A PETROGRAPHIC STUDY OF THE ANACACHO LIMESTONE (UPPER CRETACEOUS) OF TEXAS

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Presented to
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of the Requirements for the Degree
Master of Science

by
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ABSTRACT

The Upper Cretaceous Anacacho limestone is exposed in scattered outcrops from eastern Kinney County to western Bexar County. The formation unconformably overlies the Austin chalk and is overlain unconformably by the Escondido clays, occupying the stratigraphic position of the Taylor group. A total of thirty-six rock specimens were taken from seven localities along the outcrop of the Anacacho limestone. Thin sections were made from fourteen of the specimens, insoluble residues were run on seven of the specimens, and X-ray diffraction patterns were made of three specimens. A detailed study of the fabric, mineralogy, and porosity was made of each specimen.

In eastern Kinney County, the limestone members of the formation consist of an alternating succession of strata possessing the fabric of biohermal reef rock and detrital reef rock. The middle, "Milam chalk", member consists mainly of chemically precipitated calcite with some clay and detrital quartz, suggesting a lagoonal environment. The actively growing portion of the reef probably migrated back and forth, producing an interfingering of biohermal reef rock, detrital reef rock, and chalk.

Eastward from Kinney County to western Bexar County the Anacacho limestone possesses the fabric of detrital reef rock, and is overlapped from the east by the Taylor marl. The absence of biohermal reef rock from the eastern portion of the Anacacho limestone suggests that the actively growing portion of the reef existed north of the present outcrop and has been removed by erosion.

The principal fossils in the Anacacho reef are pelecypods and bryozoans.

Of the porosity visible under the binocular microscope, that which is definitely secondary is many times as great as that which is possibly primary. It was impossible to demonstrate conclusively that any of the porosity is truly primary.

In the abundantly asphaltic portions of the Anacacho, the contact between the asphaltic and nonasphaltic rock was seen to cut across the bedding both in hand specimens and in gross aspect in the asphalt mines. The cutting of the bedding planes by the asphalt contact suggests that the asphalt invaded the limestone and was not deposited contemporaneously with it. The fact that the asphalt does not entirely fill the pore space of the rock, but forms a coating on the limestone fragments suggests that the asphalt is the residuum of a lighter oil which lost its volatile constituents.

INTRODUCTION

Acknowledgements

The writer wishes to express his thanks to Dr. H. B. Stenzel for suggesting the problem and to Dr. Robert Greenwood and Mr. James N. Taggart for valuable suggestions and guidance during the research. He also wishes to thank Mr. Edward Boykin for preparing the thin sections, Mr. Daniel Shaw for making the X-ray diffraction patterns, Mr. Frank Turner and Mr. Gene Milam for granting access to their ranches, and White's Uvalde Mines and the Uvalde Rock Asphalt Company for granting access to their asphalt mines. The writer is indebted to Dr. Frank Welder for contributing the log of a well drilled by the Texas Highway Department.

Purpose

The purpose of this petrographic study of the Anacacho limestone is to determine the environment of deposition of the limestone, to determine the origin of the asphalt in the formation, and to contribute evidence on the origin of the interbedded "volcanic" material.

Regional Geology

The major structural feature of Kinney, Uvalde, and Medina Counties is the westward extension of the Balcones fault system. The Balcones fault system is a series of east-west striking normal faults which are downthrown to the south. The throw of the fault system ranges from 500 to 1500 feet. Numerous normal faults of smaller displacements lie perpendicular to the major faults.

The Balcones fault system produces an escarpment which marks the boundary between the Edwards Plateau to the north and the Gulf Coastal Plain to the south. Lower Cretaceous strata (Comanche Series) are exposed on the north (upthrown) side of the fault system and Upper Cretaceous (Gulf Series) strata are exposed on the south side. Limestones prevail in both Series. The regional dip of the area is a few tens of feet per mile southward. Eocene sediments lie unconformably on the Upper Cretaceous strata and are exposed in the southern portions of Uvalde and Medina Counties.

Numerous basalt stocks and dikes and a few phonolites are spatially associated with the Balcones fault system, extending from near Brackettville in Kinney County to near Taylor in Williamson County. Many of the intrusions cut through the Upper Cretaceous strata. However, the Tertiary strata have been eroded from the area of the intrusions so that the relationship of the intrusions to the Tertiary strata is not known.

Also spatially associated with the Balcones fault system, on the surface and in the subsurface, are a number of "volcanic" rock bodies resembling both igneous and sedimentary rocks. These rocks are discussed in "Petrography", page 39.

Location

The Anacacho limestone crops out along the south side of the Balcones escarpment from eastern Kinney County to western Bexar County. The geographic locations of the outcrops sampled for this study are shown on the map in Figure 1. Outcrops of the formation are scattered and not continuous because of alluvial cover and complex faulting associated with the Balcones fault system. The formation is best exposed in the Anacacho Mountains in eastern Kinney County.

In western Uvalde County there are scattered outcrops of the Anacacho south of U. S. Highway 90. Rock asphalt mines in the formation are located on Farm Road 481 (See map, Figure 1). A water well drilled by the Texas Highway Department (Well R-1) at White's Uvalde Mines' asphalt mine began in the Anacacho limestone and reached the base of the Anacacho at 595 feet.

In eastern Uvalde County there is a good exposure of the formation along the east bank of Blanco Creek*, extending from the Texas and New Orleans railroad to a point 2½ miles north of the railroad.

In central Medina County the upper portion of the Anacacho limestone is exposed in the bed of Seco Creek from 1½ to 3 miles north of D'Hanis. In eastern Medina County an exposure of Anacacho limestone occurs in the bed of San Geronimo Creek five miles north of Castroville.

*This stream is shown as Blanco Creek and Blanco River on various maps. The term Blanco Creek will be used here to avoid confusion with the Blanco River of Blanco and Hays Counties.

The top of the Anacacho limestone, overlain by Taylor marl, is exposed in the bed of Portranco Creek ½ mile north of U. S. Highway 90 in western Bexar County.

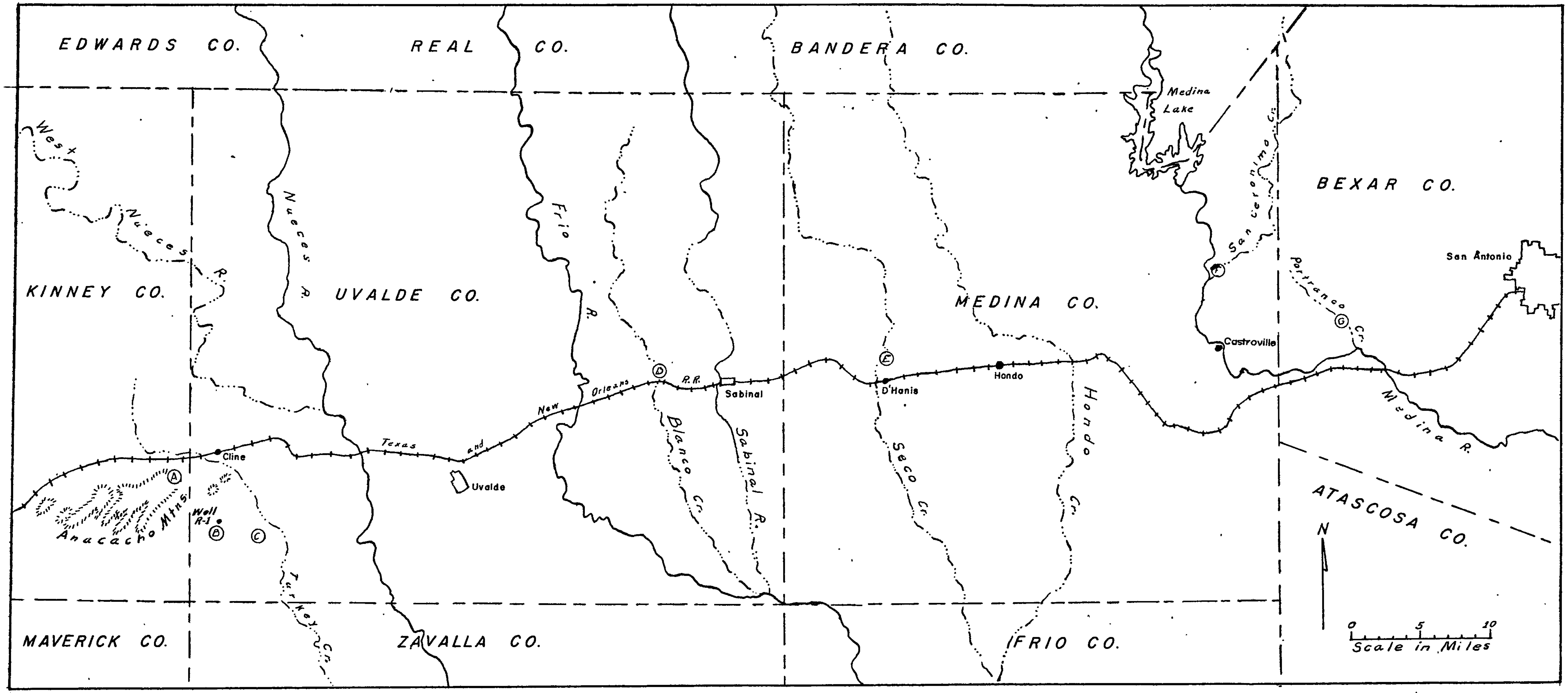
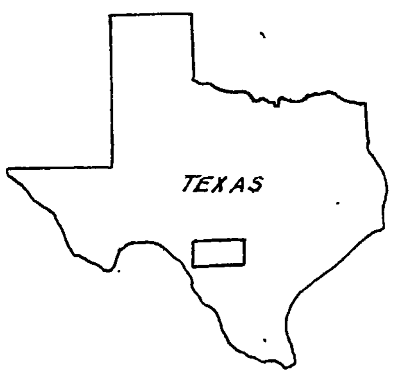


Figure 1: Index Map Showing Locations of Areas Studied.



	Samples	Columnar Sections
Ⓐ Northeast End of Anacacho Mtns.	1-13	Figure 3
Ⓑ White's Uvalde Mines	23-30	Figure 4A
Ⓒ Uvalde Rock Asphalt Co.	33-35	Figure 5
Ⓓ Blanco Creek	19-22,32, 36	Figure 6
Ⓔ Seco Creek	15-18	Figure 7
Ⓕ San Geronimo Creek	14	
Ⓖ Portranco Creek	31	

METHODS OF STUDY

Collection of Samples

Hand specimens were taken from the natural outcrops mentioned on page 3 and also from the pits of White's Uvalde Mines and the Uvalde Rock Asphalt Company. The stratigraphic position of the horizon represented by each sample was established relative to some datum. In the northwest end of the Anacacho Mountains, at the Seco Creek locality, and in the pits of the asphalt mines, the dips of the strata are too gentle to be detected with a hand level. The vertical positions of the samples taken from these localities were established by hand level traverses.

In the Blanco Creek section the strata dip 6° eastward. The thickness of the strata and the stratigraphic position of the samples from this section were established by making a traverse pérpendicular to the strike, using the clinometer of the Brunton compass, set for 6° dip, as described by Lahee (1952, p. 430).

Inasmuch as only a thin section of Anacacho limestone is exposed at the San Geronimo and Portranco Creek localities, the samples taken represent the entire exposure.

The samples were labeled in the field with an adhesive tape label, placed consistently on the top of the rock. Numbers were assigned each sample in the order in which they were taken. The samples were labeled permanently in the laboratory by painting on them a one cm. square patch with white Testor's model airplane dope and printing the sample number on the patch with India ink.

The gross features of each rock were described in the field.

The selected samples are as typical of the stratigraphic horizon as is possible, except that only the more cohesive portions of the unindurated strata were sampled. Such samples are not truly typical of the section.

Sawing of Samples

In the laboratory, a vertical cut was sawed through each sample. Samples without asphalt were sawed on a 16 inch, oil-cooled diamond saw. Asphaltic samples were sawed on an 8 inch water-cooled saw.

Thin sections were made from 14 of the sawed surfaces. In each sample that was thin-sectioned, the portion of the sawed surface to appear in the thin section was marked on both faces of each saw cut so that the thin section could be compared to the sawed surface of the opposite face.

Laboratory Descriptions

The megascopic aspects of each specimen were first described. The color of a freshly broken surface was compared to the rock color chart published by the Geological Society of America and interpolations between colors were made where necessary. The color comparison was made at arm's length to arrive at an average color.

The sawed surface of each specimen was examined megascopically for primary and secondary structures. The nature of bedding, where present, was noted. (By "nature" of bedding is meant those properties of the rock that make the bedding apparent. Examples are variations in color, grain size, or porosity, and alignment of shell fragments).

For the microscopic description of the specimens, a petrographic microscope and a binocular microscope were used side by side. The observation of porosity was made under the binocular microscope, using the sawed and freshly broken surfaces. Quantitative and qualitative determinations of porosity in thin section were considered unreliable except in the most indurated rocks.

The size, shape, composition, and quantity of the clastic and organic materials were observed. The quantity and composition of the matrix was observed. Organic structures were identified where possible.

X-Ray Studies

X-ray diffraction patterns of three samples were made by Mr. Daniel B. Shaw of the Shell Development Company. Gross samples of the "volcanic" material were used for the X-ray analyses.

A "glauconite" sample was hand-picked from sample 8. The "glauconite" grains were released from the limestone by grinding the rock in a mortar. The "glauconite" grains were observed under the binocular microscope to range in size from 1/10 to 1/2 mm. Preliminary concentration of the grains was achieved by sieving the crushed sample.

Sieves used were U. S. Standard #35 and #100. The portion of the sample which passed through the #35 sieve and failed to pass through the #100 sieve was saved for hand-picking.

Insoluble Residues

Insoluble residues were run on seven specimens (Nos. 1, 7, 8, 11, 12, 14, and 21). A 100-gram portion of each specimen was digested in dilute hydrochloric acid, and then washed over a U. S. Standard #270 sieve. The residue was then dried and examined under the binocular microscope. The grains which were not readily recognizable under the binocular microscope were identified by the use of the petrographic microscope and immersion media.

Stain Tests

Tests for aragonite were made by boiling a 1/8 to 1/4 inch thick slice of each specimen in a concentrated solution of cobalt nitrate for 30 minutes. Aragonite is stained a light purple by this procedure. Calcite is stained purple only after several hours of boiling. This method of distinguishing calcite from aragonite is known as the Meigen test. (LeRoy, 1950, p. 195).

Tests for dolomite were made by immersing a sawed surface of each rock for a few seconds in Fairbanks solution. The Fairbanks solution is prepared by mixing 0.24 grams of haematoxylin and 1.6 grams of aluminum chloride in 22 cc. of water and bringing the mixture to a boil. The mixture is then cooled, a small quantity of hydrogen peroxide added, and filtered. (LeRoy, 1950, p. 195). Calcite immersed in the solution stains a dark purple in a few seconds, whereas dolomite remains unaffected. A check on the staining method was made by examining a crushed sample of the unstained rock under the petrographic microscope. The crushed sample was placed in an immersion medium with an index of refraction of 1.67. The index of refraction of the ordinary ray of calcite (1.658) is less than the index of the immersion medium, and the index of refraction of the ordinary ray of dolomite (1.680) is greater than the index of the immersion medium.

STRATIGRAPHY

The Anacacho formation was first described by Hill and Vaughn (1898, p. 240-241) as follows:

> "In Uvalde and Kinney counties, in the stratigraphic position occupied to the eastward by the Taylor marls, is a series of hard yellow and white limestones with interbedded marls and occasional sandstone ledges, for which the local name Anacacho formation is proposed, after the locality of their characteristic occurrence, the Anacacho Mountains of Kinney County, which are capped by this formation."

Vaughn (1900, p. 31) further stated that the Anacacho formation is "the stratigraphic equivalent of the Upson clays of the Rio Grande section, and of the Taylor (*Exogyra ponderosa*) marls of central Texas. It overlies the Austin chalk, and is in turn overlain by sandy limestones, sandstones and clays".

In the Uvalde quadrangle, Vaughn (1900, p. 2) included in the Anacacho all of the rocks above the Austin chalk and below the Escondido formation. This section includes "Not less than 400 feet and may be more" of yellow limestones and yellow clays.

In Medina County, Liddle (1918, p. 58) included in the Anacacho "approximately 200 feet of organic fragmental limestone carrying asphalt in nearly all localities". The overlying marls he considered Escondido and the underlying clays he considered Upson. However, Stephenson (1927, p. 9) stated, "in eastern Medina County and western Bexar County the westward-thinning body of the Taylor marl overlaps the eastward-thinning tongue-like extension of the Anacacho."

The Anacacho limestone ends abruptly toward the west in central Kinney County, where it is contiguous with the Upson clay and San Miguel formations.

Hazzard et. al. (1956, p. 58 and 110) proposed a new correlation for the Anacacho formation in the Anacacho Mountains. They correlate the "Milam chalk" and the lower portion of the upper Anacacho member with the Pecan Gap chalk on the basis of the common occurrence of the ammonites *Pachydiscus* (*Parapachydiscus*) cf. *strecheri* and *Bostrychoceras*. The upper portion of the lower Anacacho member was correlated with the Gober chalk on the occurrence of the ammonite genera *Menabites* and *Proplacenticeras* (Hazzard et. al, 1956, p. 120-121). This correlation places the lower portion of the Anacacho in the Austin and the upper portion in the Taylor. (See Figures 2 and 3.)

Concerning the correlation of the Anacacho limestone in Medina County, Holt (1956, p. 31) states, "The Anacacho limestone overlies the Austin chalk unconformably and is equivalent in age to the Taylor marl of Bexar County."

Concerning the use of the term "Anacacho", Getzendaner (1930, p. 1429) stated "It is unfortunate that the term 'Anacacho' was ever used for anything but a strictly local formation in western Uvalde and eastern Kinney counties." He further stated (p. 1431) that "There is no Anacacho *limestone** west of the Anacacho Mountains, although the thin limestones in the basal San Miguel may be considered as

*Italicized by Getzendaner

equivalent to a part of it." Getzendaner apparently implies that the term "Anacacho" should be restricted to the limestone facies of the Taylor group, although the limestone facies extends eastward through Uvalde and Medina Counties and into western Bexar County. This investigation is directed principally toward the limestone facies above the Burditt chalk and below the Escondido clays, although the interbedded "volcanics", the "Milam Chalk" member, and the overlapping Taylor marl are included as part of the problem.

With reference to the correlation of the Taylor marl and the Anacacho limestone with the European stages, Stephenson (1928, pp. 491-492) stated:

> "Westward in Texas the Taylor marl is replaced by the Anacacho limestone,...and still farther west in the Rio Grande Valley the Anacacho is replaced by the Upson clay and the overlying San Miguel formation...
>
> "As nearly as can be determined with the present evidence, the Taylor marl finds its European equivalent in the middle part of the Senonian, including the upper part of the Santonian and probably all of the Campanian sub-divisions".

This correlation is based on the common occurrence of *Scaphites hippocrepis* Morton, ammonites related to *Mortoniceras delawarense* Morton, and species of *Inoceramus* of the *I. baribini* Morton type.

The presence of an unconformity at the top of the *Exogyra ponderosa* ledge in the Anacacho Mountains was suggested by Hazzard et. al. (1956, p. 122). Evidence given for the existence of the unconformity is the variation in the interval between the top of the *Exogyra ponderosa* ledge and the overlying Exogyra costata var. spinosa zone of from less than 10 feet to over 25 feet in less than one mile. However, this variation in the interval could possibly be caused by irregularity in the growth of the reef which constitutes the Exogyra ponderosa ledge. The confusion in correlation of the Anacacho limestone is due to the lack of adequate ammonite zoning.

Beds of greenish to greenish-yellow clay with an apparently igneous texture occur interbedded with the organic fragmental limestone of the Anacacho. The log of the Texas Highway Department well R-1 at White's Uvalde Mine's pit (see map, Figure 1) shows five beds of greenish clay ranging from 10 to 78 feet in thickness. Also, in the section studied on Blanco Creek (see map, Figure 1), there is a bed of similar clay that is 66 feet thick. These and other similar deposits of the region are discussed more fully in "Petrography."

In eastern Kinney County the Anacacho limestone forms a mesa known as the Anacacho Mountains, which stands 400 feet above the surrounding plain. The lower, gentle slope of the mesa is formed by the Burditt marl and the Upson clay. The lower Anacacho limestone member produces an abrupt rise with a prominent ledge at the top. The ledge contains a profusion of whole Exogyra ponderosa and serves as a reliable datum. Above the Exogyra ponderosa ledge is a gentle slope covered by a very dense growth of brush which marks the "Milam chalk" member. The upper Anacacho limestone member produces a final abrupt rise to the top of the mesa.

On the weathered surface, the limestone is cut by a maze of solution cavities ranging up to 6 inches in diameter, many of which are nearly circular in cross-section. The limestone at the top of the mesa is weathered to a very rough surface consisting of concave troughs separated by sharp ridges. The troughs are 1 to 3 inches wide and the ridges are ½ to 1 inch high. This kind of weathered surface was called "karrenfelder" by Vaughn (1900, p. 2).

The outcrop of Anacacho limestone on Blanco Creek in eastern Uvalde County (see map, Figure 1) forms a low hill on the east side of the creek. The lower portion of the exposed limestone forms a sheer 30-foot-high cliff rising from the bed of the creek. The limestone in this cliff is extremely porous, having solution channels ranging up to 6 inches in diameter. Echinoid fragments make up the bulk of the rock. Above the cliff is a very gentle slope produced by a 66-foot-thick bed of nonresistant "volcanic" clay. The "volcanic" bed is dissected by a number of gullies and is well exposed. A detailed description of the "volcanic" material is included in "Petrography." Overlying the "volcanic" beds is a 150 foot thickness of tough, massive, fragmental limestone. This upper limestone produces an abrupt rise and caps the hill.

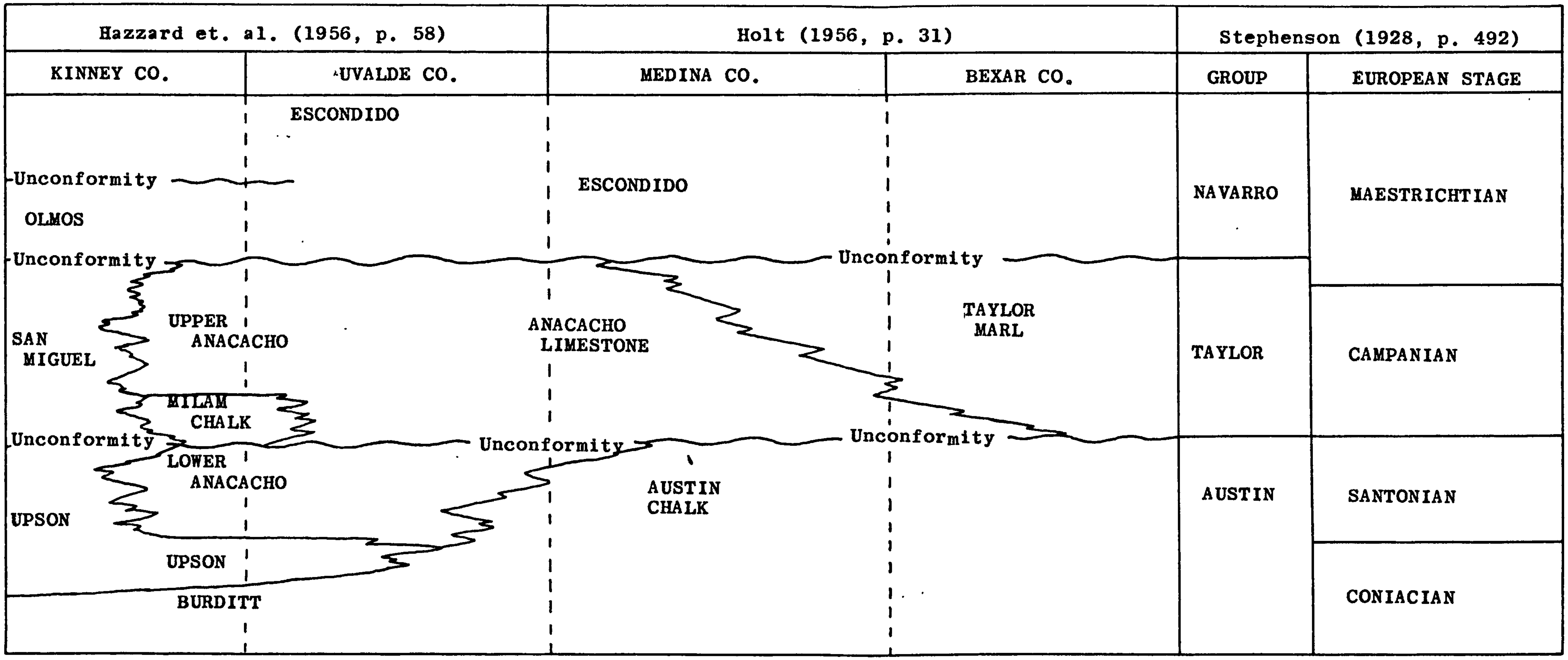


Figure 2: Stratigraphic Correlation Chart

COLUMNAR SECTION OF NORTHEAST END OF ANACACHO MTNS.
Modified from Hazzard et. al. 1956, p.58

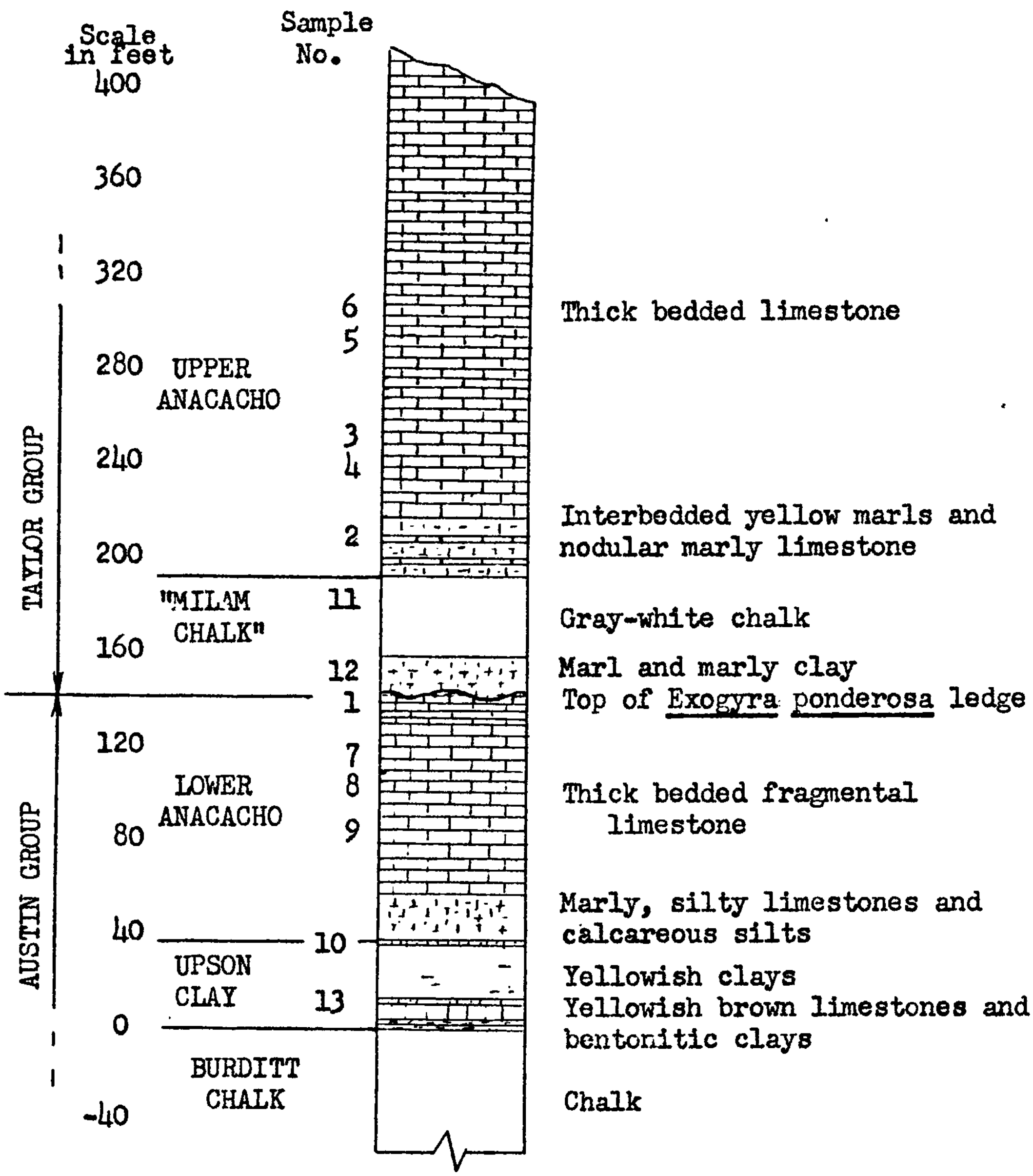


Figure: 3

COLUMNAR SECTION OF WHITE'S UVALDE MINES' ASPHALT PIT, DABNEY, TEX.

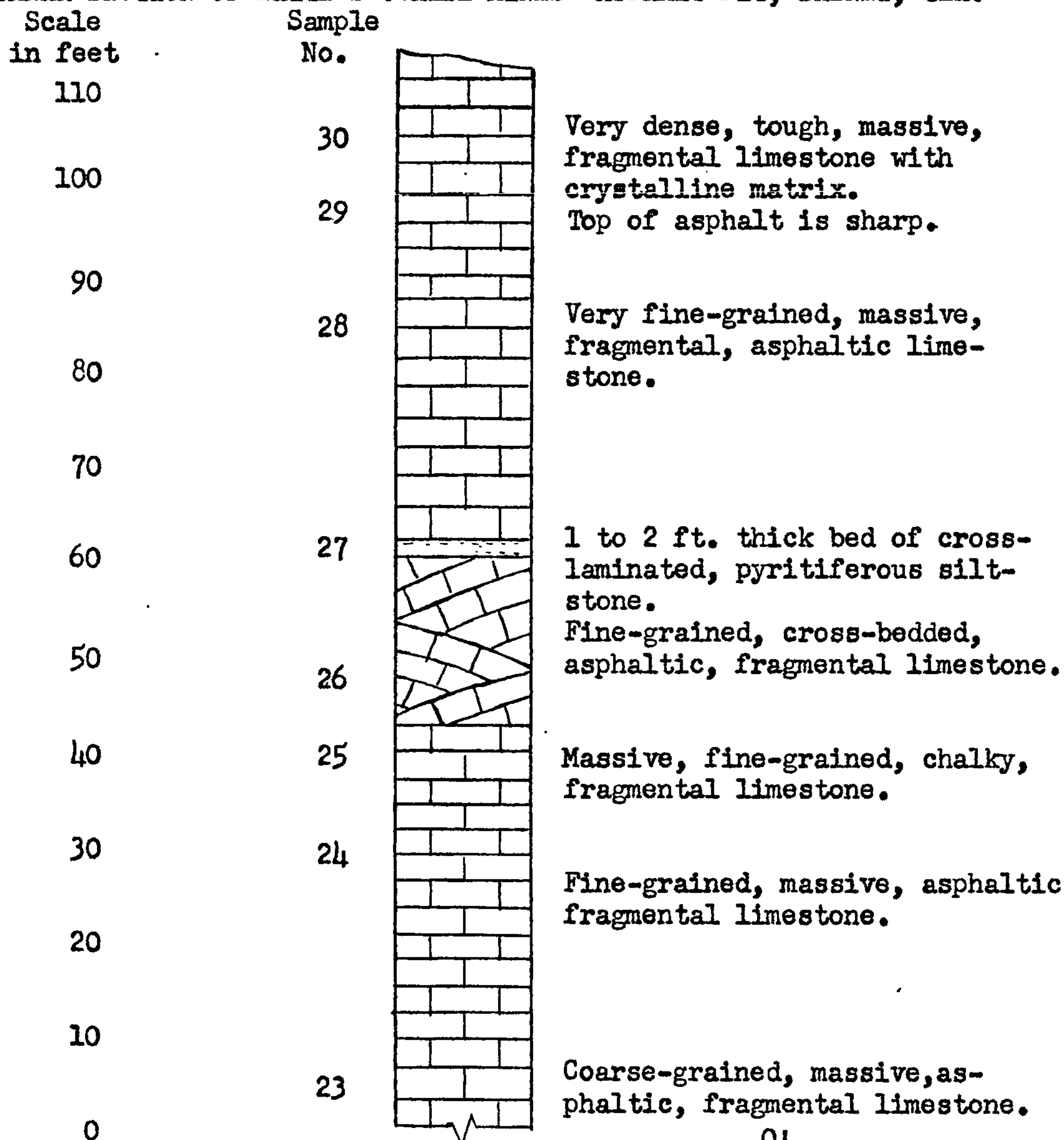


Figure 4A.

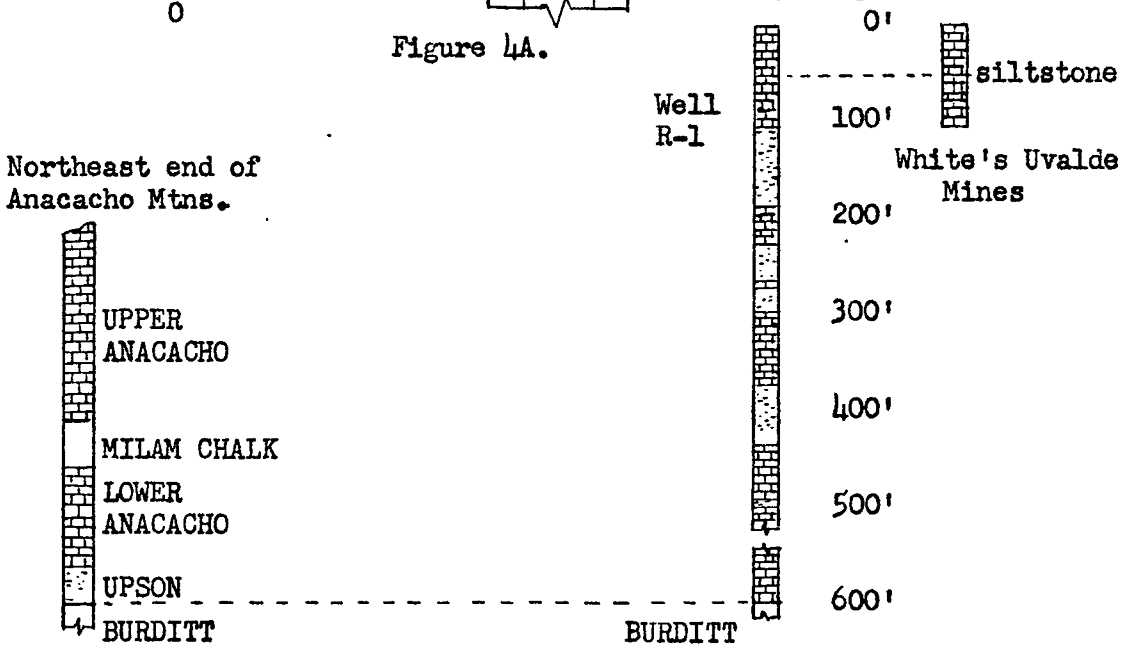


Figure 4B: Correlation of Columnar Section of Northeast End of Anacacho Mtns. with Columnar Section of White's Uvalde Mines and Well R-1.

COLUMNAR SECTION OF UVALDE ROCK ASPHALT CO. PIT,

BLEWETT, TEXAS

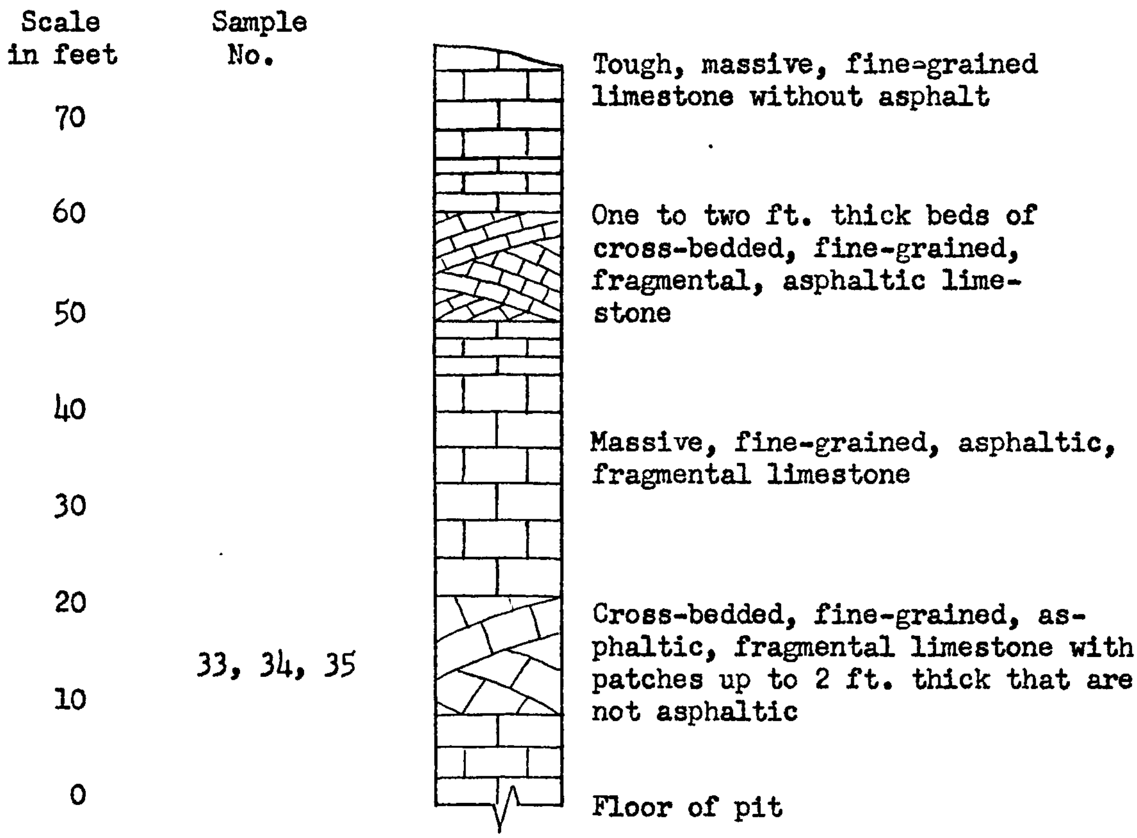


Figure: 5

COLUMNAR SECTION ON BLANCO CREEK ONE MILE NORTH OF

TEXAS & NEW ORLEANS RAILROAD

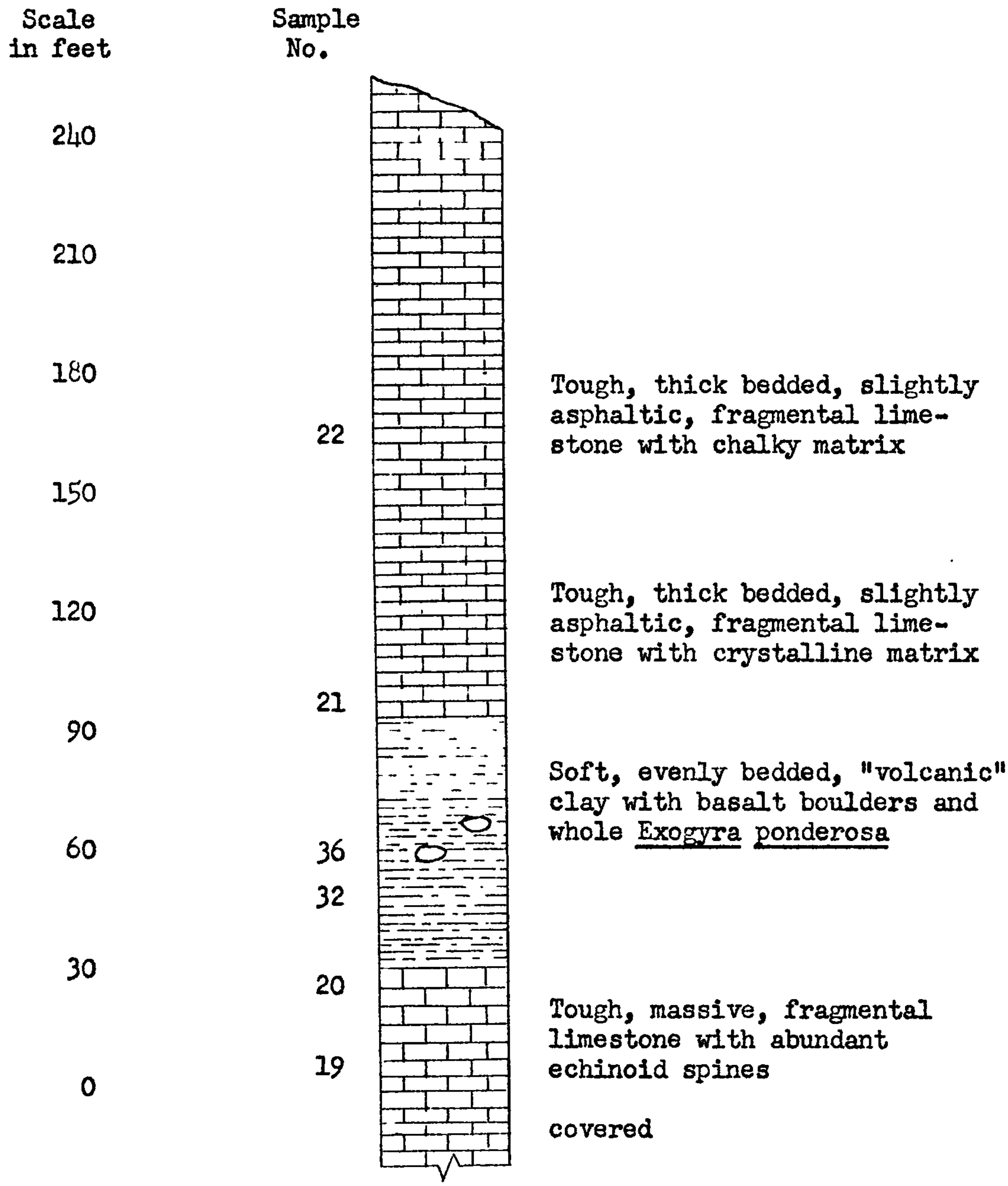


Figure: 6

COLUMNAR SECTION TWO MILES NORTH OF D'HANIS ON SECO CREEK

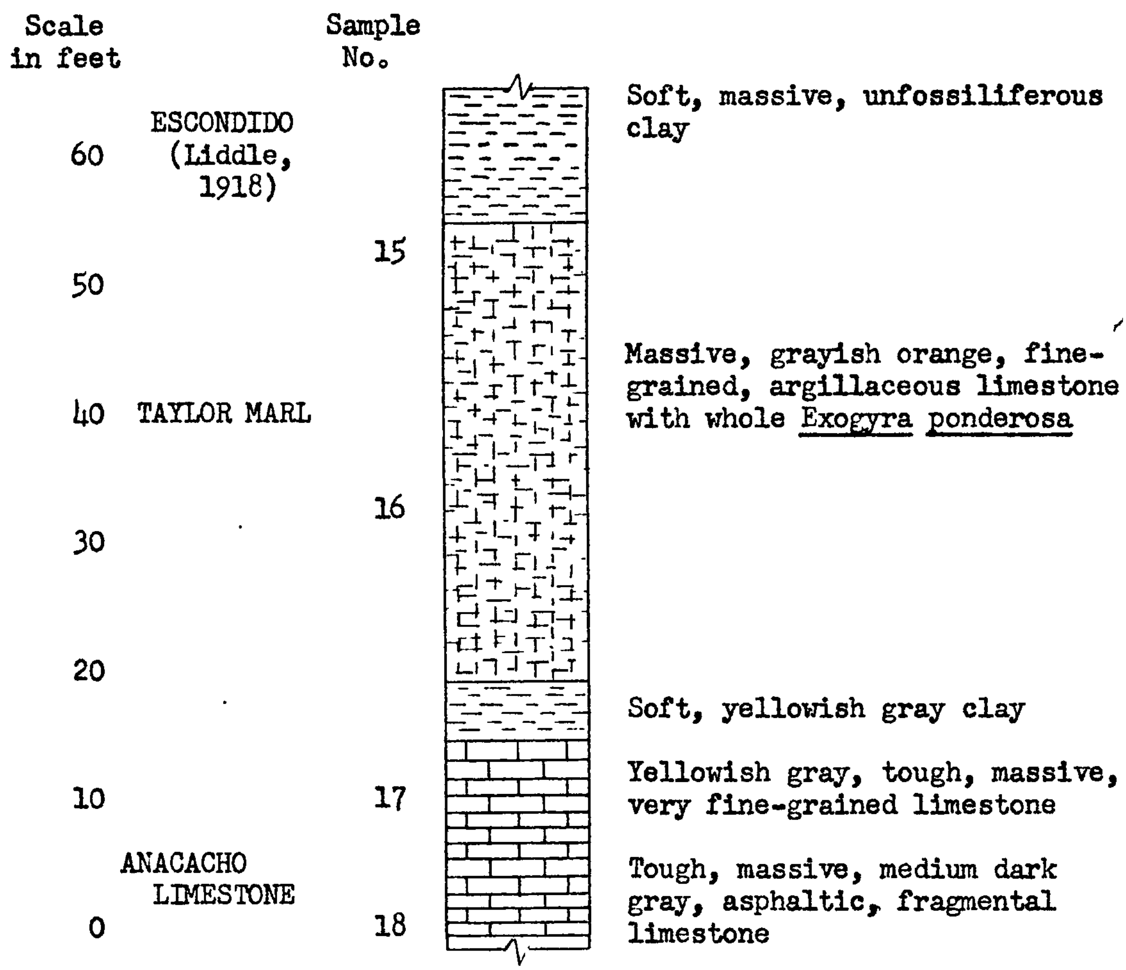


Figure: 7

MINERALOGY

Limestones

Carbonates

Calcite is the predominant constituent of all of the limestone samples studied. The calcite is present in the limestone as shell fragments, as fibrous, chalky matrix, and as coarse, granular matrix. In the fibrous matrix and in part of the shell fragments, the calcite is probably pseudomorphous after aragonite.

No aragonite or dolomite were detected by the staining tests. In a few instances, the granular calcite was only slightly stained by the Fairbanks solution. However, a check of the index of refraction of the slightly stained material proved it to be calcite in every case.

"Glauconite"

"Glauconite" is present in most of the limestone samples studied. It ranges in amount from only a trace up to 10% of the rock in sample 8. There is no consistent relationship between the abundance of "glauconite" and the fabric or position of the limestone samples studied.

The term "glauconite" is used in a dual sense. In one sense it refers to a specific micaceous mineral. In the other sense it refers to a morphological form. Burst (1958), in discussing the use of the term "glauconite" stated:

> "Students of glauconite have usually approached the problem with one of two different viewpoints. One group, usually field geologists or others making macroscopic or binocular microscopic exami-

> nations, describe all green, earthy pellet materials as glauconite, obviously a gross classification based on external appearance. The other, usually composed of laboratory analysts, confine the designation to monomineralic micaceous materials of slightly varying chemical composition and prescribe an average formula for the ideal mineral material. In this case, the description is a mineral term."

Hendricks and Ross (1941, p. 683) gave the following chemical formula as representative of several glauconites:

$$(K, Ca_{\frac{1}{2}}, Na)_{.84}(Al_{.47}Fe'''_{.97}Fe''_{.19}Mg_{.40})(Si_{3.65}Al_{.35})O_{10}(OH)_2$$

Burst (1958) classified glauconite into four major groups based on X-ray analysis. The first group "contains those materials which possess the structural properties generally attributed to the mineral glauconite." This group produces sharp, symmetrical peaks, at 10, 5, and 3.5 angstrom lines. According to Grim (1953, p. 68) the mineral glauconite is a dioctahedral illite with a unit cell composed of a single silicate layer rather than the double layer of most dioctahedral micas. The second group is also micaceous and monomineralic. The peaks, however, are subdued, and have broad bases and asymmetric sides. This suggests a less rigorous structural scheme. The third group includes inter-layered clay-mineral pellets. The fourth group contains mineral mixtures in pellet form without definite interlayering, including illite with montmorillonite and illite with chlorite.

An X-ray diffraction pattern of a hand picked portion of sample 8 (See Figure 8C), shows that the "glauconite" of this sample belongs to the second group in Burst's classification.

The "glauconite" seen in this study occurs in two distinct forms. In one form, the "glauconite" is in very dark green to black, nearly opaque, 1/10 to 1/2 mm., botryoidal masses that have a submetallic luster. In the second form, it is in light green, translucent, irregularly shaped masses that have a dull, earthy luster. The X-ray diffraction pattern was made of a mixture of both forms. In thin sections, the "glauconite" appears pale yellow to pale green in plane-polorized light, and very dark green with crossed nicol prisms. Some of the grains are faintly pleochroic.

Pyrite

Pyrite occurs intimately associated with the asphalt in the samples from the asphalt mines, but is absent from the other samples. The pyrite is in euhedral cubes and anhedral masses ranging up to 2 mm. across. In sample 27, the siltstone from the pit of White's Uvalde Mines, the pyrite also occurs in tabular plates. Most of the pyrite occurs embedded in asphalt, but a few grains are within the limestone fragments.

"Limonite"

"Limonite" pseudomorphs after pyrite ranging up to 3 mm. across are present in the insoluble residues of samples 1 and 12, from the northeast end of the Anacacho Mountains. Also in the same locality, there is a zone of spheroidal limonite concretions 156 feet above the *Exogyra ponderosa* ledge (sample 5). The concretions are probably pseudomorphs after pyrite or marcasite. The concretions range up to 30 mm. in diameter. In sample 6, a limonite concretion partly replaces a pelecypod shell indicating that the concretion formed by replacement.

Quartz

Traces of quartz are present as detrital grains in most of the limestone samples. The quartz grains are angular and mostly less than ½ mm. in diameter. Sample 12, from the lower portion of the "Milam chalk" member, with approximately 2% detrital quartz, contains more quartz than any other sample.

"Chert"

"Chert" does not occur as nodules or concretions in any of the samples studied. A trace of detrital chert is present in the insoluble residue of sample 11 from the upper portion of the "Milam chalk" member.

Chalcedony

Chalcedony in the form of clusters of spheroidal aggregates makes up approximately 3% of sample 21. The spheroids consist of radiating fibers of quartz and are 1/10 to 2/10 mm. in diameter. Sample 21 was taken from 3 feet above the "volcanic" beds of the Blanco Creek section. The silica was probably derived from the underlying "volcanic" beds and deposited by groundwater.

Chalcedony also occurs as spheroidal aggregates replacing calcite in an echinoid spine in sample 10. The spheroidal masses are 1/3 to 1/2 mm. in diameter and consist of fibers radiating inward from the walls. The growth structures of the echinoid spine pass through the chalcedony masses.

Muscovite

Traces of detrital muscovite are present in the insoluble residues of samples 1, 12, and 14, The muscovite flakes range up to ½ mm. in diameter.

Biotite

A trace of detrital biotite is present in the insoluble residue of sample 1.

Garnet

A trace of detrital garnet is present in the insoluble residue of sample 11.

"Volcanics"

Montmorillonite

The X-ray diffraction patterns of the samples of "volcanic" material from the Anacacho Mountains and from Blanco Creek show sharp peaks at the 14.7 angstrom lines. These peaks are shifted to 17 angstroms by treatment with ethylene glycol, indicating the presence of montmorillionite in the samples. Judging from the height of the peaks, the sample from the Anacacho Mountains consists predominantly of montmorillonite and in the sample from Blanco Creek montmorillonite is subordinate only to calcite.

Calcite

The presence of calcite in the samples of "volcanic" material is indicated by peaks on the X-ray diffraction patterns at the 3.0 angstrom line. Judging from the height of the peaks, calcite is the predominant constituent of the sample from Blanco Creek, whereas calcite is only a minor constituent of the sample from the Anacacho Mountains.

Dolomite

Dolomite is present in the sample from Blanco Creek as indicated by a prominent peak on the X-ray diffraction pattern at 2.9 angstroms.

Igneous Boulders from Blanco Creek

Olivine

Olivine is present in the boulders as euhedral phenocrysts ranging up to 1 mm. in length.

Augite

Augite phenocrysts ranging up to 20 mm. in length are present in the boulders.

Labradorite

Tabular labradorite crystals ranging up to 0.05 mm. in length predominate in the groundmass of the boulders.

Magnetite

Equant grains of magnetite ranging up to 0.03 mm. across are present in the groundmass and as poikilitic inclusions around the rims of the augite phenocrysts.

Serpentine

The serpentine minerals, antigorite and iddingsite, occur as kelyphitic rims around the olivine phenocrysts in the boulders. The serpentine minerals are deuteric alteration products of olivine.

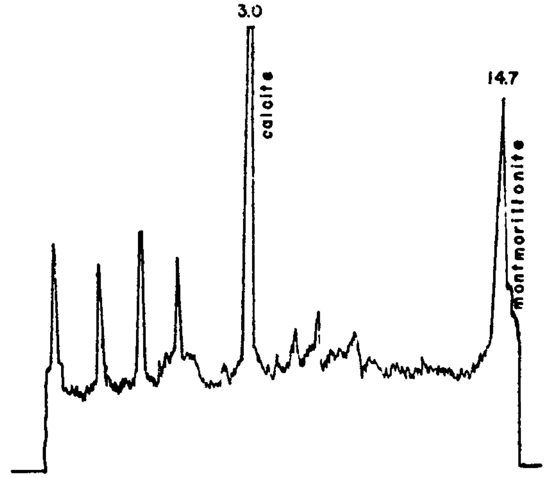


Figure 8A
"Volcanic" from Blanco Creek (Sample 32)

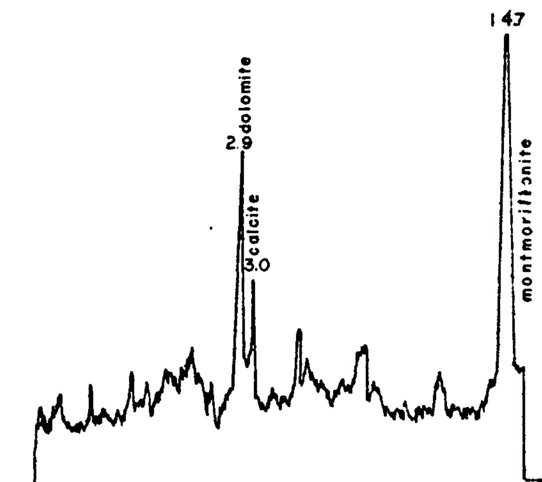


Figure 8 B
"Volcanic" from Anacacho Mtns.
The 14.7 Å peak shifted to 17.0 Å by glycolation.

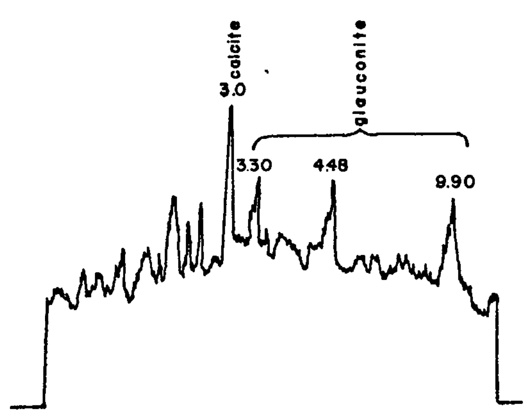


Figure 8 C
"Glauconite" from Anacacho Mtns. (Sample 8)
Note the asymmetric peaks with broad bases.

PETROGRAPHY

Depositional Fabric

MacNeil (1954, p. 390) recommended the term "reef rock" be used to include all of the rock, biohermal or detrital, of reefs or calcareous banks. He further recommended that the reef rock be subdivided into "biohermal reef rock" or rock composed of the growth lattice of organisms, and "detrital reef rock" or rock composed of detritus derived from the bioherm. This two-fold classification of reef rock lends itself well to a petrographic study because it does not involve the size or shape of the reef or its position with respect to land.

The biohermal reef rock is characterized by an abundance of unbroken shells in or near their growth positions. Shell fragments and shells of vagrant organisms fill the spaces between the unbroken shells. Bedding is absent or obscure.

The detrital reef rock is characterized by an abundance of broken, flat-lying shell fragments, and a scarcity of whole shells. Bedding is prominent, brought out by alignment of the flat-lying shell fragments and/or variations in grain size and sorting.

The term "bioherm" as used by MacNeil (1954) applies to the portion of the reef that is actively growing. The detrital reef rock is derived from the bioherm and may extend both seaward and lagoonward from the bioherm.

Samples 1, 6, and 8, taken from the northeast end of the Anacacho Mountains, are the only rocks studied in this investigation that possess the fabric of biohermal reef rock. (See Figure 3 for stratigraphic position.) The intervening fragmental limestone strata show no alignment of shell fragments parallel to the bedding, but they contain few whole shells. The repetition of the biohermal reef rock in the Anacacho Mountains section suggests that the actively growing portion of the reef migrated back and forth across the area, producing an interfingering of biohermal reef rock and detrital reef rock.

Samples 11 and 12, from the "Milam chalk" member in the Anacacho Mountains contain a small percentage of detrital quartz grains less than $\frac{1}{4}$ mm. in diameter. The lower portion of the member (sample 12) is argillaceous and contains about 50% shell fragments. The upper portion of the member (sample 11) consists almost entirely of chemically precipitated calcite. The presence of terrigenous material--the quartz grains-- and chemically precipitated calcite suggest that the "Milam chalk" member represents a lagoonal facies.

The specimens of fragmental limestone taken eastward and southward from the Anacacho Mountains possess the fabric of detrital reef rock, being composed of shell fragments aligned parallel to the bedding. Inasmuch as the detrital facies of the Anacacho limestone extends some 90 miles eastward along the regional strike, it seems unlikely that all of the detrital reef rock was derived from the biohermal facies now found in the vicinity of the Anacacho Mountains.

It appears more probable that the biohermal facies of the reef originally extended eastward parallel to, and up dip (north) from, the present outcrop of the detrital facies, and that it has been removed by erosion. If the biohermal facies did extend eastward as suggested, then it probably assumed the form of a barrier or fringing reef. The scarcity of terrigenous material in the detrital reef rock suggests that the reef was separated from the land by a lagoon, or that the land mass was an area of very low relief and contributed little terrigenous material.

Samples 16 and 17 from the upper portion of the Seco Creek section (see Figure 7), are very fine-grained argillaceous limestones or marls. They are made up mostly of clay and fine-grained, fibrous calcite crystals with some shell fragments. These samples are lithologically more similar to the Taylor marls than to typical Anacacho limestone, although the section was mapped as Anacacho by Liddle (1918). This upper portion of the section represents a distinctly different facies from the underlying detrital reef rock (sample 18), and demonstrates the overlapping relationship between the Anacacho and the Taylor marl.

Composition of the Reef Rock

The reef rock consists predominantly of shells and shell fragments in a chalky or coarsely crystalline calcite matrix, with very little terrigenous material present. The shell fragments are so broken up that it is impossible to identify the type of organism in most cases. A great abundance of elongate, curved shell fragments are present in many of the specimens, suggesting that pelecypods were the major contributors to the building of the reef. Fragments of bryozoa are easily recognizable, particularly in thin section, and are abundant in some of the specimens. Echinoid spines are also easily recognizable, and are present in several of the specimens. In samples 19 and 20, from the section of Anacacho below the "volcanic" beds on Blanco Creek, echinoid spines form the major portion of the rock. Foraminiferal tests are abundant numerically in many of the specimens, but they make up only a very small portion of the rock.

The chalky matrix of the reef rock consists of very fine-grained fibrous calcite. The matrix was probably precipitated soon after deposition of the fragmentary material.

Transparent, coarsely crystalline calcite forms the matrix of a few of the specimens (9, 18, 21, 29, 30). Three samples (1. 6, and 10), have a matrix that is mostly chalk but contain some coarsely crystalline calicte. The coarsely crystalline calcite in the matrix of these samples could have been precipitated directly or it could have formed by the recrystallization of the chalky matrix.

There is no consistent relationship between the kind of matrix and the presence of asphalt, because asphalt occurs in rocks with chalky matrix and rocks with coarsely crystalline matrix. Samples 34 and 36, taken from the same horizon in the pit of the Uvalde Rock Asphalt Company, are both abundantly asphaltic. However, sample 34 has a matrix of clear, coarsely crystalline calcite and sample 36 has a chalky matrix.

Qualitative Study of Porosity

In this study no attempt was made to measure the porosity of the samples. A simple estimate of the amount of visible pore space observed under the binocular microscope was made for the samples which have obviously high or low porosities. The porosity was expressed, quite subjectively, with such expressions as "very porous","very dense", etc.

The kind of visible porosity in each sample was studied in detail and the nature of each type of pore space was described. The possibility of two basic types of visible porosity were considered--primary and secondary. Primary porosity is pore space which has remained unfilled since the time the rock was formed. Secondary porosity is pore space that has been opened since the rock was formed. Secondary porosity includes both pore space that has been opened after the rock was formed, and pore space that was open when the rock was formed, but was subsequently filled and then reopened. The term "relic porosity", as used in this paper, applies to portions of a rock which was evidently secondary porosity at some time but which is now filled with rock material.

Visible primary porosity in organic fragmental limestone may occur as (1) cavities within organic structures, and (2) interfragmental voids. It is difficult to prove, however, that the porosity observed in a rock is actually primary. The cavities within organic structures and inter-fragmental voids may well have been filled and later opened by circulating waters.

Visible secondary porosity in organic fragmental limestone may occur as fractures and as channels opened by circulating water.

Fractures in hand specimens are generally recognizable by their planar aspect. Fractures in a hand specimen may be natural, or they may have been artificially produced by hammering when the sample was taken. The natural fractures usually show the effects of solutions by being partly to entirely filled with foreign material, or by being irregular in width as a result of some of the rock from the fracture walls being removed by solution.

The following kinds of visible pore space are considered by the writer to be indicative of porosity opened by circulating water:

1. Molds of organic structures.
2. Pore space that cuts into or through organic structures.
3. Pores with smooth, rounded walls in rocks made up of angular fragments.
4. Pore space that exceeds the average size of the fragmental particles of the rock. (In the chance packing of fragments, it is possible, but rare, for the inter-fragmental voids to exceed the size of the fragments).
5. Channels in relatively nonporous rocks which are visibly continuous for distances several times their diameter.

The first three kinds of pore space listed above are considered

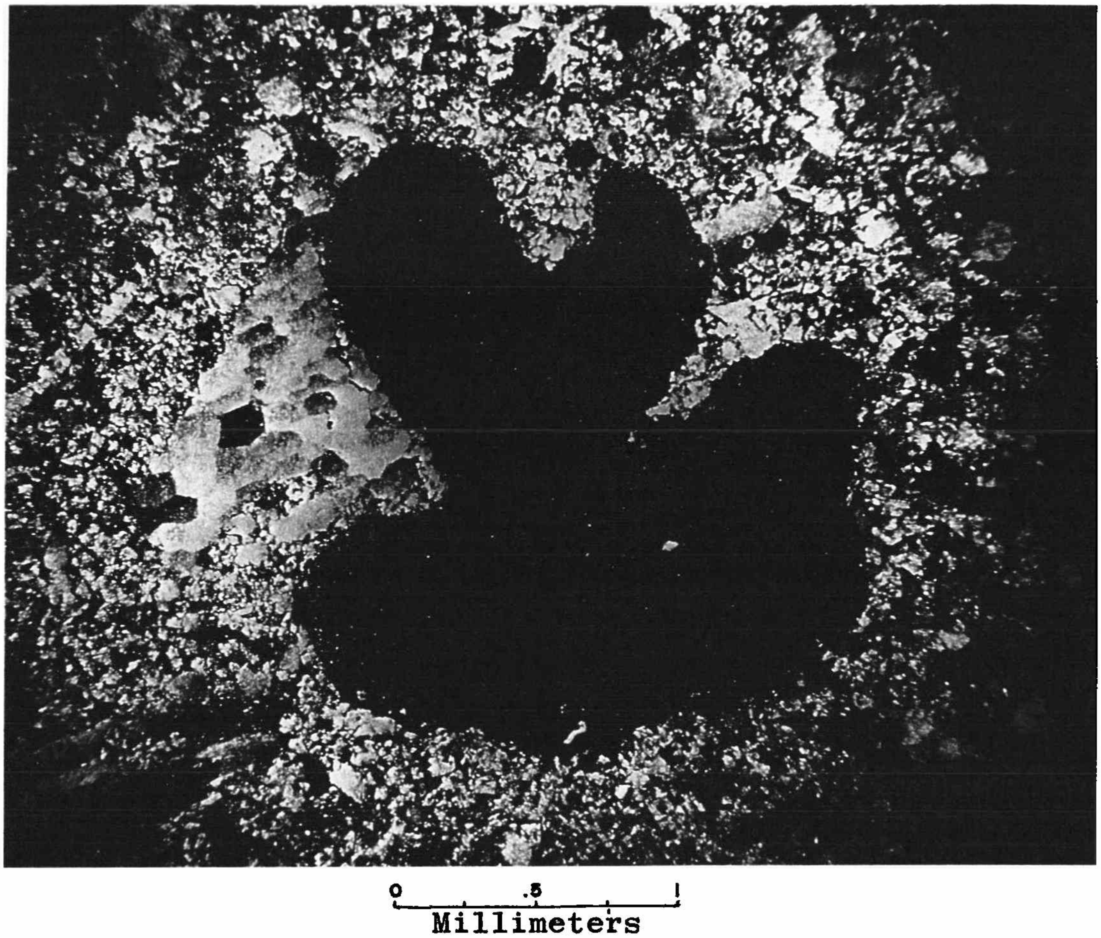


Figure 9: Photomicrograph of Thin Section of Sample 10.

This is an example of secondary porosity. The diameter of the pore space greatly exceeds the diameter of the fragmentary particles. The walls of the pore are smooth and curved, whereas the fragmentary particles are angular. Polygonal crystals of secondary calcite are shown on the left margin of the pore. (Crossed Nicols).

by the writer to be very reliable indicators of secondary porosity. The fourth kind is considered quite reliable for rocks in which such porosity is abundant. The fifth kind simply suggests secondary porosity.

The binocular microscope used for this study has a magnification of 27 power. The petrographic microscope was not used in the porosity study because it was impossible to make a reliable distinction between actual pore space and voids in the thin sections caused by peeling of the rock from the glass slide during polishing. However, in the very well indurated rocks (samples 1, 2, 4, 5, and 9), very small intergranular and intercrystal voids were seen. Submicroscopic pore space is probably present in all of the specimens.

Of the porosity visible at 27 power, in all the specimens studied, the porosity that is definitely or probably secondary is many times as great as that which is possibly primary. The visible porosity that is possibly primary is limited to unfilled foraminiferal tests and bryozoan chambers which are present in varying amounts in most of the specimen, and a small amount of interfragmental porosity in sample 3.

The prominance of secondary porosity in the Anacacho limestone is in close agreement with the conclusions of Newell (1955) concerning modern and fossil reefs. Newell (1955, p. 309) stated:

> "It is pertinent...to stress the fact that cavernous primary porosity popularly associated with reef rock (and reef talus) can characterize only the earliest stages of growth, when the reef is only a few hundred years old."

Concerning the porosity of the Permian Scurry reef of West Texas, Newell (1955, p. 304) concluded:

> "In the Permian reefs, also, inorganic deposition of calcium carbonate was a usual and characteristic phase in the early history of reef limestone. High permeability in these fossil reefs probably is not directly related to primary voids, but is generally a result of selective leaching of aragonite from calcite matrix or calcite from dolomite matrix."

"Volcanics" of the Balcones Fault Region

Spatially associated with the Balcones fault system, and extending from near Brackettville in Kinney County to near Taylor in Williamson County are a number of igneous intrusions and a number of rock bodies of uncertain origin. These rocks of uncertain origin are referred to in this paper as "volcanics".

The "volcanic" material is generally called "serpentine" by well drillers of the Balcones fault region. Lonsdale (1927) referred to the material as "sedimentary serpentine", but pointed out that the name is not truly descriptive of the material since it consists of clays and not serpentine minerals. Smiser and Wintermann (1935) applied the name "palagonite" to the producing rock of the Hilbig oil field in Bastrop County, which is similar to the other "volcanics" of the Balcones fault region. However, the use of the term "palagonite" for the material seems questionable because the kinship of the material to basaltic glass is uncertain.

The "volcanics" consist predominantly of greenish clays. They are well bedded and contain fossils in many places. However, they possess an apparently igneous texture. Most of the "volcanics" occur in the Austin and Taylor groups (Lonsdale, 1927). However, in eastern Kinney County there is a deposit of the "volcanic" material in the Grayson (Del Rio) formation (Greenwood, 1956).

Lonsdale (1927, p. 142) attributed the origin of the "volcanics" to weathering and transportation of material from nearby volcanic islands. He also considered less probable the possibility of the beds being ash or tuff deposited in the sea.

Smiser and Wintermann (1935) attributed the origin of the producing rock of the Hilbig oil field to submarine volcanic extrusions. Their principal evidence supporting this conclusion is the fragmental texture of the rock, the presence of microfossils and large fragments of chalk in the rock, and the lack of contact metamorphism or alteration of the chalk inclusions.

Greenwood (1956) suggested that the "volcanic" material in the Grayson (Del Rio) formation in eastern Kinney County is a submarine volcanic mudflow. The principal evidence supporting this conclusion is the apparently igneous texture of the rock, the presence of unaltered fossils in the rock, the presence of alkali peridotite and limestone boulders in the deposit, and intense deformation of the underlying limestone.

"Volcanics" in the Anacacho

Beds of "volcanic" material occur interbedded with the organic fragmental limestone of the Anacacho. The log of the Texas Highway Department well R-1 in western Uvalde County (see map, Figure 1) shows five beds of greenish to greenish-gray clay, ranging from 10 to 78 feet in thickness, within the Anacacho. These clays are probably genetically related to the "volcanic" material of the region. Outcrops of the "volcanic" material occur at the base of the Anacacho (top of Burditt?) at the northeast end of the Anacacho Mountains, and within the Anacacho formation along Blanco Creek (see map, Figure 1). The clays of both of these outcrops are montmorillonite (see "Mineralogy").

The "volcanic" material exposed along Blanco Creek was described by Lonsdale (1927, p. 125) as follows:

> "In the Blanco River (Creek) the most noteworthy exposure is immediately downstream from the railroad crossing, where for nearly a mile the material is exposed in a bed about 10 feet thick. The rock is dark to light greenish in fresh surfaces, and well stratified. It is apparently located immediately above the Austin chalk, since it is overlain by Anacacho limestone. Near the railroad crossing, this material is again shown and here is exceedingly well stratified and at the same time folded, dipping to the northeast".

Upstream from the locality on Blanco Creek mentioned by Lonsdale (1927), the "volcanic" beds thicken considerably, being 66 feet thick in the measured section approximately one mile north of the railroad. In the measured section, the "volcanic" material overlies a 30 foot thickness of organic fragmental limestone (samples 19 and 20). Overlying the "volcanic" material is at least 150 feet of slightly asphaltic, organic fragmental limestone (samples 21 and 22). The limestones above and below the "volcanic" beds are not deformed.

The "volcanic" material is very soft, unindurated, clayey material. It consists of angular fragments of apparently igneous material in a clay matrix. Bedding is brought out by variations in grain size of the fragmentary particles and by variations of the proportion of fragments to the matrix. The deposit is very evenly bedded with no cross-bedding apparent.

Fibrous calcite veins ranging up to 2 inches in thickness are abundant in the "volcanic" material. The veins pass upward into the overlying limestone. The "volcanic" beds are cut by many vertical joints. The joints are recemented by hydrated iron oxides and stand up as sharp ridges 1/4 to 1/2 inches high on the fresh outcrops.

Unbroken, single valves of Exogyra ponderosa are common in the float on the surface of the "volcanic" outcrop and can be seen occasionally in place in the rock. The shells do not show wear from transportation and have sharp growth ridges preserved.

From 100 to 300 yards north of the railroad bridge, there are numerous olivine basalt boulders (sample 36) in the "volcanic" beds. These boulders range up to 2 feet in diameter. They are intensely fractured and are well rounded. Many well rounded cobbles of highly vesicular lava are present in the float, but none were seen in place by the writer.

The even bedding of this deposit and the lack of wear on the fossils suggest that the material was laid down in calm water. However, extremely rough water would have been necessary to transport the olivine basalt boulders for any great distance. Although the boulders are intensely fractured, they are not vesicular. The lack of vesicularity suggests that they are not volcanic bombs. The even bedding of the "volcanic" material and the lack of deformation of the underlying limestone suggest that the deposit is not a mudflow. The presence of the joints suggests that the rock was, at some time, much more competent than it is at the present. The true nature of the deposit cannot be determined from the present evidence.

ASPHALT IN THE ANACACHO LIMESTONE

The Anacacho limestone is commonly asphaltic in the fore-reef facies. Traces of asphalt occur in the eastward tongue-like extension of the formation in Medina County, where it can be seen in the outcrops in Seco and San Geronimo Creeks. In eastern Uvalde County, portions of the formation are abundantly asphaltic and are sources of commercial asphalt rock. The asphalt is a black, semisolid, bituminous material, soluble in gasoline.

History of Asphalt Production

Asphalt rock from the Anacacho formation was first quarried in 1891. In 1893 the Litho Carbon Company erected a quarrying, crushing, and extracting plant for extracting the asphaltum from the crushed limestone. The Litho Carbon Company ceased operations in 1897 as a result of competition from asphaltum from Trinidad.

The Uvalde Asphalt Company mined the asphalt rock and extracted the asphaltum for paving purposes for a short time in 1897. In 1900 the Parker Washington Company used the crushed asphalt rock for paving purposes in San Antonio.

The deposits were not worked from 1901 until 1912. The Uvalde Rock Asphalt Company began quarrying the rock for road and street paving purposes in 1912, and has operated continuously to the present. Also operating at the present time are the Texas Asphalt Company and White's Uvalde Mines (Getzendaner, 1956, pp. 56-57).

Origin of the Asphalt

Vaughn (1897, p. 935) presented the following evidence and conclusion on the origin of the asphalt in the Anacacho limestone:

> "1. The asphalt is in shallow synclinal basins.
> 2. It is an impregnation of porous rock.
> 3. The associated sedimentary formations are largely of organic origin.
> 4. There has been much igneous disturbance, and the asphalt is clearly associated with the igneous rocks.
>
> These facts have suggested the conclusion that the heat of the basalt intrusions has acted upon the organic limestone, driving out the asphalt or bitumen, which has accumulated in the synclinal basins as impregnations of the porous rock."

Baker (1928) also attributed the origin of the asphalt to distillation by heat from the associated igneous intrusions. However, he considered the underlying bituminous shales of the Benton (Eagle Ford) a more probable source for the bituminous material, than the Anacacho itself.

Although asphalt occurs in most of the detrital reef rock, the greatest concentrations are located within a few miles of igneous intrusions. There is, however, no direct evidence from this study that the asphalt is genetically related to the igneous intrusions.

Utterback (1953, p. 125), after studying the occurrence of asphalt in the Anacacho, made the following statements:

> "The following conclusions concerning origin are obtained from this deposit:
>
> 1. The bitumen in the Anacacho limestone was deposited contemporaneously with the material with which it is associated.

2. The rock is not an impregnated coquina, but consists of fragments of limestone in a bituminous matrix.

3. It is not a residual oil pool, although under proper conditions it might have been converted into one."

In support of his argument, he stated (p. 121):

"When a polished surface of the highly impregnated rock is viewed under the microscope, it has much more the appearance of rock fragments imbedded in asphalt than of asphalt filling the pore spaces of a highly porous coquina as it has been described. The shape of the limestone particles and their relative positions bear no suggestion of a mass of fossil fragments deposited in a body of water and the pore spaces later filled with asphalt. ...The photo-micrographs show abundant fragments of limestone with no contact whatever with other limestone particles on the surface photographed."

The contact relationship between clastic grains in a rock cannot be seen in a thin section of standard thickness (.03 mm.) because the thickness of the thin section is much less than the average diameter of the clastic particles. Except in very fortuitous cases, clastic grains in thin section appear to be suspended in the cementing material or matrix although the grains are in contact in the rock. This subject has been discussed by Graton and Fraser (1935). The lack of contact between grains as seen in thin section and the "appearance of rock fragments imbedded in asphalt" are not valid criteria for concluding that the deposition of the asphalt and limestone particles were contemporaneous.

In further support of his argument, Utterbach stated (p. 121):

"Determinations of volumetric percentages by the writer (Utterbach) on five representative samples gave results of 36, 39, 40, 42, and 43 percent asphalt. These percentages are abnormal in any rock that has undergone any amount of compaction and lithification...

> "...The rock has been described as a coquina exactly similar to the shell deposits forming in places along the coast of Florida today, and it is true that those deposits characteristically possess such high porosities. The comparison, however, is not entirely apt. The modern coquinas are relatively coarse and deficient in fine materials and the high porosity is due largely to the curved nature of the unbroken shell particles. The shells composing this recent limestone are also found to be generally orientated and lying as nearly flat as their curved shape will allow in the horizontal plane of deposition. In contrast to this, the asphalt impregnated portions of the Anacacho limestone studied by the writer (Utterback), though composed of angular particles, are fine-grained and unsorted, and curved shell portions are not common. It more nearly resembles the product of a clastic calcareous deposit than it does the modern coquinas. A study of the photomicrographs also verifies the impression of complete lack of orientation gained from more extensive microscopic studies of the material."

Utterback did not mention the possibility of secondary porosity in his argument. With the exception of unfilled foraminiferal tests and Bryozoan chambers, primary porosity is lacking in all the samples studied in this investigation and the porosity of the Anacacho cannot be compared to the porosity of recent coquinas. Although <u>primary</u> porosities as great as 43% are abnormal in fine grained clastic rocks, such high <u>secondary</u> porosities are not abnormal. Furthermore, the removal of the considerable amount of original rock material to produce the high secondary porosities has served to obscure the orientation of the shell fragments.

In reference to the possibility of migration of the asphalt into the rock as petroleum, Utterback stated (p. 125):

> "Migration into as fine-grained rock as the Anacacho limestone would have had to be accomplished by a very liquid substance of low viscosity. An oil of this type upon loss of

> volatile materials would have been greatly reduced in volume and the resulting rock would have exhibited a coating of asphalt around each rock particle rather than a complete filling of the interstices between the limestone fragments."

The present writer observed that in the samples of asphalt impregnated rock, the asphalt did not entirely fill the spaces between the limestone grains, but formed only a coating around the grains, leaving abundant pore space. This is in direct opposition to the observations of Utterback.

It was observed that on a broken or freshly sawed surface (samples 23, 24, 26, 28, 33, 34, and 35) the surface of the asphalt coating is smooth and has a vitreous luster, and the space between the limestone particles is not entirely filled with asphalt. However, repeated observations under the binocular microscope during the process of polishing a sawed surface revealed that the pore space and the lustrous surface of the asphalt progressively disappeared during the polishing operation. This result is caused by the rock material being ground away and removed, and the asphalt being smeared into the pore space and not removed. The porosity was destroyed by the polishing operation. Therefore, a polished surface or a thin section of a rock containing abundant asphalt cannot be used to show the presence or absence of porosity, or to deny the possibility of shrinkage of the asphalt resulting from loss of volatiles.

Samples 26, 33, 34, and 35 show on the sawed surface, the contact between asphaltic rock and asphalt-free rock. Bedding is shown prominently on the sawed surfaces. The contact of the asphalt clearly cuts across the bedding planes

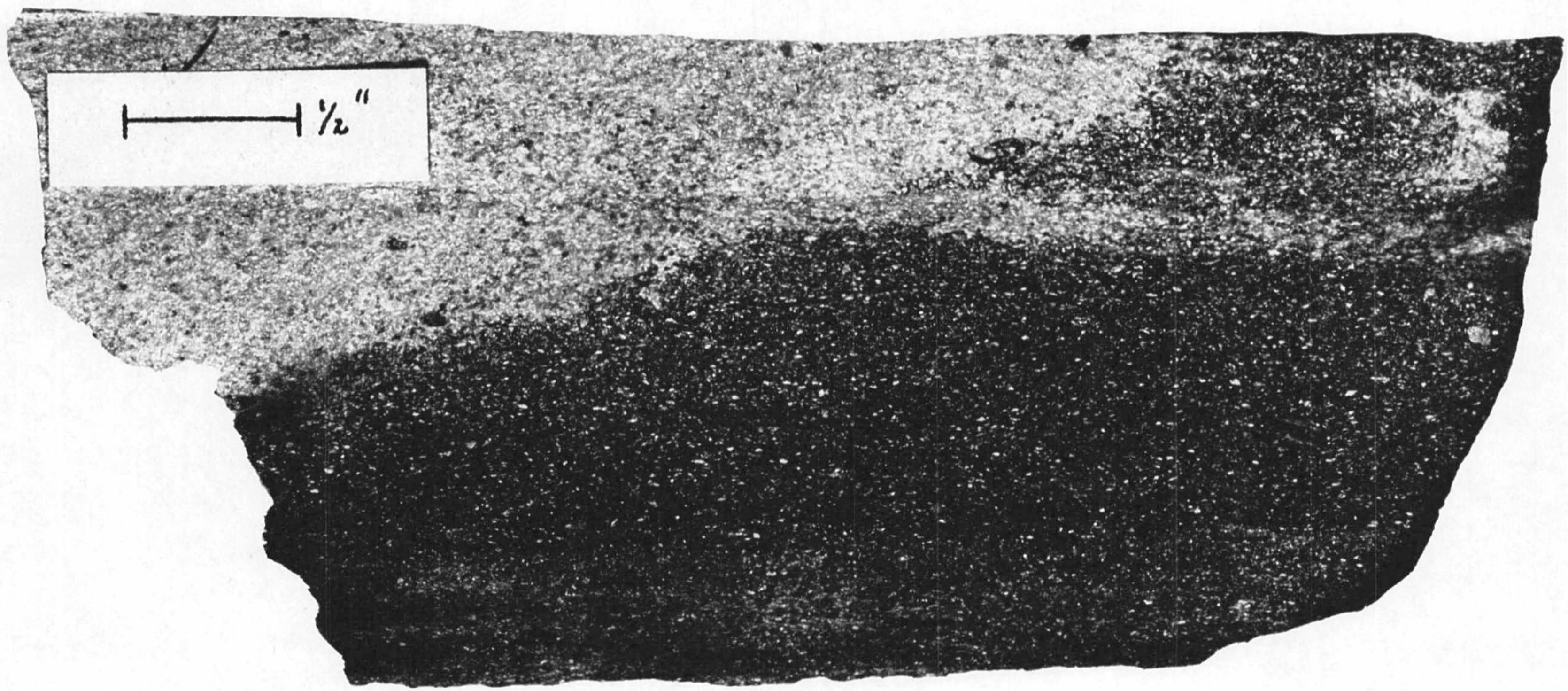


Figure 10: Photograph of Sawed Surface of Sample 26.

The bedding is brought out by alignment of shell fragments and slight variations in grain size. Note that the contact of the asphalt clearly cuts across the bedding.

in these specimens (see Figure 10). Also, on the walls of the Uvalde Rock Asphalt Company's pit, particularly in a horizon about 15 feet above the floor of the pit, there are patches of asphalt-free rock up to two feet thick and ten feet wide. The contacts of the asphalt along the edges of these barren patches clearly cut across the bedding. The upper contact of the asphalt on the south wall of this pit cuts across about ten feet of section. This relationship between the bedding and the asphalt suggests that the asphalt and the clastic limestone material were not deposited contemporaneously, and that the asphalt material invaded the limestone.

The fact that the contact of the asphalt cuts across the bedding and the evidence of shrinkage of the asphalt in place suggest that the asphalt is the nonvolatile residuum of petroleum. The volatiles were probably lost by evaporation by removal of the overlying rock during the present or some previous erosional cycle.

The location of the most abundantly asphaltic portions of the formation in shallow synclinal basins as stated by Vaughn (1897, p. 935), would suggest that the petroleum migrated into the lowest portions of structures as the water table was lowered by erosion.

Utterback further stated (p. 121):

> "Although many of the limestone fragments are of a chalky nature and would have easily been stained by contact with liquid oil, they are always white with no indication of oil stains even around the edges. Also, small porous portions of fossil structures are not filled with asphalt."

He again stated (p. 125):

> "Porous portions of fossils are frequently not filled with asphalt in the Anacacho material, while in specimens of recent coquina that were artificially saturated with asphalt, all such portions are filled. This is a fundamental difference that would be expected to exist between a substance that had been filled with a liquid material and one that had been imbedded in a semisolid substance."

The present writer's observations agree only in part with these observations by Utterback. Even in the most thoroughly asphalt-saturated specimens there are unfilled foraminiferal tests and a few unfilled bryozoan chambers. However, most of the chalky fragments show staining around the edges, and some are saturated with asphalt. There are some chalky fragments that are not visibly stained.

The fact that some of the pore space within fossils is not asphalt-filled suggests that these pores were not connected to the interfragmental pore space at the time of introduction of the asphalt. The pore space within the fossils is probably primary porosity, whereas the intra-fragmental pore space is probably secondary porosity. At least part of the primary porosity could be expected to be isolated from the secondary porosity.

The lack of thorough staining of the chalky fossil fragments suggests that the asphaltic fluid had a rather high viscosity at the time it migrated into its present position. If the asphalt reached its present position during an erosional cycle, it could be expected to have progressively increased in viscosity during migration as a result of loss of volatiles.

The presence of unfilled pores within fossils and the lack of thorough staining of chalky fragments is tenable with both the contemporaneous deposition hypothesis and the petroleum residuum hypothesis.

SUMMARY AND CONCLUSIONS

The Anacacho limestone in eastern Kinney County consists of an alternating succession of strata possessing both the fabric of biohermal reef rock and detrital reef rock. Probably the actively growing portion of the Anacacho reef migrated back and forth, producing an interfingering of biohermal reef rock and detrital reef rock.

The "Milam chalk", middle, member of the Anacacho in eastern Kinney County, consists mainly of chemically precipitated calcite with some clay and detrital quartz, suggesting that the member represents a lagoonal environment.

The green pelletal material in the limestone is glauconite, and is not related to similar material of "volcanic" origin in the area.

Eastward from Kinney County to western Bexar County, the Anacacho limestone possesses the fabric of detrital reef rock and is overlapped from the east by the Taylor marl. The absence of biohermal reef rock from the Anacacho limestone in Uvalde and Medina Counties suggests that the actively growing portion of the Anacacho reef extended eastward from the Anacacho Mountains and up dip from the present outcrops, having since been removed by erosion.

The principal fossils in the Anacacho reef are pelecypods and bryozoans. Echinoid fragments predominate in the lower portion of the Anacacho section exposed on Blanco Creek.

Of the porosity visible under the binocular microscope, that which is definitely secondary is many times as great as that which is possibly primary. It was impossible to demonstrate conclusively that any of the porosity is truly primary.

In the abundantly asphaltic portions of the Anacacho, the contact between the asphaltic and nonasphaltic rock was seen to cut across the bedding both in hand specimens and in gross aspect in the asphalt mines. The cutting of the bedding planes by the asphalt contact suggests that the asphalt invaded the limestone and was not deposited contemporaneously with it. The fact that the asphalt does not entirely fill the pore space of the rock, but forms a coating on the limestone fragments suggests that the asphalt is the residuum of a lighter oil which lost its volatile constituents.

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APPENDIX

The following terms used in the description of samples are thought by the writer to need special clarification:

"Tough" is intended to mean difficult to break with a hammer.

"Dense" is intended to mean lacking in porosity.

"Massive", as used in the rock descriptions, means that bedding is not apparent in the field, although bedding may be apparent on a sawed surface.

A "channel" is a pore space that is several times as long as it is wide.

The terms "relic channels" and "relic porosity" are applied to portions of the rock which have been removed by solution and later filled by solid material.

"Apparently replaced", where used in reference to asphalt, is not intended to suggest metasomatic replacement, but is intended to mean the filling of molds by asphalt.

The determination of the color of each rock was made by comparing a freshly broken surface to the rock color chart published by the Geological Society of America. The color names used are those suggested by the chart.

DESCRIPTION OF SAMPLES

Sample 1 (Northeast end of Anacacho Mountains, top of *Exogyra ponderosa* ledge.)

Very pale orange (10 YR 7/2), medium-grained, thick bedded, very tough, fragmental limestone with a profusion of whole *Exogyra ponderosa* shells. Forms ledge.

Sawed surface shows no structure.

Thin section shows shell fragments mostly 1/2 to 1 1/2 mm. in diameter cemented by very fine-grained, chalky matrix. Apparent pore space includes unfilled foraminiferal tests and pores with etched surfaces cutting across grain boundaries and matrix. Pore spaces range from 1/10 to 1 mm. in diameter. Some polygonal crystals of calcite are present.

Limonite grains 1/2 to 2 mm. in diameter occur in irregularly dispersed clusters.

Sample 2 (Northeast end of Anacacho Mountains, 66 feet above *Exogyra ponderosa* ledge.)

Very tough, dark yellowish-orange (10 YR 6/4), coarse-grained, fragmental, cliff-forming limestone.

Sawed surface shows no structure, but shows considerable porosity.

Thin section shows shell fragments ranging up to 1/2 mm. in length in a very fine-grained calcareous matrix. Porosity occurs as smooth-surfaced, oval-shaped pores ranging from 1/2 to 1 mm. in diameter. Some of the pores have a lining of crystalline calcite 1/10 to 2/10 mm. in thickness.

Bryozoan fragments are common and many have unfilled chambers. A few sub-rounded grains of quartz, 1/4 to 1/2 mm. in diameter are present.

Sample 3 (Northeast end of Anacacho Mountains, 114 feet above *Exogyra ponderosa* ledge.)

Dark yellowish orange (10 YR 6/4), massive, tough, fragmental limestone that weathers to a "worm eaten" surface.

Sawed surface shows recemented fractures and abundant pore space. No bedding is shown on the sawed surface.

Thin section shows shell fragments, mostly less than 1/4 mm. in diameter, in a very fine-grained matrix. Matrix predominates over fragments. Bryozoan fragments are common. One echinoid spine is present. Porosity is very irregular over the slide, ranging from less than 5% to over 50%. Porosity is greatest near the fractures. The pores range in diameter from 1/10 to 1/2 mm. The pores are almost entirely restricted to the matrix and seldom cut across the fragments.

A few scattered quartz grains less than 1/10 mm. in diameter are present.

Sample 4 (Northeast end of Anacacho Mountains, 90 feet above *Exogyra ponderosa* ledge.)

Very dense, massive, moderate yellowish brown (10 YR 5/4) fragmental limestone. Weathers to a "worm-eaten" surface. Boulders ring when struck with a hammer.

Sawed surface shows no bedding but shows cavities up to 5 mm. in diameter which are lined with rust-colored, clayey material.

Thin section shows shell fragments 1/4 to 1 mm. in diameter cemented in fine-grained matrix. Matrix is minor in amount. Bryozoa with filled chambers are common.

Pore space occurs as highly irregular pores 1/10 to 1 mm. in diameter that are commonly elongate and adjacent to shell fragments, and as smooth, oval-shaped cavities 4 to 5 mm. in diameter which are lined with clayey material.

Scattered grains of quartz and "glauconite" 1/4 to 1/2 mm. in diameter are present. The "glauconite" is transparent, light green to light yellow and has a dark green interference color and low birefringence.

Sample 5 (Northeast end of Anacacho Mountains, 156 feet above *Exogyra ponderosa* ledge.)

Grayish orange (10 YR 7/4), massive, tough, fine-grained, fragmental limestone with spheroidal limonite concretions ranging up to 20 mm. in diameter.

Sawed surface shows no bedding but shows numerous hair-like, recemented fractures.

Thin section shows shell fragments 1/10 to 1/4 mm. in diameter in fine-grained matrix. Matrix is minor in amount. Porosity includes 1/10 to 1/5 mm. pores cutting across grains and with irregular, frosted surfaces; unfilled foraminiferal tests; and cavities 2 to 5 mm. in diameter which are lined with a 1/2 to 1 mm. thickness limonite.

Scattered grains of "glauconite" and quartz 1/4 to 1/2 mm. in diameter are present. The "glauconite" is a transparent, light yellow crypto-crystalline mineral with a dark green interference color.

Sample 6 (Northeast end of Anacacho Mountains, 174 feet above *Exogyra ponderosa* ledge.)

Very tough, massive, grayish orange (10 YR 7/4), fragmental limestone with abundant limonite concretions 5 to 10 mm. in diameter and fragments of pelecypod shells 40 to 50 mm. in length.

Sawed surface shows no bedding but shows a cross-section of a pelecypod shell 30 mm. in length, a porous limonite concretion 8 mm. in diameter, and abundant oval-shaped pores 1 to 3 mm. in diameter. The oval-shaped pores are aligned with their long axes vertical. The limonite concretion partly replaces the long pelecypod shell.

Thin section shows unsorted shell fragments in a subordinate fine-grained groundmass. Filled foraminiferal tests and gastropod shells are common. Portions of the large pelecypod shells have been dissolved and crystalline calcite precipitated in the openings. Recrystallized calcite is common throughout the slide.

Porosity occurs as a few irregularly shaped pores 1/10 to 1/2 mm. in diameter and oval-shaped pores 1 to 3 mm. in diameter.

A few, scattered quartz grains 1/10 mm. in diameter are present.

Sample 7 (Northeast end of Anacacho Mountains, 21 feet below *Exogyra ponderosa* ledge.)

Pale grayish orange (10 YR 7/2), very tough, massive, fragmental limestone.

Sawed surface shows no bedding but shows a refilled solution channel 3 to 8 mm. wide. Solution channel contains very fine-grained, chalky limestone with a small percentage (10-15%) of shell fragments and shows faint banding parallel to the channel walls.

Thin section shows shell fragments 1/10 to 1 mm. in diameter and foraminifera in a fine-grained, chalky matrix. Matrix is more abundant than shell fragments and foraminifera. Foraminifera are abundant. Some Bryozoan fragments are present.

Porosity includes unfilled foraminiferal tests and irregular openings 1/10 to 1 mm. in diameter. Irregular openings are mostly in matrix.

No quartz is present.

Sample 8 (Northeast end of Anacacho Mountains, 36 feet below *Exogyra ponderosa* ledge.)

Grayish orange (10 YR 7/4), massive, tough, clayey, fragmental limestone.

Sawed surface shows no bedding, but shows considerable porosity and abundant "glauconite".

Thin section shows shell fragments 1/10 to 3 mm. in diameter in a very fine-grained matrix. Bryozoans are very abundant. Some Bryozoan chambers are unfilled. One echinoid spine is present. Porosity is mainly 1/10 to 1/2 mm., very irregular pores which cut across grain boundaries and matrix.

No quartz is present. "Glauconite" grains appear pale yellow to pale green in thin section, are faintly pelocroic, have dark green interference color, are 1/10 to 1/2 mm. in diameter and are cryptocrystalline.

Sample 9 (Northeast end of Anacacho Mountains, 54 feet below *Exogyra ponderosa* ledge.)

Massive, moderate yellowish brown (10 YR 5/4), very tough, crystalline limestone.

Sawed surface shows no bedding but shows porosity to be very unevenly distributed.

Thin section shows shell fragments 1/2 to 2 mm. in diameter in a fine-grained matrix. Foraminifera are abundant. Entire rock is recrystallized to an interlocking mass of calcite crystals 1 to 2 mm. across. Porosity occurs as highly irregular pores, 1/10 to 1 mm. in diameter, that cut across grain boundaries and matrix. Some pores have a lining of calcite crystals.

Scattered grains of pale yellow to pale green, faintly pleocroic cryptocrystalline "glauconite" with dark green interference color occur.

Sample 10 (Northeast end of Anacacho Mountains, 112 feet below *Exogyra ponderosa* ledge.)

Dark yellowish orange (10 YR 6/6), massive, tough, clayey limestone.

Sawed surface shows no bedding, but shows scattered, white shell fragments 2 to 8 mm. long in a yellowish-brown, fine-grained matrix.

Thin section shows shell fragments 1/20 to 1/2 mm. in diameter in a very fine-grained matrix. Matrix predominates over fragments. One echinoid spine 5 mm. long is present. Spheroidal masses of chalcedony 1/3 to 1/2 mm. in diameter occur along the axis of the echinoid spine. The chalcedony fibers radiate inward from the walls of the masses. The growth structures of the echinoid spine are seen to pass through the chalcedony masses. Masses of secondary calcite 1 to 3 mm. across made up of polygonal crystals 1/10 to 2/10 mm. in diameter are scattered throughout the slide.

Porosity occurs as smooth-sided pores 1 to 3 mm. in diameter which cut across fragments and matrix.

No detrital quartz is present.

Sample 11 (Northeast end of Anacacho Mountains, 44 feet above *Exogyra ponderosa* ledge.)

Very pale orange (10 YR 8/2), soft massive chalk. Sawed surface shows faint bedding. Bedding is brought out by slight difference in grain size and porosity. Rock consists of soft calcareous fragments and calcite crystals less than 1/10 mm. in diameter in a soft, chalky matrix. A few scattered quartz grains less than 1/10 mm. in diameter are present. No recognizable organic structures are present.

Rock is extremely porous. Pores are mostly round in cross section and are lined with a white, dusty chalk coating. Pore spaces range in diameter from 1/10 to 1 mm.

Sample 12 (Northeast end of Anacacho Mountains, 6 feet above Exogyra ponderosa ledge.)

Dark yellowish orange (10 YR 6/6), massive, friable, sandy marl. Sawed surface shows no bedding. The rock consists of 1/10 to 1/2 mm. white shell fragments in a dark yellowish-orange, chalky matrix. The shell fragments are mostly tabular in shape but show no alignment. The matrix and shell fragments are about equal in abundance. A few scattered quartz grains less than 1/4 mm. in diameter are present.

Visible porosity occurs as 1/4 to 1/2 mm. wide channels. The walls of the channels are smooth and are coated by a thin layer of clay. The clay coating shows dessication cracks. The shell fragments protrude into the channels. The chalky matrix is apparently very porous as the rock absorbs considerable water when wet.

Sample 13 (Northeast end of Anacacho Mountains, 125 feet below Exogyra ponderosa ledge.)

Dark yellowish-orange (10 YR 6/6), brittle, fine-grained, massive, limestone.

Sawed surface shows no bedding but shows rock to be slightly porous. Pores do not exceed 1/2 mm. in diameter.

Thin section shows fragments not exceeding 1/10 mm. in diameter in fine-grained matrix. Many fragments are recrystallized and show good cleavage.

Scattered grains of transparent, light yellow, cryptocrystalline "glauconite" with a dark green interference color are present.

No quartz is present.

Sample 14 (Bed of San Geronimo Creek 600 feet upstream from Farm Road 471 bridge. Stratigraphic position within Anacacho not known.)

Pale yellowish-brown (10 YR 6/2), tough, thickbedded, fragmental limestone. Bedding is prominent on a sawed surface. The bedding is brought out by alignment of shell fragments. The rock consists of shell fragments 1/2 to 20 mm. in length in a fine-grained, chalky matrix. Matrix is subordinant in amount to shell fragments. Chalk-filled foraminiferal tests are common.

A few scattered "glauconite" pellets ranging up to 1/2 mm. in diameter are present. Hard, irregularly shaped limonite grains ranging in diameter up to 1/2 mm. are common. Present porosity is limited to 1/4 to 1/2 mm. cavities adjacent to the limonite grains.

Relic, chalk-filled pores up to 10 mm. in width are present. Relic pores cut across shell fragments and matrix.

Sample 15 (Bank of Seco Creek north of D'Hanis, top of Anacacho limestone.)

Massive, grayish-orange (10 YR 7/4), fine-grained argillaceous limestone. Bedding is faintly visible on sawed surface, brought out by slight changes in color and alignment of the few large shell fragments. The rock consists of a mesh of fibrous calcite crystals ranging up to 1/2 mm.

in length in a chalky matrix. The matrix is subordinate in amount to the crystals. A few shell fragments up to 10 mm. in length are present. Some of the shell fragments are partially to entirely replaced by limonite. Porosity is present as channels 1/4 to 1/2 mm. in diameter. The walls of the channels are coated by a film of chalky material, and some have a drusy coating of calcite crystals.

Sample 16 (Bank of Seco Creek north of D'Hanis, 18 feet below the top of the Anacacho limestone.)

Grayish-orange, massive, fine-grained, argillaceous limestone. Sawed surface shows faint bedding brought out by the distribution of "glauconite". The rock consists predominantly of shell fragments and fibrous calcite crystals 1/2 to 1 mm. in length in a chalky matrix with a few larger shell fragments ranging up to 10 mm. in length. "Glauconite" pellets 1/10 to 1/2 mm. in diameter are abundant. A limonite concretion 3 mm. in diameter containing relic shell fragments is present. Visible porosity includes 1/4 to 1/2 mm. chalk-lined channels. The matrix is apparently very porous, as the rock absorbs a considerable amount of water.

Relic porosity is present as 1/2 to 1 mm. channels filled by fibrous calcite.

Sample 17 (Bank of Seco Creek north of D'Hanis, 44 feet below top of Anacacho limestone.)

Yellowish-gray (5 Y 8/1), tough, massive, very fine-grained limestone. Sawed surface shows no bedding. The rock consists of scattered shell fragments 1/4 to 1/2 mm. in length in a matrix of very fine-grained calcite. A few scattered "glauconite" and limonite grains less than 1/4 mm. in diameter are present. No visible porosity is present, and the rock absorbs very little water.

Sample 18 (Bank of Seco Creek north of D'Hanis, 50 feet below the top of Anacacho limestone.)

Medium dark gray (N4), tough, massive, coarse-grained, fragmental, asphaltic limestone. Sawed surface shows bedding brought out by alignment of shell fragments and faint variations in color. The rock consists of poorly-sorted shell fragments ranging up to 15 mm. in length in a matrix of coarsly crystalline calcite. Porosity is present as molds of shell fragments.

Most of the pores are filled or partly filled with asphalt. The asphalt near the weathered surface has a dull, earthy luster and crumbles easily. The asphalt away from the weathered surface has a bright, vitreous luster and is semisolid. Pores which contain no asphalt are lined with chalky material.

Sample 19 (Bank of Blanco Creek north of T. & N. O. railroad, 24 feet below the base of "volcanic" beds.)

Medium yellowish-orange (10 YR 7/6), massive, argillaceous, fragmental limestone. The sawed surface shows no bedding. The rock consists of approximately 50% echinoid spines ranging up to 20 mm. long and 2.5 mm. in diameter. Other fragmentary material includes curved shell fragments and a few foraminifera. The matrix is very fine-grained and chalky. Portions of a few of the echinoid spines are replaced by silica. The silica appears very dark gray in reflected light and is translucent.

A few scattered grains of "glauconite" ranging up to 1/4 mm. in diameter are present. A few scattered grains of limonite ranging up to 1/2 mm. in diameter are also present.

The rock is extremely porous. Observed porosity includes channels ranging up to 10 mm. wide and visibly continous for as much as 30 mm. The channels cut across shell fragments and matrix and their walls are smooth and chalk-lined. Some foraminiferal tests are unfilled. Some relic, chalk-filled channels are present. (The amount of observed porosity in this specimen that is actually relic porosity is undetermined. Washing the sawed surface with water obviously removed a considerable amount of the chalky channel filling.)

<u>Sample 20</u> (Bank of Blanco Creek north of T. & N. O. railroad, top of ledge at base of "volcanic" beds.)

Moderate yellowish-brown (10 YR 5/4), tough, massive, fragmental limestone. Faint bedding, brought out by alignment of shell fragments and slight variations in grain size, is shown on the sawed surface. The rock consists of unsorted shell fragments in a chalky matrix. The matrix is minor in amount. Echinoid spines predominate among the shell fragments. Bryozoan fragments are abundant. Portions of some echinoid spines are replaced by silica. A very few "glauconite" pellets less than 1/10 mm. in diameter are present. Portions of the matrix consist of transparent, crystalline calcite.

Visible porosity consists of unfilled bryozoan chambers and smooth-walled channels up to 1 mm. in width. The channels cut across shell fragments and matrix. All of the channels contain some chalk or clay. Some relic channels filled with chalk, clay, and transparent calcite are present. Some of the clay in the channels swells when wet. (The amount of observed porosity in this specimen that is actually relic porosity is undetermined. Washing the sawed surface with water obviously removed a considerable amount of the chalky channel filling.)

Sample 21 (Bank of Blanco Creek north of T. & N. O. railroad, 3 feet above top of "volcanic" beds.)

Dark grayish orange (10 YR 6/4), tough, massive, fragmental, asphaltic limestone. Sawed surface shows faint bedding brought out by alignment of shell fragments and slight variations in grain size. The rock consists of shell fragments not exceeding 2 mm. in length in a matrix of crystalline calcite. Some of the shell fragments are replaced by silica. Foraminiferal tests and bryozoan fragments are abundant.

Present porosity is limited to a few channels, ranging up to 1 mm. in diameter, which have smooth walls and cut across the shell fragments and matrix. Relic chalk-filled channels ranging up to 2 mm. in diameter are abundant. Asphalt is present as impregnations of the matrix, as fillings of relic channels, and as a coating on the walls of relic channels.

The asphalt is black, has a dull earthy luster, crumbles easily, and is soluble in gasoline.

Sample 22 (Bank of Blanco Creek north of T. & N. O. railroad, 72 feet above top of "volcanic" beds.)

Grayish-orange (10 YR 7/4), tough, massive, fragmental, asphaltic limestone. Rock consists of shell fragments less than 1 mm. in length and fibrous calcite crystals cemented with transparent calcite. No bedding is apparent on the sawed surface. No organic structures are recognizable. The rock is streaked by limonite stains. A trace of asphalt is present in the rock. The asphalt is black, has a dull earthy luster, crumbles easily, and is soluble in gasoline.

The rock is very porous, with channels ranging up to 4 mm. in width. The channels cut across fragments, crystals, and cement.

Sample 23 (White's Uvalde Mines pit, 6 feet above floor of pit.)

Medium light gray (N6), tough, massive, fragmental, asphaltic limestone. Bedding is prominently shown on the sawed surface. The bedding is brought out by variations in grain size and asphalt content, and by alighment of shell fragments. The rock consists of shell fragments up to 5 mm. in length in a matrix of asphalt. The shell fragments are predominantly elongate and curved, but bryozoan fragments and foraminiferal tests are abundant.

Some of the bryozoan chambers and foraminiferal tests are filled with chalk, but most are unfilled; none contain asphalt. Channels up to 1 mm. wide cut through the shell fragments. Some of the channels are coated with asphalt, which has a smooth surface with a vitreous luster. Other channels have no asphalt coating. The asphalt is black, semisolid, and tenacious. Some of the shell fragments are stained brown by the asphalt, but most are chalky white.

Sample 24 (White's Uvalde Mines pit, 30 feet above the floor of the pit.)

Dark yellowish-gray (5 Y 7/1), tough, massive, fragmental, asphaltic limestone. Bedding is faintly shown on the sawed surface brought out by alignment of shell fragments. The rock consists of well sorted shell fragments not exceeding 2 mm. in length in a chalky, asphaltic matrix. Most of the shell fragments are curved and elongate. A few foraminiferal tests are present. The foraminiferal tests are unfilled. A few "glauconite" pellets less than 1/4 mm. in diameter, and a few quartz grains less than 1/2 mm. in diameter are present. Some of the curved shell fragments are "apparently replaced" by asphalt.

Asphalt coated channels up to 1/2 mm. in diameter are present. The asphalt coating has a smooth surface with a vitreous luster.

The asphalt is black, semisolid, and tenacious. Some of the shell fragments are stained brown by the asphalt, but most are chalky white.

Sample 25 (White's Uvalde Mines pit, 40 feet above floor of pit.)

Very light gray (N 8), tough, massive, very fine-grained limestone. Polished surface shows no bedding, but shows a myriad of hair-like fractures which are aligned sub-parallel to horizontal. The fractures appear to pass around the few large shell fragments rather than through them. The fractures are straight to slightly curved in gross aspect, but appear crenulated in detail. The crenulations average 1/10 mm. in amplitude and distance between crests.

The rock consists of shell fragments 1/10 to 1/2 mm. in length, with a few shell fragments ranging up to 10 mm. The fragments are cemented in clear, crystalline calcite. A few foraminiferal tests and bryozoan fragments are present. Some shell fragments are replaced by clear, crystalline calcite. Present porosity occurs as a few unfilled foraminiferal tests and as channels 1/10 to 1 mm. wide and visibly continuous up to 30 mm. Asphalt is present as channel fillings up to 2/10 mm. in diameter and in some of the hair-like fractures.

Sample 26 (White's Uvalde Mines pit, 48 feet above floor of pit.)

Tough, massive, fragmental limestone showing contact between asphaltic and nonasphaltic rock. The nonasphaltic portion is very pale orange (10 YR 8/20), and the asphaltic portion is light olive gray (5 Y 6/1). Bedding is shown prominently on the sawed surface. The contact of the asphalt cuts across the bedding. The bedding is brought out by the alignment of shell fragments and slight variations in grain size.

The rock consists of shell fragments in a chalky matrix. The chalky matrix is saturated with asphalt in the asphaltic portion. The shell fragments are well sorted and are mostly about 1/2 mm. in length. A few scattered grains of "glauconite" less than 1/10 mm. in diameter are present. A few grains of quartz about 1/2 mm. in diameter are also present. Anhedral grains of pyrite occur in the asphaltic portion.

Present porosity exists as channels 1/10 to 2 mm. in diameter. The channels have smooth walls and are much more abundant in the non-asphaltic portion.

<u>Sample</u> <u>27</u> (White's Uvalde Mines pit, 61 feet above floor of pit.)

Pyritiferous, cross-laminated siltstone. The rock consists of calcareous laminae 1/2 to 1 mm. thick and pyritiferous clay laminae 5 to 10 mm. thick. The calcareous laminae are yellowish-gray (5 Y 7/2) and the clay laminae are greenish-gray (5 GY 4/2). The calcareous laminae are made up of shell fragments and calcite crystals less than 1/10 mm. in diameter. The clay laminae contain pyrite crystals ranging up to 1/10 mm. in diameter. The clay laminae contain as much as 25% pyrite in places. The pyrite occurs in anhedral, tabular, and cubic grains. A few calcareous grains are scattered throughout the clay laminae. Quartz grains less than 1/10 mm. in diameter are present in both the calcareous and clay laminae.

The laminae show truncation and cross-bedding and are greatly contorted in places.

<u>Sample</u> <u>28</u> (White's Uvalde Mines pit, 79 feet above floor of pit.)

Medium gray (N 5), tough, massive, asphaltic, fragmental limestone. The rock is flexible and tenacious. The rock consists of well-sorted shell fragments 1/2 to 1 mm. in length in a matrix of asphalt. Most of the shell fragments are elongate and curved. Foraminifera are abundant.

The sawed surface shows no bedding.

A few anhedral grains of pyrite less than 1/2 mm. in diameter are present in the asphalt matrix and replacing shell fragments.

Porosity occurs as asphalt-coated channels 1/4 to 1 mm. in diameter, and as spherical voids less than 1/4 mm. in diameter in the asphalt. A few unfilled foraminiferal tests are present. The surface of the asphalt in the pores is smooth and has a vitreous luster.

Most of the shell fragments are stained around the edges with asphalt.

<u>Sample</u> <u>29</u> (White's Uvalde Mines pit, 97 feet above floor of pit and 6 inches above top of asphalt).

Pale yellowish-brown (10 YR 7/2), dense, tough, massive, fine-grained limestone. The sawed surface shows no bedding. The rock consists of well-sorted shell fragments less than 1/4 mm. in diameter in a matrix of clear, crystalline calcite. A few anhedral grains of limonite ranging up to 1 mm. in diameter are present.

Porosity is limited to a few smooth-walled channels 1/4 to 1 mm. in diameter. Some of the channels are lined with a layer of banded calcite.

Sample 30 (White's Uvalde Mines pit, 106 feet above floor of pit and 9 feet above top of asphalt).

Pale yellowish-brown (10 YR 7/2), dense, very tough, fragmental limestone. Bedding is prominently shown on the sawed surface, brought out by alignment of shell fragments and variation of grain size. The rock consists of elongate shell fragments ranging from 1 to 20 mm. in length in a matrix of clear, crystalline calcite. No porosity is visible in the rock.

Sample 31 (Bed of Portrano Creek north of U. S. Highway 90. Top of Anacacho limestone).

Pale yellowish-brown (10 YR 6/2), tough, massive, fragmental limestone. The sawed surface shows bedding faintly. The bedding is brought out by alignment of shell fragments. The rock consists of unsorted shell fragments, ranging from less than 1/10 mm. to 30 mm. in length, set in a chalky matrix. Irregular, hair-like fractures aligned subparallel to the bedding are shown on the sawed surfaces. The fractures appear to be chalk-filled.

Some shell fragments are replaced by crystalline calcite and some are "apparently replaced" by asphalt. The asphalt is black and crumbles easily. It is soluble in gasoline.

Sample 32 ("Volcanic" from Blanco Creek)

Pale greenish-yellow (10 GY 6/4), soft friable clay The rock consists of angular dark green clay fragments resembling phenocrysts in a pale greenish-yellow clay matrix. The angular fragments are 1/2 to 2 mm. across and make up approximately 30% of the rock. Bedding is brought out by variations of grain size and by variations of the proportion of fragments to the matrix.

The rock is intensely fractured and crumbles easily.

Sample 33 (Uvalde Rock Asphalt Company pit, 15 feet above floor of pit).

Tough, massive, fragmental limestone showing the contact between asphaltic and nonasphaltic rock. The asphaltic portion of the rock is medium dark gray and the nonasphaltic portion is very pale orange (10 YR 8/2).

Bedding is shown on the sawed surface, brought out by alignment of shell fragments. The contact between the asphaltic and nonasphaltic rock clearly cuts across the bedding. The rock consists of poorly sorted shell fragments, ranging in length from 1/10 to 3 mm., in a matrix of chalk. Most of the shell fragments are elongate and curved. A few bryozoan fragments and foraminiferal tests are present.

The asphalt occurs as a coating on the shell fragments. The surface of the asphalt is smooth, concave, and has a vitreous luster.

Present porosity includes asphalt coated pores and channels, spheroidal voids in the asphalt, and a few unfilled foraminiferal tests.

The asphalt is balck, semisolid, and yields plastically under a steady force, but breaks with a conchoidal fracture under a sudden force.

A few anhedral grains of pyrite less than 1/10 mm. in diameter are present in the asphaltic portion of the rock.

Sample 34 (Uvalde Rock Asphalt Company pit, 15 feet above floor of pit).

Tough, massive, fragmental limestone showing contact between asphaltic and nonasphaltic rock. The asphaltic part of the rock is medium dark gray (N4), and the nonasphaltic part of the rock is very pale orange (10 YR 8/2).

Bedding, brought out by alignment of shell fragments and sharp variations in grain size, is prominent on the sawed surface. The contact between the asphaltic and nonasphaltic rock clearly cuts across the bedding planes.

The rock consists of unsorted shell fragments, ranging from 1/10 to 40 mm. in length in a matrix of transparent, crystalline calcite and asphalt. Most of the shell fragments are elongate and curved, but bryozoan fragments and foraminiferal tests are very abundant.

The asphalt occurs as a coating on the shell fragments and on the walls of channels. The channels are 1/4 to 2 mm. wide. The surface of the asphalt is smooth, concave, and has a vitreous luster. Spheroidal voids are present in the asphalt.

Present porosity includes the asphalt-coated channels and pores, unfilled foraminiferal tests adn bryozoan chambers, and a few channels with no asphalt. Most of the foraminiferal tests and bryozoan chambers in the rock are unfilled, although some are chalk-filled and a very few contain asphalt.

The asphalt is black, semisolid, and yields plastically under a steady force, but breaks with a conchoidal fracture under a sudden force.

A few curved shell fragments are "apparently replaced" with asphalt.

"Glauconite" is present as a few scattered pellets less than 1/10 mm. in diameter.

Sample 35 (Uvalde Rock Asphalt Company pit, 15 feet above floor of pit).

Tough, massive, fragmental limestone showing contact between asphaltic and nonasphaltic rock. The asphaltic part of the rock is medium dark gray (N4) and the nonasphaltic part of the rock is very pale orange (10 YR 8/2).

Bedding is shown on the sawed surface, brought out by alignment of shell fragments and sharp variations in grain size. The contact between the asphaltic and nonasphaltic rock clearly cuts across the bedding planes.

The rock consists of poorly sorted shell fragments, ranging in length from 1/4 to 4 mm., in a matrix of chalk and asphalt. The shell fragments are mostly elongate and curved, but foraminiferal tests and bryozoan fragments are present.

The asphalt occurs as a coating on the shell fragments and on the walls of channels. The channels are less than

1/4 mm. in diameter. The surface of the asphalt is smooth, concave, and has a vitreous luster.

Present porosity includes the asphalt-coated channels and pores, unfilled foraminiferal tests and bryozoan chambers, and a few channels with no asphalt. Most of the foraminiferal tests and bryozoan chambers in the rock, however, are filled with chalk.

The asphalt is black, semisolid, and yields plastically under a steady force, but breaks with a conchoidal fracture under a sudden force.

"Glauconite" is present as a few scattered pellets less than 1/10 mm. in diameter. The asphaltic portion of the rock contains a few anhedral grains of pyrite which are less than 1/10 mm. in diameter.

<u>Sample 36</u> (Boulder in "volcanic" beds 300 yards north of T. & N. O. Railroad bridge on Blanco Creek).

Very dark gray (N2), hard, dense, olivine basalt porphyry. Phenocrysts make up approximately 10% of the rock. Approximately 10% of the phenocrysts are augite crystals ranging up to 20 mm. in length. Most of the augite phenocrysts are less than 2 mm. in length. Poikilitic magnetite in grains up to 1/20 mm. in diameter are abundant in zones along the margins of the augite phenocrysts. Some of the augite phenocrysts show zoning brought out by variations in the extinction angles.

Approximately 90% of the phenocrysts are euhedral olivine crystals which range up to 1 mm. in length. The olivine phenocrysts have kelyphitic rims of antigorite and, in a few places, iddingsite.

Tabular labradorite crystals ranging up to 0.05 mm. in length, equant magnetite grains up to 0.03 mm. across, and intersertal glass make up the groundmass. The approximate composition of the groundmass is labradorite, 85%; magnetite, 5%; and glass, 10%.

LOG OF TEXAS HIGHWAY DEPARTMENT WELL R-1

(Cuttings described by Dr. Frank Welder)

35	Limestone, light brown, medium-to coarse-grained, hard, pelecypod-coquina, glauconitic
35-45	do.
45-55	Hit shale at 52'; limestone, light brown, medium- to coarse-grained hard, pelecypod-coquina, glauconitic, and clay, dark blue, "clean", not tenacious*
55-65	Asphalt rock at 56'; limestone, white, medium- to coarse-grained, hard, pelecypod-coquina, saturated with black asphalt
65-75	do.
75-85	do.
85-95	do.
95-105	do. (finer grained)
105-115	Bottom of asphalt at 107'; clay, light green, slightly tenacious, calcareous*
115-125	Clay, light green, many calcareous fragments*
125-135	do.*
135-145	do.* and 15% limestone, rusty brown, ferruginous
145-155	Clay*, light green, many calcareous fragments and some limestone, rusty brown, ferruginous and limestone, dark gray, fine- to medium-grained, hard
155-165	Clay, light green, many calcareous fragments*
165-175	do.* with trace of gray and pink limestone
175-185	Clay, light green, calcareous fragments and limestone (at 185'), with trace limestone, rusty brown
185-195	Limestone, white, medium-grained, trace of pyrite, asphaltic
195-205	do. (no pyrite)
205-215	do.
215-225	Marl, white, with black asphaltic specks and calcareous fragments

* may be bentonitic

225-235	Clay, light green, calcareous fragments
235-245	do. (trace of asphalt)
245-255	Clay, greenish-gray, calcareous
255-265	Clay, greenish-gray, calcareous and limestone, gray, medium-grained, calcareous shell fragments, slightly asphaltic
265-275	Limestone, gray, medium-grained, calcareous shell fragments, trace asphalt
275-285	Clay, greenish-gray, calcareous, with some limestone, rusty red and limestone, gray, medium-grained
285-295	Clay, bluish-gray, calcareous and limestone, bluish-gray, fine- to medium grained, hard with trace of brown limestone
295-305	Limestone, dark gray, medium-grained, pelecypod-coquina, trace of asphalt with trace of limestone, rusty brown and trace of clay, blue-gray
305-315	Limestone, dark gray to light gray, fairly asphaltic
315-325	Limestone, cream-colored, medium-grained with trace of asphalt to saturated with asphalt
325-335	do. (very high asphalt content)
335-345	Limestone, gray, medium-grained, pelecypod-coquina, slightly asphaltic
345-355	Limestone, gray, medium-grained, pelecypod-coquina and limestone, white, medium- to coarse-grained, pelecypod-coquina, asphaltic
355-365	Limestone, white, medium-grained, pelecypod-coquina, asphaltic with trace of caly, rusty brown
365-375	Limestone, gray, medium-grained, pelecypod-coquina, slightly asphaltic
375-385	Clay, greenish-gray and limestone, bluish-gray, fine-grained
385-395	Clay, greenish-gray with some limestone, rusty brown and trace of pyrite
395-405	Clay, gray with some limestone, gray and trace of pyrite
405-415	Clay, greenish-gray, slightly calcareous, some limestone, rusty red, and one piece of white calcite

415-425	Clay, greenish-gray, slightly calcareous and limestone, gray, asphaltic with trace of blue clay, firm
425-435	Clay, greenish-gray and clay, bluish-gray with some limestone, brown, asphaltic, firm, friable
435-445	Limestone, brown, asphaltic, firm, friable
445-455	Clay*, yellow-green, with black specks and limestone, dark brown, fine-grained
455-465	Limestone, gray, medium-grained, pelecypods
465-475	do.
475-485	do. (also some blue shale and pieces of pyrite)
485-495	Same as 455-465--gray limestone, asphaltic
495-505	Shale*, blue and limestone, white, medium-grained, pelecypods
505-515	Limestone, white, medium-grained, pelecypods
515-525	do.

544-554	Limestone (fine cuttings), medium-grained, gray to white, pelecypods with black specks and trace of limestone, rusty brown
554-564	Limestone, gray to white, medium-grained, with black specks, chalky
564-574	do.
574-584	do.
584-594	do.
594-604	chalk

* slowly disintetrates in water

INSOLUBLE RESIDUES FROM 100 GRAM SAMPLES

Sample No.	Wt. of residue in grams	Mineral	Est. % residue	Grain size in mm.	Remarks
1	less than 1	limonite	90	1/10 to 1/2	Pseudomorphs after pyrite
		quartz	9	1/10 to 1/2	Angular, detrital grains
		muscovite	1	1/10 to 1/4	
		biotite	trace	1/4	
7	less than 1	"glauconite"	100	1/20 to 1/10	
		quartz	trace	1/20 to 2/10	Angular, detrital grains
8	10	"glauconite"	100	1/2 to 1	
		quartz	trace	1/20 to 1/10	Angular, detrital grains
11	less than 1	quartz	98	1/20 to 1/10	Angular, detrital grains
		chert	2	1/20 to 1/10	Angular, detrital grains
		garnet	trace	1/10	
12	2	quartz	90	1/10 to 2	Angular, detrital grains
14	less than 1	"silica"	50	1/2 to 3	Silicified shell fragments
		"glauconite	30	1/2 to 1	
		quartz	20	1/20 to 1/10	Angular detrital grains
		muscovite	trace	1/10	
21	3.3	chalcedony	95	1 to 4	Clusters of 1/10 to 2/10 mm. spheroidal aggregates
		"glauconite"	5	1/2 to 2	
		quartz	trace	1/20 to 1/10	Angular, detrital grains