ocean. The limestone is dominantly granular because of large quantities of fossil debris and much coarsely crystalline, clear calcite cement. Aphanitic, stromatolitic reef limestone is common in the Point Peak and San Saba members; the limestone in the San Saba in part is replaced by dolomite.

Sedimentation was continuous but conditions changed gradually in latest Cambrian and earliest Ordovician time; therefore, the boundary between the two systems is purely a paleontologic one and seldom can be located stratigraphically closer than a few tens of feet. The limestone of the Lower Ordovician (Ellenburger) is mostly aphanitic, commonly intraclastic, and is thought to have formed in an open-sea banks-type environment similar to that of the Bahama Banks today; whereas the granular limestone in the Upper Cambrian formed in a broad arm of the sea with the shoreline nearby.

The Lower Ordovician rocks are cherty to noncherty dolomites and limestones with outcrop thickness ranging from a maximum of about 1,800 feet in the southeastern part of the Llano region to a minimum of 830 feet in the northwestern part of the region. The various units of the Ellenburger are remarkably constant in thickness, and the reason for the difference in total thickness is truncation. Truncation was essentially complete by the start of the Devonian and may have been accomplished much earlier, as indicated by remnants of Upper Ordovician (Burnam limestone) preserved in collapse structures. The Llano region was awash--first in, then out of the sea--from the end of the principal truncation to near the beginning of the Pennsylvanian. During periods of submersion, rocks accumulated; during periods of emergence they were mostly removed, being preserved only as remnants in collapse structures or as disconnected lenticles that escaped erosion. The Barnett formation (Mississippian) is the oldest widespread unit to escape destruction by erosion following the long period of near-sea-level stability, and it too occurs in disconnected lenticles in the southeastern part of the Llano region. The Pennsylvanian units, except for the phosphorite, are widespread and more uniformly distributed.

Normal faults related to the Ouachita orogeny formed during the Strawn and produced fault blocks mostly tilted less than 10 degrees. The initiation of the Llano uplift dates from about this time; it may have been rejuvenated later. The Paleozoic rocks in the Llano region, except where preserved in grabens, were removed by erosion by the start of Cretaceous sedimentation. Cretaceous rocks, still very little disturbed structurally, accumulated until the Llano uplift was buried; the first unit to cover it was probably the Edwards limestone. Younger Cretaceous rocks were probably deposited but there is no record of them now. The rest of the stratigraphic sequence consists of terrace and alluvial materials. In the not-too-distant past, erosion again exhumed the Precambrian, during which time the edge of the Edwards Plateau receded. Only outliers of the Plateau now remain along the route of the excursion.

ACKNOWLEDGMENTS

The geologic data presented are compiled from various sources, mainly from work by the writer and associates. Bibliographic references are omitted; these may easily be found in The University of Texas and Bureau of Economic Geology publications. "Bibliography of Texas Geology, 1933 to 1950", to be published during 1958, will be especially useful for this purpose.

To quarry and plant operators and landowners, the writer wishes to express his appreciation for their very generous cooperation, including release of data on quarry and plant operations. Specifically he wishes to express his appreciation to Mr. and Mrs. Clayton Stribling (Stop 1) for making the Honeycut Bend locality accessible to all geological groups who wish to see this very informative locality; to Mr. V. E. Childers (Stop 2) for information about the operation of Pure Stone Company; to Mr. H. L. Hicks (Stop 3) for information about the operation of Texas Granite Corporation; to Mr. Ramsey Clinton (Stop 5) for information about the operation of the Burnet Stone Division of Texas Construction Material Company; to Mr. Robert Miller (Stop 6) for information about the operation of Southwestern Graphite Company; and to Mr. W. D. Johnson (Stop 7) for information about the operation of Texas Quarries, Inc.

STOP 1

Honeycut Bend of Pedernales River, Blanco County

Please refer to "Geologic map of Honeycut Bend area, Blanco County, Texas" (fig. 2), and "Pennsylvanian, Mississippian, Devonian, and Ordovician rocks, Honeycut Bend, Blanco County, Texas" (fig. 3). Stay west of fence along western side of Archer ranch. Walk north toward Pedernales River, cross east-west fence, and follow fence eastward to bluff along river.

The following stratigraphic units crop out in this area:

- Cretaceous
  - Lower Cretaceous
    - Upper Trinity (Shingle Hills formation)
      - Glen Rose limestone member
      - Hensell sand member
    - Middle Trinity
      - Cow Creek limestone member
- Pennsylvanian
  - Lower Pennsylvanian
    - Marble Falls limestone
      - Spiculite facies
      - Biohermal limestone and shale facies
- Mississippian
  - Barnett formation
  - Chappel limestone
- Mississippian and Devonian
  - Houy formation
    - Ives breccia
- Devonian
  - Lower or Middle Devonian
    - Stribling formation
  - Lower Devonian
    - Pillar Bluff(?) limestone
- Ordovician
  - Lower Ordovician
    - Honeycut formation (upper third of Ellenburger group)

The thickest section (679 feet) of Honeycut rocks in the Llano region is exposed along Pedernales River. The Honeycut formation is roughly divisible into three units in this section--a lower alternating limestone-dolomite unit, a middle dolomite unit, and an upper limestone unit. Only the uppermost part of the limestone unit will be viewed. The limestone is aphanitic, very light gray, and in 6-inch to 2-foot beds. Chert, mostly in angular fragments, somewhat translucent, gray with an olive-green cast, is rather sparsely distributed. On the top surface some brownish, opaque, fossiliferous chert contains Hormotoma sp., Ceratopea cf. C. tennesseensis Oder, and Orospira sp. In places the top ledge is a coquinite of Hormotoma, mostly unsilicified.

A pocket of impure yellowish-brown limestone enclosed by the Ellenburger strata has been assigned to the Pillar Bluff(?) limestone. The evidence of the fossils alone is equivocal, and the rock could be Helderberg, Oriskany, Onondaga, or even Silurian age, but the Stribling formation is early Onondaga. There is no evidence that the material in question reached its present position through an opening that penetrated the Stribling formation, thus representing strata that formerly overlay the Stribling rocks but are now absent from this vicinity. Moreover, there is little resemblance between the fauna of the pocket and that of the Stribling formation itself, so it is unlikely that the pocket filling represents Stribling rocks. Therefore, one can infer that the filling sediments were deposited in the pocket before Stribling time. The only pre-Stribling Devonian so far known in central Texas is the Pillar Bluff limestone, and the fossils from the pocket are compatible with assignment to the fauna represented by those contained in the Pillar Bluff limestone at the type locality.

The Stribling formation, about 10 feet thick, is a microgranular limestone, medium light gray ranging to reddish gray and yellowish gray with an olive-gray cast. The basal 2 inches is yellowish gray and contains sand grains. Bedding is irregularly lenticular from almost fissile to 6 inches thick. Except for the lower 2 feet the rock is mostly cherty; the chert, translucent to subtranslucent in upper part, ranges downward to opaque in lower part, brownish to grayish, and occurs as irregular lenses and false joint fillings.

The Ives breccia member of the Houy formation, about 18 inches thick, is composed mostly of angular chert fragments and a small amount of phosphatic limestone matrix. The rounded pieces of chert in the Ives appear to be unbroken chert nodules rather than water-worn chert pebbles. The predominance of angular pieces may be due to disintegration of the chert along incipient fractures. It seems likely that the Ives at this point is an accumulation, essentially in place, of the insoluble constituents of the Stribling formation. Conodont- and bone-bearing phosphatic and calcareous beds are associated with the Ives in several places in the eastern part of the Llano uplift. Such an occurrence was exposed here by the record-breaking flood of 1952. At locality 2-421, north of the river, a bed a few inches thick composed almost entirely of conodonts is weakly radioactive.

The Chappel limestone is present at only a place or two in this area. The best exposure is across the fence on the Archer ranch between the foot of the bluff and where the cars are parked. It is only about a foot thick, is brownish gray and crinoidal, the crinoid columnals being mostly smaller and less distinct than in the overlying biohermal unit of the Marble Falls.

Until the flood of 1952 the nearest exposure of shale of the Barnett formation was several miles to the northeast at Elm Pool. Now there is an exposure about 2 miles downstream in the bed of the Pedernales River. Exposed here at the same time is a pocket of glauconitic material in the Stribling formation similar to the basal few inches of the Barnett in the exposures just mentioned. Dr. W. H. Hass, U. S. Geological Survey, reports obtaining conodonts from the upper faunal zone of the Barnett formation in a quarter-inch crack-filling in the basal beds of the Stribling formation. Numerous crack-fillings in the Ellenburger may also be from the Barnett formation.

The lower biohermal unit of the Marble Falls limestone is composed of bioherms of limestone interspersed with distinctly bedded limestone and black shale and a 21-inch black shale bed at the base, which has considerable lateral persistence. A thin phosphatic zone is at the base of the shale. Fossils collected 12 years ago from the biohermal unit are regarded by Dr. G. A. Cooper, U. S. National Museum, as of Morrow age. This unit crops out for about 1.5 miles northeastward but only in limited outcrops beyond.

The overlying spiculite unit is dark gray and calcareous; in thin section it is seen to be a mat of spicules in a calcareous groundmass. Where leached at the outcrop, it ranges in color on fresh breaks from white to yellowish gray or even yellowish orange or darker depending on the amount of iron.

The Stribling and Honeycut rocks are truncated by the overlying Mississippian and Pennsylvanian rocks, and at least 100 feet of truncation can be demonstrated within the map area. All of the Paleozoic units described are truncated within a short distance by flat-lying Cretaceous rocks. The immediately overlying unit of the Cretaceous is the Cow Creek limestone, which wedges out against Honeycut rocks within the map area. From here westward mostly Hensell sand and rarely Glen Rose limestone rest directly on the Paleozoic rocks. No more Cow Creek limestone is present.

The Hensell sand member of the Shingle Hills formation forms the bench on which the cars are parked. The Hensell sand is mostly poorly sorted and composed of a wide variety of materials including cobbles, pebbles, granules, sand, silt, clay, variously mixed, and in addition an appreciable amount of calcareous material, which becomes more abundant upward until the Glen Rose limestone is reached. The basal part of the Hensell is reddish, the color rising stratigraphically westward toward the ancient shore. The top part of the Hensell is gray, and the boundary between the two color phases forms an irregular lateral as well as vertical transition. The Hensell sand is a shoreward facies of the Glen Rose limestone; eastward it disappears; westward the top of the Hensell rises higher and higher until no Glen Rose limestone remains. The base of the Hensell also becomes younger as it climbs the Llano uplift westward.

The Glen Rose limestone is an alternating series of hard, but mostly impure, limestone beds with softer, marly, shaly or sandy beds. This alternation of soft and hard beds causes the characteristic stairstep topography of the Glen Rose. The basal bed of the unit forms a bench a short distance south of the road. A thickness of several hundred feet of Glen Rose beds crops out between here and the divide a mile or so to the south. Westward the Glen Rose limestone thins as beds at its base grade to terrigenous material toward the ancient shore. A bed to the south near the middle of the Glen Rose is characterized by the fossil Corbula; westward at Hye the Corbula bed becomes the basal bed of the Glen Rose and a short distance beyond the Gillespie County line it disappears, being replaced by Hensell sand. Near Cross Mountain at Fredericksburg, only 55 feet of Glen Rose remains and 5 miles north of Cross Mountain it has graded entirely to Hensell sand.

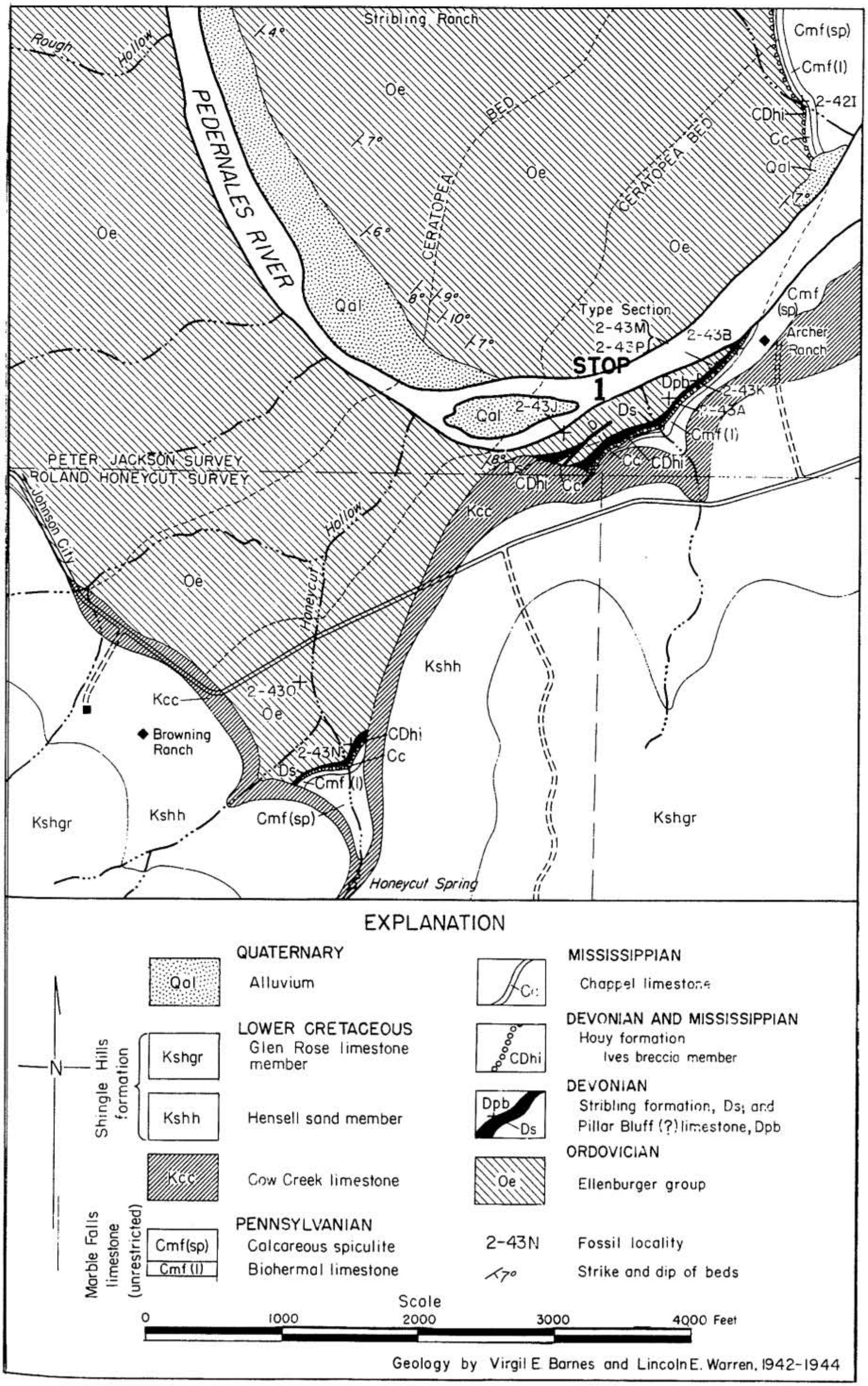
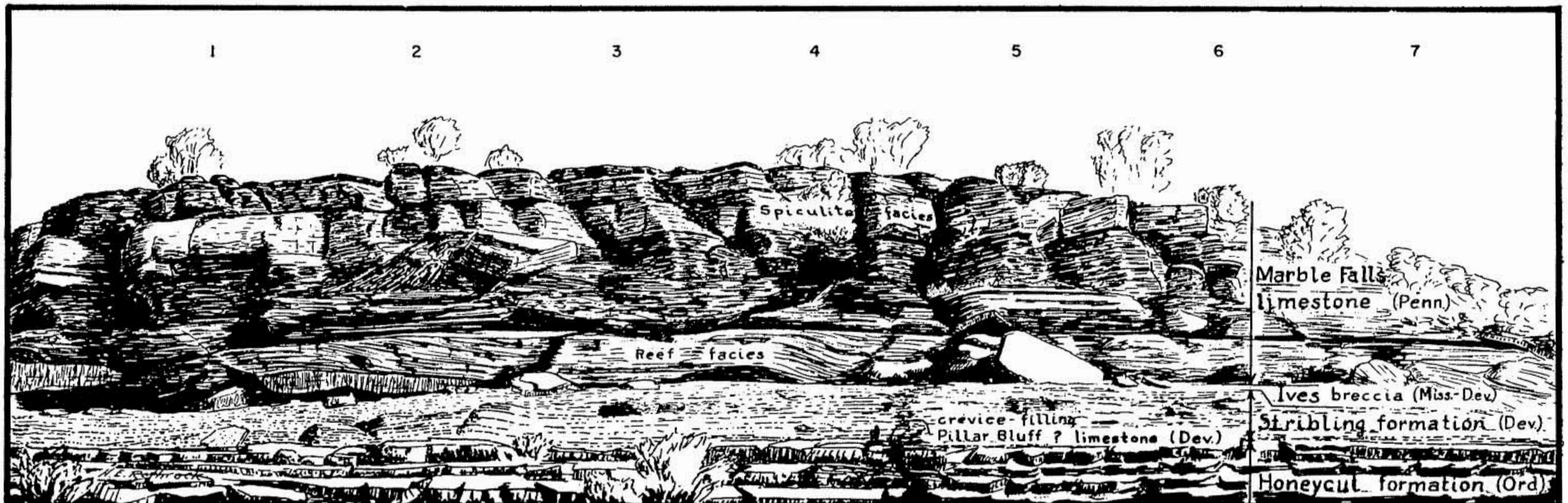


Figure 2. GEOLOGIC MAP OF HONEYCUT BEND AREA, BLANCO COUNTY, TEXAS.



(Reproduced through the courtesy of the San Angelo Geological Society)

Figure 3. PENNSYLVANIAN, MISSISSIPPIAN, DEVONIAN, AND ORDOVICIAN ROCKS, HONEYCUT BEND, BLANCO COUNTY, TEXAS.

STOP 2

High-calcium Limestone Reef, Marble Falls Area, Burnet County

Please refer to "Geologic map of an area in vicinity of Marble Falls, Burnet County, Texas" (fig. 4), and to "Lithology and insoluble residues of Marble Falls limestone in type section" (fig. 5). A distant view of the reef may be obtained from the vicinity of Marble Falls dam. Units exposed within the map area include the following:

- Pennsylvanian
  - Lower Pennsylvanian
    - Smithwick shale
    - Marble Falls limestone
- Mississippian
  - Barnett formation
  - Chappel limestone
- Mississippian and Devonian
  - Houy formation
    - Ives breccia
- Ordovician
  - Lower Ordovician (Ellenburger group)
    - Honeycut formation

The Marble Falls dam rests on beds of microgranular dolomite in the middle dolomitic facies of the Honeycut formation. The microgranular dolomite is essentially free of cavities and provides an excellent base for the dam. Limestone dipping beneath lake level at the northern end of the dam is cavernous but has been effectively sealed, as little water is lost around the dam.

The main purpose of this stop is to examine a portion of a high-purity limestone reef in the Marble Falls limestone. The high-purity limestone was first recognized in 1951 while the writer was measuring, sampling, and describing the type section of the Marble Falls limestone before it was submerged by the lake behind Marble Falls dam.

The reef limestone is fine-grained and dense, and in thin section a number of foraminifera, a few grains of detrital calcite, and calcitic spicules can be seen. These spicules appear entirely similar to siliceous ones in the surrounding and overlying beds except that they are calcite. The reef is well exposed on the north bank of Colorado River, its outcrop is shown on figure 4, and it is estimated that 6 to 10 million tons of high-purity limestone are present. The manner in which the reef differs from the rest of the Marble Falls limestone is shown on figure 5, which shows lithology and amount of insoluble residue. The reef contains very little insoluble residue, yet laterally it grades into rocks which are as impure as those above the reef in the diagram. It is puzzling how a limestone so pure could have formed in a sea which at the time was depositing limestone so high in silica.

Analyses of the reef limestone follow.

Chemical Composition of Reef in Lower Part of Marble Falls Limestone at Type Section (in percent)

Feet above base	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Ignition loss	Total
95-115	0.16	0.07	0.24	0.12	54.33	0.97	43.80	99.69
75- 95	0.06	0.04	0.13	0.08	54.45	0.83	43.94	99.53
55- 75	0.09	0.03	0.08	0.05	54.45	0.84	43.91	99.45
35- 55	0.11	0.04	0.14	0.09	54.33	0.91	43.98	99.60
5- 20	0.08	0.03	0.12	0.09	54.21	1.05	43.96	99.54
Average	0.10	0.04	0.14	0.08	54.35	0.93	42.92	99.56

In 1953, as a direct result of the publication of figure 4 and these chemical analyses, a quarry was opened in the reef limestone north of the river where the outcrop is narrow and the overburden away from the outcrop is excessive. The quarry was opened by V. E. Childers (Pure Stone Company) at this location because of a favorable lease, even though the quarry site is unfavorable, and the quarry is near the margin of the reef where tongues of impure rock might complicate the quarrying. Visual examination of the outcrop and exploratory drilling gave no hint of the cavernous condition existing. The caverns, well exposed at the south end of the quarry, are mostly filled by silty and sandy red clay probably introduced either during the transgression of the Cretaceous sea or during the present erosional cycle. Since the base of the Cretaceous near the quarry was only a few feet above the highest part of the present surface, a quarry site lower topographically might be free of such material.

Underground mining was originally considered beyond the limit where quarrying was economical, but when it was found that narrow cracks in the overlying extremely siliceous Marble Falls led into mostly filled caverns in the limestone beneath, plans were made for transferring quarry operations. Late in 1955, exploratory drilling was followed by the opening of a quarry in a rather pure, massive zone in the Honeycut formation, shown on figure 4. It was found that this limestone is of uniform quality and, even though it contains about 2 percent silica, is desirable for glass. In mid-1957 the entire operation was shifted to the quarry in the Honeycut formation, where percussion drilling on a wagon drill is used, and blasting is with ammonium nitrate activated by dynamite. A 2-yard Pettibone-Mullikan bucket loader was found to be versatile as it could be used at both the quarry and the plant.

The plant, situated along a railroad spur in Marble Falls, is equipped with a 50-40 Dixie hammer mill feeding to two 4 x 10 Tyler-Hummer screens where the -16 mesh is removed and the oversize (+16 mesh to $-\frac{1}{2}$ inch) goes to a 30-inch Williams hammer mill in closed circuit with the Tyler-Hummer screens. Part of the -16 mesh is fed to three Sweco screens to take off the -40 mesh. Aeration removes most of the dust from the remaining -16 mesh, and this dust and other dust from the operation is collected using Cyclones; it is then fed back to the Sweco screens to remove foreign matter. All the -40 mesh material from the Sweco screens is fed to a Raymond air separator, which removes about two-thirds of the -200 mesh. The plant produces 40 tons per hour distributed among the following products:

-16 mesh, most of dust removed--for glass manufacture
-40 mesh, with maximum of 25 percent -200 mesh--for asphalt tile and shingles
-200 mesh--for whiting substitute for texture paints and other uses

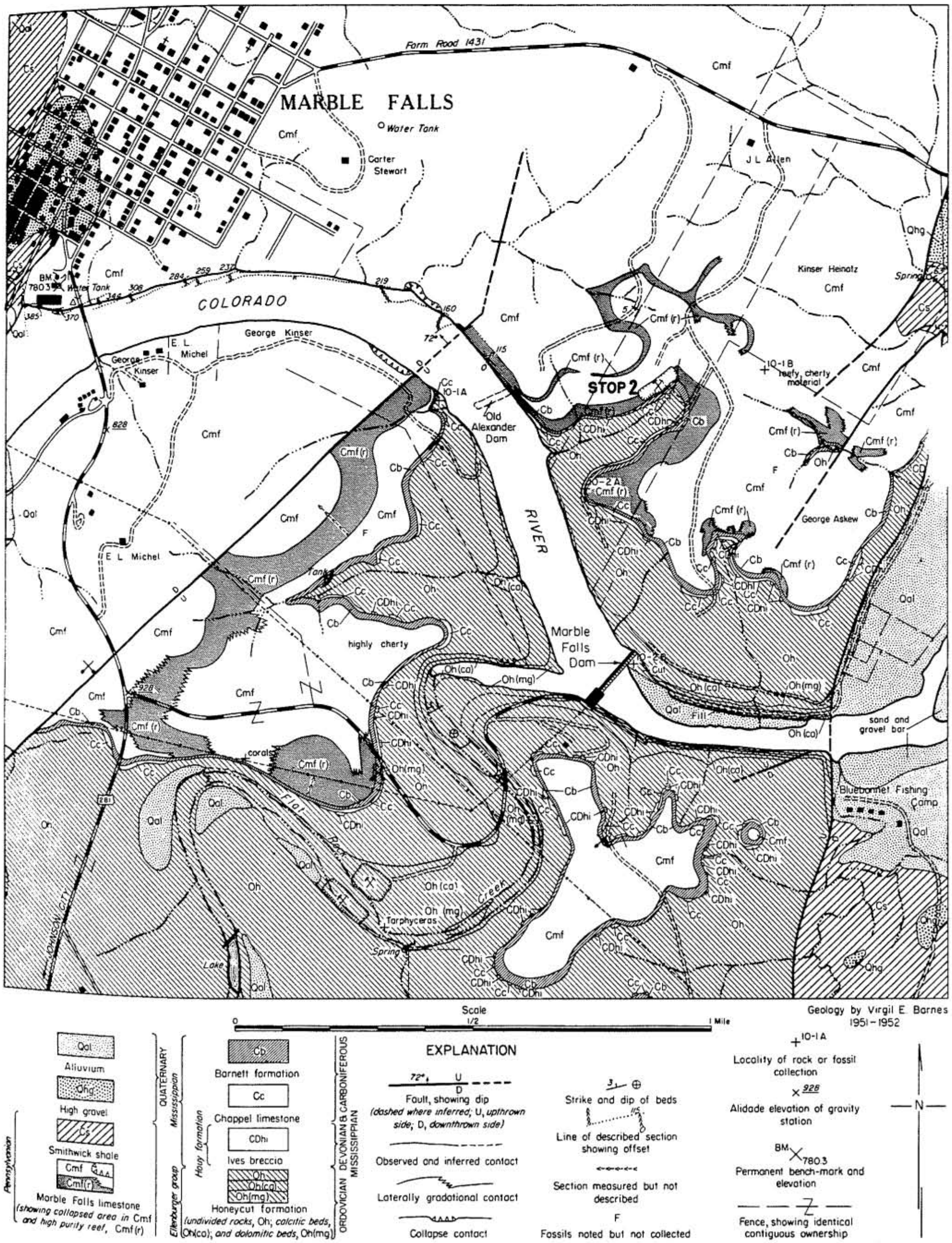


Figure 4. GEOLOGIC MAP OF AN AREA IN VICINITY OF MARBLE FALLS, BURNET COUNTY, TEXAS.

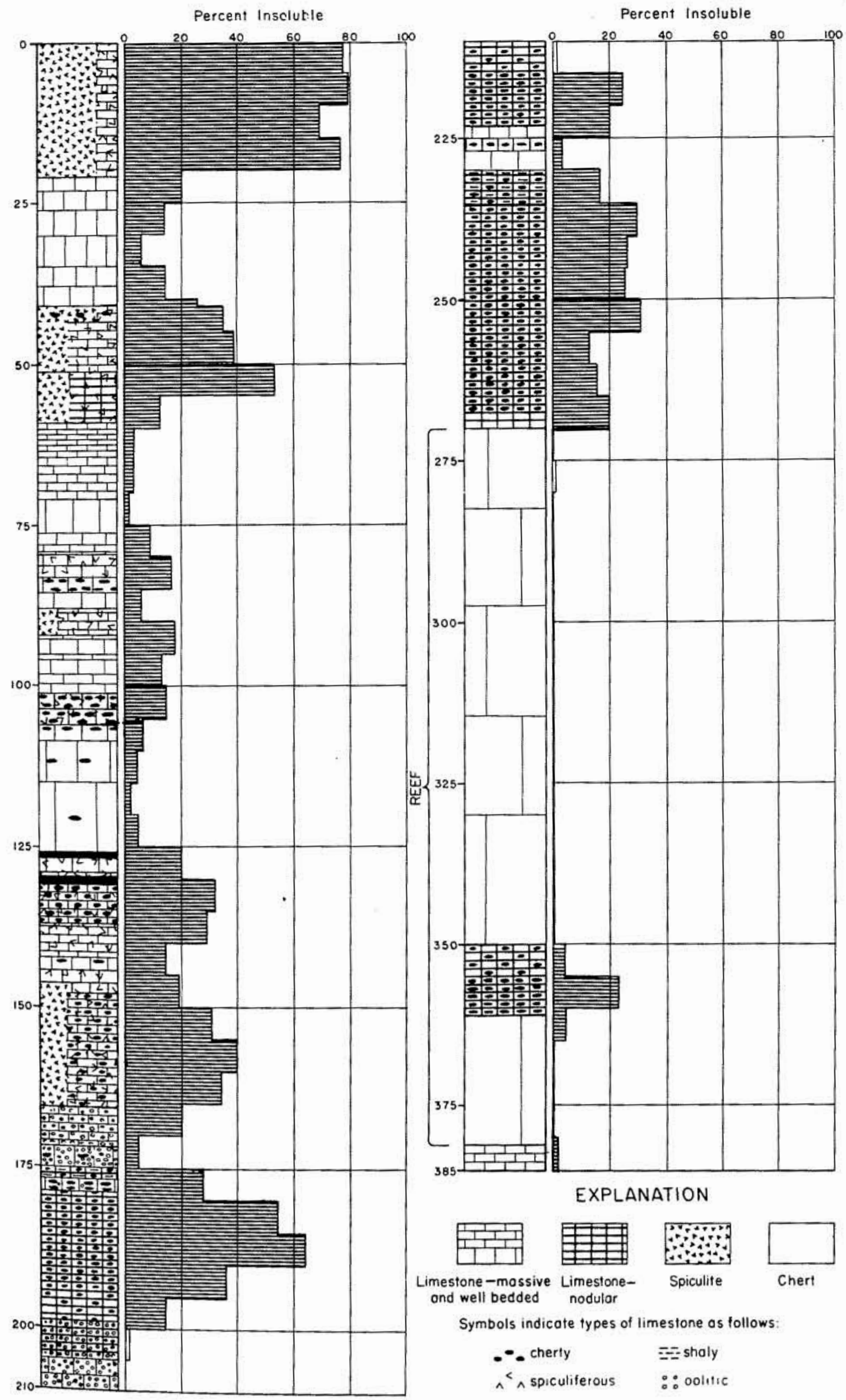


Figure 5. LITHOLOGY AND INSOLUBLE RESIDUES OF MARBLE FALLS LIMESTONE IN TYPE SECTION.

STOP 3

Granite Mountain, Marble Falls Area, Burnet County

Please refer to "Geologic map of Granite Mountain area, Burnet County, Texas" (fig. 6). The Granite Mountain quarry was opened in 1882 on an exfoliation dome of the Granite Mountain granite mass, which is one of the Town Mountain granite bodies. The granite is composed mostly of microcline, microperthite, plagioclase, and rutilated quartz, and some biotite and hornblende. Accessory minerals, in addition to rutile, include magnetite, titanite, apatite, zircon, and allanite. Rarely, large microcline phenocrysts are mantled by plagioclase; a few such phenocrysts are well displayed on the eastern end of the office building. Chemical analysis and calculated mineral composition follow.

Chemical analysis

	Percent
SiO_2	73.02
Al_2O_3	13.55
Fe_2O_3	0.53
FeO	2.12
MgO	0.16
CaO	1.18
Na_2O	3.55
K_2O	5.02
H_2O+	0.18
H_2O-	0.06
CO_2	0.05
TiO_2	0.31
P_2O_5	0.08
MnO	0.05
BaO	0.05
F	0.14
S	tr.
	100.05
Less O	0.06
	99.99

Normative mineral composition

	Percent
Quartz	29.76
Orthoclase	29.47
Albite	29.87
Anorthite	4.73
Corundum	0.61
Hypersthene	3.44
Magnetite	0.70
Ilmenite	0.61
Apatite	0.20
Fluorite	0.29
Calcite	0.10

Normative plagioclase . . $Ab_{87}An_{13}$

Sp. Gr. $t^o/4^o$ 2.657

The quarry, first operated by prison labor, was opened for stone to construct the Texas Capitol building in Austin. The Texas Pink Granite Company took over the operation of the quarry in 1893 and up to 1940 shipped between 33.5 and 34 million tons of stone from Granite Mountain. Several million cubic feet of this granite was used in New York and may be seen in such buildings as the Whitney Wing and East Wing of the American Museum of Natural History and the Grand Central Station. The stone was also used in the Times Building, Los Angeles; the Northwestern Life Insurance Building, Seattle; the Leif Erickson Memorial, Iceland; numerous tombs and mausoleums in New Orleans; and for seawalls and jetties along the Gulf Coast of Texas and Louisiana.

During 1950, the Texas Granite Corporation, of which Mr. H. L. Hicks is General Manager, acquired Granite Mountain. This company is a subsidiary of the Cold Spring Granite Company, Cold Spring, Minnesota, which operates quarries in several other places in the United States. Such an integration of companies seems ideal for marketing.

Since the Texas Granite Corporation began operations at Granite Mountain, stone valued at about $600,000 has been used in the Los Angeles County Courthouse and valued at about $350,000 in each of the Prudential Life Insurance Buildings, Houston, Texas, and Minneapolis, Minnesota. Since 1950, this stone has gone into structures in practically every state in the Union. The new State Office Building and the new Courts Building in Austin, under construction, are to be faced with Granite Mountain stone. Stone is also produced for jetties and similar uses.

Between 110 and 115 Texans living within the Marble Falls trade area are now employed by the Texas Granite Corporation, and about 30,000 square feet of finished stone are produced per month. At the present time, quarrying is accomplished by channeling, but wire sawing is soon to be introduced. An innovation, possibly practiced only at the Granite Mountain quarry, is the burning of channels, using oxygen and kerosene. Per unit length, such channeling is much more expensive than by conventional methods; therefore, it is used only for freeing large blocks a hundred feet or so in size to relieve strain so that the granite can be cut by conventional methods without binding.

Finishing is conventional except that a unique method of producing a very attractive natural cleavage finish has been perfected. The surface of the stone is heated by a torch in conjunction with water as a coolant with the result that a thin layer of the granite flakes off to the natural mineral cleavages in a snow of flakes as the torch progresses.

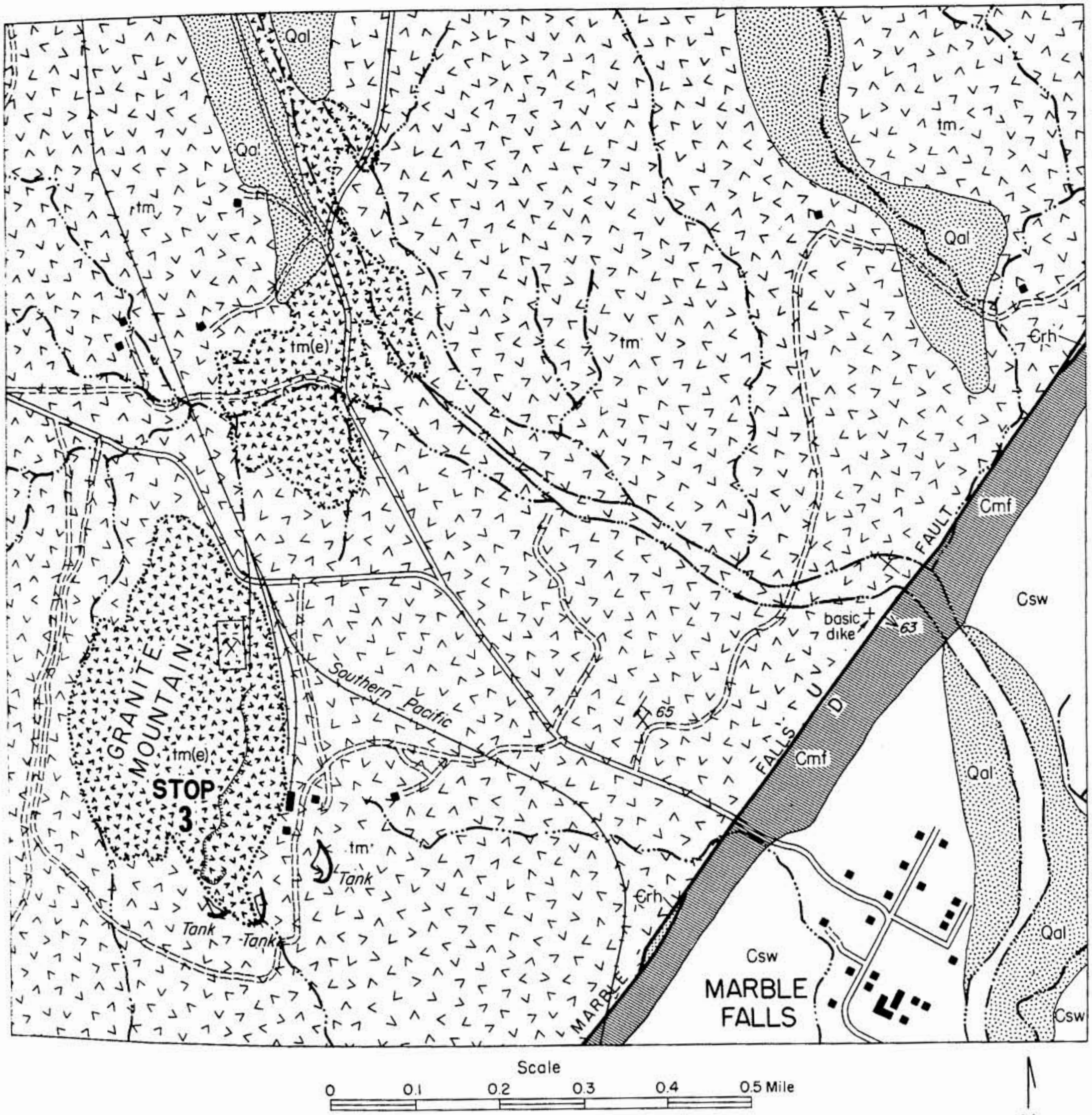


Figure 6. GEOLOGIC MAP OF GRANITE MOUNTAIN AREA, BURNET COUNTY, TEXAS.

EXPLANATION. The geologic units mapped are shown by the following letter symbols: Quaternary deposits--alluvium, Qal; Pennsylvanian rocks--Smithwick shale, Csw, and Marble Falls limestone, Cmf; Cambrian rocks--Hickory sandstone, Ꞓrh; and Precambrian rocks--Town Mountain granite, tm, showing larger exfoliation domes and bare rock surfaces, tm(e). Base from U. S. Department of Agriculture Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939-1940. Geology by Virgil E. Barnes and T. A. Anderson, 1951.

STOP 4

Base of Cambrian, Slaughter Gap, Marble Falls Area, Burnet County

Please refer to "Geologic map of an area in vicinity of Slaughter Gap, Burnet County, Texas" (fig. 7). In addition to faulting, this map clearly shows the relief on the Precambrian surface at the time the Hickory sandstone was deposited. The exfoliation domes of granite now surrounded by Cambrian rocks stood several hundred feet above the general level of the surrounding granite at the time the Cambrian sea transgressed.

The prospect pits and drill holes near the middle of the map are in Cap Mountain limestone, which overlaps two of the domes. Galena is very sparsely distributed locally in the Cap Mountain limestone near the granite.

The contact between the Hickory sandstone and the Town Mountain granite is not exposed in the vicinity of the stop; the manner in which the large sandstone blocks are draped suggests that they are riding downward on disintegrated granite possibly formed before the sandstone was deposited. The very coarse-grained, pink granite which is part of the Granite Mountain granite mass is overlain by pinkish-gray, slightly cross-bedded, conglomeratic Hickory sandstone consisting mostly of small pebbles and granules of quartz and microcline in a fine to very coarse sand matrix; all particles are angular except for slight rounding of the small pebbles. A few larger pebbles mostly in float blocks of sandstone are probably slightly wind abraded. The contact at this point is fairly low on the Precambrian surface, as indicated by the abundance of large microcline fragments in the sandstone. However, the paucity of large quartz pebbles suggests that this is not the lowest point on the old landscape.

The base of the Hickory sandstone is also fairly well exposed in an area of low relief, and this contact may be reached by continuing from Stop 4 northward to Fairland, then going eastward 0.85 mile. Large blocks turned over during road construction reveal that the Hickory sandstone is "porphyritic" with closely spaced, large, zoned, microcline "phenocrysts".

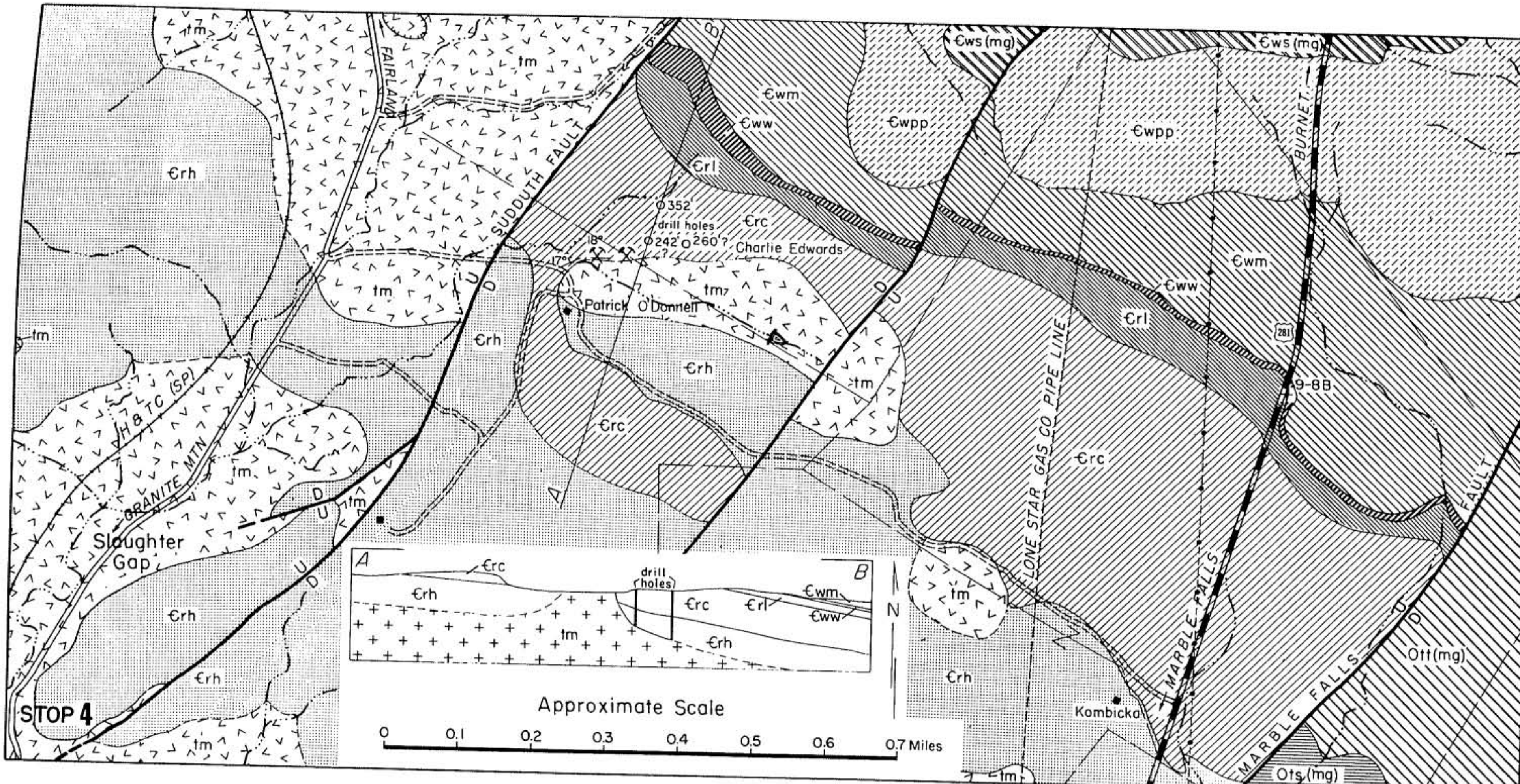


Figure 7. GEOLOGIC MAP OF AN AREA IN VICINITY OF SLAUGHTER GAP, BURNET COUNTY, TEXAS.

EXPLANATION. The Lower Ordovician is represented by the Tanyard formation of the Ellenburger group, members of which are indicated by the following symbols: Ots(mg), dolomitic facies of the Staendebach member; Ott(mg), dolomitic facies of the Threadgill member. The Upper Cambrian is represented by two formations, comprised of seven members, shown by the following symbols: Wilberns formation: Ꞓws(mg), dolomitic facies of the San Saba member; Ꞓwpp, Point Peak member; Ꞓwm, Morgan Creek limestone member; Ꞓww, Welge sandstone member. Riley formation: Ꞓrl, Lion Mountain sandstone member; Ꞓrc, Cap Mountain limestone member; Ꞓrh, Hickory sandstone member. The Precambrian is represented by coarse-grained Town Mountain granite, tm. Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939-1940. Geology by Virgil E. Barnes and Lincoln E. Warren, 1945.

STOP 5

Texas Construction Material Company, Burnet Stone Division Quarry, Burnet County

Please refer to "Geologic map along part of U. S. Highway 281 and from Burnet to Mormon Mill, Burnet County, Texas" (fig. 8). The quarry is along the railroad about 3 miles south of Burnet. Rock from several geologic units is produced in this one quarry, including a rather pure, coarse-grained dolomite in the San Saba member of the Wilberns formation (western floor of quarry); aphanitic limestone, in part dolomitic, probably in the Threadgill member of the Tanyard formation of the Ellenburger group (northwestern edge of quarry); cherty, fine-grained dolomite probably in the San Saba member (beneath the limestone); and cherty and very slightly sandy, very fine-grained to microgranular dolomite in the Gorman formation of the Ellenburger (east of the fault).

The quarry, opened in 1948 by Houston Clinton, was acquired January 1, 1958, by the Texas Construction Material Company; this operation is known as the Burnet Stone Division, and Ramsey Clinton is General Manager.

The quarry operation requires very little stripping. However, this advantage is countered by the quarry bottom being beneath ground-water level. It is necessary to operate continuously two electrically driven pumps having a combined capacity of 750 gallons per minute. Part of this water is used in the operation.

Gardner-Denver drills are used to make holes 5 inches in diameter to the depth of the quarry; each hole is loaded with 500 pounds of ammonium nitrate and 300 pounds of dynamite. After the initial blast and some secondary blasting, the rock is loaded into Euclids by a $2\frac{1}{2}$-yard Northwest shovel and hauled to a 30 x 42 Pioneer crusher installed on the quarry floor, where the undersized is screened out before the rest passes through the crusher. The flow sheet beyond the crusher is shown in figure 9. Part of the production passes through the plant without additional handling and is loaded directly into railroad cars; the rest is stockpiled. Riprap, produced only from the limestone, does not pass through the plant.

As shown on the flow sheet, chemical stone, after initial crushing, is processed separately. This is mostly used for steel mill fluxing rock and agricultural purposes. The rest of the production is mostly for railroad ballast, highway and concrete aggregates, and filter media. The highway materials include ten grades or sizes of aggregate as well as hot-mix aggregate.

Production from 1952 to 1957 inclusive amounted to about 3 million tons, of which between two-thirds and three-fourths was used for construction and maintenance, between one-sixth and one-fifth for chemical stone, and the rest for other purposes. Reserves of chemical stone are between 5 and 10 million tons and of other types stone, approximately 10 million tons.

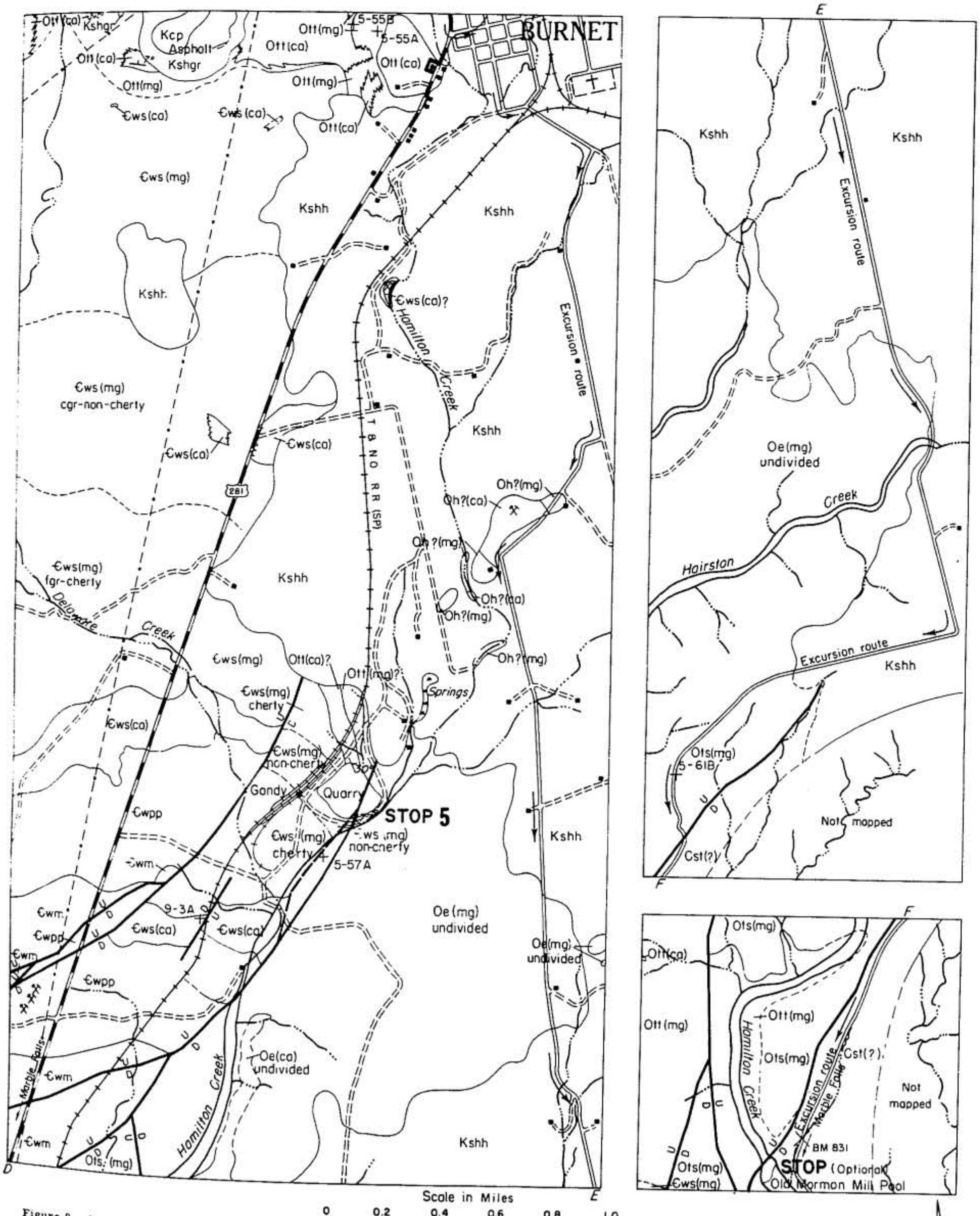


Figure 8. GEOLOGIC MAP ALONG PART OF U.S. HIGHWAY 281 AND FROM BURNET TO MORMON MILL, BURNET COUNTY, TEXAS.

—N—

EXPLANATION. The geologic units mapped are shown by the following letter symbols: Cretaceous rocks--Comanche Peak limestone, Kcp, Glen Rose limestone, Kshgr, and Hensell sand, Kshh; Pennsylvanian rocks--Strawn group (?), Cst(?); Ordovician rocks--Ellenburger group in part undivided showing dolomite, Oe(mg), and limestone, Oe(ca), Honeycut formation (?) including dolomite, Oh ?(mg), and limestone, Oh ?(ca), Tanyard formation showing dolomitic facies of Staendebach member, Ots(mg), dolomitic facies of Threadgill member, Ott(mg), and calcitic facies of Threadgill member, Ott(ca); Cambrian rocks--Wilberns formation showing dolomitic facies of San Saba member, Ews(mg), calcitic facies of San Saba member, Ews(ca), Point Peak member, Ewpp, and Morgan Creek limestone member, Ewm. The symbol +9-1B indicates the location of a fossil collection. Base from U.S. Department of Agriculture Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939-1940. Geology by Virgil E. Barnes and Lincoln E. Warren, 1944-1945.

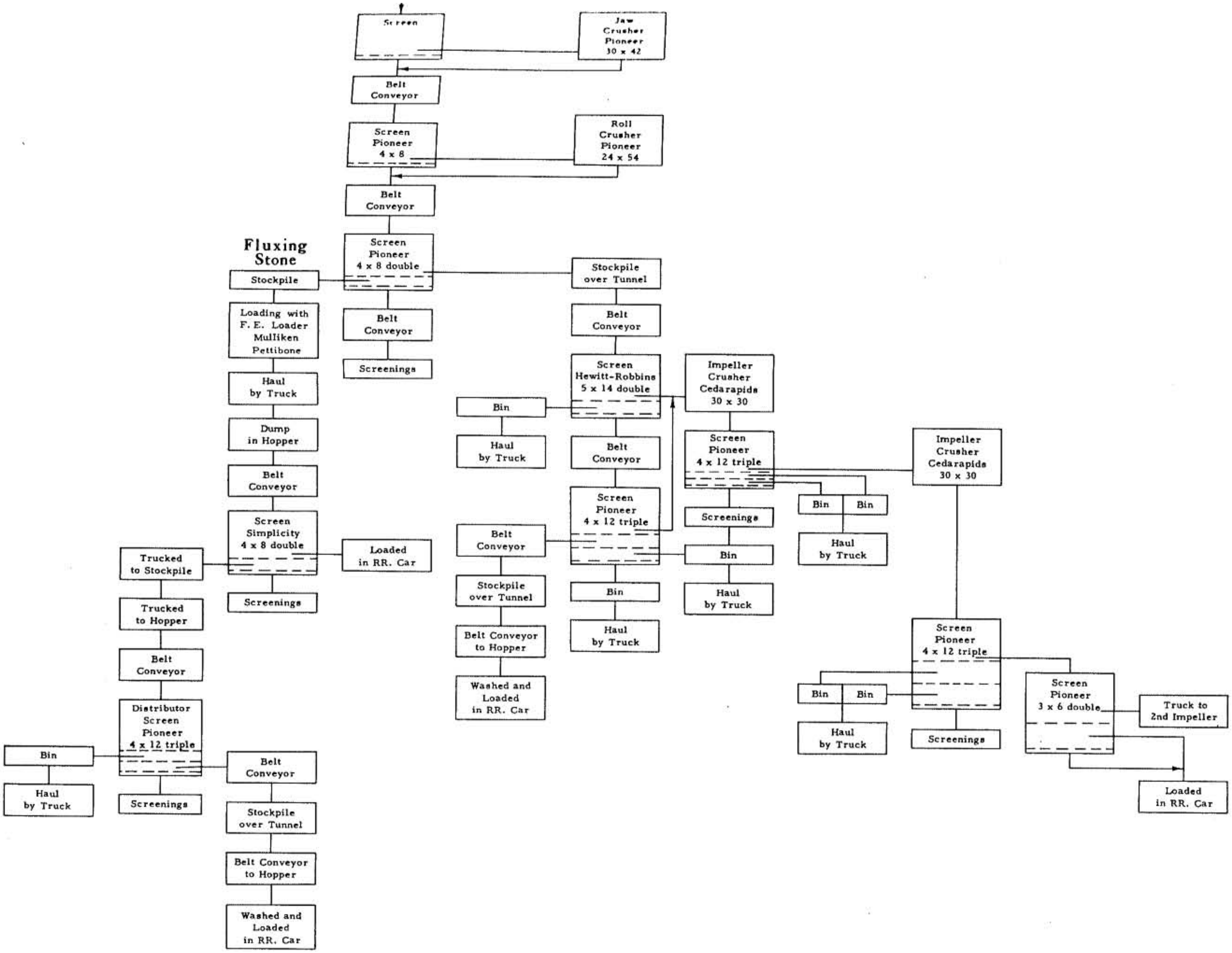


Figure 9. FLOW SHEET OF QUARRY OPERATION OF TEXAS CONSTRUCTION MATERIAL COMPANY, BURNET STONE DIVISION.

OPTIONAL STOP

Mormon Mill Locality, Burnet County

Please refer to "Geologic map along part of U. S. Highway 281 and from Burnet to Mormon Mill, Burnet County, Texas" (fig. 8) and to "Geologic map of an area in vicinity of Mormon Mill, Burnet County, Texas" (fig. 10). A fault of about 2,000 feet displacement is well displayed at the edge of a picturesque pool in Hamilton Creek, formed in soft Pennsylvanian rocks. The upthrown side at this point is dolomite of the Threadgill member of the Tanyard formation in which Hamilton Creek has cut a solid-rock gorge. Hamilton Creek formerly flowed southwestward from Mormon Mill through the broad valley bottomed by alluvium (fig. 10). Before its capture it entered Colorado River at Marble Falls; now it empties into the Colorado about 5 miles downstream.

Pebbles, now indicated only by molds, in steeply dipping sandstone beds at the edge of the pool may have been of Marble Falls limestone similar to pebbles found in sandstone elsewhere in this area. Such pebbles indicate that the Marble Falls was exposed to erosion at the time these pebbles formed and that the beds containing them must be younger than the Marble Falls--Smithwick sequence. The sandstone, therefore, must at least be Strawn in age.

Massive sandstone at the lower end of the pool is in sharp folds; 300 yards downstream the folds are gentle. Still farther downstream, at a point designated on figure 10, thin sandstone beds in shale are in overturned folds which in places have broken to form thrust faults. The folds indicate compression, whereas the fault at Mormon Mill indicates tension; both are believed to be related to the Ouachita orogeny. The fault perhaps formed first; if this is true, then the massive Ellenburger would have formed a buttress against which the softer Pennsylvanian rocks were deformed.

The foundation of the mill, from which this locality received its name, is situated near the fault. A commemorative monument describing the establishing here of a Mormon colony more than a century ago is on high ground about 100 feet to the east. The monument is on a burnt-rock mound belonging to one of the earlier Indian cultures.

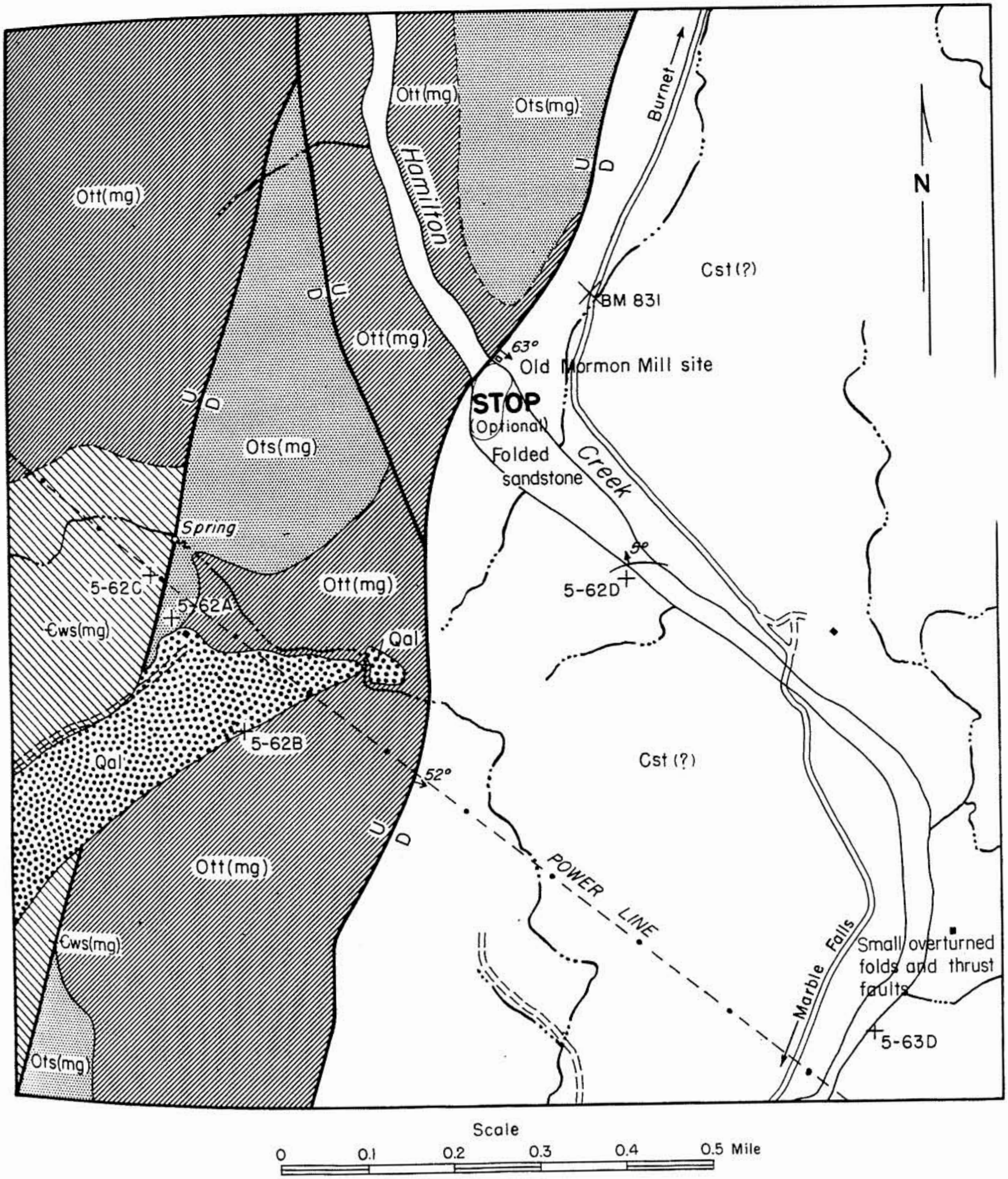


Figure 10. GEOLOGIC MAP OF AN AREA IN VICINITY OF MORMON MILL, BURNET COUNTY, TEXAS.

EXPLANATION. The geologic units mapped are shown by the following letter symbols: Quaternary deposits--alluvium, Qal; Pennsylvanian rocks--Strawn group(?), Cst(?); Ordovician rocks--Tanyard formation including dolomitic facies of the Staendebach member, Ots(mg), and dolomitic facies of the Threadgill member, Ott(mg); Cambrian rocks--dolomitic facies of the San Saba member, €ws(mg). The symbol +5-62A indicates the location of a fossil collection. Base from U. S. Department of Agriculture Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939-1940. Geology by Virgil E. Barnes and Lincoln E. Warren, 1945.

STOP 6

Southwestern Graphite Company, Burnet County

Please refer to "Geologic map of the Clear Creek area, Burnet County, Texas" (fig. 11) and "Geologic map of Southwestern Graphite Company property, Burnet County, Texas" (fig. 12). The graphitic schist is distributed in such a manner as to suggest strongly that the graphite is from carbonaceous beds deposited in the sedimentary sequence from which the Packsaddle schist formed. The graphitic zone is mostly thin except locally; where thickened, the masses may be caused by migration of graphitic material to low-pressure areas during folding. Other rocks in the Packsaddle sequence within the area of figure 11 include hornblende schist, amphibolite, mica schist, tourmaline schist, and marble.

The Southwestern Consolidated Graphite Company, formed about 1916, established a mill along Clear Creek about 9 miles west of Burnet. This mill burned in 1927 and was replaced by a plant equipped with oil-froth flotation machinery and an electrostatic separator. Production continued until some time in 1929.

According to Robert P. Miller, Jr., Vice-President and General Manager, the property was acquired in 1935 by the Miller and Clemson interests and at the request of the War Production Board again produced graphite from the property in 1942. Production has continued since then, except during 1954 and the first quarter of 1955. During the period of plant inactivity, sufficient graphite was on hand to fill all orders.

All the graphite produced has been sold for industrial use except part of the production from 1948 to 1953 which was for the Government stockpile. Sales of graphite until mid-1949 were through brokers; at that time a sales organization was formed, resulting in improved sales.

The ore is produced by standard open-pit methods; 18-foot benches are used, 2.25-inch holes 18 feet deep are drilled by a drifter mounted as a wagon drill, and blasting is with dynamite. About 20 years' supply of open-pit ore remains.

Milling consists of crushing, grinding, and flotation designed to remove most of the graphite and still yield a superior grade of finished product. The ore averages about 4.5 to 5 percent graphite, and improved technology in the plant allows 96 to 97 percent graphite to be recovered for special uses. For many uses the graphite need not be this pure. All grades of graphite are now produced, except that specifications of a larger flake size for certain types of crucibles preclude the use of this graphite at present in such crucibles.

Water for the operation ordinarily must be pumped 2 miles from Inks Lake and raised about 150 feet, but since the end of the drought Clear Creek has furnished some of the supply.

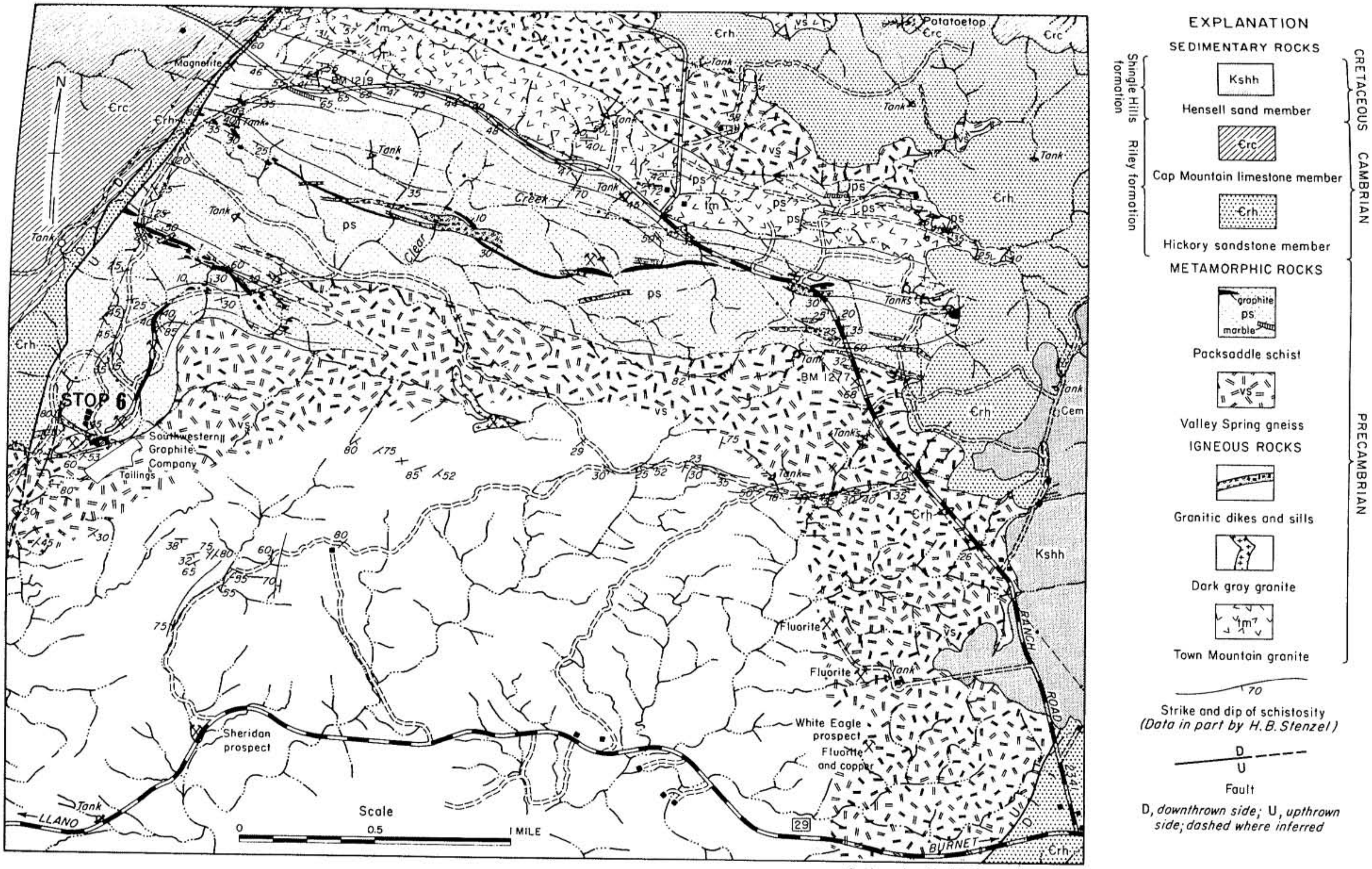


Figure 11. GEOLOGIC MAP OF THE CLEAR CREEK AREA, BURNET COUNTY, TEXAS. Geology by Virgil E. Barnes, 1951-58

FIGURE 12
GEOLOGIC MAP OF SOUTHWESTERN GRAPHITE COMPANY PROPERTY BURNET COUNTY, TEXAS

FROM FILES OF THE BUREAU OF ECONOMIC GEOLOGY
AUTHOR UNKNOWN

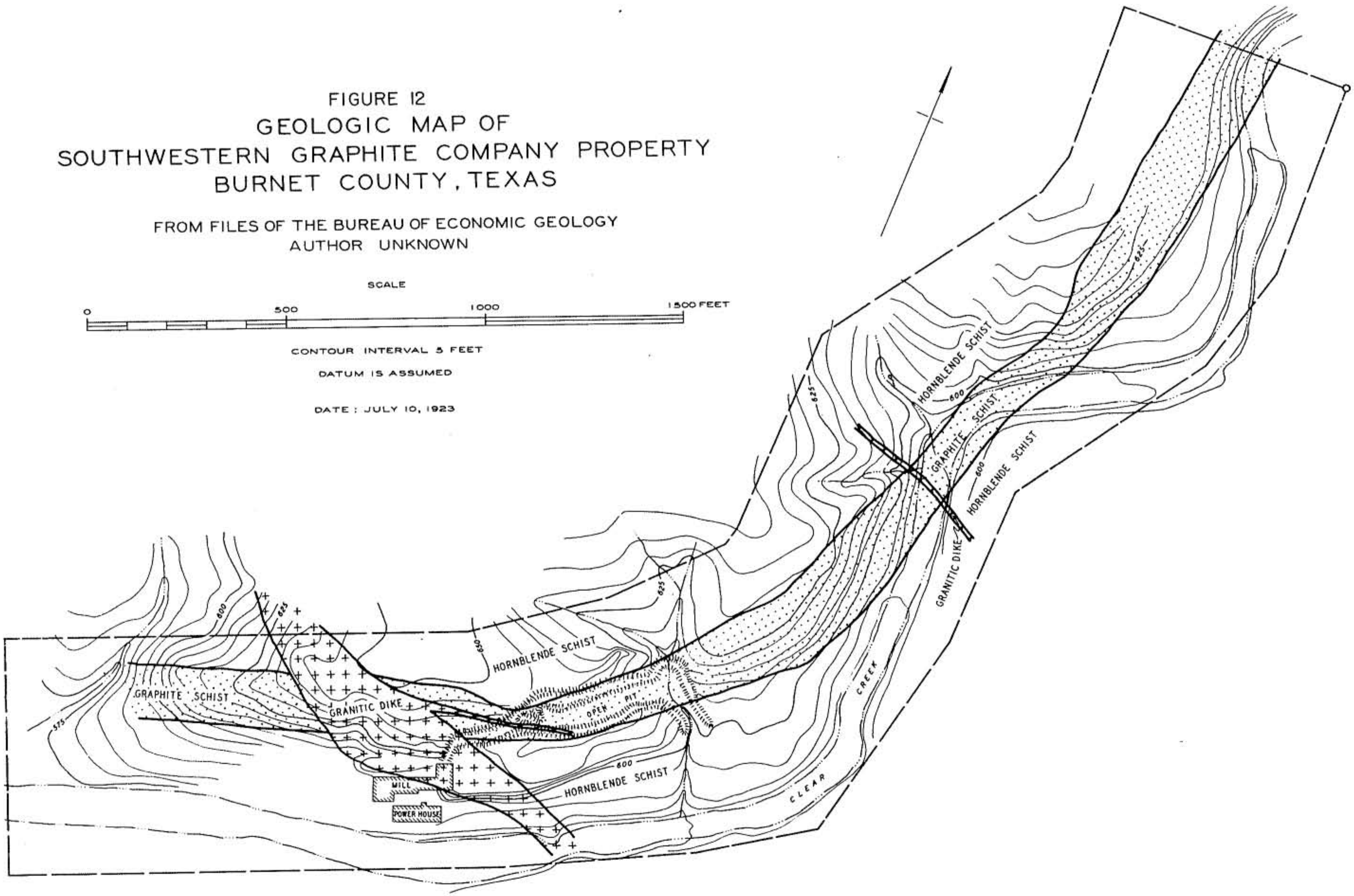
SCALE

0 500 1000 1500 FEET

CONTOUR INTERVAL 5 FEET

DATUM IS ASSUMED

DATE: JULY 10, 1923



STOP 7

Quarries in Cedar Park Limestone, Travis and Williamson Counties

Limestone has been used for more than a hundred years for building in central Texas; however, it was not until 1929, when Texas Quarries, Inc., started operation in the Cedar Park area, that the use of Texas limestone became nationwide. Because of the economic importance of this rather thin limestone unit, which is part of the Walnut clay, it has been named the Cedar Park limestone member of the Walnut clay.

The limestone, mostly 10 feet or less in thickness, is oolitic and in addition to ooids contains microfossils and finely comminuted fossil debris. In places beneath the oolite, a distinctive limestone up to 4 feet thick contains exquisitely preserved casts of Trigonia.

The following properties of the Cedar Park limestone are quoted from a sales brochure of Texas Quarries, Inc.; tests made by Southwestern Laboratories, Dallas, Texas.

Chemical analyses (in percent)--

	Oolitic limestone	Shell limestone
SiO_2	0.32	0.25
Fe_2O_3 and Al_2O_3	0.38	0.42
CaO	55.88	56.08
SO_3	0.16	0.13
Ignition loss	43.75	43.88

Weight in pounds per cubic foot dry--

Oolitic limestone	128.3
Shell limestone	122.3

Absorption in percent--48-hour soak--

	By weight	By volume
Oolitic limestone	11.5	22.7
Shell limestone	6.4	13.4

Absorption in percent--5-hour boil--

	By weight	By volume
Oolitic limestone	13.4	26.6
Shell limestone	8.6	18.2

Ultimate tensile strength--pounds per square inch--

	Parallel to bedding plane	Perpendicular to bedding plane
Oolitic limestone	398	243
Shell limestone	388	308

Ultimate compressive strength--pounds per square inch--

	Parallel to bedding plane	Perpendicular to bedding plane
Dry stone		
Oolitic limestone	2,517	2,070
Shell limestone	1,629	2,005
Wet stone		
Oolitic limestone	2,130	2,004
Shell limestone	1,783	1,130

Figures are not available for total production of stone from this area; however, on the basis of a report in an unpublished University of Texas thesis that about 300,000 cubic feet of stone was produced by one company during 1950, it is possible that total production has reached 10 million cubic feet.

The outstanding example of the use of the shell limestone is probably the San Jacinto Memorial near Houston, which rises 570 feet above the surrounding battlefield. Both the shell and oolitic limestone can be found in buildings across the Nation--from May Department Store in Los Angeles to the Shamrock Hotel in Houston to the Pelham Bay Memorial on Long Island, New York. Popular both for interior and exterior decoration, it has been used in such widely diverse places as the Central Methodist Episcopal Church, Brooklyn, New York, and on the luxury liners Independence and Constitution of the American Export Lines. This stone has been used throughout the United States in post-office, courthouse, and other governmental and privately owned buildings too numerous to list. Locally, the limestone has been used in hundreds of homes, the Travis County Courthouse, and in the Texas Union, Hogg Memorial Auditorium, Texas Memorial Museum, Architecture Building, and Music Building, all on The University of Texas campus.

At present, Texas Quarries, Inc., according to one of their brochures, "has available more than four thousand acres of proven quarry property," and, according to Mr. W. D. Johnson, President, at least 40 years' supply is in sight. The stone is marketed under three different classifications--Cordova Cream, oolitic limestone of mostly light cream color and mostly free of shell markings and voids; Cordova Shell, a shelly limestone with numerous fossil casts, in part almost white and in part of a "golden color with a pleasing range of color intensity"; and Cordova Travertone, having much the appearance of the Cordova Cream but with "a scattering of small shell and voids."

The quarries are situated in a relatively flat area with the outcropping edge of the Cedar Park limestone mostly forming a lip for the deeply incised area bordering Colorado River. Overburden ranges from almost none to as much as 60 feet. Following stripping, a 30-ton guy derrick with a 70- to 100-foot boom and a 30-ton three-drum electric hoist is erected, and the surrounding stone is quarried in 125-foot squares. Electric channeling machines with channeling bars 8 feet 4 inches apart are operated on carefully aligned tracks to make channels 2 inches wide for the length of the square. The track is then skidded 4 feet 2 inches to one side and a second pair of channels made, producing in all three blocks or "cuts." The channeling machines are turned at right angles, and the three cuts are divided into blocks that can be handled by the derrick. After these blocks are removed, the rest of the square is channeled into 125-foot cuts which are freed at each end, usually cut in the middle, then wedged off at the base before turning on their sides, where they are drilled and wedged into blocks that can be handled by the derrick.

The quarry blocks are sawed to specified thicknesses in the nearby cutting shed, using gang saws of steel faced with hard metal. The sawed slabs are then shipped to the finishing plant in Austin, where they are milled to specification. Milling is classified into four general types--plain ashlar, straight moulded work, a combination of planing and hand cutting, and turned work. For plain ashlar work the slabs, previously sawed to correct thickness, are ripsawed to course height, using a circular steel blade set with replaceable diamond teeth. Next, the course height is planed to exact dimension and the face is planed. Straight moulded work differs only in that special tools of the shape desired for the finished work must be made for use in the planer. Combination of planing and hand cutting is used where surfaces, such as in a simple lug sill, must be planed below the level of the stone at either end. After planing, the rest of the surface is finished by hand. Turned work, as the name implies, is cut on a lathe.