GEOLOGY OF THE LAVON AREA, COLLIN COUNTY, TEXAS

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I. ABSTRACT

The Lavon area, in southeastern Collin County, Texas, includes approximately 35 square miles. The rocks are of Cretaceous and Cenozoic age.

Cretaceous rocks are represented by the marine Taylor Formation, here divided on the basis of chemical and physical characteristics into four members: siltstone, lower marl, glauconitic limestone, and upper marl, named in ascending order.

The siltstone consists mostly of dark gray silt, and averages approximately 20 per cent solubles. The lower marl, the base of which is marked by a thin zone of irregular phosphatic nodules, is a pale brown, calcareous clay averaging about 55 per cent solubles. A disconformity separating the siltstone and lower marl is interpreted as a minor stratigraphic break of submarine origin. The glauconitic limestone is a very pale brown, sandy, and glauconitic fragmental rock that averages approximately 65 per cent solubles. The upper marl is similar in lithology to the lower marl but averages 47 per cent solubles. A hard, light gray layer of limestone occurs in the upper portion.

Tentatively, the siltstone is correlated with the Wolfe City member of the Taylor Marl. The overlying lower marl and glauconitic limestone members presumably are the equivalent of the Pecan Gap Chalk though radically different in lithology.

The Cenozoic strata are fluvial deposits in terraces and floodplains. The alluvium is composed mostly of clay and silt with subordinate amounts of pebble gravel.

In the Cretaceous sequence the attitude of bedding can be determined at only a few localities. The siltstone and glauconitic lime-

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stone members strike NNE, and even though slight steepenings occur locally, the average dip probably is less than one degree toward the east.

Joints are abundant in the Cretaceous rocks, especially in the lower marl. Several sandstone dikes, similar to those near Rockwall, Texas, cut the upper marl.

II. Introduction

The Lavon area, Collin County, Texas, (fig. 1) measures approximately 35 square miles. The area drains southward through the East Fork of the Trinity River, a sluggish perennial stream with intermittent tributaries. The total relief is 181 feet. Elevations range from 439 feet above sea level along the East Fork in the southern part of the area, to 620 feet in the upland north of the town of Nevada. Slopes rise gently from the floodplains to rolling uplands. The only steep slopes are along recent gullies.

Along East Fork and Pilot Grove Creek, levees have been constructed to prevent flooding of the bottom land. Construction of the Lavon Dam on the East Fork north of the St. Louis and Southwestern Railroad crossing was begun in 1948 and completed in 1953. The mapping of the Lavon area was completed in 1948 before the Lavon Reservoir filled up with water. The artificial lake has concealed part of the map area (pl. I). The dam controls floodwaters and provides water to surrounding towns, farms, and ranches.

There is no published account of detailed geological studies in the Lavon area, although there are several reports on the regional geology. Hill (1901) described the Cretaceous rocks in the Black and Grand Prairies of Texas, and Stephenson (1918) published an account of the stratigraphy of northeastern Texas. Stratigraphic reports by Dane and Stephenson (1928) and Stephenson (1929) include references to the Lavon area. Goldberg (1948) has mapped the area north of the Lavon area, and Clement (1950) the area to the southeast.

The Lavon area was mapped in detail (see pl. I). In the stratigraphic discussion emphasis is placed on the lithology of the Taylor beds. Mapping was done on aerial photographs with a scale of approximately 3 inches to 1 mile. A sketchmaster was used to transfer the contacts to an enlarged topographic base map adapted from the McKinney topographic sheet.

This study is part of a broader program of studies on the Upper Cretaceous stratigraphy and areal geology of northeastern

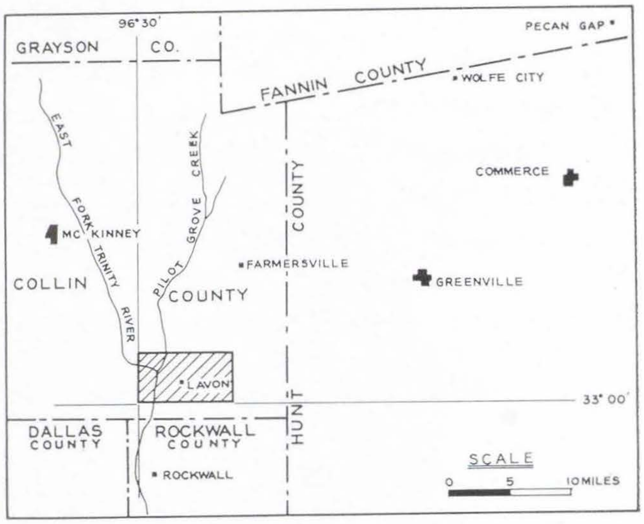

Figure 1. Map of a portion of northeastern Texas showing the location of the Lavon area (ruled section).

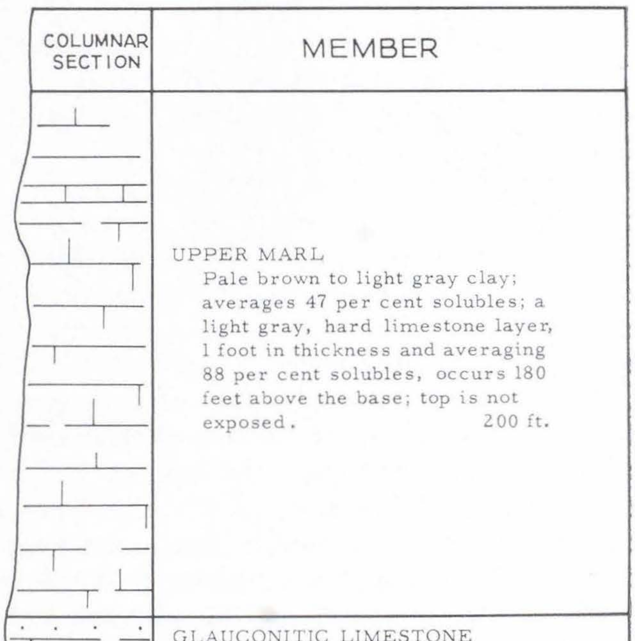

Figure 2. Generalized columnar section of the Taylor Formation in the Lavon area, Collin County, Texas.

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III. Stratigraphy

Upper Cretaceous Rocks

Taylor Formation

The Cretaceous rocks in the Lavon area are part of a sequence, first known as the "Blue Bluffs division" or "*Exogyra ponderosa* marls," and later named "Taylor marl" by Hill (1892, p. 73). It lies between the Austin and Navarro formations and is estimated (Stephenson, 1918, p. 154) to be 500 to 600 feet thick in northeastern Texas. Stephenson *(loc. cit.)* states that the Taylor of northeast Texas is chronologically equivalent to only the upper part of the formation at its type locality in Williamson and Travis counties.

In the Lavon area the Taylor is mostly concealed by alluvium or soil. The best exposures are in gullies and artificial excavations, and the more enlightening of these localities have been numbered on Plate I.

On the basis of chemical and physical characteristics, that portion of the formation which crops out in the Lavon area is divided into four members: siltstone, lower marl, glauconitic limestone, and upper marl (see fig. 2).

Siltstone—The siltstone member, which contains particles ranging in size from fine sand to clay with silt predominant, is when wet, dark gray and plastic, and when dry, light brownish gray. This member is somewhat sandy, and commonly shows shaly parting. In places it is fossiliferous, containing *Exogyra ponderosa* Roemer, poorly preserved baculitids, small pelecypods, and gastropods. The soluble content of eighteen samples tested ranged from 11 to 31 per cent and averaged 21 per cent.

The member crops out at only two places within the area. At locality 1, there are exposed ten to fifteen feet of light brownish gray, indistinctly bedded siltstone, containing scattered *Exogyra ponderosa.* Three feet of dark gray siltstone are present at locality 2, with *Exogyra ponderosa* scattered on the surface. The maximum thickness of 15 feet was measured along Bear Creek at locality 1. The base of the siltstone is not exposed in the Lavon area.

Two thin-sections from locality 1 showed scattered, irregular grains of quartz and calcite embedded in an extremely fine-grained, light brownish gray, granular matrix (pl. II, fig. 1). There are several microfossils, including *Heterohelix* and *Globigerina.* Minute grains of an opaque substance present could not be identified.

Lower marl member—The lower marl member is a calcareous clay, medium olive gray on moist fresh exposures but drying pale brown to light gray. It weathers to plastic clay. The thirty samples tested varied from 48 to 66 per cent solubles and averaged 54 per cent. This represents an average of 17 per cent increase in solubles over the siltstone member.

At the base of the member is a two-inch zone of irregularly shaped brown to black phosphatic nodules. These range from a fraction of an inch to 4 inches across, and are oriented with the longest dimensions parallel to the bedding. Associated with the irregular nodules are phosphatized shark teeth and phosphatic casts of gastropods, ammonites, and pelecypods. Many of the nodules contain irregular openings evidently formed by boring organisms. Bryozoans and pelecypods, attached to some of the nodules, show no signs of wear.

The phosphatic zone is clearly exposed at the base of about 10 feet of a light gray marl at localities 1 and 2. Exposures of the overlying marl may be seen in gullies trending eastward at locality 3, where 3 to 5 feet of a very pale brown marl crop out. At locality 4 there are exposed approximately 15 feet of a light gray marl with indistinct bedding. The total thickness of the member is estimated at between 30 and 40 feet.

A thin-section of the lower marl from locality 1 shows foraminiferal tests and scattered, irregular grains of quartz and calcite set in an extremely fine-grained, light gray granular matrix (pl. II, fig. 2).

Two thin-sections of a phosphatic nodule collected from locality 1 reveal that approximately two-thirds of the nodule consists of scattered, extremely irregular quartz grains. The remaining third is composed of a matrix of black, opaque, phosphatic material of unknown composition. Scattered irregular grains of glauconite and calcite and calcite fillings are present (pl. II, fig. 3).

A thin-section of a phosphatic gastropod cast shows abundant, irregular quartz grains embedded in a light brown, fine-grained phosphatic matrix of unknown composition. *Inoceramus* prisms and grains of calcite and glauconite are also present. Scattered minute grains of an opaque substance could not be identified (pl. II, fig. 4).

Relation of the siltstone and lower marl members—At localities 1 (fig. 3a) and 2 the lower marl rests unevenly upon the siltstone with angular discordance of 4 to 5 degrees. The light gray marl fills channels and cracks cut in the underlying light brownish gray siltstone, and irregular fragments of siltstone are set in the light gray marl (fig. 4). The origin of the extremely irregular surface is not known. However, the contact between the two members is clearly one of erosion and indicates a disconformity. Furthermore, the distribution of microfossils at this locality indicate a "faunal break" at the contact (see table I).

Phosphatic nodules, as already described, occur along and immediately above the erosional contact. Such nodules may form where a sea bottom has attained the base level of deposition (Twenhofel, 1939, p. 475). Teal (1900, p. 382) states that:

> " . . . phosphatic nodules represent long periods of time," and that "they occur in areas of minimum sedimentation, or where the sediment once formed has been subsequently removed by submarine erosion, probably not long after its accumulation."

Both the siltstone and lower marl members were formed under marine conditions as the abundant Foraminiferida attest. However, the erosional contact and the concentration of phosphatic nodules along that surface could indicate either subaerial or submarine conditions during the hiatus.

Stephenson (1929, p. 1331) refers to the "unmistakeable unconformity" one half mile south of Lavon (loc. 1). According to Stephenson, an "unconformity" indicates the following succession of events: (1) uplift of a sea bottom, (2) subaerial erosion of that surface, (3) the sinking of that area, and (4) the continuation of sedimentation.

Figure 3.
a. Contact between the siltstone and lower marl members at locality 1. Arrows denote joints.
b. Glauconite limestone member 2 miles northeast of Lavon.

Twenhofel (1936, p. 696) states that:

> " . . . phosphatic nodules may be allothogenic in the sense that they were released on subaerial weathering from strata in which they were more or less widely scattered, and if such is the case they can have no bearing on the occurrence of a submarine unconformity. On the other hand they may be pene-authigenic in that they developed in the sediments of the bottom and when subsequent conditions lowered the base level of deposition the finer materials were removed and the nodules concentrated. Again, they may be of strictly authigenic deposition with other sediments developed in association moved concomitantly on formation leaving the nodules. A submarine discontinuity exists in the last two cases."

Specific evidence for subaerial conditions, such as terrestrial deposits or soil profiles, is lacking. Delicate features of the phosphatic nodules as well as fossil shells adhering to them would likely be worn or removed under subaerial conditions. They do not show much wear. In fact, there is no reason for supposing that subaerial conditions existed here in lower Taylor time. The microfauna and phosphatic nodules both indicate a marine environment. The irregular surface of unconformity could have been produced by the combined activities of boring organisms and submarine currents working on bottoms built to the profile of equilibrium. During the interval when sedimentation was at a stand-still, the phosphatic nodules grew. When sediments again accumulated, these were incorporated in the base of the lower marl member.

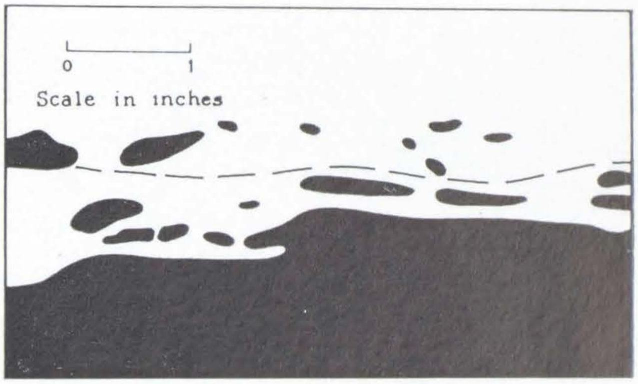

Figure 4. Drawing of the uneven surface between the siltstone (shaded area) and the overlying lower marl members at locality 1. Dashed line represents a weak yellow shaly parting.

Glauconitic limestone member.—This is an indistinctly bedded sandy limestone containing up to 15 per cent glauconite. It is very pale brown on fresh exposures but weathers yellowish. Ten samples tested indicated 58 to 74 per cent soluble matter and averaged 64 per cent. The insoluble fraction is largely of sand-size glauconite and quartz grains with a few grains of brown resinous material of unknown composition. Texturally, this member is a sandstone.

TABLE I

DISTINCTIVE FORAMINIFERIDA IN THE BEDS ABOVE AND BELOW THE UNCONFORMITY

LOWER MARL	
Bolivinoides decorata (Jones)	A
Bolivinopsis rosula (Ehrenberg)	R
Bulimina reussi Morrow	C
Chrysalogonium eximium Cushman	N
Dentalina alternata (Jones)	R
Dentalina fragments	C
Dentalina gracilis d'Orbigny	R
Gaudryina ellisorae Cushman	R
Globorotalia? multiloculata Morrow	R
Globorotalites micheliniana (d'Orbigny)	N
Heterostomella austinana Cushman	R
Lagena sulcata (Walker and Jacob)	R
Loxostomum sp.	C
Nodosaria sp.	R
Stilostomella stephensoni (Cushman)	A
UNCONFORMITY	
SILTSTONE	
Frondicularia sp.	R
Heterohelix carinata (Cushman)	R
Heterohelix globocarinata (Cushman)	N
Marginulina texasensis Cushman	R
Pseudoclavulina sp.	A
Textularia sp.	R

EXPLANATION:
R = Rare, 1-3 C = Common, 8-15
N = Numerous, 3-8 A = Abundant, 15+

Plano-convex objects with chevron markings on the convex side are scattered over the surface near the base of this member. They are weak yellow, vary in length from 1 to 4 inches, and are composed of resistant sandy limestone. Their origin is unknown.

At localities 7 (fig. 3b) and 9, ten to fifteen feet of yellowish gray glauconitic limestone is exposed. Phosphatic pebbles and pebble casts, *Inoceramus* prisms, and specimens of a thin-shelled pelecypod readily weather from the upper portion of these sections. At localities, 5, 6, and 8, one to four feet of yellowish gray, glauconitic limestone, containing scattered phosphatic pebbles, overlie two to three feet of the lower marl member. The very pale brown marl contains poorly preserved baculitids, pelecypods, and gastropods.

The maximum exposed thickness of 15 feet is visible at localities 7 and 9. The total thickness of the glauconitic limestone member in the Lavon area is estimated at 30 feet.

Thin-sections from localities 7, 8 and 9 show abundant irregular grains of quartz and glauconite set in a matrix of calcite. *Inoceramus* prisms, foraminifers, and minute grains of zircon are noted (pl. III, fig. 1). *Globigerina* and *Heterohelix* are the most abundant Foraminiferida present. *Nodosaria* and *Planulina* occur but are rare.

Microscopic examination of a sandstone object showing chevron markings, collected north of locality 5, shows a matrix of calcite

Figure 5. Meander scar in upper marl member in tributary of Bear Creek south of the St. Louis Southwestern railroad.

enclosing larger, abundant, irregular grains of quartz. Scattered grains of glauconite and *Inoceramus* prisms are noted (pl. III, fig. 2). Microfossils present include *Globigerina, Nodosaria, Heterohelix, Planulina,* and ostracods.

Upper marl member.—The upper marl member is lithologically similar to the lower marl member. Thirty samples tested varied from 38 to 56 per cent solubles with a progressive increase toward the southeast. The average solubility is 47 per cent.

At locality 10 (fig. 5), approximately ten feet of very pale brown marl crops out. Other outcrops from 2 to 5 feet thick are exposed in gullies at localities 11, 12, and 13.

The greatest observed thickness of 10 feet is exposed at locality 10. The top of the member is not exposed in the Lavon area. The estimated thickness of the upper marl member is two hundred feet.

A thin-section from locality 10 shows scattered irregular and rounded calcite grains embedded in an extremely fine-grained, light brownish gray, granular matrix (pl. III, fig. 3). Several *Planulina, Heterohelix, Globigerina,* and minute grains of quartz are present. Marcasite occurs in small spheroidal and botryoidal masses.

Toward the southeastern corner of the area, a light gray, hard, massive, limestone layer 10 to 13 inches thick is present in the upper marl. The layer contains scattered large pelecypods, smaller gastropods, and baculitids. The solubility of the limestone layer ranges from 86 to 91 per cent, while the marl above and below varies from 45 to 60 per cent. This layer is typically developed near the junction of two small creeks at localities 14C and 14D. Other exposures may be examined 1.5 miles to the north of these outcrops (locs. 14A & 14B). Nowhere in the Lavon area was the upper marl seen in contact with the underlying glauconitic limestone member.

A thin-section from locality 14B shows that nearly two-thirds of the limestone layer is composed of clay. The remaining third consists of almost perfectly spherical bodies. These peculiar grains are surrounded by a wall of finely granular, crystalline calcite. The center of the cells, though often hollow, commonly is filled with minute calcitic crystals (pl. III, fig. 4). Mrs. Keathley (per-

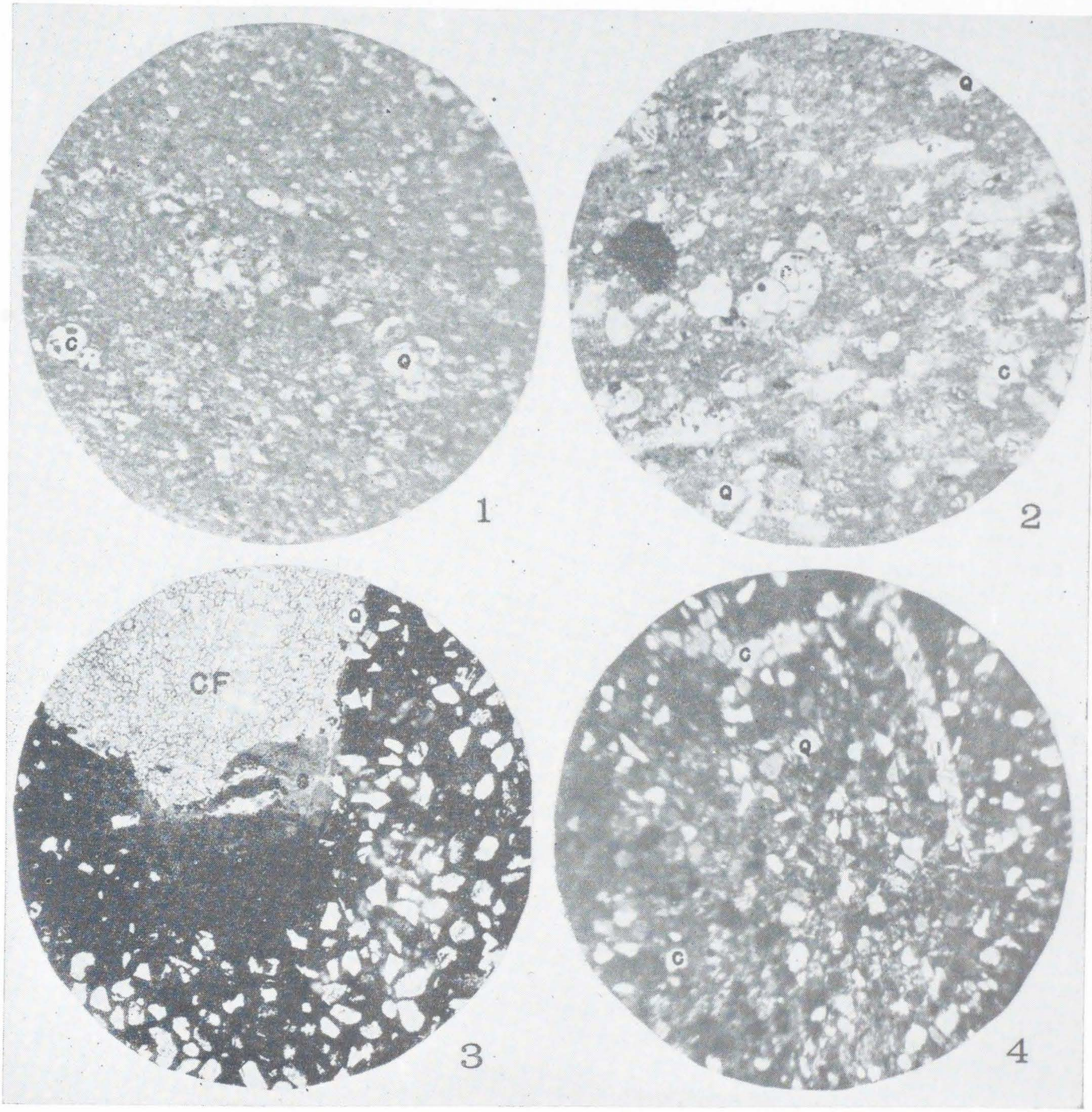

PLATE II. PHOTOMICROGRAPHS

1. Siltstone from locality 1. The clear material, quartz (Q) and calcite (C), is embedded in a dark granular matrix. Ordinary light, X 75.

2. Lower marl from locality 1. The clear material, embedded in a dark-colored matrix, is quartz (Q) and calcite (C). Ordinary light, X 52.

3. Phosphatic nodule from locality 1. The clear, irregular grains, embedded in the black phosphatic matrix, are quartz (Q). Calciite grains (C) are present, and the upper portion, labeled CF, is a calcite filling. Note the patch of glauconite (G) in the end of the filling. Ordinary light, X 30.

4. Phosphatic gastropod cast from locality 1. The clear material, quartz (Q) and calcite (C), is embedded in a dark-colored matrix of phosphatic material. Note the *Inoceramus* prism of calcite (I) in the upper right portion. Polarized light, X 45.

sonal communication) states that these bodies are not Foraminiferida. Tarr (1925, p. 263) identified similar bodies in the English Chalk as chemically formed oölites.

Correlation.—On the State Geologic Map (Darton, *et al.,* 1937) the Taylor Formation in the Lavon area is divided into the lower marl, the Wolfe City Sand, the Pecan Gap Chalk, and the upper marl. The Wolfe City and Pecan Gap members were named by Stephenson (1918, p 154-156) for localities in Hunt and Fannin Counties. Stephenson *(loc. cit.)* states that at its type locality the Wolfe City is a fine calcareous gray sand or sandy marl containing *Exogyra ponderosa* Roemer. The Pecan Gap at its type locality consists of bluish gray, slightly bituminous, more or less argillaceous and sandy chalk, weathering to light gray and white.

Dane and Stephenson (1928, p. 42-43) state that at the type locality of the Pecan Gap Chalk

> " . . . the basal chalk is glauconitic, contains numerous phosphatic nodules, and rests upon the somewhat irregular surface of the top of the Wolfe City Sand. The Wolfe City elsewhere contains irregular beds and lenses of some of these, well within the base of the Pecan Gap."

They further state that, at a point 1.2 miles north of Lavon, the basal Wolfe City is a glauconitic marly sand containing casts of fossils and irregular phosphatic nodules. The "glauconitic marly sand" is undoubtedly the glauconitic limestone of this report. Thus, according to their interpretation, the glauconitic limestone is Wolfe City and the underlying siltstone and lower marl members belong in the "lower marl" as shown on the state map. However, Rouse (1944, p. 525-526) places the contact between the Wolfe City and Pecan Gap in the Farmersville area (fig. 1) along a phosphatic zone at the base of a series of glauconitic limestone beds which are lithologically identical with the glauconitic limestone of this report. By this correlation the glauconitic limestone is Pecan Gap.

In the writer's opinion the only stratigraphic break, that at the base of the lower marl member, is the logical horizon for separating the Wolfe City equivalent from the Pecan Gap equivalent. Tentatively the siltstone is correlated with the Wolfe City Sand. The siltstone member is somewhat sandy, contains *Exogyra ponderosa* Roemer and therefore is similar in important respects to the Wolfe City at its type locality. It would follow that the lower marl and glauconitic limestone members are Pecan Gap time equivalents.

Quaternary Beds

The Quaternary of the Lavon area consists predominantly of terrace and floodplain deposits of the East Fork of the Trinity River and its tributaries. Deposition continues along the present floodplains.

Terrace Deposits—Terrace deposits are present on both sides of the floodplains of the East Fork and Pilot Grove Creek. The particles of the deposits range from pebble size down to clay. There are three good exposures in the Lavon area. At locality 15, a two inch basal pebble conglomerate is overlain by 9 feet of pale yellow sands containing thin pebble lenses. Small patches of a pebble conglomerate may be seen in abandoned gravel pits at localities 16 and 17. Most pebbles are pink to white quartzite of unknown provenance. They could not have been derived from any of the formations over which the East Fork flows. Their immediate origin may well have been terrace deposits stripped from the higher areas.

Floodplain Deposits—The floodplains of the East Fork of the Trinity River and Pilot Grove Creek have average widths of about one mile. The alluvium includes clay, silt, sand, and gravels, essentially the same materials found in the terraces.

Clay galls, along creek bottoms in the eastern part of the Lavon area, consist of fragments of Taylor Marl that have been rolled along the bottoms of gullies, gathering pebbles and sticky marl fragments and building more or less spherical balls up to 8 inches in diameter. Most of them crumble when collected.

IV. Structure

Strike and Dip

At only a few outcrops could the attitude of the beds be determined, as exposures are generally small and dips so gentle that the beds appear to be essentially horizontal. At locality 1 the siltstone strikes N 28° W and dips 3° NE. The glauconitic limestone at locality 7 strikes NNE and dips 2 to 3°. The overall strike appears to be NNE but the average dip could not be determined.

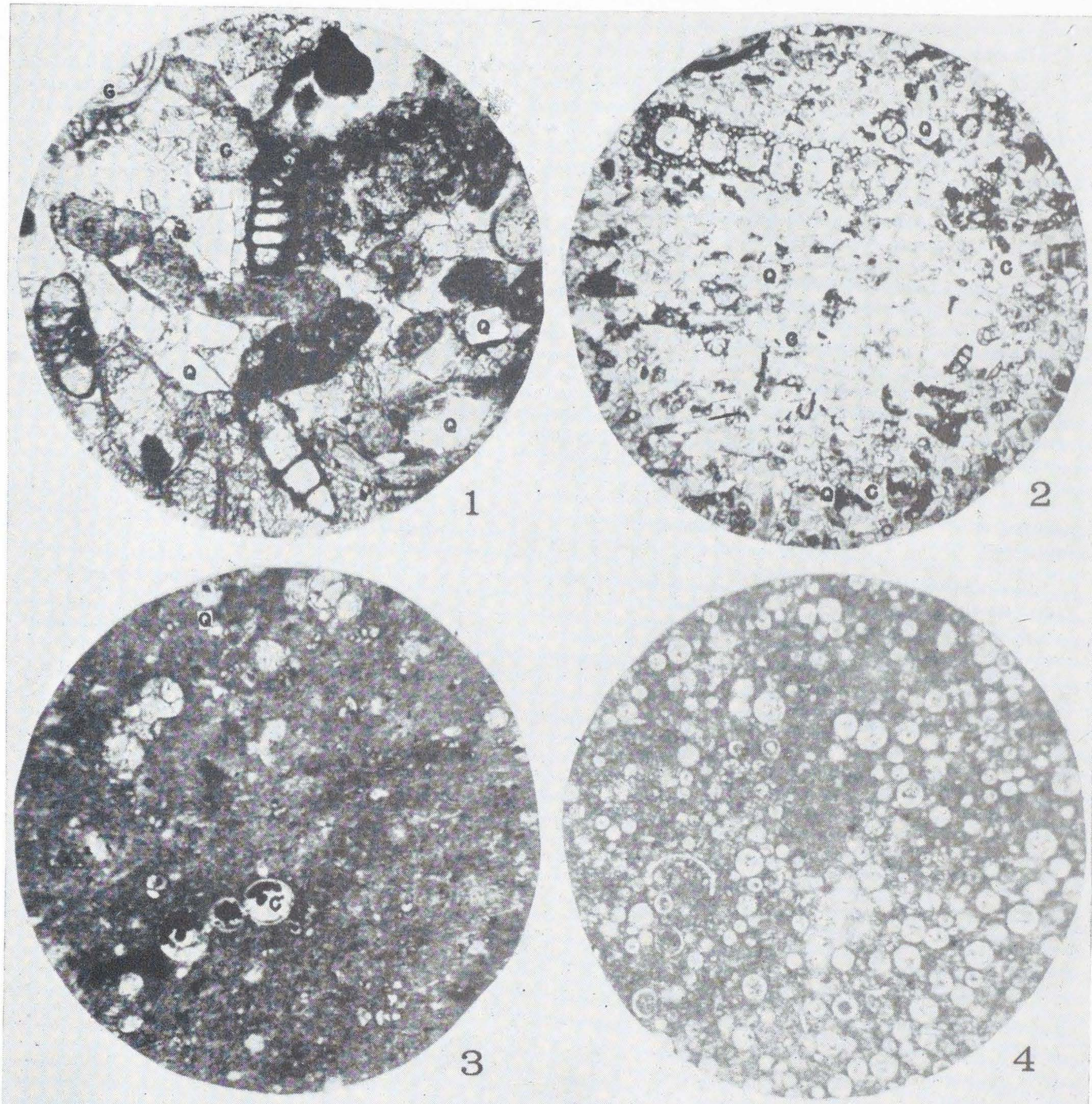

PLATE III. PHOTOMICROGRAPHS

1. Glauconitic limestone from locality 7. The clear material is quartz (Q), and the gray material mainly the matrix of calcite. The darker grains are glauconite (G), while the 6 sided grains are of calcite (C). Note the microfossils in the lower and central portions. The rounded shape in the extreme right portion is a calcite-filled microfossil. Ordinary light, X 60.
2. Sandstone showing chevron markings from north of locality 5. The matrix of calcite encloses the abundant clear grains of quartz (Q) and dark grains of glauconite (G). Note the large microfossil in the upper portion. Ordinary light, X 26.
3. Upper marl from locality 10. The rounded, clear material, calcite (C), and the smaller, irregular grains of quartz (Q) are enclosed by a dark, finely granular matrix. The small, rounded, black opaque material within the larger calcite grains in the lower left portion is marcasite. Ordinary light X 75.
4. Limestone layer from locality 14B. The clear rounded spherical bodies of calcite are embedded in a dark-colored matrix. Ordinary light, X 45.

Joints

Joints are numerous in the Cretaceous rocks of the Lavon area and may be observed at nearly every locality cited in this report. However, they are more common in the lower and upper marl members. Locally, in these members the marl tends to fracture into long rectangular blocks 1 to 3 inches thick on both sides of the joint plane. Many of the joint planes are iron stained and filled with clay and sand particles.

Sandstone Dikes

Several sandstone dikes penetrate the upper marl member. Outcrops are limited to meander scars and deep gullies, but many dike fragments are scattered over the creek and gully bottoms in the eastern part of the area. The dikes vary in thickness from a fraction of an inch to 3 to 4 inches, commonly occurring in pairs, separated by a few feet of marl.

A vertical sandstone dike, striking N 40° E, at locality 10 cuts through the outcrop of marl and can be traced several yards to the south. The marl appears to have slumped downward and toward the dike for approximately 2 feet on both sides.

V. Summary of Conclusions

1. The Taylor Formation in the Lavon area may be divided into four members: siltstone, lower marl, glauconitic limestone, and upper marl.

2. A disconformity exists between the siltstone and lower marl. This does not necessarily signify uplift and subaerial erosion of the siltstone as Stephenson has assumed. It is simpler to suppose the break marks a bottom that was scoured by submarine currents during a pause in sedimentation. This lapse of time permitted the growth of accumulation of phosphatic nodules, which were later incorporated in the base of the lower marl.

3. The siltstone is tentatively correlated with the Wolfe City Sand and the lower marl and glauconitic limestone members with the Pecan Gap Chalk. However, the Pecan Gap Chalk at its type locality differs in lithology from any of the members given in this report, and it would be confusing to use the name for any of the rocks in this area.

VI. Literature Cited

Adkins, W. S., 1932, The Mesozoic systems in Texas *in* The Geology of Texas: Texas University, Bull. 3232, v. 1, Stratigraphy, p. 455-463.

American Commission on Stratigraphic Nomenclature, 1961, Code of stratigraphic nomenclature: Amer. Assoc. of Petrol. Geol., Bull., v. 45, p. 645-665.

Clement, Mark Anthony, 1950, Stratigraphy of the Taylor and Navarro Groups in the Royse City area, Collin County, Texas: Master's Thesis (unpublished), Southern Methodist University, 41 pp.

Dane, Carle H., and Lloyd W. Stephenson, 1928, Notes on the Taylor and Navarro formations in east-central Texas: Amer. Assoc. of Petrol. Geol., Bull., v. 12, p. 41-58.

Darton, N. H., Lloyd W. Stephenson, and Julia Gardner, 1937, Geologic Map of Texas: U. S. Geological Survey.

Goldberg, Jerald M., 1949, Geology of the Coperville area, Collin County, Texas: Master's Thesis (unpublished), Southern Methodist University, 35 pp.

Hill, R. T., 1892, On the occurrence of artesian and other underground waters in Texas, eastern New Mexico, and Indian Territory, west of the ninety-seventh meridian *in* Final geological reports of the artesian and underflow investigations between the ninety-seventh meridian of longitude and foothills of the Rocky Mountains to the Secretary of Agriculture: 52nd Congress, 1st Session, Ex. Doc. 41, Pt. 3, p. 73.

Hill, R. T., 1901, Geography and Geology of the Black and Grand Prairies, Texas, with detailed descriptions of the Cretaceous formations and special reference to artesian waters: U. S. Geological Survey, 21st An. Rept. (1899-1900), Pt. 7 - Texas, p. 329-341.

Rouse, John T., 1944, Correlation of Pecan Gap, Wolfe City, and Annona formations in East Texas: Amer. Assoc. of Petrol. Geol., Bull., v. 28, p. 522-530.

Stephenson, Lloyd W., 1918, A contribution to the geology of northeastern Texas and southern Oklahoma: U. S. Geological Survey, Professional Paper 120-H, p. 154-157.

Stephenson, Lloyd W., 1929, Unconformities in Upper Cretaceous series: Amer. Assoc. of Petrol. Geol., Bull., v. 13, p. 1323-1324.

Tarr, W. A., 1925, Is the chalk a chemical deposit?: Geological Magazine, v. 62, p. 252-264.

Teal, J. J. H., 1900, The natural history of phosphate deposits: Proceedings of the Geologists Association, v. 16, p. 369-387.

Twenhofel, William H., 1936, Marine unconformities, marine conglomerates, and thickness of strata: Amer. Assoc. of Petrol. Geol., Bull., v. 20, p. 677-703.

Twenhofel, William H., 1939, Principles of Sedimentation: McGraw-Hill Book Co., New York and London, p. 475-476, 512-514.