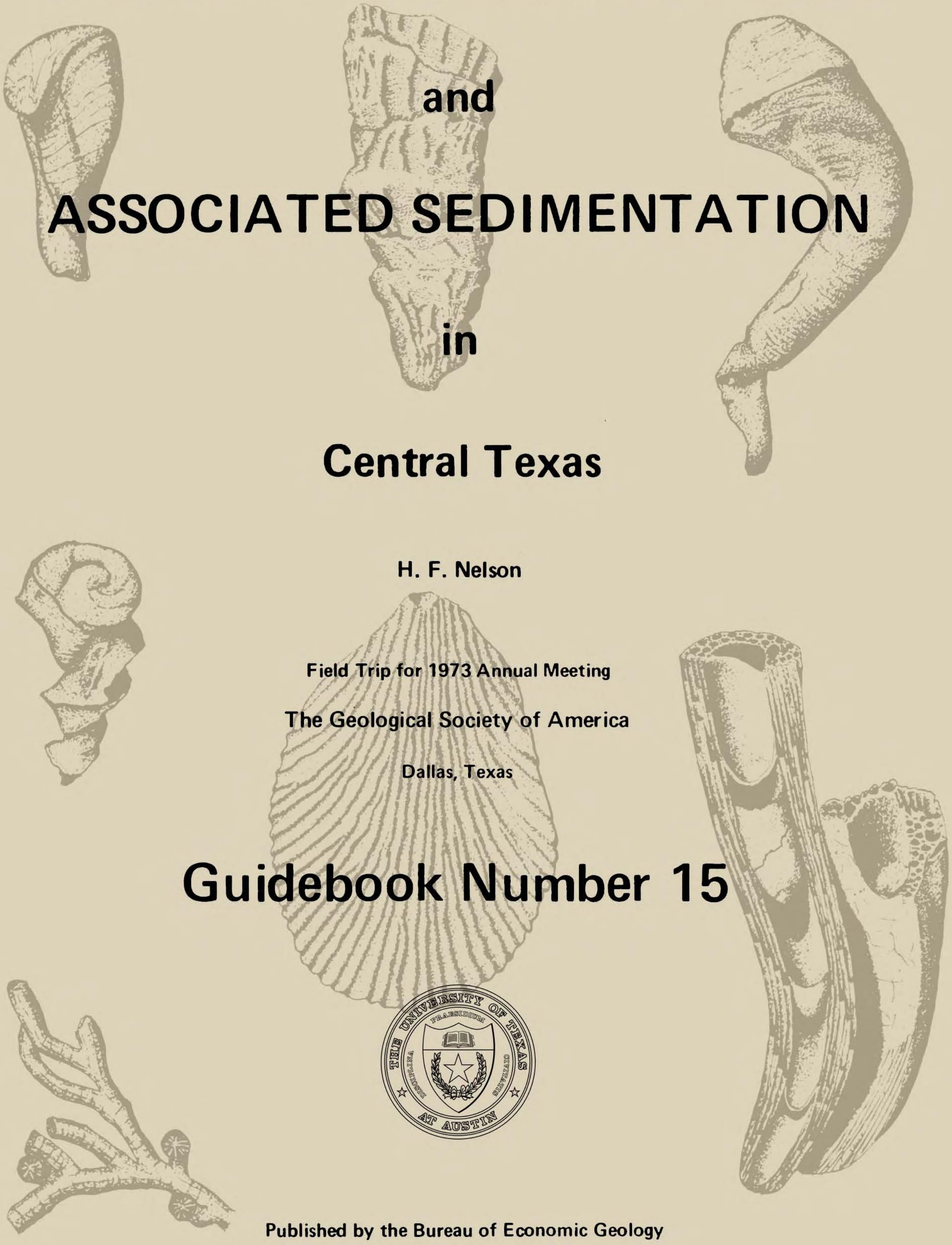
THE EDWARDS REEF COMPLEX

and

ASSOCIATED SEDIMENTATION

in

Central Texas



H. F. Nelson

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THE EDWARDS (LOWER CRETACEOUS) REEF COMPLEX AND ASSOCIATED SEDIMENTS IN CENTRAL TEXAS

Henry F. Nelson[1]

INTRODUCTION

The Fredericksburg Group is one of three groups of rocks which comprise the outcropping Lower Cretaceous sediments in north central Texas. Four formations form this group; from the base upward these are the Paluxy, Walnut, Comanche Peak and Edwards (fig. 1). The Paluxy is made up of terrigenous clastics—red and gray sandstone plus some shale and conglomerate—that were deposited in subaerial and shallow nearshore marine environments. The Walnut consists of nodular chalk and microgranular limestone (micrite), marl, and pelecypod shell beds. The Comanche Peak is a massively bedded, compressed nodular, slightly argillaceous micrite. Both of these formations were deposited on a shallow marine backreef shelf. The Edwards Formation, the primary subject of this field trip, is made up of many types of both primary and diagenetic limestones, dolomite, chert, and evaporites that were formed in both normal marine and hypersaline environments. Sediments deposited in the latter environment were subsequently altered to a considerable extent by secondary processes. Numerous studies have demonstrated that each of these formations grades both upward and laterally to the south into the formation immediately above. In southern Oklahoma the Paluxy (or sandstones having other names) forms a major part of the Fredericksburg Group. In north central Texas the Walnut and Comanche Peak make up the major thickness of the group. In central Texas the Edwards forms almost the entire Fredericksburg section. Deep in the subsurface, the Edwards forms the entire Fredericksburg Group and, in places, is lithologically indistinguishable from the underlying Trinity and overlying Washita sediments.

Outcrops in north central Texas are ideally located to demonstrate the regional facies changes from the subaerial and nearshore sites of deposition, across the shallow marine backreef shelf, through the reef complex, and into the restricted lagoon. However, because time does not permit a study of this complete transition, the field trip concentrates upon the features of the reef complex and its transition into the adjoining backreef sediments and restricted lagoon deposits that have been extensively altered. Six localities (fig. 2) have been chosen to show the major physical features of this part of the Fredericksburg Group. The trip begins in the north end of the area where the Edwards reef complex overlies the backreef sediments (Stops 1 and 2). It then proceeds to a locality (Stop 3) where the upper part of the reef facies and its onlap by interreef sediments can be seen. The last three localities show the physical features formed by diagenesis. In this discussion, localities are referred to by their originally assigned numbers (Nelson, 1959) and by local names for those localities which were not included in the previous study.

RESUME OF REGIONAL STRATIGRAPHY AND GEOLOGIC HISTORY

To fully appreciate the interrelationship of field trip stops and to fit all the stops into one coherent regional picture, it is essential to briefly review the regional stratigraphy and geologic history of the middle part of the Lower Cretaceous rocks of northern and central Texas. A convenient starting point for this resume is the middle part of the Trinity Group. Personal research and the work of others have shown that at the time of deposition of this part of the Lower Cretaceous sequence, the Llano Uplift and the surrounding Central Texas Platform formed a high

[1] Mobil Research & Development Corporation, Field Research Laboratory, Dallas, Texas

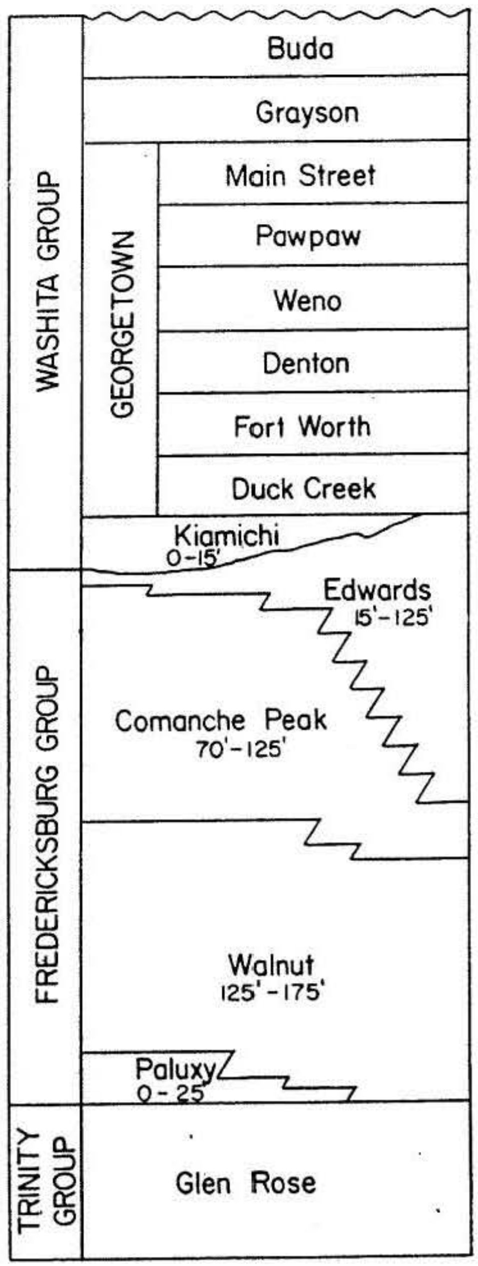

Figure 1. Columnar section of Early Cretaceous formations in north central Texas.

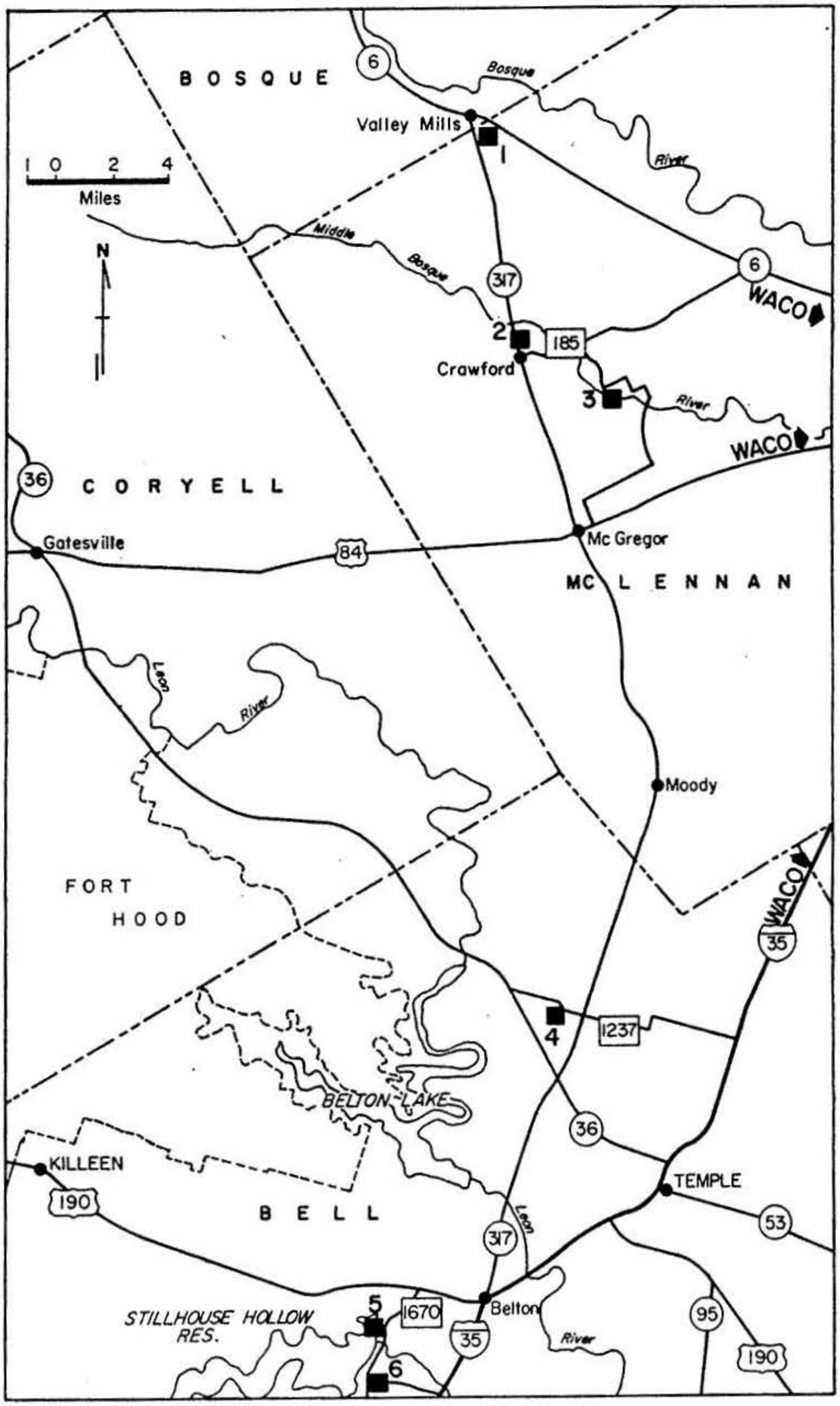

Figure 2. Location of area and field trip stops.

area. Plunging southeastward from this high area was the San Marcos Arch. The Angelina-Caldwell Flexure crossed the San Marcos Arch between the present positions of San Antonio and the Texas coast and parallel to the latter. At the beginning of Rodessa-Upper Glen Rose deposition the rudistids (a collective term used to include pelecypods of the Rudistaceae, Chamaceae, Pernidae, and Mytilacea) and associated organisms became established along this flexure and began to construct the barrier reef which ultimately became one of the major reef trends in the geologic column (figs. 3, 4). Behind this reef trend the North Texas Basin extended without obvious interruption from the Central Texas Platform into Louisiana and north to the mountains of Oklahoma. Terrigenous clastics were deposited along the northwestern edge of this basin while limestone interbedded with shale and, periodically, anhydrite accumulated farther offshore. Dark fine-grained limestone and shale were deposited in the forereef basin southeast of the reef trend.

The pattern of deposition noted above remained fairly stable until the end of Trinity or the beginning of Fredericksburg deposition. At this time the reef-building organisms began to transgress landward along two main paths: (1) northwestward around the flank of the Llano Uplift and across the shallow shelf in north central Texas and (2) northward over the rising Sabine Uplift as far north as southwestern Arkansas and southeastern Oklahoma. A view of the northwestward protruding tongue of the main barrier reef is the objective of this field trip. By the end of Fredericksburg deposition, the tongue of the reef complex in north central Texas had effectively subdivided the former North Texas Basin into two very different environments of deposition behind the main barrier reef trend: an open marine shelf which is herein referred to as the Tyler Basin and a shallow restricted basin, the Kirschberg Lagoon (formerly referred to as the Austin Lagoon by this writer), over the Central Texas Platform. Fredericksburg deposition in north central Texas was brought to a close by slight emergence and the development of a minor unconformity.

THE EDWARDS REEF COMPLEX

RELATIONSHIP OF THE REEF COMPLEX TO ADJOINING FORMATIONS

The reef complex (synonymous with Edwards Formation) is made up of reef and associated interreef deposits. The complex ranges in thickness from a minimum of 13 feet in northern McLennan County to a maximum of 125 feet in northern Bell County. It both overlies and is laterally equivalent to the Comanche Peak (backreef facies) as noted earlier. In any one outcrop, the two formations are in sharp contact with no evidence of transition. However, by observing a large number of outcrops distributed over a large area, the transition of one formation into the other is made evident by (1) the appearance and gradual increase in abundance of the reef-building organisms in the upper part of the Comanche Peak; (2) a change in texture from slightly argillaceous chalky micrite of the Comanche Peak to skeletal limestone (limestones formed by the essentially in situ growth of organisms), shell debris, calcarenite, hard chalky micrite, and chert of the Edwards; (3) a change from massive beds having a small compressed nodular structure in the Comanche Peak to either a massively bedded reef facies or to prominently bedded interreef sediments in the Edwards; and (4) an intercalation of Edwards lithology with Comanche Peak lithology.

The reef complex is unconformably overlain by the Kiamichi Shale as far south as southeastern Coryell County; south of here it is unconformably overlain by the Duck Creek Limestone (Washita). The top of the formation is oxidized and case-hardened, pitted, and bored with the boreholes being filled by either Kiamichi shale or dolomite; nodules of iron oxide pseudomorphic after pyrite or marcasite are common at this contact. All of these features are more common in the top of the reef facies than in the top of the interreef sediments. Less commonly, fossils with the former body chamber and/or inner shell wall filled with dolomite occur in the top of a reef at this contact.

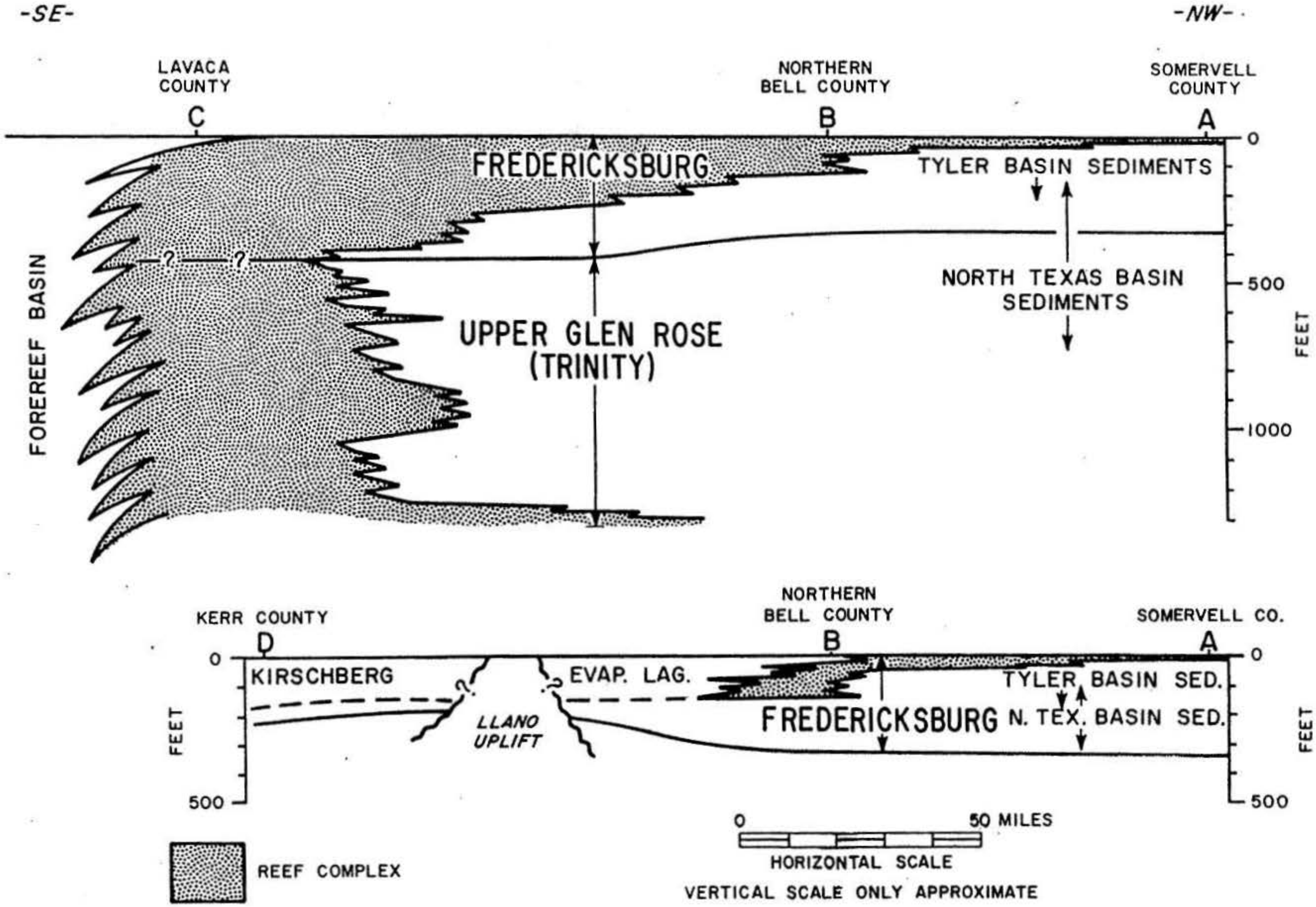

Figure 3. Stratigraphic relationship of rudistid reef complex (stippled) to equivalent sediments of Upper Trinity and Fredericksburg age.

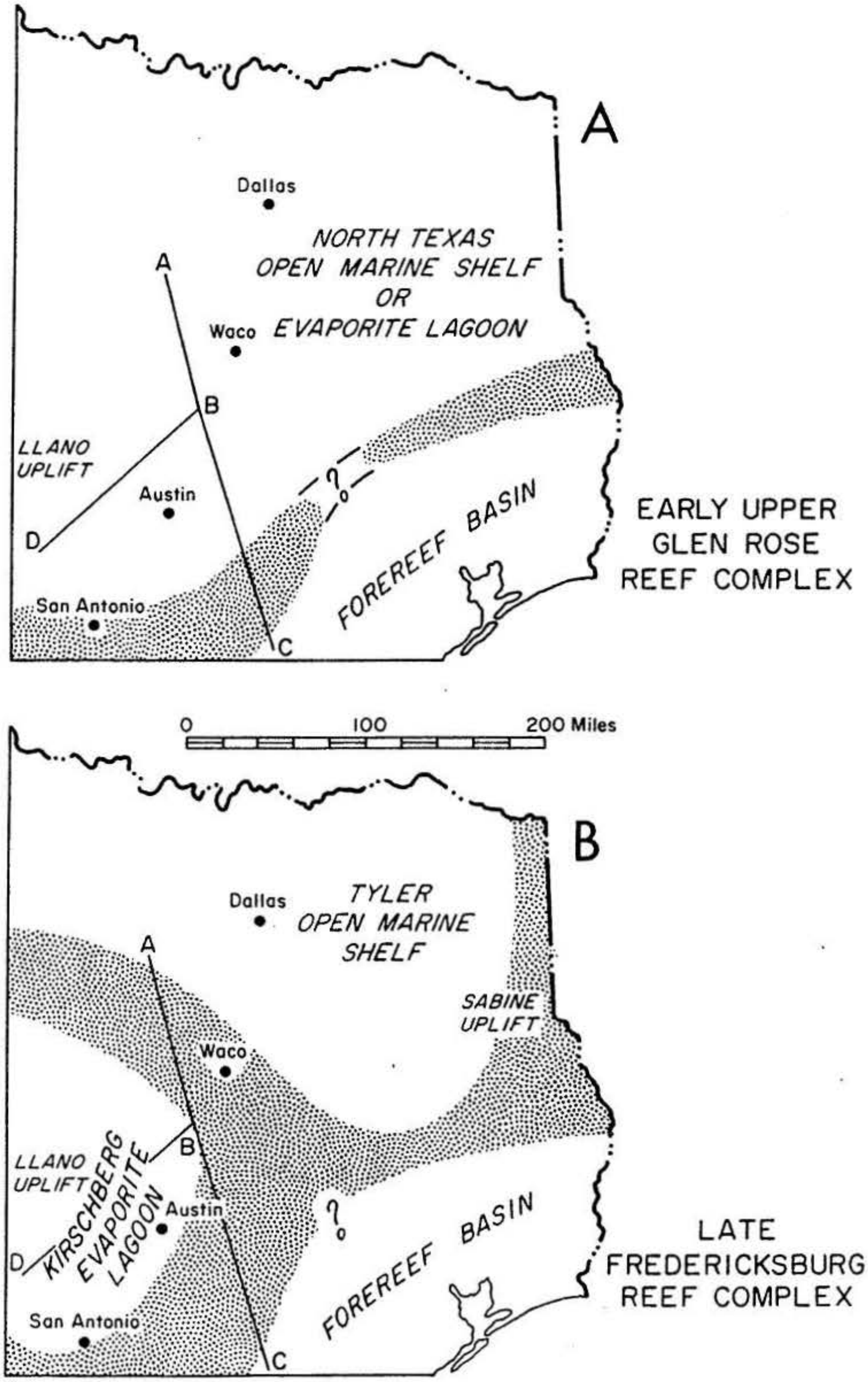

Figure 4. Transgression of the rudistid reef complex (stippled) during deposition of Upper Trinity and Fredericksburg sediments. Data derived from personal research, Lozo (1959), Nelson (1959), Tucker (1962), Winter (1962), Frost (1967), Moore (1967, 1969a, 1969b), Fisher and Rodda (1969), Marcantel (1969), and Rose (1972).

RELATIONSHIP OF REEF TO INTERREEF FACIES

The reef facies ranges in thickness from zero to at least 50 feet and possibly to as much as 75 feet in Coryell County. Variations in thickness are due to (1) local and regional facies changes into the Comanche Peak (backreef facies), (2) local doming due to reef growth, and (3) post-Edwards erosion. The reef facies has both a biohermal and biostromal shape. Individual bioherms may be smoothly concentric, flat-topped, or merely great concentrations of fossils that did not stand above the surrounding interreef sediments (fig. 5; Pls. 1, 2). Biohermal reefs may be masses which extend all the way through the Edwards completely surrounded by interreef deposits, or they may be only small knobs on a vastly larger biostrome of unknown extent. As a biostrome, the reef facies may be only a thin bed joining bioherms, a thick mass of fossils comprising the entire Edwards (either devoid of bedding or made up of very massive beds), or a thick mass of fossils formed by the coalescing of smaller biohermal reefs.

The reef facies may be onlapped by the interreef facies with no apparent gradation between the two (in the outcrop), or it may grade into the interreef facies with either no inclination of the bedding or with dips as great as 35° away from the reef core. In spite of the great variation in thickness of the reef facies, no evidence has been found to substantiate compaction of subreef sediments beneath the core of a reef.

LITHOLOGY OF THE REEF FACIES

The reef facies is formed primarily by pelecypods which grew attached to the sea floor or to other shells. Gastropods and the coral *Cladophyllia* are also common but are volumetrically subordinate (Pl. 3). Young (1959) noted that there are several faunal zones in the Edwards north of McLennan County and attributed this zonation to the depth of water and wave energy. The cores of the reefs are made up of fossils embedded in a very fine-grained matrix of micrite. The fossils are formed of both original shell material (shell material showing the original shell structure) and sparry calcite casts.

The flank beds are made up of a multitude of types of limestone. The lithology of these beds may be tongues of the reef core that extend into the interreef facies, obviously comminuted but unabraded and unsoiled shell debris in a matrix of micrite, and highly abraded shell debris in either a micrite matrix or in sparry calcite cement. Commonly, the reef flank may appear to be more fossiliferous than the reef core as a result of the large fossil fragments having been deposited in a more close-packed state than they were in the reef core.

LITHOLOGY OF THE INTERREEF FACIES

The interreef facies is comprised of well-sorted to unsorted micrite, calcarenite, and shell debris. Except for the sediment close to the reefs, the grains that make up the calcarenite and shell debris are highly abraded. The grains that make up the rock framework include original shell fragments (gray in thin section and show original shell structure), recrystallized grains (have an envelope of micrite surrounding a mosaic of sparry calcite), opaque grains (pellets? micritized shell debris?), oolites, composite grains, and microfossils. Among these grains, the latter three types are volumetrically unimportant in the area of this field trip. A complete gradation from original shell material to recrystallized grains to opaque grains is present. Chert occurs in the interreef facies south and west of McLennan County. It is present as both beds and nodules. Beds of chert break up into nodules and these, in turn, become smaller close to the reefs. No nodules have been found in the reefs; the only chert present in reefs is secondary silica that replaces shell material. Evidence from an earlier study shows that the chert is of both primary and secondary origin.

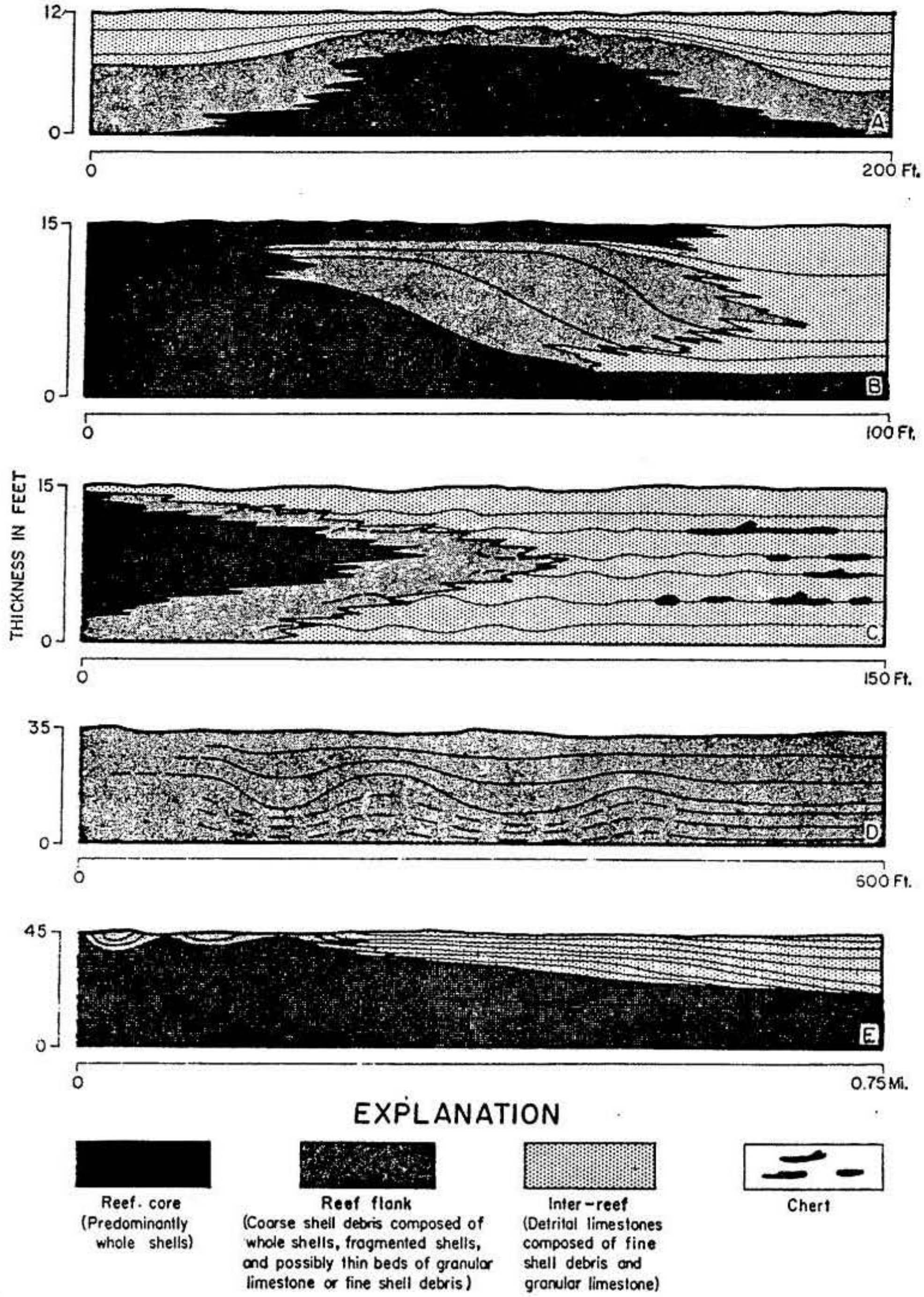

Figure 5. Stratigraphic relationship of reef and interreef sediments as seen in outcrops of the Edwards Formation in central Texas: (A) smoothly concentric biohermal reef onlapped by younger interreef deposits; (B) flat-topped biohermal reef with steeply dipping flank beds grading into interreef sediments; (C) gradation of reef into contemporaneously deposited interreef sediments with no evidence of topographic relief at the time of deposition; (D) undulatory reef flank beds with no reef core exposed; and (E) biostromal reef with small bioherms on the crest.

THE BACKREEF OPEN MARINE FACIES IN THE NORTH TEXAS AND TYLER BASINS

The Paluxy, Walnut and Comanche Peak Formations form the backreef open marine shelf facies in the North Texas and Tyler Basins. Of these formations only the Comanche Peak is seen on this field trip. This formation has a very uniform lithology that consists of light gray, slightly argillaceous, very fine-grained micrite. Characteristically, it is very massively bedded and has a compressed nodular structure. Fossils are common but no where are they sufficiently abundant to form pelecypod banks or reefs like those in the Walnut and Edwards Formations.

THE BACKREEF FACIES IN THE KIRSCHBERG LAGOON

The Fredericksburg Group in the Kirschberg Lagoon is characterized by the very widespread occurrence of dolomite, gypsum, and diagenetic limestones. Only the northeastern rim (in Bell County) of the lagoon has been studied by this writer. Here, at least three types of dolomite are present: (1) hard, gray, and only slightly porous dolomite that is interbedded with the reef complex (Pl. 2, G); (2) soft to moderately hard gray and brown dolomite with excellent intercrystalline, moldic and vuggy porosity (Pl. 4); and (3) white pulverulent dolomite. The genetic relationship of these dolomites to each other and to associated limestones has not been fully determined.

The first of these dolomites has been seen at only one locality; it is texturally like the dolomite found in boreholes and in the body chambers of fossils (Pl. 5, A, C). This similarity and the relationship to the associated limestones described in Plate 2, G, suggest that this dolomite is either primary or very early diagenetic.

The second of these dolomites is the most widespread. It occurs as thin-to-massive even beds of porous and only slightly fossiliferous dolomite, and as massive porous dolomite containing great numbers of molds of rudistids and associated organisms (Pls. 2, F; 4, 6). It grades into associated primary limestones by replacing them; replacement begins in the matrix. During dolomitization, fossil remains functioned as molds to enhance the intercrystalline porosity formed during the process. This dolomite is believed to have formed after the preexisting carbonates were lithified. How long after lithification dolomitization occurred is unknown. It may have occurred at the same time as sediments in the central part of the Kirschberg Lagoon were altered by pre-lithification diagenesis.

The third type of dolomite is of uncertain origin. It is possibly the result of deep weathering of the dolomite just described. It is present at Stop 6 on this field trip.

There is a multitude of types and manners of occurrence of limestones that are essentially unique to the Kirschberg Lagoon. These diagenetic limestones occur as (1) irregular masses and beds of pulverulent chalk, (2) even- to irregular-bedded, hard, brown microcrystalline limestone and limestone so fine grained that individual particles cannot be delineated, (3) texturally similar brown limestone interlaminated with microstalagmites and stalactites, (4) concretions, (5) collapse breccias, (6) veins, and (7) thin-bedded brown travertine. Also present are carbonate rocks that are lithologically similar (as seen in the field and in hand specimens) but which are, in fact, calcified dolomite.

Among all the types of carbonate rocks that seem to be unique to the Kirschberg Lagoon, only one is considered to be clearly primary. This is a light yellowish-gray, thin-bedded, hard micrite that contains pseudomorphs of calcite after gypsum; it is the most fine-grained carbonate rock that has been seen in this area. This micrite has been found in only two places, one of which is at Stop 4 of this field trip.

The mode of origin of the many types of diagenetic carbonates is only partly known. That most of the dolomite originated after the primary limestones were lithified seems certain in view of the fact that both interreef and reef deposits have been converted to dolomite, and there is good evidence for early lithification of the primary limestones. Among the modes of origin that seem clearly established for carbonates other than the dolomite noted above are:

(1) Recrystallization of preexisting limestone as indicated by remnants of primary textures.
(2) Concretionary growth of microcrystalline calcite in some unknown manner.
(3) Precipitation of calcite as stalactites, stalagmites, vein fillings and wall coatings in small vugs and caverns.
(4) Precipitation of calcite in the void space of dolomite to form concretions, beds, and irregular masses of calcified dolomite.
(5) Replacement of dolomite by calcite (dedolomitization).
(6) Solution and collapse to form breccias.

Less certain, but a distinct possibility as another mode of origin for some of the diagenetic micrite, is deposition of lime mud in caverns in the vadose zone followed by dehydration and mudcracking(?). Limestones with this feature are present at Stop 4.

Even less known than the mode of origin of the diagenetic carbonates are the time of origin and the controlling factors. Obviously important factors are: (1) The presence of faults that provided paths for ground water to enter the Edwards. This is well shown at Stop 6 (Pl. 7). (2) The presence of porous and permeable dolomite that also provided a path for ground-water migration as shown at Stops 5 and 6.

Diagenetic limestones are also found where there is no evidence that faults or dolomite were ever present. Thus it is necessary to seek factors other than the occurrence of faults and dolomite. The first inclination is to consider the possibility that gypsum was formerly present and has been replaced by limestone. Unfortunately, except for the calcite pseudomorphs after gypsum that occur at Stop 4, no evidence of gypsum has been found.

The possibility that the presence or absence of the Kiamichi Shale above the Edwards was a factor must be considered inasmuch as diagenetic limestones are extensively developed only where the shale is absent. Conceivably, the shale could have inhibited the downward percolation of ground water, thus preventing extensive limestone diagenesis beneath it. If this is an important factor, then the time of diagenesis needs to be considered. Did it occur prior to deposition of the Duck Creek Limestone when the post-Edwards unconformity developed, or has it accompanied development of the present-day topography?

CONCLUSIONS

It is clear from this brief discussion that there is much work to be done to understand the origin of the diagenetic carbonates in the Edwards Formation in north central Texas. My experience suggests that diagenetic limestones like those in the Edwards are volumetrically unimportant in the geologic column. It is possible, however, that they have not been recognized because the natural inclination is to think of limestones as marine deposits and to relate them to a marine environment. However, if they are related to a non-marine environment and are the result of weathering, then their recognition in the geologic column would indicate the possible presence of unconformities, faults, and conceivably the movement of ground water.

STRATIGRAPHIC DESCRIPTION OF SIX FIELD TRIP STOPS

STOP 1

Location: 154-T-1. Santa Fe Railroad cut on southeast side of Valley Mills, Bosque County.

The upper part of the Comanche Peak, the entire Edwards and Kiamichi, and the lower part of the Duck Creek Formations are exposed at Stop 1. This exposure provides a good view of a cross section of the Edwards reef complex; the best view is exposed in the north wall of the cut.

A biohermal reef is exposed at each end of the cut; the reefs are joined by reef flank sediment. The interreef facies onlaps and extends over the bioherms, subduing but not completely eliminating the original topographic relief on the reef surface; as a result, the 7.5 feet of relief on the reef surface is reduced to 2 to 3 feet at the base of the Kiamichi. The Edwards and Kiamichi are very chalky as a result of modern weathering and the development of caliche; masses of white pulverulent chalk (caliche) are present at each end of the cut at the level of these formations. The section at Stop 1:

	Thickness (feet)
Duck Creek Formation	Exp. 7.0
Kiamichi Formation	15.0
Edwards Formation	
Units 7-3: Interreef facies.	
Unit 7: Calcarenite; yellowish gray, fine grained, well sorted. Made up of highly abraded bioclastic debris and a great abundance of miliolids which have been highly micritized; pebbles of this unit are present in Kiamichi. Intergranular space is clear calcite cement. Upper surface is oxidized and burrowed, and contains oxidized pyrite or marcasite concretions.	2.5
Unit 6: Calcarenitic micrite; light gray, chalky, irregularly bedded. Coarse material is recrystallized bioclastic debris. Gradational into unit below.	3.5
Unit 5: Brecciated argillaceous micrite; very angular fragments lithologically similar to units above and below. Physical appearance suggests pre-lithification brecciation.	3.5
Unit 4: Argillaceous micrite; medium gray, very thinly laminated. Contains some bioclastic debris, small unabraded and whole pelecypods, and fragments of thin laminae. Thin laminae in upper foot are crumpled, broken, and bent beneath a tilted block of limestone like unit. 6. Upper foot is jointed; joints are filled with limonitic calcarenite. Unit onlaps and thins over bioherms.	0.5-5.0
Unit 3: Shale; calcareous, brown between bioherms, red over westernmost bioherm. Thins over bioherms.	0.2-0.4
Unit 2: Reef facies. Micritic rudistid skeletal limestone and micritic shell debris. Skeletal limestone forms core of westernmost bioherm and part of easternmost bioherm; in both structures the skeletal limestones grade upward and laterally into a patchy distribution of skeletal limestone and shell debris which form the flanks of the bioherm and the biostrome. No bedding planes separate the reef cores from the reef flanks. Both original and recrystallized whole and fragmented shell form framework of the reef facies. *Caprinuloidea*, *Eoradiolites*, and *Chondrodonta* are common fossils. *Toucasia* is also present; the coral *Cladophyllia* is common in basal part of reef. Crest of westernmost bioherm is truncated by a	

	Thickness (feet)
disconformity having a relief of 6 inches; relief decreases down the bioherm and the disconformity becomes a smooth bedding plane. Crest of bioherm is oxidized and contains numerous boreholes filled with dolomite, sparry calcite, and micrite from the overlying interreef bed. Sharp contact with formation below.	2.5-11.0
Comanche Peak Formation	
Unit 1: Backreef facies. Micrite; light gray, slightly argillaceous, massively bedded, compressed nodular structure. At the base of the exposure at the north end of the railroad cut is 5 feet of limestone which lacks the nodular structure of the Comanche Peak; this is believed to be an attenuated tongue of the Edwards that extends eastward from a much thicker section near the Coryell county line.	Exp. 27.0

STOP 2

Location: 154-T-2. Roadcut 1 mile north of Crawford on State Highway 317, McLennan County.

Essentially the same stratigraphic sequence as Stop 1 is exposed at Stop 2. Here, however, the Edwards is thicker, the reef facies is only biostromal, and the interreef facies is coarser grained. This outcrop is located near the point where the deepest part of an interreef basin was formerly located. From here, the reef facies increases in thickness to the west until it makes up essentially the entire Edwards near the McLennan-Coryell county line. To the southeast, it decreases in thickness and is either absent or very thin at 2.0 miles east-southeast of Crawford. Beyond this point to the southeast, the reef facies again increases in thickness and constitutes all of the exposed Edwards at Stop 3; presumably, it makes up the entire Edwards section. The exposed sequence at Stop 2:

	Thickness (feet)
Duck Creek Formation	Exp. 4.0
Kiamichi Formation	6.5
Edwards Formation	
Units 7-3: Interreef facies.	
Unit 7: Shell debris; very light yellowish gray, thick to massively bedded. Made up of highly abraded, poorly sorted original and recrystallized shell fragments and opaque grains; recrystallized shell fragments are dominant. Whole unabraded fossils are common. The top of the formation is oxidized and contains boreholes filled with Kiamichi Shale.	7.0
Unit 6: Calcarenite; very light yellowish gray, very fine to medium grained, medium to massively bedded, cross laminated. Made up of well rounded and moderate to well sorted grains similar to those in the unit above.	13.0
Unit 5: Calcarenitic micrite; gray, massive, composed predominantly of opaque grains.	6.5
Unit 4: Argillaceous calcarenitic micrite.	1.5
Unit 3: Calcarenite; light gray, intensively burrowed. Boreholes are filled with dolomitic calcarenite.	0-1.0
Unit 2: Reef facies. Micritic rudistid skeletal limestone. Whole and unabraded fossils form the rock framework; micrite forms the matrix. Fossils are preserved as original shells and calcite casts. *Eoradiolites* appears to be dominant in the lower part of the biostrome; *Caprinuloidea* appears	

	Thickness (feet)
dominant in the upper part. *Dictyoconus walnutensis* is very abundant. Body chamber filling in *Caprinuloidea* is dolomitic. Sharp contact with Comanche Peak.	8.7-7.7
Comanche Peak	
Unit 1: Backreef facies. Micrite; light gray, slightly argillaceous, compressed nodular structure, massively bedded.	Exp. 24.0

STOP 3

Location: 154-T-14. Bend of Middle Bosque River, 3 airline miles southeast of Crawford, McLennan County.

Stop 3 is the last exposure of the Edwards Limestone before it extends into the Tyler Basin. This stop presents an excellent picture of the stratigraphic and structural features in the top of a reef.

The bluff which forms the west bank of the river exposes massive horizontally bedded rudistid skeletal limestone overlain by prominently bedded well-sorted coarse-grained calcarenite and poorly sorted shell debris. The mechanically deposited sediments are near the top of the Edwards here; to the northwest near the center of the interreef basin (upstream), they are near the bottom of the Edwards.

On the walk downstream, note the small quarry which shows beds of very coarse rudistid debris dipping gently to the south away from the core of a reef. Farther downstream, the gently undulatory upper surface of the reef facies is visible in the river bed. Finally, at the bend of the river, one reaches a point where the upper surface of the reef facies is strongly undulatory. The core of the reef facies is in the river bed; reef flank beds made up of coarse shell debris interbedded with rudistid skeletal limestones dip as much as 30° away from the reef core on both sides of the river. *Chondrodonta* and *Caprinuloidea* are the most abundant reef-building organisms. As at other localities, dolomite fills the body chambers, replaces the inner shell wall of some tests, and partially fills the intergranular pores in some beds of shell debris. Around the bend of the river, a portion of the original reef surface still remains and exhibits the features which are so common to it—pits and boreholes, nodules of oxidized pyrite, and oxidation of the upper few feet of the reef. The section at Stop 3:

	Thickness (feet)
Fort Worth and Duck Creek Formations	Not meas.
Kiamichi Formation	2.5
Edwards Formation	
Unit 2: Interreef facies. Interbedded white well-sorted calcarenite and poorly sorted fine to very coarse shell debris. The rock framework is made up of highly abraded original and recrystallized bioclastic debris and opaque grains. Bedding is well developed. Beds have a topset, foreset, bottomset relationship; those at the top of the Edwards at the south end of the west bank of the river are near the bottom of the Edwards farther to the north (upstream and toward Stop 2). This unit varies in thickness as a result of variation in thickness of the underlying reef facies. Immediately west of the bend in the road this unit is approximately 10 feet thick; downstream, it pinches out where the reef facies climbs to the top of the Edwards.	0-10.0

Thickness (feet)

Unit 1: Reef facies. Light gray massive micritic skeletal limestone. *Caprinuloidea* and *Chondrodonta* are the most conspicuous organisms. Near the bend in the road, this facies is very massively and horizontally bedded. Downstream, the upper surface of the reef facies becomes undulatory and beds of reef limestone interfinger with beds of coarse shell debris. Beyond the point where the interreef beds pinch out, the top of the reef is oxidized, bored, pitted and dolomite has replaced the inner shell wall of some fossils. Exp. 12.0

STOP 4

Location: Hagler Quarry (Pl. 7); now owned by the B. F. W. Construction Co., Temple, Texas. Located on Farm Road 1237, 1 mile west of State Highway 317, north of Belton, Bell County.

Twenty feet of primary and diagenetic Edwards limestone are exposed in the quarry face. Neither the bottom nor the top of the formation is present; however, the top of the exposure probably is very close to the contact with the overlying Duck Creek Formation. The Kiamichi Shale which overlies the Edwards in McLennan County to the north is not present in surface exposures in Bell County. Units 2 and 3 are lithologically allied to similar rocks which define the Kirschberg Evaporite Lagoon. The sediments exposed in this and other nearby quarries and outcrops were deposited near the northeast limit of the evaporite lagoon. The section at Stop 4:

Thickness (feet)

Edwards Formation

Unit 3: Kirschberg lagoon facies. Primary micrite; yellowish gray, thin and smoothly bedded, non-porous for the most part. Some beds contain pseudomorphs of calcite after gypsum. This unit is the most fine-grained limestone that has been seen in Bell, Coryell, and McLennan Counties. Exp. 3.0

Unit 2: Kirschberg lagoon facies. Diagenetic limestone; brown, extremely hard; excellent vuggy and cavernous porosity. Very thin to thick beds are separated by bedding planes which range from smooth to very irregular surfaces. The brown part of the limestone is uniformly very fine grained (<.062 mm), but the texture may range from a mosaic of tightly interlocking very irregular-shaped calcite crystals to a groundmass of calcite particles too small to delineate individual particles. The brown fine-grained carbonate may be uniformly developed across an entire bed or it may occur as the fragments in a collapse breccia, as concretions, very thin broken beds, and as irregular-shaped "patches" having poorly defined edges and cut by numerous irregular hair-like cracks that suggest pre-lithification desiccation or fracturing. The space between the beds, "patches," and concretions are partially to completely filled with white and brown calcite that was precipitated as pore-wall coatings or as microstalactites and stalagmites, A crudely polygonal fracture pattern is present on some bedding surfaces; it may represent mudcracks. 7.0

Unit 1: Interreef facies. Yellowish gray, thick to massively bedded, well-sorted coarse-grained calcarenite grading downward into poorly sorted micritic shell debris. The rock framework is made up of highly abraded opaque grains, original shell material, and recrystallized bioclastic debris; the

Thickness (feet)

latter predominates. Partial recrystallization obscures patches of the original texture but does not totally destroy it. Porosity is highly variable; practically all pores are irregular-shaped vugs. Exp. 10.0

STOP 5

Location: 14-T-8. Roadcut on abandoned Farm Road 1670 where it descends into now flooded Stillhouse Hollow Creek southwest of Belton, Bell County.

The Edwards is approximately 70 feet thick at this locality, but only the lowermost 22 feet are well exposed; it overlies the Comanche Peak. This outcrop shows the diagenetic change from primary limestone to post-lithification dolomite and the still later diagenetic change to calcified dolomite. Dolomitization is believed to have been genetically related to development of the Kirschberg Evaporite Lagoon and possibly to development of the post-Edwards unconformity. The exposed section is as follows:

Thickness (feet)

Edwards Formation

Unit 2: Post-lithification diagenetic carbonates and primary micritic shell debris. A small patch of micritic shell debris grades upward and laterally into dolomitic micritic shell debris. The latter grades into dolomite and rudistid mold dolomite which are irregularly cemented and partially dedolomitized by late calcification. The shell debris is made up of original and recrystallized shell fragments. Dolomitization of the shell debris begins in the matrix. There is little change in the porosity and permeability until the dolomite content reaches approximately 60 percent. The dolomite is soft, microcrystalline, and has very good intercrystalline and moldic porosity. The calcified dolomite is extremely hard and non-porous. Most of the calcite is void-filling, but part has probably replaced dolomite. Contacts between the dolomite and calcified dolomite are sharp but irregular. There is a small amount of chert formed by silicification of the dolomite. Prior to dolomitization, much of the Edwards Limestone at this locality was reef facies; the eastern end of the exposure may have been bedded interreef facies. The contact with the formation below is gradational. Exp. 22.0

Comanche Peak Formation

Unit 1: Post-lithification dolomitic micrite and primary micrite (backreef facies). Post-lithification dolomitic micrite grades downward into light gray, chalky, massively bedded micrite which has a compressed nodular structure. Dolomite decreases progressively downward until it disappears about 15 feet below the Edwards. Exp. 40.0

STOP 6

Location: Stillhouse Hollow spillway excavation approximately 0.50 mile south of Stillhouse Hollow Dam on the Lampasas River, Bell County.

The spillway excavation south of the Stillhouse Hollow Dam exposes 63 feet of the Edwards Formation. This exposure is particularly interesting because there is very little primary limestone remaining here and much of the first diagenetic carbonate, dolomite, has been altered. The lithology here is closely allied to the sediments of the Kirschberg Evaporite Lagoon. Alteration products of at least three stages of diagenesis can be recognized. From the earliest to the latest these are (1) soft dolomite with good intercrystalline and moldic porosity, (2) brown-colored concretions composed of calcified dolomite and cryptocrystalline limestone developed by complete replacement of the preexisting dolomite (dedolomitization), and (3) irregular patches of rock cemented by white and brown sparry calcite. Additionally, there is pulverulent dolomite and chalk that may have been formed at either the same time as one of the diagenetic products noted above or in a different stage. Of particular note are the large number of collapse structures, the great amount of cavernous and vuggy porosity, and the influence of faulting upon rock cementation. East of the road there is a downwarp which presumably is related to collapse beneath the level of the excavation floor. The following section is exposed in the north wall of the excavation:

	Thickness (feet)
Edwards Formation	
Units 11-7 are present in the downwarp east of the road.	
Unit 11: Rubble; large blocks of limestone (some if not all are diagenetic limestone) in a pulverulent chalk matrix similar to unit below. Gradational contact below.	Exp. 0-3.0
Unit 10: White to yellow pulverulent chalk surrounding blocks of limestone. Blocks are fossiliferous micritic calcarenite; tan, very hard, slightly dolomitic. Microfossils very abundant. Patchy recrystallization, particularly in the matrix. Fair vuggy porosity. Sharp contact at base.	1.0-3.0
Unit 9: Interreef facies(?). Calcarenite(?). Single thick bed that is thinly laminated and cross laminated; contains 3-inch-thick bed of chert 2 inches above the base. In places, top 3 inches have good lamellar porosity that has been partially reduced by late calcite cementation. Sharp contact at base.	1.5
Unit 8: White pulverulent chalk enclosing hard recrystallized carbonate concretions and shell fragments. Sharp contact below.	2.3
Unit 7: Interreef facies. Fossiliferous micrite; yellowish gray in the lowest 1.5 feet, becoming mottled light gray and brown in the remaining 6.5 feet. Brown-colored patches are more porous than gray limestone. Vuggy and lamellar porosity partially reduced by late calcite cementation are irregularly developed along the length of the outcrop. Incipient recrystallization obscures fossil fragments. Two nodular chert beds are present—one 2.5 feet below the top of the unit and the other 1.3 feet above the base. The upper chert is a silicified, dolomitized, fossiliferous micrite that may have been calcified and partially dedolomitized prior to silicification. Sharp but irregular contact at base.	8.0
Unit 6 is present on both sides of the road.	
Unit 6: Interbedded white pulverulent chalk, light gray pulverulent dolomite, and yellow and brown mottled very hard microcrystalline limestone. Microcrystalline limestone is thinly laminated as a result of diagenesis. Laminae made up of alternating brown non-porous crystalline limestone and very porous crystalline limestone. Microstalactites and stalagmites extend into lamellar vugs. There are a few vague remnants of microfossils. Upper 6 inches of unit is an unlaminated vuggy breccia.	6.5
Units 5-1 are present west of the road.	
Unit 5: Microcrystalline limestone; tan, very hard, non-dolomitic. Contains a few vague remnants of shell fragments. Top is more iron-stained than	

		Thickness (feet)
	remainder of bed. Forms the single bed that extends along most of excavation wall west of road.	2.0
Unit 4:	White and brown pulverulent chalk. Contains hard concretions of recrystallized limestone.	0.7
Unit 3:	Interreef facies. Fossiliferous micrite; yellowish gray. Hard angular fossil fragments and whole microfossils are common; latter appear to be mostly miliolids. Scattered throughout are pores that look like molds of corroded dolomite crystals. Light yellowish color and dark speckled appearance suggest that there has been incipient recrystallization.	0.3
Unit 2:	Chert. This unit and unit 3 are persistent along most of excavation wall. They are obscured near faults where there has been intensive calcite cementation; they are part of the breccia in the collapse structures.	0.5
Unit 1:	Dolomite; gray soft, and massively bedded. Very good intercrystalline and moldic porosity at west end of wall. At this end there are concretions of silicified dolomite (chert) as well as concretions and thin beds of calcified dolomite. Eastward, toward the road, unit 1 becomes increasingly calcified—in places to the extent that the unit is now a mass of interlocking concretions, many of which are not merely calcified dolomite but instead are microcrystalline limestone formed by replacement of the preexisting dolomite (dedolomitization). Several collapse structures are present in the top of the dolomite; some are filled with collapse breccia, others are caves. Several small faults cut across the outcrop. Along these faults, and for some distance from them, there is a large amount of late stage cement comprised of white and brown sparry calcite (travertine). It coats the concretions formed by the earlier stage of cementation (calcification) and fills fractures and solution cavities; part of these fillings are in the form of thin horizontal beds of travertine which suggest precipitation associated with a changing water table.	Exp. 35.0

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PLATES 1-7

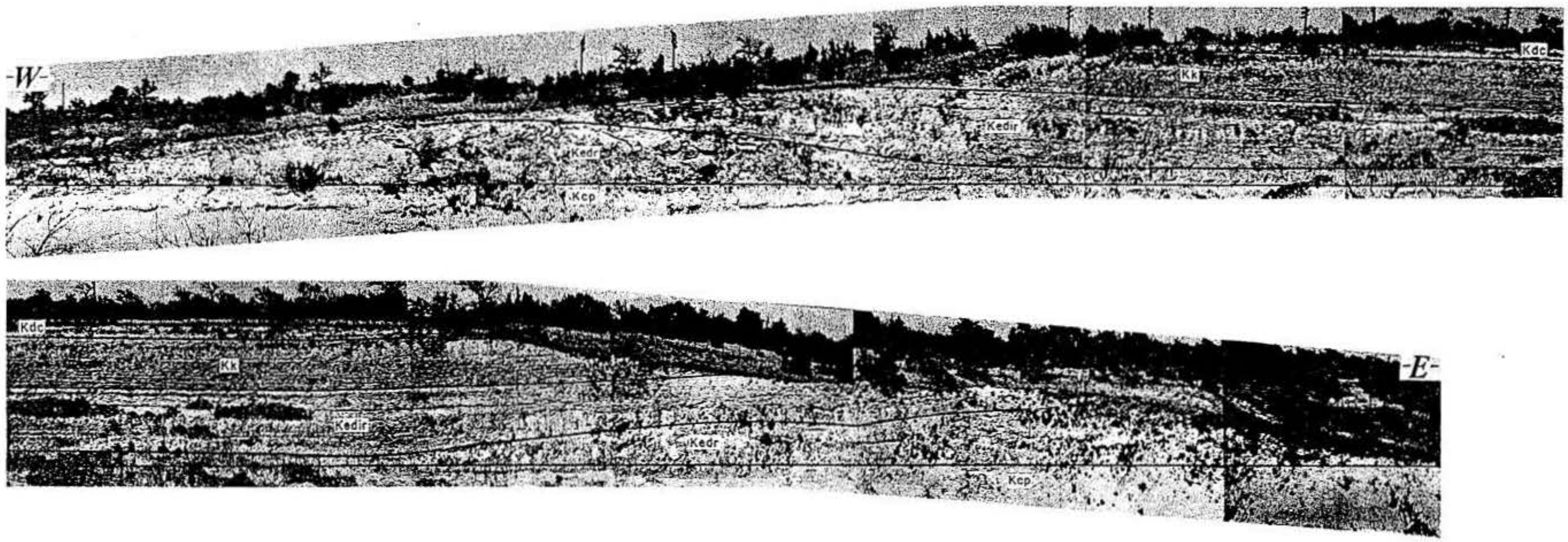


PLATE 1

Edwards reef complex. Rudistid biohermal reefs (Kedr) at each end of the railroad cut are joined by a biostromal reef. The reef facies is underlain by the backreef facies (Kcp) and overlain by the interreef facies (Kedir); the latter onlaps the reef facies rather than grading into it as at some other localities. The entire sequence is overlain by the Kiamichi (Kk) and Duck Creek (Kdc) Formations. Locality 154-T-1, Stop 1.

PLATE 2

A. Edwards reef complex. The sequence at this locality is the same as that shown in Plate 1. Here, however, the reef facies is only biostromal and the interreef sediments are more coarse grained. Locality 154-T-2, Stop 2.

B. Biohermal reefs at the top of the Edwards southeast (downstream) from the locality shown in A. The core of the reef is in the foreground. The beds in the background are reef flank deposits; they dip toward the trees with a maximum inclination of 35°, and in the opposite direction to the right of the photograph. Locality 154-T-14, Stop 3.

C. Edwards reef complex. Prominently bedded interreef sediments grade into and onlap the massive reef facies. Downstream (to the left), the interreef facies becomes thinner and finally pinches out where the reef facies extends to the top of the Edwards (Photograph B, 0.5 mile away). Upstream, the interreef facies forms an increasingly greater thickness of the Edwards until it constitutes almost the entire formation 1.5 miles away. Locality 154-T-14, Stop 3.

D. Reef flank beds exposed in Hog Creek 3.2 miles southwest of Valley Mills. These beds are made up of a mass of unsorted, coarse rudistid debris in a matrix of micrite. Locality 154-T-15.

E. Interreef facies. At this locality the facies is made up of nodular, bedded, calcarenitic micrite and chert. This sequence grades both to the right and left into the reef facies. Close to the reefs the irregular bedded chert changes to beds of chert nodules which, in turn, become progressively smaller close to the reef. Chert, if present in the reef, occurs as a diagenetic replacement of shells rather than as bedded chert. Formerly locality 50-T-7; now destroyed.

F. Interreef and diagenetic carbonates. Units 2 and 3 are dolomitic calcarenite and shell debris; units 4 and 5 are similar but non-dolomitic and better sorted. All units are mechanically deposited interreef sediments. Units 2 and 3 grade laterally into the sequence shown in G. Unit 6 is a dolomitized rudistid biostromal reef; unit 7 is interbedded dolomite and diagenetic limestone. This locality is thought to be near the northeastern edge of the Kirschberg Evaporite Lagoon. Locality 14-T-1.

G. Interbedded calcarenite (light) and calcarenitic dolomite (dark). Each type of lithology contains boreholes filled with the lithology of the overlying bed; however, the boreholes are most abundant in the limestone beds. The contacts between limestone over dolomite are more irregular than those between dolomite over limestone. The nature of these contacts and the relative abundance of boreholes in the different lithologic units reflect greater organic activity during deposition of calcarenite beds. Locality 14-T-1.

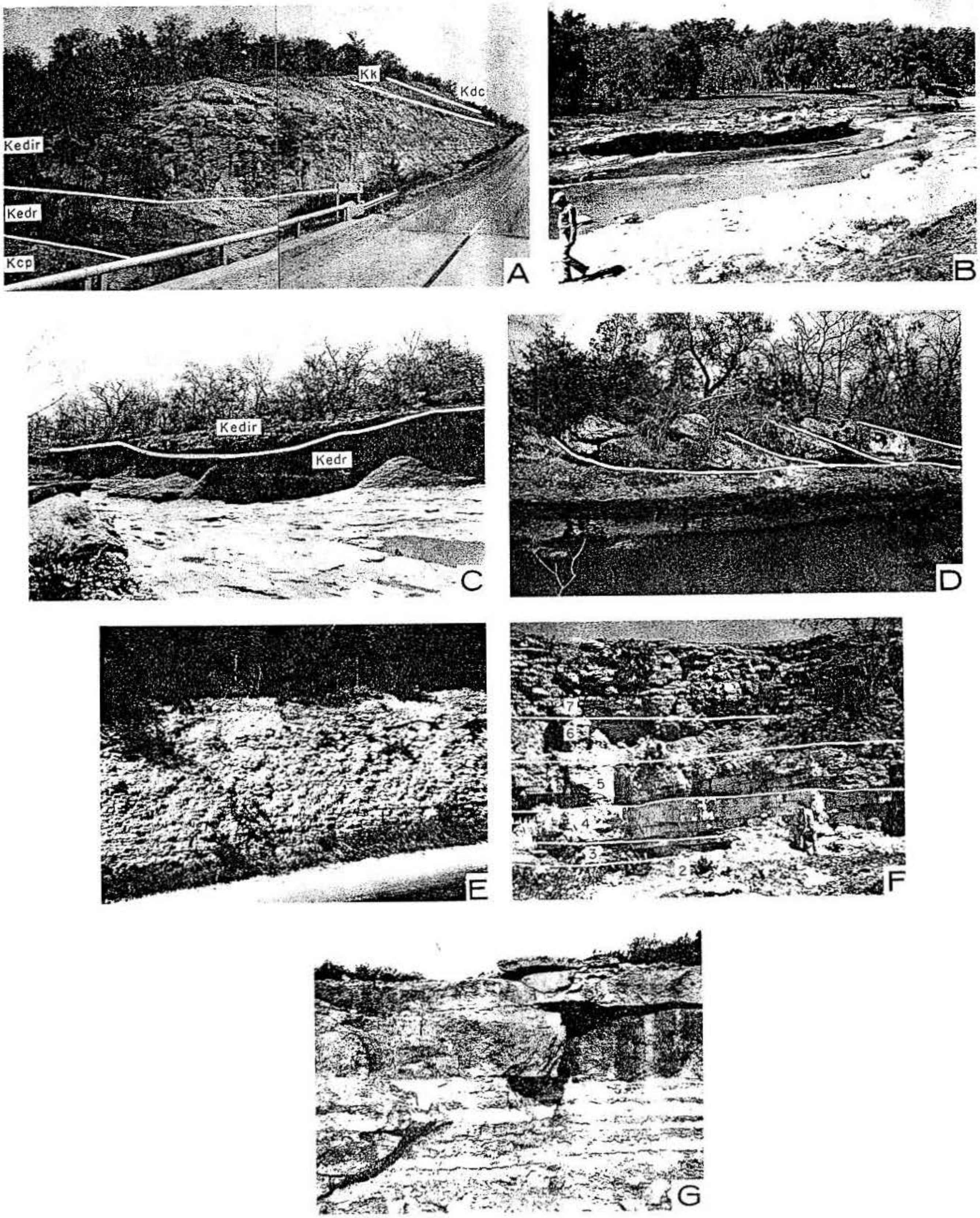

Kk
Kdc
Kedir
Kedr
Kcp
A
B
Kedir
Kedr
C
D
E
7
6
5
4
3
2
F
G

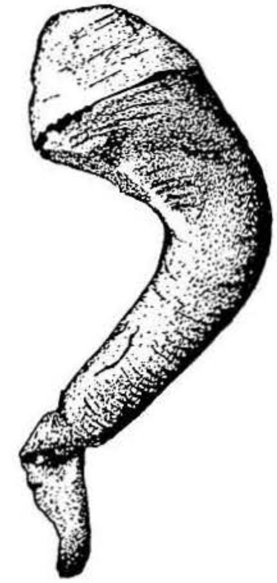
PLATE 3

Typical genera of the Edwards limestone tabular reef. *Eoradiolites* is a Rudistaceae; *Toucasia*, *Monopleura*, and *Caprinuloidea* are Chamaceae; *Chondrodonta* belongs to the Pernidae, Mytilacea; and *Cladophyllia* to the Actinaria. Illustrations about two-thirds to three-quarters natural size (Young, 1959).

PLATE 3

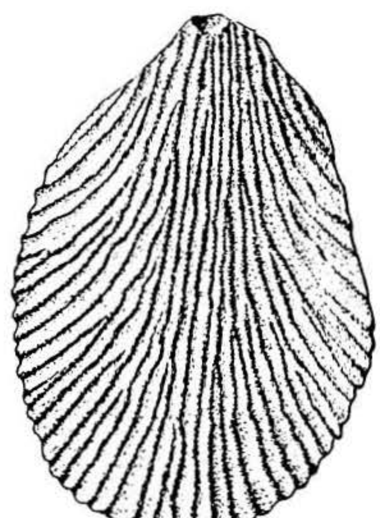
Monopleura

Eoradiolites

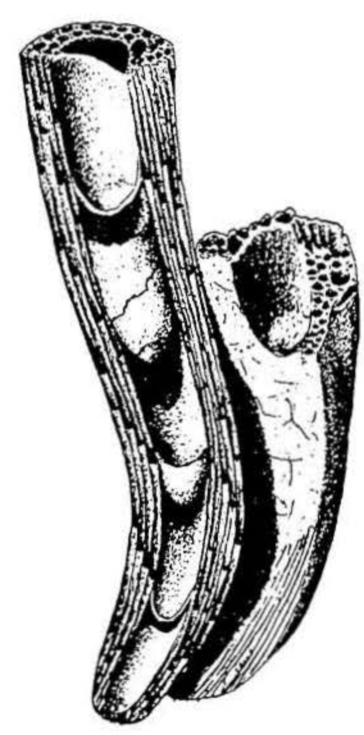


Caprinuloidea

Toucasia



Chondrodonta



Caprinuloidea

Cladophyllia

PLATE 4

Relationship of primary interreef deposits (micritic shell debris) and diagenetic carbonates. Locality 14-T-8, Stop 5.

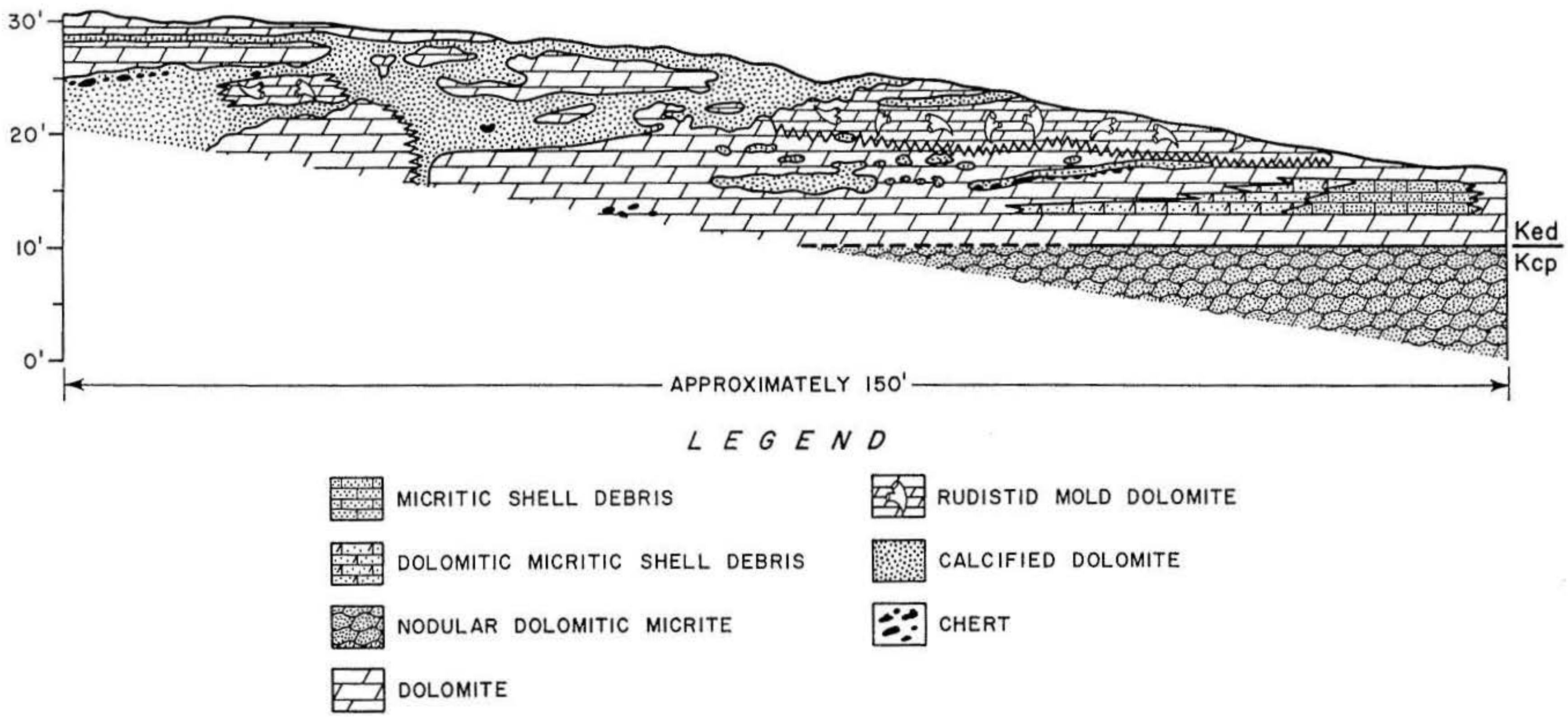

30'
20'
10'
0'
Ked
Kcp
APPROXIMATELY 150'
LEGEND
MICRITIC SHELL DEBRIS
DOLOMITIC MICRITIC SHELL DEBRIS
NODULAR DOLOMITIC MICRITE
DOLOMITE
RUDISTID MOLD DOLOMITE
CALCIFIED DOLOMITE
CHERT

PLATE 4

PLATE 5

A-C. Upper surface of rudistid reefs, Edwards Formation.

A. Upper surface of reef just beneath the Kiamichi/Edwards contact has dolomite concentrated in the body chambers of fossils. In addition to this restricted occurrence, dolomite may also replace the inner shell wall of some fossils. Where dolomite occurs in these restricted manners, it is essentially absent in the matrix. Locality 154-T-16.

B. The pitted, bored, and oxidized surface of a reef just beneath the Kiamichi/Edwards contact. This is a common feature of the upper surface of the reefs at this contact; it is much less apparent at the contact of interreef sediments with the Kiamichi. Locality 154-T-14, Stop 3.

C. Cross section of the upper surface of a reef within the Edwards Formation showing the borings and oxidations. Most of the boreholes are filled with interreef micrite. One borehole is filled with dolomite(D) at the bottom, sparry calcite cement(C) in the middle, and interreef micrite(M) at the top that is slightly oxidized like the surrounding rock. This relationship is considered to be indicative of very early cementation. There is no evidence of dolomitization of the surrounding rock; the dolomite in the borehole is considered to be either primary or very early diagenetic. Oxidation and boreholes in the reef surface are less apparent down the flank of the reef and along the contact of the biostromal reef with the overlying interreef sediments. Nodules of limonite pseudomorphic after pyrite are common on the upper surface of the reef facies.

D. Comanche Peak Formation. This is the immediate backreef facies of the Edwards reef complex in central Texas. It is characteristically a chalky micrite with a compressed nodular structure and is very massively bedded. Locality 50-T-7.

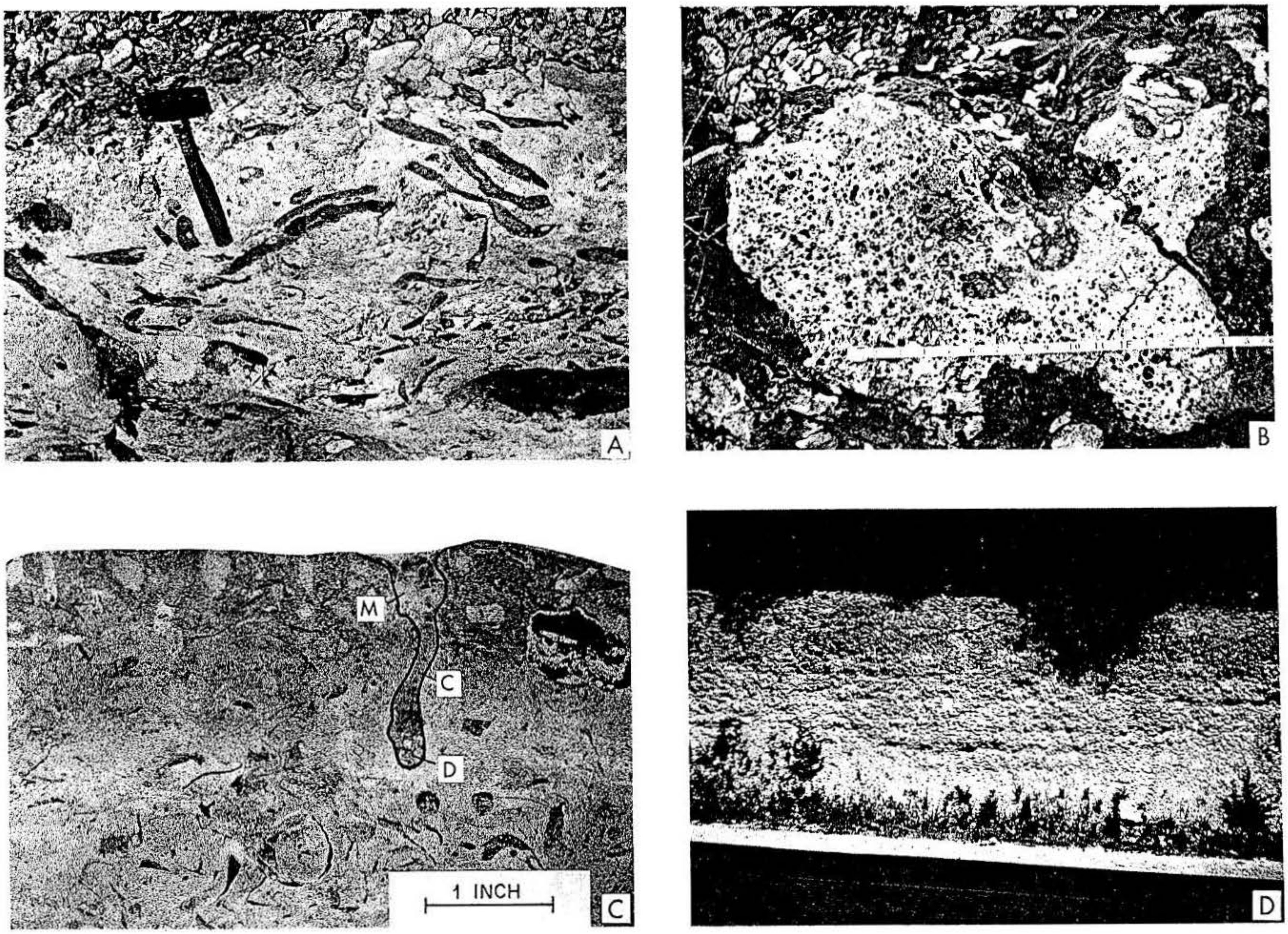


PLATE 5

PLATE 6

A-F. Stillhouse Hollow Dam excavation; north wall west of highway.

A. Dolomite (unit 1) at west end of north wall. The thin beds are horizons where the dolomite is calcified.

B. Collapse structures in the top of the dolomite. Units 2, 3, and 4 are either not present or are obscured. Collapse structures or caverns (see D) are common in the top of the dolomite.

C. Collapse breccia. Portions of units 2 and 3 have fallen into a former cavern in unit 1. Along with other collapsed material and concretions of calcified dolomite they are cemented by brown sparry calcite. The very thin beds between the concretions and breccia are sparry calcite as is the vein(V).

D. Calcification along a fault. Units 2-4 are obscured by calcification. The area of massive calcification shown here changes laterally into beds of calcification in massive dolomite.

E. Close-up view of calcification along a fault showing brown sparry calcite cementing concretions of calcified dolomite or microcrystalline limestone formed by dedolomitization of unit 1.

F. Concretionary area in unit 1. The concretions are like those noted in E.

PLATE 6

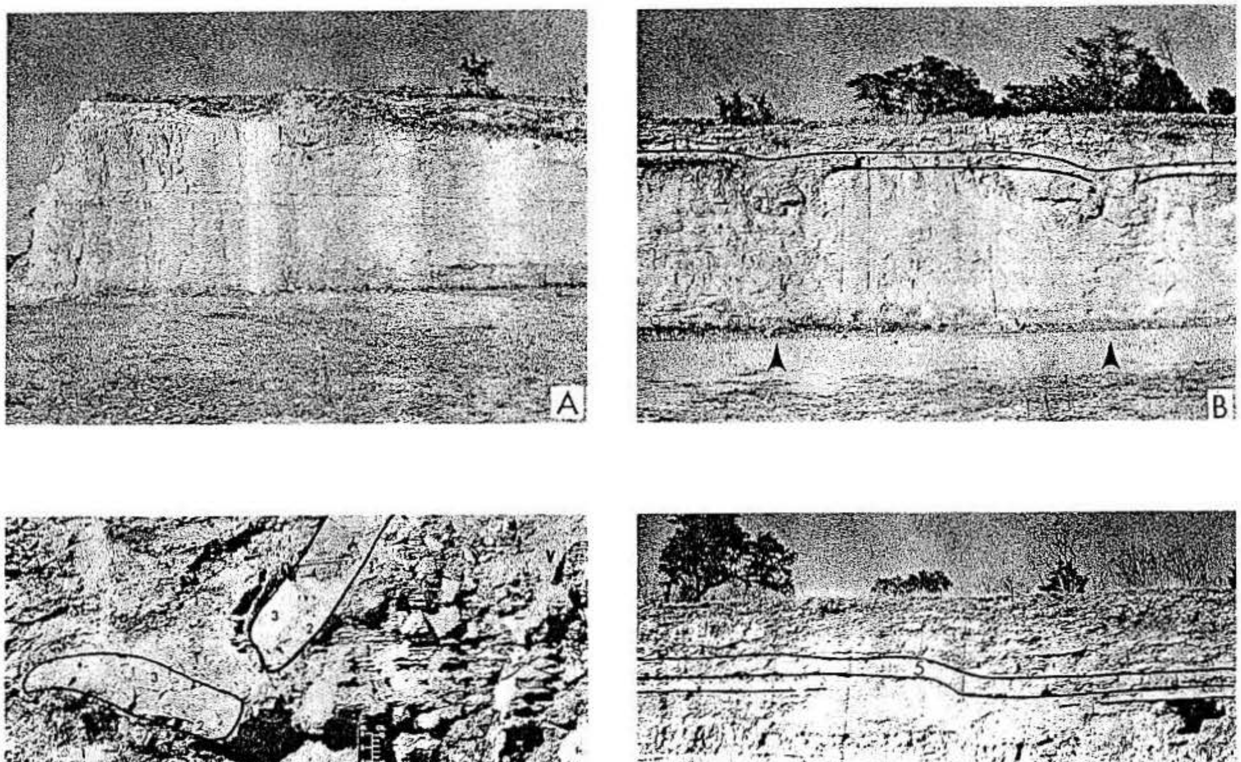


PLATE 7

A-E. Hagler quarry, Stop 4.

A. Units 1 and 3 are primary limestones; unit 2 is a diagenetic limestone.

B. Unit 2 showing the cavernous porosity and the bed of diagenetic limestone concretions cemented with brown sparry calcite at the base of the unit.

C. Block of calcite cemented concretions derived from the base of unit 2.

D. Microstalactites developed in interbed pore space; derived from unit 2.

E. Vadose zone mudcracks(?), also derived from unit 2. This is a fairly common feature in unit 2.

PLATE 7