GEOLOGIC REVIEW OF PROPOSED DALLAS - FORT WORTH AREA SITE FOR THE SUPERCONDUCTING SUPER COLLIDER (SSC)

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June 30, 1987

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INTRODUCTION

In June 1987, the Texas National Research Laboratory Commission asked the Bureau of Economic Geology, The University of Texas at Austin, to review and briefly report on the geology of the proposed Dallas - Fort Worth area site for the Superconducting Super Collider (SSC) and to provide a surface geologic map of the site. An informal task force was organized, consisting of Jay A. Raney (Coordinator and Structural Geology) of the Bureau of Economic Geology, Peter M. Allen (Environmental Geology and Stratigraphy) of Baylor University, Donald F. Reaser (Structural Geology and Stratigraphy) of The University of Texas at Arlington, and Edward W. Collins (Structural Geology) of the Bureau of Economic Geology. This task force report serves as an explanatory note for the geologic map (Plate 1) of the proposed Dallas - Fort Worth area site near Waxahachie, Texas.

REGIONAL SETTING

The proposed Dallas - Fort Worth area site for the Superconducting Super Collider is located in Ellis County in North-Central Texas. The area lies in the northwestern part of the West Gulf Coastal Plain and is within the Blackland Prairie physiographic province (Fenneman, 1938). Regional topographic relief is about 350 ft across the site; elevations range from +750 to +400 ft (MSL).

Upper Cretaceous Eagle Ford, Austin, and Taylor strata crop out and dip regionally about 1° east-southeastward in the vicinity of the site. Bedrock strata within the site include Austin Chalk and Ozan Formation marl ("lower Taylor marl") (Plate 1 and Plate 2). The site is bounded on the west by Eagle Ford Group shale. East of the site, Wolfe City Formation marl, sandstone, and mudstone occur. Quaternary terrace deposits and alluvium overlie bedrock strata along streams that cross the area.

Normal faults strike northeast to east-northeast across the area and are part of the regional Balcones Fault Zone. Normal faults of the Balcones Fault Zone have a regional en echelon pattern that extends from Dallas southward to San Antonio, where the zone bends west-southwestward toward Del Rio. This trend closely follows the structural grain of the Paleozoic Ouachita fold and thrust belt (Weeks, 1945). Eastward and parallel to the Balcones Fault Zone are the Luling and Mexia normal fault zones. These fault zones and the Talco Fault Zone of northeast Texas are thought to be related to flexure around the perimeter of the Gulf of Mexico (Murry, 1961). Some fault movement may have begun during the Late Cretaceous, although most of the movement may have occurred during the late Oligocene or early Miocene (Weeks, 1945).

STRATIGRAPHY

The stratigraphy of the project area near Waxahachie is presented in Plate 1 and accompanying text. Plate 1 represents a compilation of mapped information from Ingels (1957), Reaser (1957, 1961), Reed (1957), Peabody (1958, 1961), Pitkin (1958), Dooley (1960), Barnes (1972), and Allen (1975), and more recent field and photogeologic interpretations by Allen (this report) at a scale of 1:48,000.

The map units (fig. 1, Plate 1) in descending order are: Recent Alluvium, Pleistocene Fluviatile Terrace Deposits, and the Upper Cretaceous units Wolfe City Formation, Ozan Formation, Austin Chalk, and Eagle Ford Group.

The Cretaceous map units are part of a 1,750- to 4,400-ft-thick wedge of Cretaceous-aged sediments that strike north-northeastward and dip southeast from 50 to 100 ft per mile (Thompson, 1967). These sandstones, limestones, and shales overlie Paleozoic rocks in Ellis County. The Eagle Ford Shale is exposed only in the westernmost past of the mapped area. It is not discussed further as it is not present in the proposed site.

The structural geology of the Waxahachie area is described separately because most of the faulting postdates the deposition of the Cretaceous units and predates the deposition of the Pleistocene and Recent units (Reaser, 1961). Most investigators have not reported evidence of major structural control on the deposition of the outcropping units. One exception to this is noted by Beall (1964, p. 16), who reports that some of the faulting in the Ozan Formation, south of the study area near Waco, was apparently contemporaneous with deposition. Beall (1964) notes that the downthrown side of this fault system received more sediment than the upthrown side.

Recent Deposits: Quaternary Alluvium

Recent deposits consist of brown to black waxy clays and brown silty clays along rivers in the Waxahachie area. Deposits range from a few feet to more than 30 ft thick and are commonly underlain by stratified calcareous sands and gravels. A

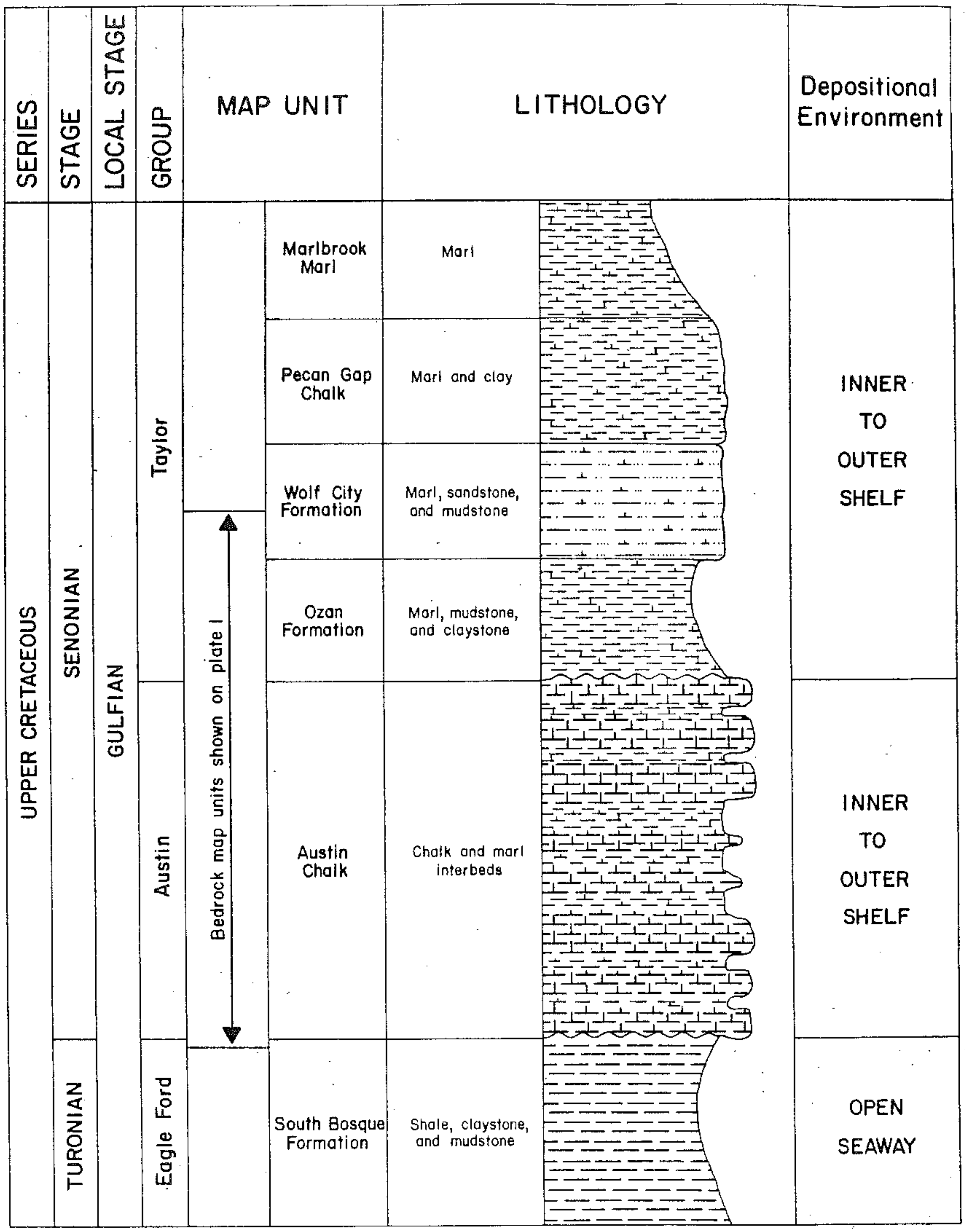

Figure 1. Geologic column for Cretaceous map units in the vicinity of the proposed Dallas - Fort Worth area SSC site. (Modified from Reaser and others, 1983.)

basal lag of exotic quartzite pebbles and cobbles is common in the alluvium mapped in the eastern portion of the proposed Dallas - Fort Worth area site.

Pleistocene: Fluviatile Terrace Deposits

Terrace deposits consist of dark gray, calcareous clays and yellowish to light-brown sand and sandy clays that are often underlain by beds of stratified water-bearing sands and gravels. Sands and gravels are estimated to underlie about 50 to 72 percent of the mapped terrace deposits (Brooks and others, 1964, p. 64). Gravel deposits in the eastern map area often contain quartzite cobbles, petrified wood, and fossil fragments. Locally, Reaser (1957, p. 89) describes the basal gravel as being cemented with calcium carbonate. In the area near Ferris, Texas, these mapped terraces have been correlated with the Love Field and Carrollton Terraces of Taggart (1953). Terrace deposits range in thickness from 5 to 30 ft and were mapped on the basis of work by Brooks and others (1964), photogeologic interpretation, and minor field verification.

Cretaceous: Taylor Group

The Taylor Group (fig. 1) is divided into four formations (Barnes, 1972; for nomenclature see McFarland, 1986, p. 12). Of these four formations, only the Ozan and Wolfe City Formations crop out in the proposed Dallas - Fort Worth area site (Plate 1). These units strike approximately north-northeast at 012°-016° with an average southeasterly dip of 91 ft per mile (Beall, 1964, p. 18).

From its contact with the Austin Chalk, the Ozan thickens eastward into the subsurface in Ellis County to about 500 ft (Jackson, 1983). The Wolfe City Formation thickens southward toward McLennan County. According to well log analysis by Jackson (1983), the Wolfe City Formation has an average downdip thickness of about 150 ft to the east of the proposed Dallas - Fort Worth area site in Ellis County. Thompson (1967) and Pitkin (1958) estimate the thickness observed in outcrop to range from 70 to 80 ft.

The Ozan Formation is mapped over the eastern one-third of the proposed site. According to Reaser (1957, p. 89), in Ellis County the Austin-Ozan contact is unconformable and is marked by a reddish-brown clay zone 1 to 3 inches thick that contains reworked Inoceramus prisms and phosphatic nodules. The contact is locally cut by normal faults (Plate 1). The Ozan occurs as eastward-dipping beds of fine-grained, uniformly laminated, marl and calcareous mudstone, and shale. The fresh, blocky shale displays conchoidal fractures but becomes fissile upon weathering. Fresh exposures are bluish-black or gray, whereas weathered surfaces vary from light gray to tan or yellow-brown. Orange limonite stains are common on weathered exposures. Secondary gypsum is common along joint and bedding planes.

According to Reaser (1957, p. 89), the lowermost Ozan marl is overlain by darker, medium gray to blue-gray calcareous shales and mudstones that have a lower carbonate content. This zone of less calcareous shales and mudstones was encountered about 100 ft above the Ozan-Austin contact (Reaser, 1957, p. 89). Pitkin (1958, p. 78) states that the carbonate content of the Ozan varies from 10 to 35 percent (based on 25 samples). The dominant clay mineral in the Ozan, as determined by X-ray diffraction, is dioctahedral montmorillonite (Beall, 1964, p. 19). McFarland (1986, p. 104) also presents data on clay types of the map units (Table 1).

Table 1. Relative mineral composition* of Taylor and Navarro Groups on the western margin of East Texas Basin, in the vicinity of Waco, east-central Texas.

Formation	Montmorillonite	Illite	Kaolinite	Calcite	Feldspar
Austin Chalk (Marl Unit)	84	0	0	16	0
Lower Blackland Marl	82	8	1	9	Tr
Middle Blackland Marl	66	15	10	6	2
Upper Blackland Marl	62	21	10	3	4
Wolfe City Sand	73	16	7	3	1
Lower Neylandville Marl	92	5	1	1	Tr
Upper Neylandville Marl	89	4	4	2	1
Nacatoch Sand	93	2	1	2	2
Upper Navarro Clay	45	44	5	3	4
Kincaid (L. Tertiary)	32	65	1	1	Tr

Tr<0.5%

*Quartz was used as a standard in calculating above percentages and thus is excluded from the table. The three dominant clay minerals are montmorillonite, illite, and kaolinite, and the prominent nonclay minerals are calcite and feldspar. Note that the montmorillonite dominates the clay mineralogy of the section from Austin Chalk to Nacatoch Sand; however, illite dominates the clays in the upper Navarro clay and the overlying Tertiary units. (Adapted from McFarland, 1986, p. 104.)

The Wolfe City Formation in the Dallas - Fort Worth site consists of a sandy calcareous clay (marl) interbedded with a fine-grained glauconitic quartz arenite. Interbedded sandstone lenses (less than 1 inch to 1.5 ft thick and commonly 1 to 2 inches thick) increase in abundance upward in outcrop and often weather into lenticular fragments that occur as "float" on the surface of the outcrop. The conformable contact of the lower Wolfe City with the underlying Ozan is gradational and is characterized by a decrease in sand- to silt-sized mineral grains and a corresponding increase in the percentage of clay (Beall, 1964, p. 19; Reaser and others, 1983, p. 70).

The calcareous sandstone is light bluish-gray on fresh exposures, yellow to buff brown on weathered surfaces. The sandy calcareous clay is gray to bluish-black on fresh exposures and weathers brown to greenish-brown. The sandstone lenses, which are more resistant to erosion than the calcareous sandy clays, form small ledges in outcrop. Crossbedding and filled borings are more apparent on weathered profiles (Beall, 1964, p. 15). On the basis of limited analysis near Palmer, Texas, Pitkin (1958, p. 81) estimates that the sandstone averages 45 percent by weight soluble in dilute hydrochloric acid. Seventy percent of the noncalcareous residue from the calcareous sandstone consisted of angular to subangular grains of quartz (1/8 to 1/16 mm) with lesser amounts of feldspar, mica, and glauconite. Heavy minerals constituted less than 0.1 percent by weight.

The sandy calcareous clay fraction of the Wolfe City Formation analyzed by Pitkin (1958) averaged 78 percent noncalcareous material. The residue consisted predominantly of quartz grains (1/8 to 1/16 mm) with some feldspar, mica, and glauconite (Pitkin, 1958).

A comprehensive depositional model of Taylor Group rocks, including the Wolfe City Formation, was given by McFarland (1986). In general, the Ozan Formation represents the beginning of a period of pronounced shelf mud deposition (Jackson, 1983, p. 36; McFarland, 1986, p. 123). The Ozan is a neritic perideltaic marine unit deposited near the eastern edge of the stable Texas Craton. According to Reaser and others (1983), the lithofacies of the Wolfe City Formation have been variously interpreted as marginal marine sands (Adkins, 1932), deltaic sands (Beall, 1964), middle to outer shelf sands (Richardson, 1972), and tidal sand bodies (Dawson, 1981). McFarland (1986, p. 123) interprets the Wolfe City Formation as delta-front to prodelta sands.

Cretaceous: Austin Chalk

The Austin Chalk ranges from more than 500 ft in northern Ellis County to 300 ft in southern Ellis County (Koger, 1981) and strikes north-northeast at 010°-012° and dips 60 ft per mile to the southeast. The Austin thins south of Ellis County (fig. 2), apparently owing to the erosional contact with the overlying Taylor Group. It is composed of marine coccolith-rich beds of blue gray, white-weathering chalk, interbedded with some dark gray, gray-weathering marl.

The Austin Chalk is quite homogeneous in overall character, although the percentage and thickness of contained beds of calcareous shale increase somewhat in the middle portion of the unit. Massive chalk beds and chalky marl beds are common throughout. Various authors have proposed informal subdivisions of the Austin Chalk in North-Central Texas based upon subtle changes in lithology (Dallas Geological Society, 1965; Pessagno, 1969; Koger, 1981; Jackson, 1983). Attempts to apply these subdivisions to field studies in the Waxahachie area (Ingels, 1957; Reed, 1957; Peabody, 1961; Allen, 1975; Files, 1977) have produced inconsistent results, probably due to poor exposures and the gradational nature of the changes in lithologic

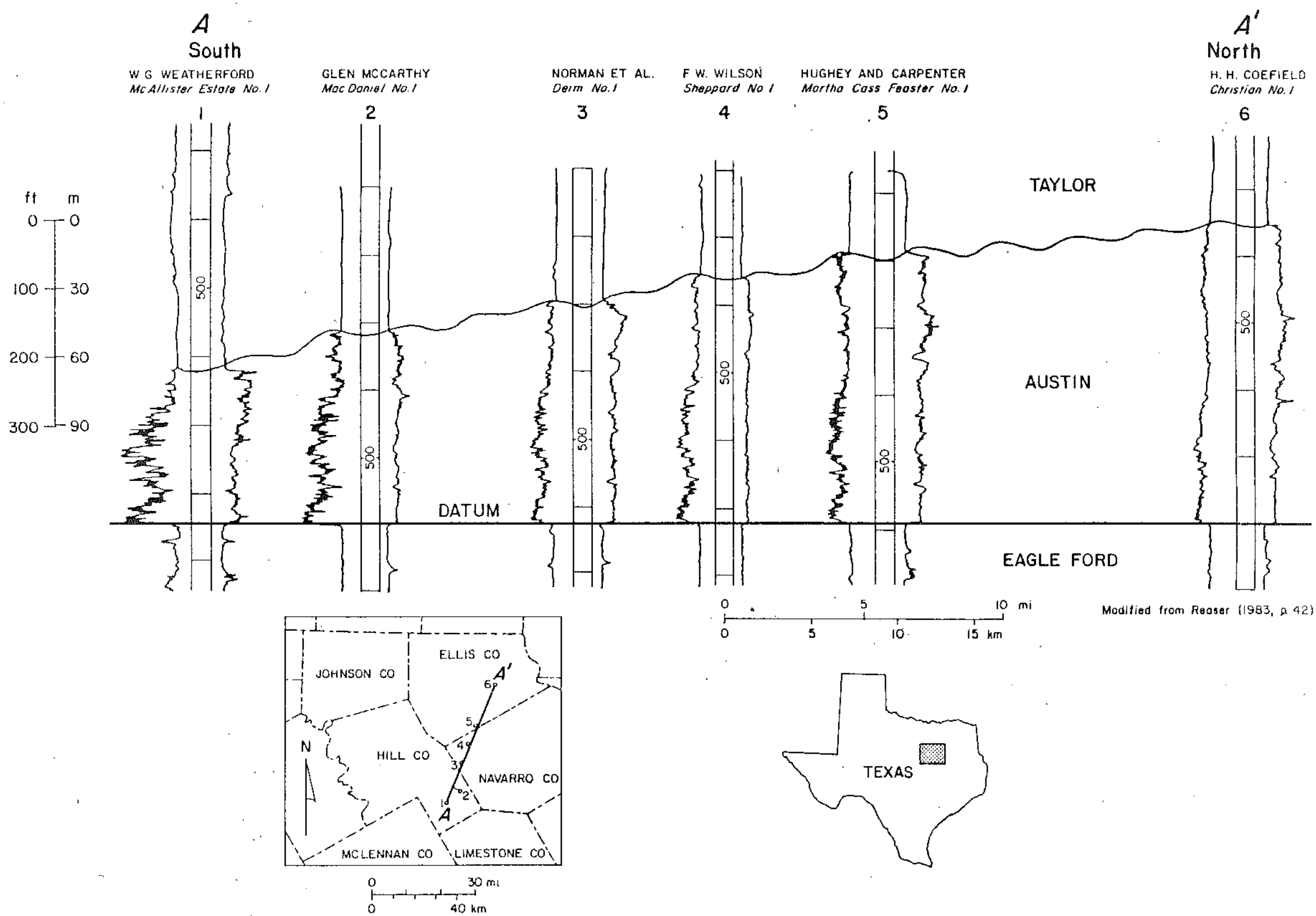

Figure 2. Stratigraphic section of upper Eagle Ford, Austin, and lower Taylor in Ellis, Hill, and Navarro Counties, Texas. Vertical scale: 1 inch = 100 ft.

character. For engineering purposes, the Austin Chalk appears to have nearly homogeneous properties, and no attempt is made to subdivide it on the geologic map. The depositional history of the chalk was most recently described by Reaser (1983) and Koger (1981). Reaser (1983, p. 2) suggests an open outer shelf to inner shelf depositional environment for the Austin Chalk (fig. 1).

STRUCTURAL GEOLOGY

Most normal faults in the area strike northeast to east-northeast and dip 50° to 70° toward the northwest and southeast (Plate 1). Two narrow grabens, about 1,000 to 1,200 ft wide at the surface, have been identified within the Waxahachie area, and others have also been mapped in the vicinity of the Dallas - Fort Worth site. Some of the single faults mapped within the site may also bound narrow grabens that cannot be recognized in the field or on aerial photographs because of poor bedrock exposure. Maximum throw on the faults is difficult to determine due to a lack of detailed subsurface control, but estimates based on surface mapping indicate that displacements rarely, if ever, exceed 100 ft. Gentle flexures, possibly related to faulting, produce local areas where strata generally dip southeastward at up to 10 degrees. There is no evidence that faults or flexures present in the bedrock units have disturbed overlying Quaternary terrace deposits or alluvium.

Cretaceous strata adjacent to major faults exhibit fault drag and fracturing. Both normal and reverse drag are present, although normal drag is more common. Fractures adjacent to major faults that bound narrow grabens were studied in detail at two localities to determine fracture geometries and densities associated with the faults (fig. 3). Austin Chalk is in fault contact with Ozan marl and mudstone at both localities. Poor exposures of Ozan strata prevent detailed fracture analysis in this unit. Austin strata are more resistant and better exposed. Joints and minor normal faults with displacements of less than 2 ft are abundant in Austin strata adjacent to the major faults. A fault exposed near the Lake Waxahachie spillway bounds a narrow graben on the southeast and has excellent exposures of fractured Austin Chalk. The trace of this fault strikes east-northeast at about 070° and is easily recognized on aerial photographs (Plate 1). The major fault plane exposed east of the spillway appears to be slightly irregular and strikes more east-west to slightly west-northwest. The fault contact between the Austin Chalk and Ozan marl is sharp.

Fractured chalk adjacent to the major fault can be divided into three zones. They are (1) zone of complex minor faulting, (2) zone of abundant minor faults and joints, and (3) zone of abundant joints (fig. 3a). The zone of complex minor faulting occurs along the major fault plane and is 3 to 6 ft wide. Small "fault blocks" have formed, and they are bounded by minor faults that strike in various directions and dip from 90° to horizontal. Adjacent to the zone of complex minor faults is a zone of abundant minor faults and joints that is 50 to 65 ft wide. Minor faults in this zone strike in two general directions. Most of the minor faults strike subparallel to the major fault at 060° to 100° and dip between 40° and 70° in both northerly and southerly directions. Fewer minor faults strike north-northwesterly at 340° to 355°. They also terminate against the minor faults striking 060° to 100°, indicating they formed later and are probably secondary to the northeast to east-west striking minor faults. Joints in this zone of faulted and jointed strata terminate against the faults, indicating that they developed after the faults. Adjacent to the faulted and jointed

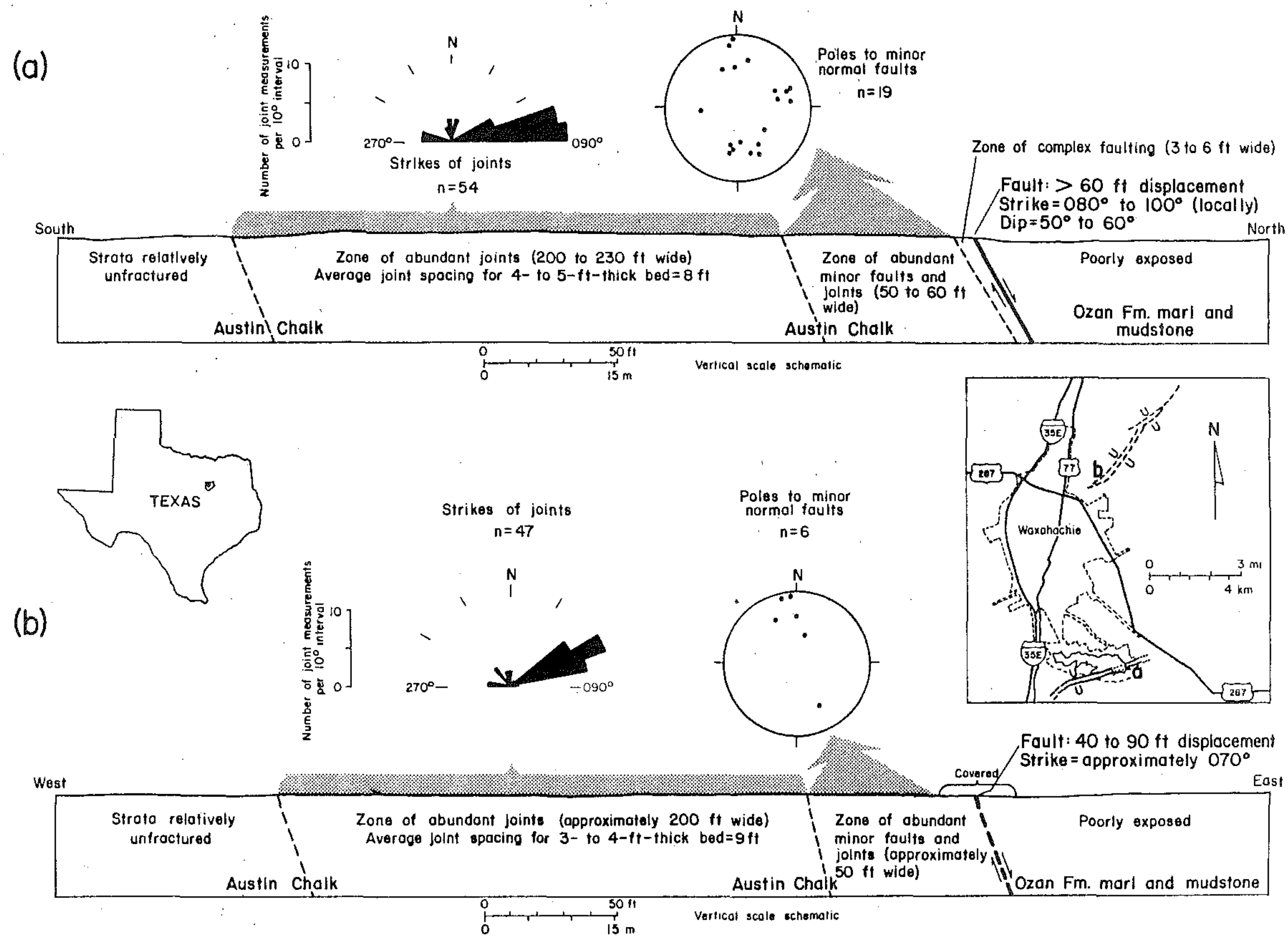

Figure 3. Fracture styles, geometries, and intensities of adjacent major normal faults at (a) graben near Lake Waxahachie and (b) graben northeast of Waxahachie.

strata zone is a 200- to 230-ft wide zone of abundant joints. Most of the joints are near vertical and strike 060° to 110°. Some joints also strike 340° to 020°. Average joint spacing for 4- to 5-ft thick chalk beds within the jointed strata zone is about 8 ft.

It is difficult to trace the lateral extent of the major faults at the surface because of thick soils, Quaternary surficial deposits, and vegetation. Faults are observed only in exposures along streams; thus, more faults probably occur within the study site than have been mapped. Surface mapping indicates that the proposed SSC tunnel may cross several faults in the vicinity of Red Oak at the northern part of the study site (Plate 1). The proposed tunnel may also cross two possible faults at the southern part of the study site. These two faults are based on interpretations by earlier researchers (Barnes, 1972), but the existence of these faults could not be verified in the field. The northward strikes of these faults also do not coincide with the strikes of other faults that were observed in the area. Continued detailed studies, possibly utilizing closely spaced boreholes in selected areas, are necessary to identify and characterize faults that may intersect the proposed SSC tunnel.

ACKNOWLEDGMENTS

This report was done under Contract No. IAC(86-87)-1708.

Typing for this report was done by Ginger Zeikus. Editing was done by Amanda Masterson. Illustrations were drafted by Annie Kubert-Kearns, Don Thompson, and Teresa Weaver, under the supervision of Richard L. Dillon, Bureau of Economic Geology, The University of Texas at Austin.

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