BUREAU OF ECONOMIC GEOLOGY
The University of Texas
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John T. Lonsdale, Director

Report of Investigations — No. 41

Stratigraphy of the Blach Ranch--Crystal Falls Section (Upper Pennsylvanian), Northern Stephens County, Texas

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ABSTRACT

Three mappable members in the upper part of the Thrifty formation (Blach Ranch limestone, unnamed shale, and Breckenridge limestone), two in the lower part of the overlying Harpersville formation (Quinn clay and Crystal Falls limestone), and six minor lentils, all in the outcropping Cisco group, northern Stephens County, Texas, have been mapped and are described. The Blach Ranch, Breckenridge, and Crystal Falls limestone members, which are important regional stratigraphic markers in surface Cisco rocks of the Brazos Valley, have been redescribed at type localities in the area.

Plummer and Moore's original Thrifty and Harpersville formations are used, but future revision of the classification, based on additional detailed mapping in the Brazos Valley, is recommended. Cisco is recognized as a group (rock unit), that includes the Graham, Thrifty, and Harpersville formations, rather than as a series (time-rock unit).

The rocks (about 100 feet thick) were deposited under cyclic, rapidly changing shallow marine to nonmarine conditions. Thin fossiliferous persistent limestone beds mark maximum but shallow marine transgression; they are separated by clay and shale containing sandstone beds and channels that mark maximum regression for this section in the area. Each limestone member is cut by one or more channel sandstones that originated in the overlying clay and shale members. Minor local calcareous units, which are commonly fossiliferous, near-shore deposits, pinch out laterally and/or change composition abruptly.

INTRODUCTION

PURPOSE OF STUDY

Pennsylvanian rocks of the upper Thrifty and lower Harpersville formations of the Cisco group in northern Stephens and southern Young counties have been studied, and five members and several lentils have been mapped (fig. 1). The members included are the Blach Ranch limestone, unnamed shale, and Breckenridge limestone members of the Thrifty formation, and the Quinn clay and Crystal Falls limestone members of the Harpersville formation (fig. 2). The purpose of the investigations was to clarify ambiguous type localities, establish adequate type reference sections for the Blach Ranch, Breckenridge, and Crystal Falls limestone members, which were originally defined by Plummer and Moore (1922) in northern Stephens County (fig. 3), and provide stratigraphic data to aid in future regional studies.

The Blach Ranch and Breckenridge limestones are among the most persistent, mappable units in the upper Cisco group of the Brazos River valley and thus are important regional stratigraphic markers. Study of the type areas of the limestone members is a prerequisite for any future studies of the Cisco in this area. The study was restricted to physical stratigraphy, but the occurrence of fossils was noted.

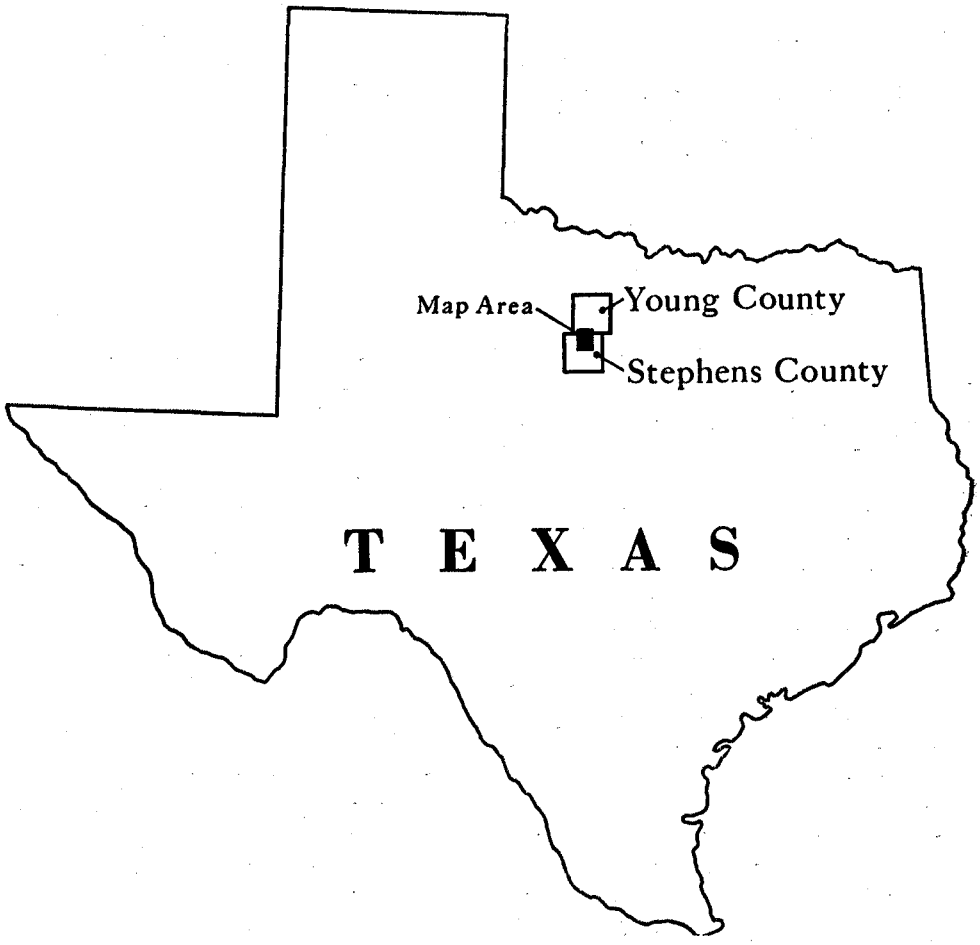


FIG. 1. Index map showing area of study.

PREVIOUS WORK

Cummins (1891) and Drake (1893) outlined surface Pennsylvanian geology in north-central Texas and outlined the stratigraphic classification. Drake (1893) proposed many stratigraphic terms for the Colorado River valley, but rocks were not further subdivided in the Brazos Valley until after World War I when petroleum exploration became intensive. Plummer (1919) offered a preliminary classification which included formations defined in the Brazos River valley, but Plummer and Moore (1922) proposed a more comprehensive classification. A short paper by Moore and Plummer (1922) probably preceded publication of Plummer and Moore (1922); however, the latter is more detailed and is accepted as the reference for type designations proposed by those authors. The Thrifty and Harpersville formations and three key limestones—Blach Ranch, Breckenridge, and Crystal Falls—were named in the more comprehensive report (table 1).

Lee (1938) described general stratigraphy of the Thrifty and Harpersville formations in southern Young and northern Stephens counties and included sections and a generalized map of several limestones. Plummer et al. (1949) included a generalized map of the Breckenridge limestone, Quinn clay, and Crystal Falls limestone in Stephens and southern Young

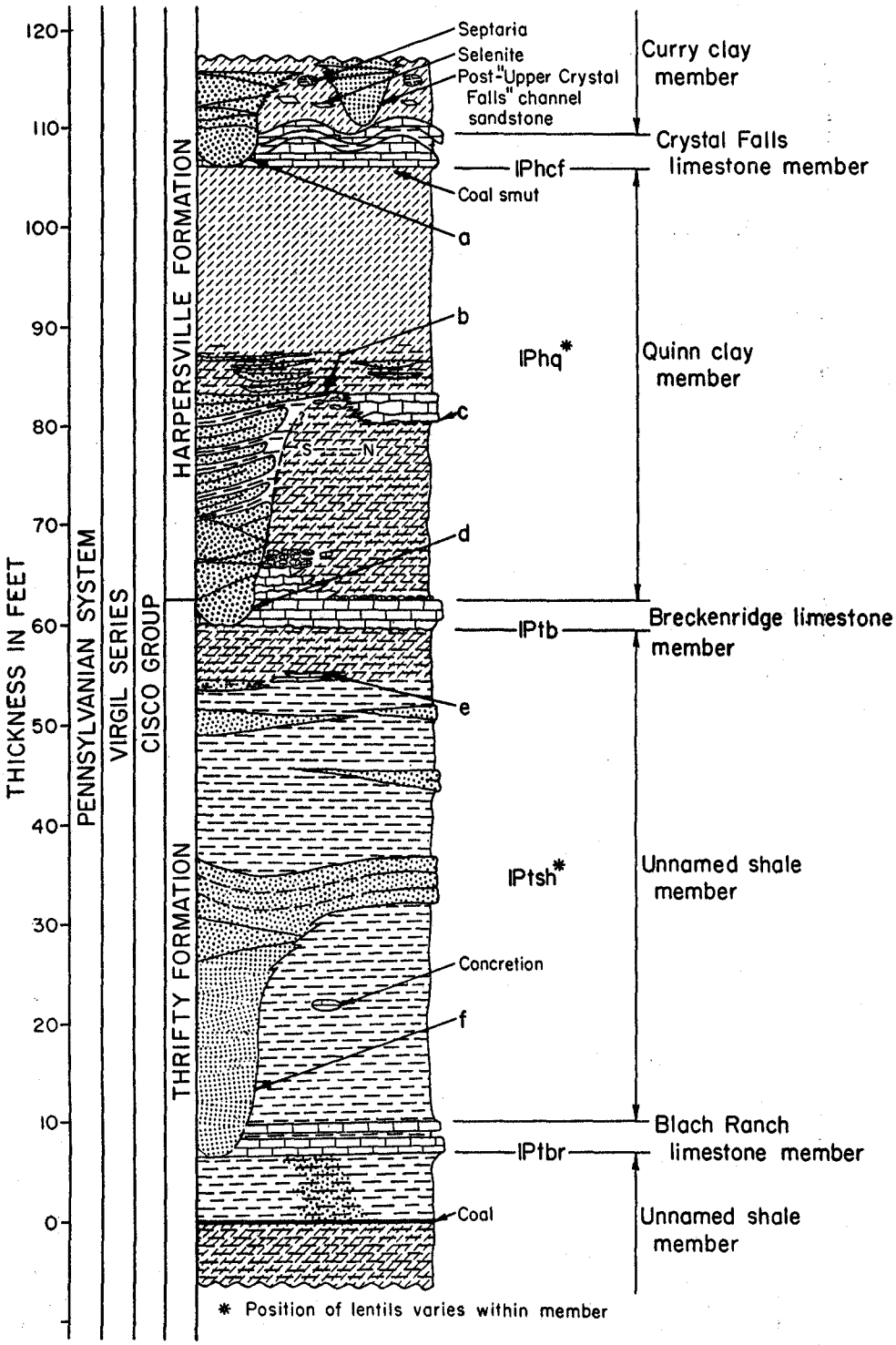


FIG. 2. Composite diagrammatic section, upper Thrifty—lower Harpersville formations, northern Stephens County, Texas.

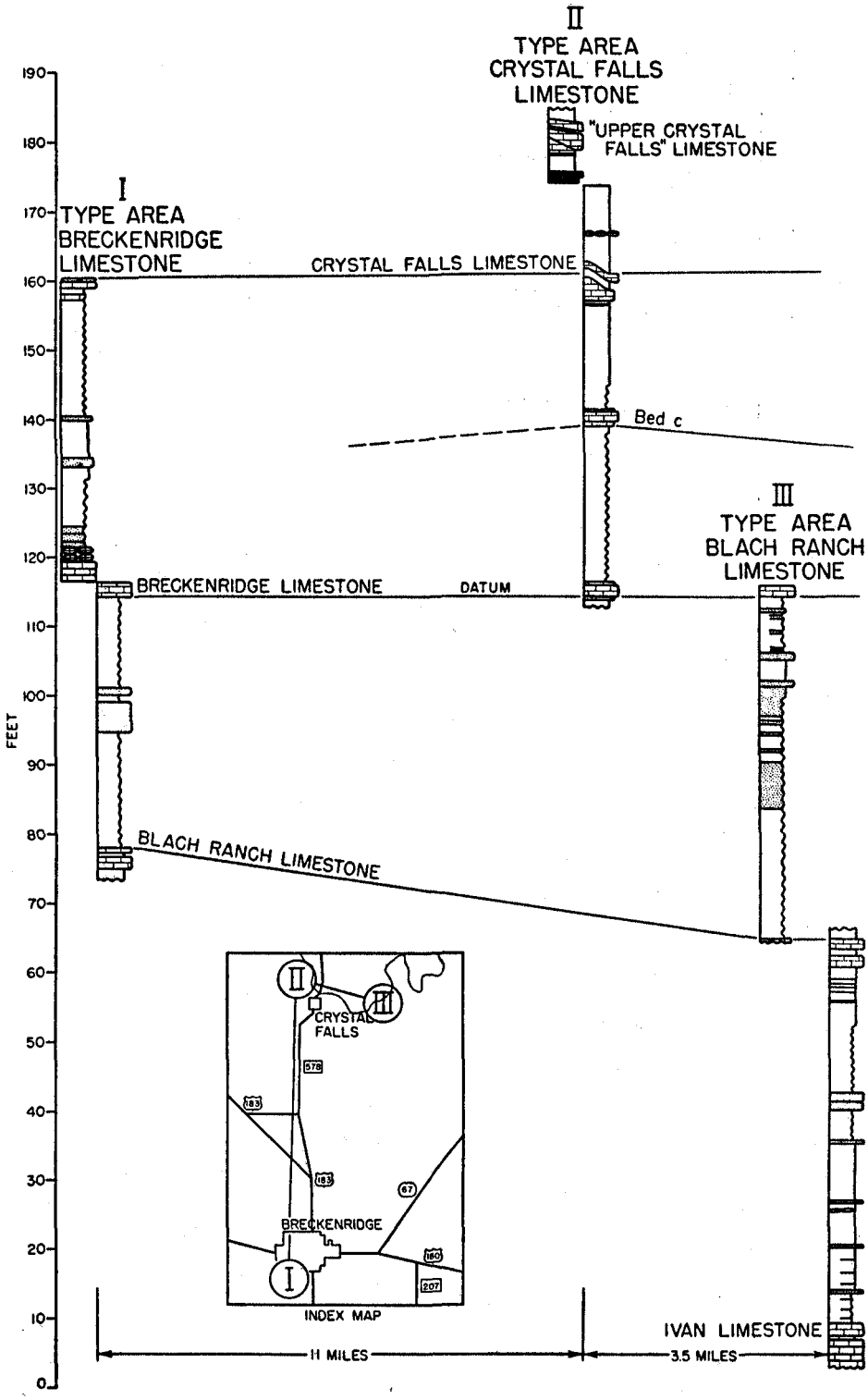


FIG. 3. Correlation of type sections.

counties. D. A. Myers, of the United States Geological Survey, has completed manuscript and map of the Wayland 15-minute quadrangle, southern Stephens County, based on field work during intervals from 1956 to 1958.

PRESENT STUDY

Location.—The area is in northern Stephens and southern Young counties, Texas; it is bounded on the north and south by latitudes 32°58′30″ N. and 32° 43′30″ N. and on the east and west by the outcrop of the Blach Ranch and Crystal Falls limestones, respectively. U. S. Highway 183 and Farm Road 578 follow the western boundary between Breckenridge and Crystal Falls, and State Highway 67 and Farm Road 701 traverse the eastern part of the area from Breckenridge to Eliasville.

Topographic maps available for the area are the U. S. Geological Survey 30-minute Breckenridge sheet (1888), the 7.5-minute Breckenridge quadrangle (1958), and the Abilene sheet, scale 1:250,000 (NI 14–11, 1954).

Field work.—Reconnaissance of Cisco outcrops in the Brazos Valley was made in the fall of 1957; field work for this report was conducted during two and a half months in the spring and summer of 1958. Geologic contacts were plotted on 1:20,000 stereographic aerial photographs.

Acknowledgments.—Many individuals contributed to the accomplishment of the project resulting in the present report and map, and the writer expresses his appreciation to the following for the especial aid each gave: John A. Kay and Robert I. Roth cooperated in the initiation of studies in north-central Texas by discussion of surface stratigraphic problems in Upper Pennsylvania rocks of the area; W. J. Wilson and Daniel Bakker examined certain sandstone channels and suggested methods of determining current direction; D. A. Myers in field reconnaissance provided pertinent information on the Wayland quadrangle; and W. C. Bell, D. H. Eargle, and P. T. Flawn gave helpful suggestions with a critical reading of the manuscript.

STRATIGRAPHIC NOMENCLATURE

Upper Pennsylvanian rocks in the Brazos Valley consist of shale and numerous thin beds of sandstone, limestone, and coal. Many limestone and some sandstone beds are widespread and, with the intervening shale, are basic mappable units. This study is concerned with these basic rock units, but limited consideration of larger rock units is also necessary.

Tarr (1890) and Dumble (1890) recognized major Carboniferous rock "divisions" or "series" in north-central Texas, and Cummins (1891) defined them more specifically as Bend, Millsap, Strawn, Canyon, Cisco, and Albany divisions. Drake (1893) adopted Cummins' Strawn, Canyon, Cisco, and Albany divisions with revised boundaries and in the Colorado Valley divided them into field units called "beds," which correspond to members of later classifications.

Plummer and Moore (1922) called the divisions of Cummins and Drake "groups" and divided each group into formations that include a heterogeneous section of shale, sandstone, and limestone between persistent, mappable limestone or sandstone members. Subsequently, other classifications have been proposed (table 1). Some resulting classification and nomenclature problems have been previously discussed (Brown, 1959).

MEMBERS

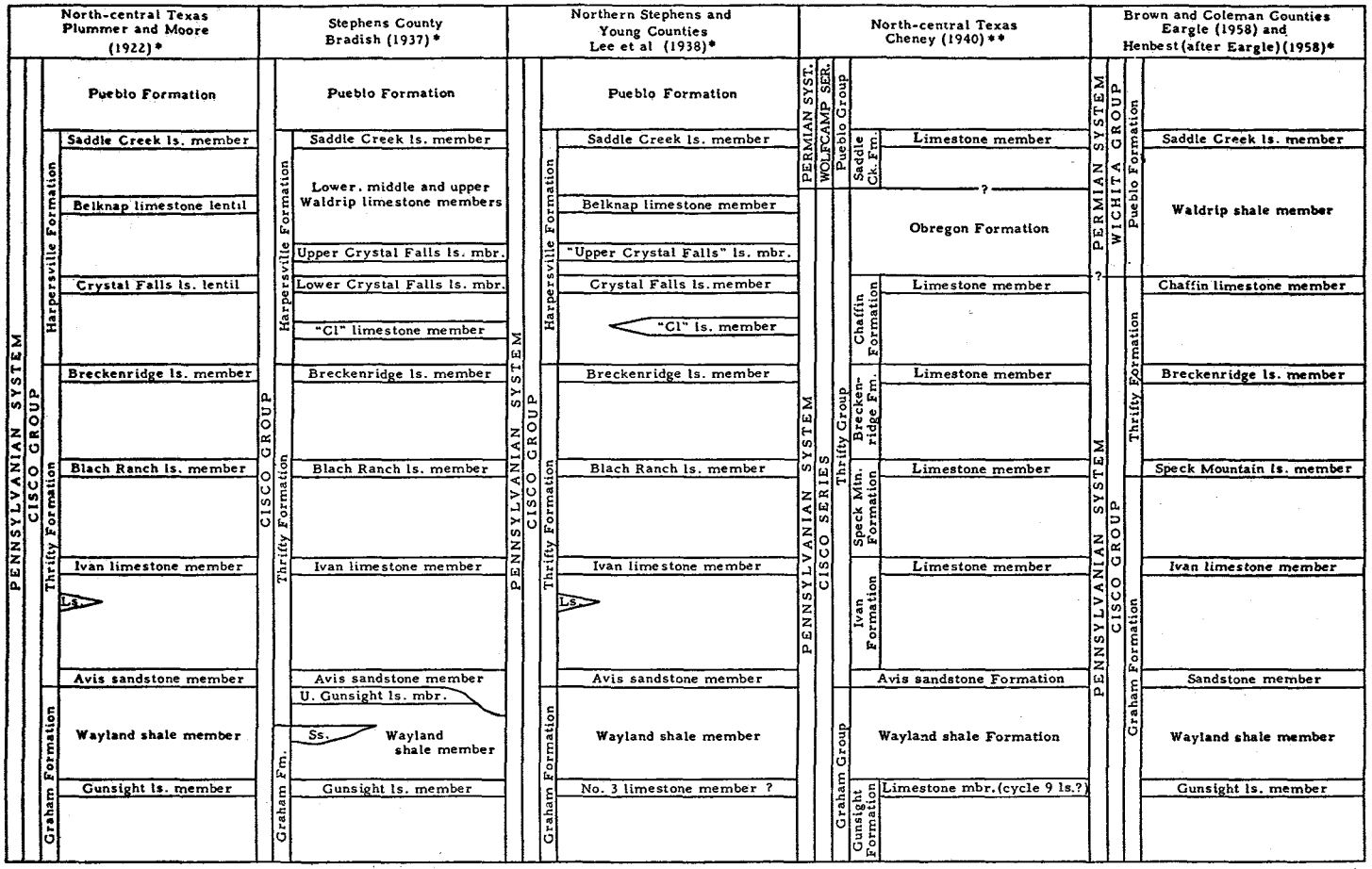
The terms Blach Ranch, Breckenridge, and Crystal Falls are retained (table 1) for limestone beds in the Brazos Valley named by Plummer and Moore (1922, pp. 154, 161), even though Crystal Falls and Blach Ranch are probably equivalent, respectively, to the earlier named Chaffin and Speck Mountain limestones of the Colorado Valley. The names Crystal Falls and Blach Ranch have been used for 36 years. The term Quinn clay, used by Plummer et al. (1949, Pl. IV, *Cq*) in northern Stephens County, is retained. No name is proposed for the "unnamed shale member" between the Blach Ranch and Breckenridge limestones. These rock units are fundamental mappable beds and are members of Plummer and Moore's (1922) Thrifty and Harpersville formations. Other minor rock units without formal names are designated herein by letters (e.g., bed *e*). Lines on the map (Pl. I) represent approximate outcrop of thin beds or members. However, when the outcrop of a thin bed or member has greater areal extent than the line representing it on the map, the line represents the *base* of the rock unit.

Cheney (1940, pp. 66, 90–92) elevated Plummer and Moore's (1922) members to "formations" (table 1). He defined the Speck Mountain [Blach Ranch?], Breckenridge, and Chaffin [Crystal Falls?] formations to include these limestone members and subjacent beds of sandstone and shale. In addition, Cheney (p. 91) proposed the "Obregon formation" for the interval between the Chaffin limestone and his Pennsylvanian-Permian "disconformity." The "disconformity" at the top of the "Obregon formation" is not mappable and, thus, is not a field rock unit. Acceptance of Cheney's formations presents problems: (1) Some units are too narrow to map on a scale of 1 inch to a mile; (2) a multitude of formation names is unnecessary and confusing; (3) the upper and lower limits of Cheney's numerous formations, which are also defined by sandstone and limestone beds, multiply classification problems resulting from lateral changes in lithology; (4) individual formations were not specifically discussed, defined, or mapped; and (5) existing names of limestone or sandstone members were applied to the new formations, which are mainly shale. Cheney's terminology is, therefore, not used in this report.

OTHER STRATIGRAPHIC DIVISIONS

Formations in the upper part of the Pennsylvanian of north-central Texas (table 1) are arbitrary rock units separated by "contacts" drawn at the top or bottom of key mappable sandstone or lime-

TABLE 1. *Stratigraphic classification, Upper Pennsylvanian, Lower Permian, north-central Texas.*



*Slightly modified from charts and figures or compiled from text.

**Modified from fig. 1 (Cheney, 1940, p. 66); stratigraphic limits of redefined formations interpreted from scattered statements in text.

stone beds. The formations are useful in discussing heterogeneous sections of shale, limestone, and sandstone or in charting them on geologic maps. Such formations are convenient "groupings" of mappable beds at a useful scale (American Com. on Strat. Nomen., 1956, p. 2006).

The rocks of this report are included in Plummer and Moore's (1922, pp. 152, 160) Thrifty and Harpersville formations (table 1). The Thrifty-Harpersville contact was drawn (idem) at the top of the Breckenridge limestone, but the present study shows that the base of the limestone is more easily mapped than the top. Also, limited reconnaissance of the original Graham-Thrifty contact (base of Avis sandstone) and Harpersville-Pueblo contact (top of Saddle Creek limestone) shows that these contacts may not be mappable throughout the Brazos Valley. Eargle (1958) adopted different formation contacts for detailed mapping in the Cisco group of the Colorado Valley.

In the writer's opinion, Plummer and Moore's classification should be retained until further detailed mapping and stratigraphic study have been completed in north-central Texas, and any revision should be a conservative modification of this older, field-oriented classification. To improve its use in the field, a revised classification should have contacts drawn at the base rather than the top of key beds (Moore, 1936, pp. 20–21), and more than one classification for the outcrop belt may be necessary.

Cheney (1940, pp. 66, 93–94) elevated the Graham, Thrifty, Pueblo, and other formations named by Plummer and Moore (1922) to group rank, but this revision does not improve the original classification. Cheney (pp. 66, 91) also expanded the Thrifty and Pueblo "groups" to include the Harpersville formation of Plummer and Moore, but the Thrifty (expanded)—Pueblo (expanded) contact drawn at his Pennsylvanian-Permian "boundary" is not mappable. The description of this contact indicates its problematical position. Cheney stated that "... the upper boundary for the Cisco series and the Pennsylvanian system evidently should be placed at some widespread disconformity in the Harpersville formation above the Waldrip-Newcastle coal zone and below the *Schwagerina*-bearing 'Waldrip limestone No. 3,' and the Saddle Creek limestone." He further stated that ". . . the Permian-Pennsylvanian boundary is 40–150 feet below the Saddle Creek limestone. 'Harpersville' beds below this boundary are assigned to the Obregon and Chaffin formations of the Thrifty group, those above this systemic boundary to the Saddle Creek formation of the expanded Pueblo group." Cheney redefined these formations to correspond to a time-stratigraphic boundary and, therefore, they were not designed for field use. The "Saddle Creek-Obregon" contact is based on faunal rather than rock criteria.

Eargle revised the Pennsylvanian and lower Permian classification (table 1) in the Colorado Valley (Eargle, 1958, pp. 50–51; Henbest, 1958, p. 41; and Myers, 1958, pp. 677–678). He lowered the Thrifty (expanded)—Pueblo (expanded) contact (Cheney, 1940, pp. 66, 91) to the top of the Chaffin limestone [Crystal Falls?], a bed mappable in the Colorado Valley, and raised the Graham-Thrifty contact (Plummer and Moore, 1922, p. 154) from the base of the Avis sandstone to the base of the Speck Mountain [Blach Ranch?] limestone, a more useful map unit in that area. Eargle did not recognize the Harpersville formation.

The top of the Chaffin or Crystal Falls limestone is not a satisfactory marker in much of the Brazos Valley. The limestone is commonly replaced by sandstone between Cisco and Breckenridge in southwestern Stephens County, and it pinches out (?) northeastward in north-central Young County. In northern Stephens and southern Young counties, the limestone is commonly covered by weathered debris from overlying channel deposits, and the bed can also be confused with "Upper Crystal Falls" limestone (table 1).

For many years the term "Cisco" (Cummins, 1891) has been used to refer to shale and thin beds of limestone and sandstone in the uppermost part of the Pennsylvanian

of north-central Texas. The top of the Cisco, unfortunately, has changed with each revision of the Pennsylvanian-Permian boundary. The term Cisco group is used herein to refer to rocks comprising the Graham, Thrifty, and Harpersville formations. The unit has no stratigraphic value, but Cisco is an established name useful in discussing this section of rock in north-central Texas.

Cheney's (1940, p. 90) redefinition of the Cisco group to "series" is not followed. Use in Texas of the Mid-Continent term Virgil series avoids duplication and simplifies interregional studies. Fossil zones that serve as criteria for standard Mid-Continent series can be used for time-stratigraphic correlations in Texas without establishing another set of formal series names for the State.

THRIFTY FORMATION

The Thrifty formation was named by Plummer and Moore (1922, pp. 152–154) ". . . for the town of Thrifty located near the center of Brown County," and the formation was defined to include 120 to 200 feet of strata ". . . from the bottom of the Avis sandstone to the top of the Breckenridge limestone . . ." (table 1). Plummer and Moore (idem) reported that they mapped or traced the formation from western Jack County to the area southwest of Brady, McCulloch County. The Thrifty formation, consisting of ". . . alternating, more or less lenticular beds of shale, sandstone and limestone," was divided by Plummer and Moore into the following units:

Breckenridge limestone member
Shale
Blach Ranch limestone member
Shale, sandstone, and conglomerate
Ivan limestone member
Shale and sandstone, with locally a limestone lentil
Avis sandstone member

The upper three members of the Thrifty formation—Blach Ranch limestone, unnamed shale, and Breckenridge limestone—are considered in this present report. Problems in nomenclature and classification of the formation are discussed under "Stratigraphic Nomenclature" (p. 10).

BLACH RANCH LIMESTONE MEMBER

Original type description.—Plummer and Moore (1922, pp. 154–155) proposed the term Blach Ranch (fig. 2) for "A limestone which occurs about 30 feet in most sections above the Ivan member...." They described the limestone ". . . from typical exposures in the vicinity of the Blach Brothers Ranch east of Breckenridge." However, the type locality is that given for a section (idem, p. 156) measured on "Blach" Brothers Ranch ". . . four miles east of Crystal Falls." Plummer and Moore described the limestone as light gray, massive, weathering to large buff or brown slabs or rounded boulders, and rather fossiliferous. They reported the average thickness to be 3 or 4 up to 8 feet.

New type description.—The redescribed type Blach Ranch limestone is on the original Black Brothers ranch, now two ranches owned by heirs Jack and Bill Black and B. H. Trammell of Breckenridge. The type section is 3.75 miles east of Crystal Falls, northeast of Breckenridge in north-central Stephens County (Pl. II, C). The ranch name was misspelled in the original description.

The limestone crops out in a north-south belt across the Black and Trammell ranches. The new type section is located in and near a railroad cut on the Chicago, Rock Island and Pacific Railroad. It can be reached by ranch roads, and more accessible roadside exposures occur in the area. The site was selected because of (1) original type description, (2) exceptional railroad cut exposure, and (3) occurrence of a measurable section from the Ivan to the Breckenridge limestone.

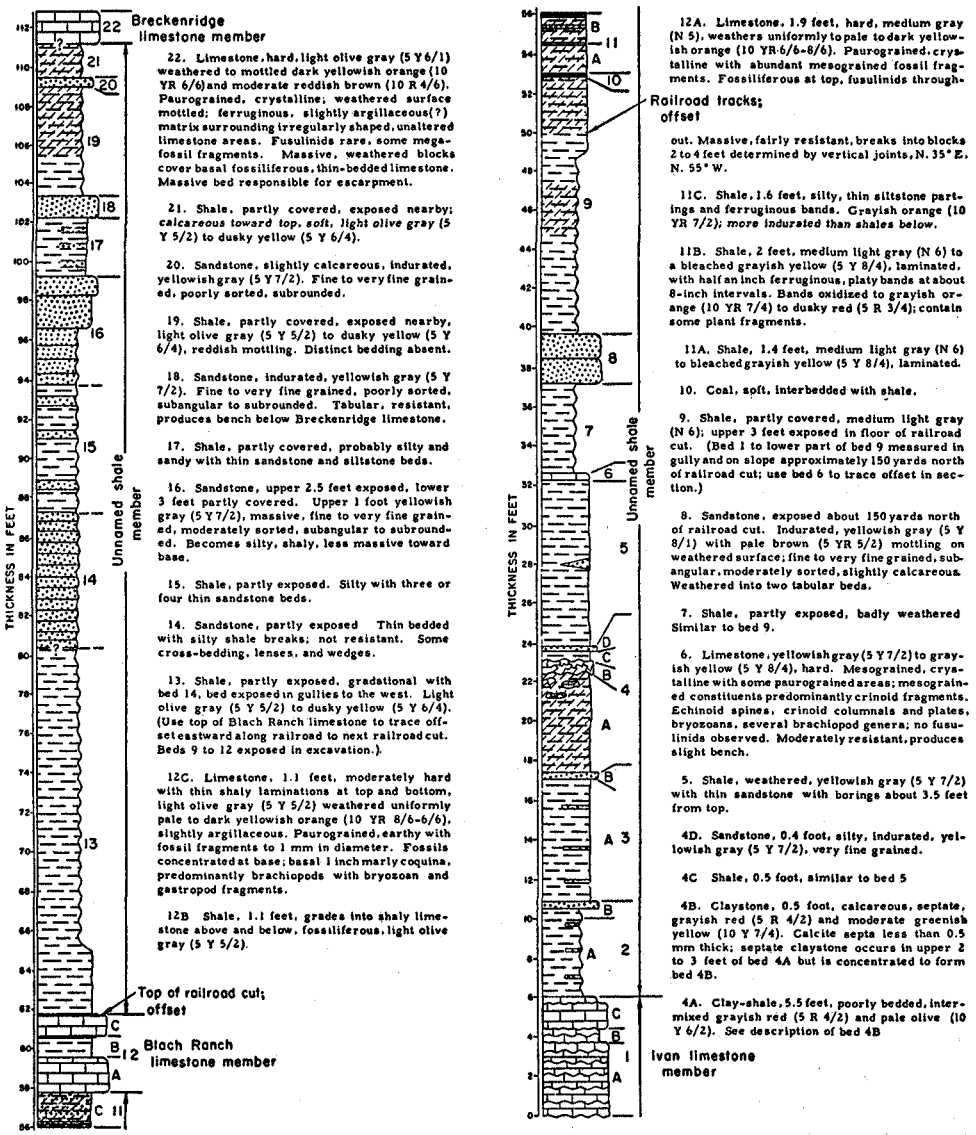
A section (fig. 4; Pl. II, C) from the base of the Ivan limestone to the top of the Blach Ranch limestone (beds 1A—12C) was measured on the north side of the railroad, from the head of a small gully southeast to the top of the railroad cut. The upper part of the section (beds 12C–22), which is offset west along the outcrop of the Blach Ranch limestone, is described from the top of the Blach Ranch, about 40 yards south of the railroad, south to the top of the Breckenridge limestone escarpment. The section is moderately exposed except for the sandstone beds between the Breckenridge and Blach Ranch limestones.

General features.—The Blach Ranch limestone is a uniform, persistent unit throughout the area (Pl. III, B-B′). The lower limestone bed is about 1.4 feet thick and is separated by about 1 foot of shale from the upper 0.8 to 1-foot limestone bed. About 1 foot of platy, argillaceous, fossiliferous limestone commonly occurs at the top of the upper bed, but it weathers rapidly and is rarely exposed (locality

214-T-99 and small Blach Ranch inliers, C-8,[1] Pl.I).

The lower limestone bed weathers along prominent fractures into massive, rectangular blocks and is covered at most places by smooth, rounded limestone slabs of the upper bed. The gray limestone weathers to a distinctive, uniform light gray to yellow brown. The outcrop of the limestone is commonly a low, subdued escarpment on which grows some scrub vege-

[1] Coordinates, Plate I.



22. Limestone, hard, light olive gray (5 Y 6/1) weathered to mottled dark yellowish orange (10 YR 6/6) and moderate reddish brown (10 R 4/6). Paurograined, crystalline; weathered surface mottled; ferruginous, slightly argillaceous(?) matrix surrounding irregularly shaped, unaltered limestone areas. Fusulinids rare, some megafossil fragments. Massive, weathered blocks cover basal fossiliferous, thin-bedded limestone. Massive bed responsible for escarpment.

21. Shale, partly covered, exposed nearby; *calcareous toward top, soft, light olive gray* (5 Y 5/2) to dusky yellow (5 Y 6/4).

20. Sandstone, slightly calcareous, indurated, yellowish gray (5 Y 7/2). Fine to very fine grained, poorly sorted, subrounded.

19. Shale, partly covered, exposed nearby, light olive gray (5 Y 5/2) to dusky yellow (5 Y 6/4), reddish mottling. Distinct bedding absent.

18. Sandstone, indurated, yellowish gray (5 Y 7/2). Fine to very fine grained, poorly sorted, subangular to subrounded. Tabular, resistant, produces bench below Breckenridge limestone.

17. Shale, partly covered, probably silty and sandy with thin sandstone and siltstone beds.

16. Sandstone, upper 2.5 feet exposed, lower 3 feet partly covered. Upper 1 foot yellowish gray (5 Y 7/2), massive, fine to very fine grained, moderately sorted, subangular to subrounded. Becomes silty, shaly, less massive toward base.

15. Shale, partly exposed. Silty with three or four thin sandstone beds.

14. Sandstone, partly exposed Thin bedded with silty shale breaks; not resistant. Some cross-bedding, lenses, and wedges.

13. Shale, partly exposed, gradational with bed 14, bed exposed in gullies to the west. Light olive gray (5 Y 5/2) to dusky yellow (5 Y 6/4). (Use top of Blach Ranch limestone to trace offset eastward along railroad to next railroad cut. Beds 9 to 12 exposed in excavation.).

12C. Limestone, 1.1 feet, moderately hard with thin shaly laminations at top and bottom, light olive gray (5 Y 5/2) weathered uniformly pale to dark yellowish orange (10 YR 8/6-6/6), slightly argillaceous. Paurograined, earthy with fossil fragments to 1 mm in diameter. Fossils concentrated at base; basal 1 inch marly coquina, predominantly brachiopods with bryozoan and gastropod fragments.

12B Shale, 1.1 feet, grades into shaly limestone above and below, fossiliferous, light olive gray (5 Y 5/2).

12A. Limestone, 1.9 feet, hard, medium gray (N 5), weathers uniformly to pale to dark yellowish orange (10 YR 6/6-8/6). Paurograined, crystalline with abundant mesograined fossil fragments. Fossiliferous at top, fusulinids throughout. Massive, fairly resistant, breaks into blocks 2 to 4 feet determined by vertical joints, N. 35° E, N. 55° W.

11C. Shale, 1.6 feet, silty, thin siltstone partings and ferruginous bands. Grayish orange (10 YR 7/2); *more indurated than shales below.*

11B. Shale, 2 feet, medium light gray (N 6) to a bleached grayish yellow (5 Y 8/4), laminated, with half an inch ferruginous, platy bands at about 8-inch intervals. Bands oxidized to grayish orange (10 YR 7/4) to dusky red (5 R 3/4); contain some plant fragments.

11A. Shale, 1.4 feet, medium light gray (N 6) to bleached grayish yellow (5 Y 8/4), laminated.

10. Coal, soft, interbedded with shale.

9. Shale, partly covered, medium light gray (N 6); upper 3 feet exposed in floor of railroad cut. (Bed 1 to lower part of bed 9 measured in gully and on slope approximately 150 yards north of railroad cut; use bed 6 to trace offset in section.)

8. Sandstone, exposed about 150 yards north of railroad cut. Indurated, yellowish gray (5 Y 8/1) with pale brown (5 YR 5/2) mottling on weathered surface; fine to very fine grained, subangular, moderately sorted, slightly calcareous. Weathered into two tabular beds.

7. Shale, partly exposed, badly weathered Similar to bed 9.

6. Limestone, yellowish gray (5 Y 7/2) to grayish yellow (5 Y 8/4), hard. Mesograined, crystalline with some paurograined areas; mesograined constituents predominantly crinoid fragments. Echinoid spines, crinoid columnals and plates, bryozoans, several brachiopod genera; no fusulinids observed. Moderately resistant, produces slight bench.

5. Shale, weathered, yellowish gray (5 Y 7/2) with thin sandstone with borings about 3.5 feet from top.

4D. Sandstone, 0.4 foot, silty, indurated, yellowish gray (5 Y 7/2), very fine grained.

4C Shale, 0.5 foot, similar to bed 5

4B. Claystone, 0.5 foot, calcareous, septate, grayish red (5 R 4/2) and moderate greenish yellow (10 Y 7/4). Calcite septa less than 0.5 mm thick; septate claystone occurs in upper 2 to 3 feet of bed 4A but is concentrated to form bed 4B.

4A. Clay-shale, 5.5 feet, poorly bedded, intermixed grayish red (5 R 4/2) and pale olive (10 Y 6/2). *See description of bed 4B*

3B Sandstone, 0.5 foot, indurated, slightly calcareous, yellowish gray (5 Y 7/2), very fine grained, poorly sorted.

3A. Shale, 5.9 feet, exposed to south in gullies, olive gray (5 Y 5/2) to a grayish yellow (5 Y 8/4). Several thin, very fine-grained intercalated sandstone

2B. Sandstone, 0.4 foot, similar to bed 3B.

2A. Shale, 4.5 feet, partly covered, similar to bed 3A.

1C. Limestone, 1.5 feet, hard, brownish gray (5 YR 4/1), weathered to pale yellowish brown (10 YR 6/2); some dark yellowish-orange (10 YR 6/6) mottling at top. Mesograined, crystalline, some paurograined matrix; abundant 0.1- to 1-mm fossil (mainly colonial coral) fragments. Massive, with 0.5-foot colonial coral zone at top; occasional solitary corals; fusulinids rare.

1B. Limestone, 0.6 foot, similar to bed 1C except wavy bedded, moderately resistant. Coral, echinoid, crinoid, and brachiopod fragments.

1A. Limestone, 3.8 feet, light olive gray (5 Y 6/1); texture similar to bed 1C. Irregular, slaby bedding; echinoid and brachiopod fragments.

FIG. 4. Type section of Blach Ranch limestone.

PLATE II

A. Type locality, Crystal Falls limestone.

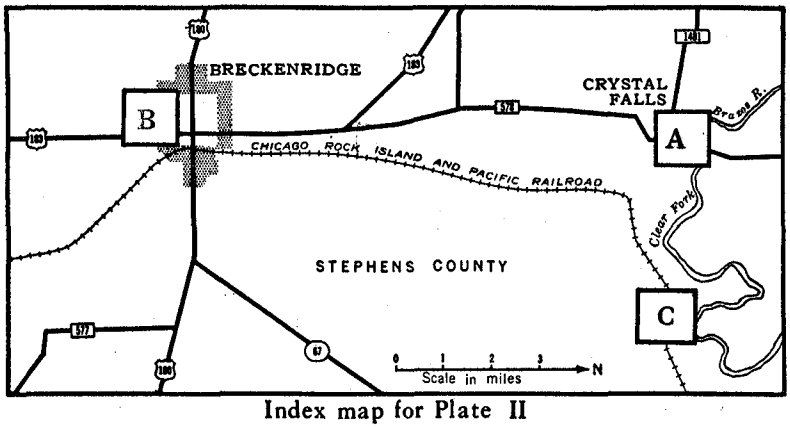
IPh$_2$—"Upper Crystal Falls" limestone
IPh$_1$—Curry clay
IPhcf—Crystal Falls limestone
IPhq—Quinn clay
c——Limestone lentil
IPtb—Breckenridge limestone
⟩⟩⟩—Line of section
Exp. 1—Clay exposure no. 1
Exp. 2—Clay exposure no. 2
Cut 1—Abandoned railroad cut no. 1
Cut 2—Abandoned railroad cut no. 2
X——Abandoned old bridge road
Y——Dam
Z——New bridge road

B. Type locality, Breckenridge limestone.

IPhcf—Crystal Falls limestone
IPhq—Quinn clay
b——Sandstone lentil
d——Sandstone channel deposit
IPtb—Breckenridge limestone
IPtsh—Unnamed shale
IPtbr—Blach Ranch limestone
1——Gully no. 1
2——Gully no. 2
3——Gully no. 3
⟩⟩⟩—Line of section
~~~—Breckenridge limestone removed by channeling

C. Type locality, Blach Ranch limestone.

IPtb—Breckenridge limestone
IPtsh—Unnamed shale
IPtbr—Blach Ranch limestone
IPt$_2$—Shale between Ivan and Blach Ranch limestones (unnamed)
IPt$_1$—Ivan limestone
⟩⟩⟩—Line of section



Index map for Plate II
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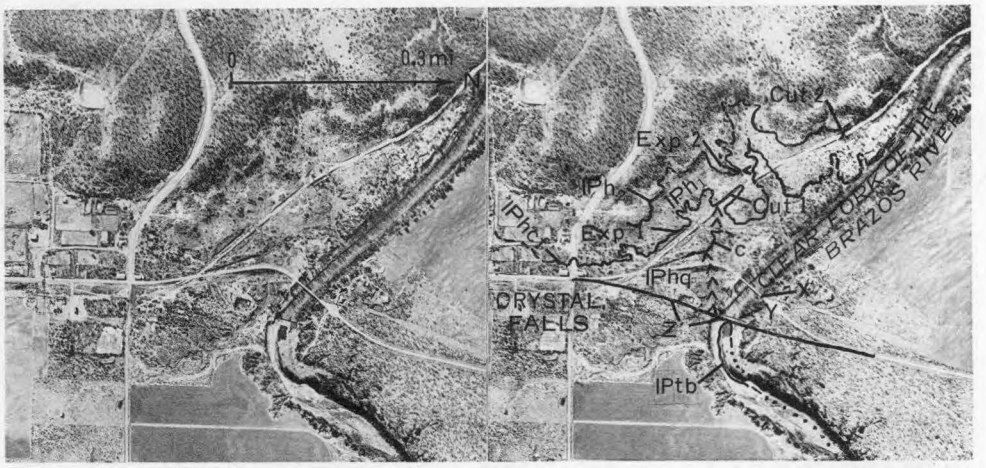
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Cut 2
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CRYSTAL FALLS
CLEAR FORK OF THE BRAZOS RIVER
IPtb

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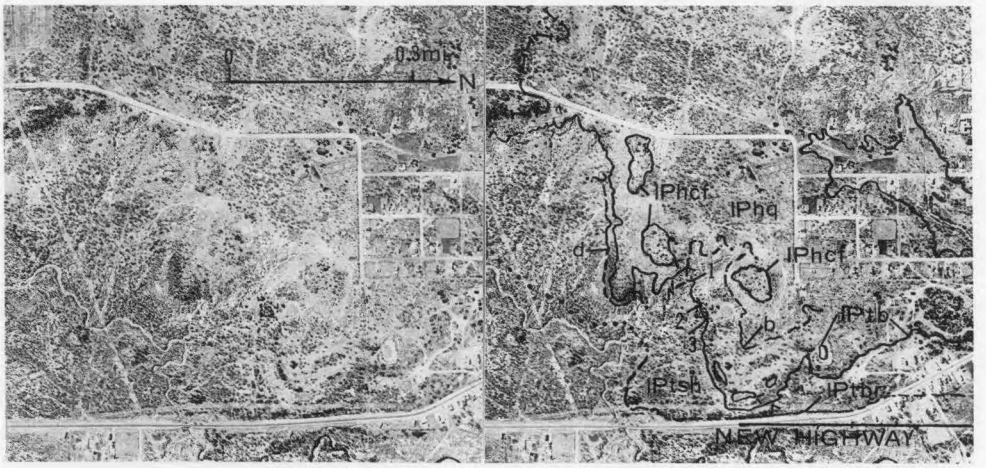
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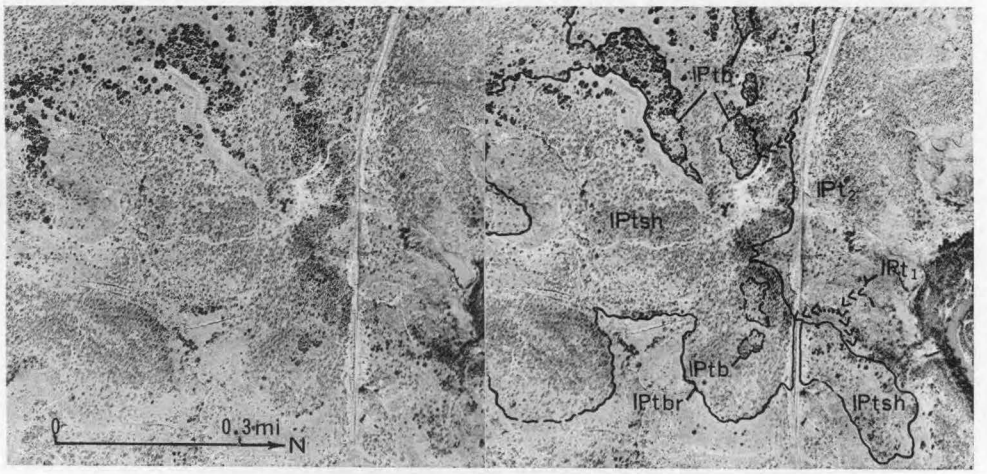
NEW HIGHWAY

B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C

tation. The limestone is well exposed except southeast of Breckenridge, where channel sandstone deposits (Pl. I, bed *f*) directly overlie or replace it, and at several places along the Clear Fork of the Brazos River, where high terrace deposits cover the limestone.

UNNAMED SHALE MEMBER

General description.—The shale between the Blach Ranch and Breckenridge limestones (fig. 2) has no formal name and none is proposed. In this report the unit is called the unnamed shale member of the Thrifty formation. The shale is 50 feet thick in the north part of the area but thins to 36 feet in the south (Pl. III, B-B′, C-C′). The upper part of the interval between the Breckenridge limestone and the bench-forming sandstone beds below is exposed in many places; the shale below the sandstone beds is rarely well exposed except along steep escarpments.

Mesquite trees commonly grow on weathered debris accumulated near the base of the shale, but the steep upper slopes are relatively free of vegetation. Post-oak trees grow on the outcrop of the thicker sandstone lentils throughout the area, and exposures of calcareous sandstone beds locally support vegetation similar to that on outcrops of the Breckenridge limestone.

Calcareous concretion zones.—Two beds of distinctive calcareous concretions are present locally in the shale. At several localities subrounded limestone concretions 1 to 2 feet long were observed between the Blach Ranch limestone and the first overlying sandstone. They are well exposed 11 feet above the Blach Ranch limestone in a gully 50 yards northwest of the outcrop of the Blach Ranch in the county road in G-11 (Pl. I).

The second concretion zone is 10 to 15 feet below the Breckenridge limestone at several localities. At Section 25 (p. 35), elongate limestone concretions from 0.2 to 1.0 foot long were observed 14 feet below the Breckenridge limestone. Septaria from 0.1 to 1 foot in diameter crop out 16 feet below the Breckenridge limestone on a small hill at a sharp bend on the northeast side of Gonzales Creek (C-8, Pl. I); here the septaria are calcareous, ferruginous claystone. Fossils were not observed in any concretion zone.

Sandstone, slightly calcareous and rarely fossiliferous (fig. 4, bed 20; Section 29, bed 7) occurs at about the level of the second concretion zone. Southeast of Breckenridge the upper few inches of a thin sandstone (Section 4, bed 3; Section 31, bed 1) about 12 feet below the Breckenridge limestone contains fossil fragments—crinoids, pelecypods, bryozoans. There is a similar occurrence of fossiliferous sandstone below the Breckenridge limestone at locality 214-T-101.

Limestone lentil.—A 1-foot thick crinoidal limestone lentil, bed *e* (D, E-2, Pl. I and Pl. III, C-C′), is present 9 feet below the Breckenridge limestone southeast of Breckenridge. The lentil and the Breckenridge limestone crop out in road material pits (D-2, Pl. I); for example, localities 214-T-108 and 214-T-109 and Section 32. It is equivalent (?) to a soft, irregularly bedded sandstone (Section 4, bed 5; Section 31, bed 3) with abundant small holes and tubes, exposed east of Gonzales Creek (C-2, Pl. I). The limestone lentil is either directly above or in lateral contact with a sandstone in the floor of road material pits east of locality 214-T-109, suggesting that limestone detritus was probably deposited on the uneven, eroded surface of a sandstone (Section 31, bed 1?), filling low areas and surrounding higher isolated remnants of the sandstone.

This limestone lentil (bed *e*) and the thickened basal unit of the Breckenridge limestone (Section 32, bed 4A) only occur southeast of Breckenridge and may represent remnants of facies (Pl. III, C-C′) which were present south and east of the present outcrop. Several inches of very fossiliferous marly limestone was observed at the base of bed *e* at localities 214-T-108 and 214-T-109. This limestone contains abundant well-preserved brachiopods, bryozoans, corals, and crinoid fragments. Other fossil localities were observed along the outcrop of bed *e*.

Sandstone lentils and channel deposits.—Several sandstone beds 0.5 to 2 feet thick are in the upper part of the unnamed shale member above the widespread sandstone which is locally a channel deposit (Pl. III, B-B′). These sandstone beds are discontinuous lentils at various levels.

The lowest and most persistent sandstone bed in the unnamed shale is 3 to 5 feet thick but thickens abruptly where it fills a channel (Pls. I and III, bed *f*). The base of a channel is exposed in the spillway at Lake Grand (E-4, Pl. I) where channel deposits rest on the Blach Ranch limestone. Festoon cross-lamination and primary current lineation (Stokes, 1953, pp. 21–29) in the spillway suggest a north-to-south current direction, whereas changes in thickness of bed *f* along its outcrop indicate an approximate northeast-to-southwest trend. The sandstone is about 20 feet thick near Section 22.

Another channel deposit about 25 feet thick is exposed in a railroad cut (F-13, Pl. I) near the Clear Fork of the Brazos River. Festoon cross-lamination indicates a north-to-south current direction, a trend which generally agrees with outcrop evidence. North of the railroad cut is a prominent elongate north-south ridge in line with the trend of the channel sandstone. The Clear Fork of the Brazos River bends sharply around this topographic feature, suggesting that the mile-long ridge is supported by a linear mass of channel sandstone, bed *f*.

An area of channel deposits was mapped southeast of Breckenridge (D, E, F, G-1, and G-2, Pl. I) where a thin sandstone, bed *f*, fills what was probably a broad, shallow channel, in contrast to the narrow channels discussed above. Bed *f* is not over 6 feet thick where it has replaced the Blach Ranch limestone. The Blach Ranch limestone is locally preserved beneath (1 to 5 feet) the sandstone at a few places, for example, at the small outliers in F-1, 2 (Pl. I). The Blach Ranch limestone was replaced by bed *f* southeast of an east-northeast-trending line extending from D-1 to H-2 (Pl. I). The channel area is outlined by an abrupt increase in post-oak trees that grow on the shallow sandy soils. D. A. Myers (oral communication, March 1959) stated that the channel area extends southeast of the map limits (Pl. I).

BRECKENRIDGE LIMESTONE MEMBER

Original type description.—Plummer (1919, p. 144) applied the name "Breckenridge formation" to a section containing three persistent limestone beds and one local limestone, thick shale beds, and lenticular sandstones above his "Gunsight" limestone. The three limestone beds which "... form escarpments around the east end of the Breckenridge oil field" (idem) are the Breckenridge, Blach Ranch, and Ivan limestones of Plummer and Moore's (1922) classification.

The Breckenridge limestone member was defined by Plummer and Moore (1922, p. 155) as the upper limestone of the Thrifty formation. They stated that "It forms a prominent escarpment in and about the town of Breckenridge. . . ." It was described as gray, massive, and resistant, from 3 to 4 feet thick and lying 25 to 45 feet above the Blach Ranch member (fig. 2). Plummer and Moore did not include a measured section of the Breckenridge limestone in its type area, and the nearest sections to it were measured at the type Blach Ranch area, 10.5 miles northeast of Breckenridge and ". . . in the escarpment two miles northeast of Harpersville . . ." (idem, p. 156), about 8 or 9 miles south of Breckenridge.

The line labeled "Breckenridge limestone" on Plummer and Moore's Plate I is not the outcrop of the Breckenridge limestone according to their type description (1922, p. 155) but is the outcrop of the Blach Ranch limestone. Bradish (1937, *Cn*) and Plummer et al. (1949, Pl. IV, *Cbu*) traced the outcrop of the type Breckenridge limestone in the type area, and Lee (1938) traced the Breckenridge limestone in northern Stephens County. Mapping by the writer shows that the limestone which Plummer and Moore labeled "Breckenridge" in each of their measured sections in Stephens and Young counties correlates with their type Breckenridge (1922, pp. 155–156). For this reason, the inconsistency between the type description of the

Breckenridge limestone and the outcrop map is interpreted as mislabeling of the map and not an error in type description.

New type description.—A type reference section (Pl. II, B) on the Harris Veale property, near the south city limits of Breckenridge, west of U. S. Highway 183 (C-2, Pl. I), is described. The site was selected for the following reasons: (1) location agrees with original type description; (2) occurrence of the only measurable section in central Stephens County from the base of the Blach Ranch to the top of the Crystal Falls limestone; (3) occurrence of the only satisfactory exposures of two upper units of the Breckenridge limestone; and (4) occurrence nearby (Section 32) of a basal unit of the Breckenridge limestone. Factors which make the locality less desirable for type reference are (1) an extensive area of post-Breckenridge-pre-Crystal Falls channeling which removed the Breckenridge limestone south of the type area, (2) presence of surface slumping in the area, and (3) the necessity for an offset in the measured section to include good exposures of three units of the limestone member. There are many other localities of the limestone near Breckenridge away from the area of surface slumping and channeling (Pl. I).

The lower part of the section in the **Breckenridge limestone type area (Pl. II,** B) was measured from the base of the Blach Ranch limestone at road level on the west side of U.S. Highway 183 westward to a pond excavated in the Breckenridge limestone at the top of the prominent escarpment (fig. 5, beds 1A–5A). The upper part of the section is offset westward along the outcrop (Pl. II, B) of the massive mottled bed of the Breckenridge (fig. 5, bed 5A); the upper interval was measured from the base of the bioclastic limestone bed of the Breckenridge, exposed in gully no. 1, northwest 20 yards and thence southwest to the sandstone above the Crystal Falls limestone at the top of an isolated hill (fig. 5, beds 5B–12). All three units of the Breckenridge limestone member (beds 5A, B, and C) are partly exposed in gullies no. 2 and 3, but beds 5B and 5C are best exposed in gully no. 1 (Pl. II, B).

General features.—The Breckenridge limestone outcrop is a prominent escarpment throughout most of the area. The resistant, massive mottled bed of the **Breckenridge limestone member (fig. 5, bed 5A)** that caps this escarpment and many outliers is of uniform thickness and lithology (Pl. III). This limestone bed averages 1.8 feet and weathers into angular, irregular fragments, usually mottled gray to orange or reddish brown. About 1 foot of nodular or irregularly bedded limestone occurs above and below the massive mottled bed except near Breckenridge, where these limestone units thicken to 3 or 4 feet. Abundant fusulinids are in the thin limestone bed at the base of the member.

In northern Stephens and southern Young counties, the Breckenridge limestone probably is the most useful marker in the Cisco group. The outcrop of the limestone is commonly covered by small live-oak trees; in many places a narrow dense hedge-like belt of scrub vegetation, some of it evergreen, follows the outcrop. The distinctive mottled limestone bed, the topographic prominence, and the characteristic vegetation make the Breckenridge limestone member an easily mapped rock unit in this part of the Brazos Valley. The base **of the Breckenridge limestone can be more** readily mapped than the top, which is the Thrifty-Harpersville contact (p. 12).

The Breckenridge limestone is locally covered by calcareous terrace deposits (C-6, 7, 8, Pl. I) that are well exposed at locality 214-T-84; south of Breckenridge (B, C-1, 2, Pl. I) the limestone was removed by channeling.

Limestone units.—North of U. S. Highway 180 the Breckenridge limestone is of relatively uniform thickness and rock type (Pl. III). An example of the Breckenridge limestone in this area is at the type locality of the Crystal Falls limestone (fig. 6, bed 2); another example is in a railroad cut, locality 214-T-62, where the well-exposed limestone contains fusulinids, brachiopods, and fragments of crinoids, bryozoans, and corals. The distinctive massive mottled bed

of the Breckenridge is overlain by 0.5 to 1 foot of less resistant, fossiliferous, commonly crinoidal limestone that grades upward into limestone nodules in the lower Quinn clay; this upper limestone bed is rarely well exposed. Below the massive limestone bed in this same area is another 0.5 to 1-foot bed of slabby limestone containing abundant fusulinids.

South of U. S. Highway 180, the Breckenridge limestone member abruptly thickens (Pl. III, A-A′, C-C′). The 0.5 to 1-foot thick crinoidal and nodular limestone above the massive mottled bed north of Breckenridge thickens near locality 214-T-98 and can be observed in Breckenridge (localities 214-T-102, -103, and -112). At the Breckenridge type section (fig. 5) this upper limestone is 5.2 feet thick and consists of two distinctive units—an upper 2.2 feet of nodular limestone (bed 5C) and a lower 3 feet of faintly cross-bedded bioclastic limestone (bed 5B) that rests on 2.2 feet of the massive mottled limestone (bed 5A).

The 0.5 to 1 foot of slabby limestone at the base of the massive mottled bed north of Breckenridge also thickens to about 4 feet southeast of Breckenridge (Section 32, bed 4A; localities 214-T-108, -109). This basal limestone unit is gradational with the massive bed above and grades downward into thin-bedded nodular limestone, used as road material by the town of Breckenridge.

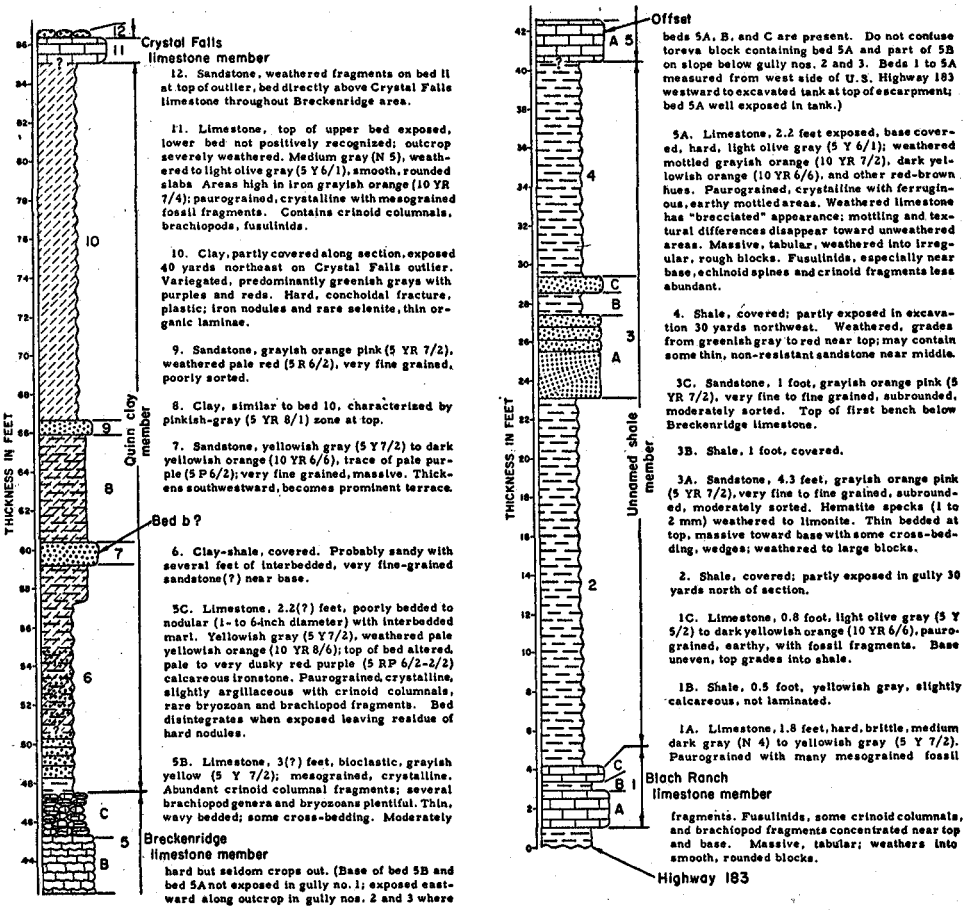


FIG. 5. Type section of Breckenridge limestone.

HARPERSVILLE FORMATION

The Harpersville formation (Plummer and Moore, 1922, pp. 160–162) was named ". . . from the small town of Harpersville in Stephens County located 10 miles south of Breckenridge." The formation was defined to include 200 to 275 feet of ". . . strata from the top of the Breckenridge limestone to the top of the Saddle Creek limestone or its equivalent stratum" (table 1). Plummer and Moore reported that the formation can be followed from north-central Young County to Cretaceous sand southwest of Lohn in McCulloch County. The Harpersville formation was described as basal thick, coarse sandstone or conglomerate beds; middle beds of alternating fossiliferous limestone, calcareous sandstone, carbonaceous and ferruginous shale and thin coal; and upper beds of thick massive sandstone commonly capped by hard gray limestone. The Harpersville formation was divided by Plummer and Moore into the following units:

Saddle Creek limestone member
Shale and sandstone
Belknap limestone lentil
Shale, sandstone, limestone, and coal
Crystal Falls limestone lentil
Sandstone and shale

The lower two members or lentils of the Harpersville formation—sandstone and shale (Quinn clay) and Crystal Falls limestone—are described in the present report. Problems in nomenclature and classification of the formation are discussed under "Stratigraphic Nomenclature" (p. 10).

QUINN CLAY MEMBER

Type locality and description.—Plummer et al. (1949, pp. 5–6) proposed the name Quinn clay (fig. 2) for the clay ". . . between the Parks Mountain sandstone or its probable equivalent, the Cisco Lake sandstone, and the upper Breckenridge limestone...." They stated that "... it is most conveniently mapped as the clay between the lower Crystal Falls limestone and upper Breckenridge limestone" and that the Quinn clay ". . . is best described as the next to lowest clay in the Harpersville formation...." (See following discussion.) The type locality is located (idem, p. 6) ". .. on the Quinn tract, on the north side of the Eastland-Cisco highway (U. S. Highway No. 80), 2 miles east of Cisco."

The Quinn clay in northern Stephens County, according to Plummer et al. (1949, Pl. IV, *Cq*), is the clay between the Crystal Falls and "upper Breckenridge limestone." The present study shows that this "upper Breckenridge limestone" (idem, *Cbu*) in northern Stephens County is type Breckenridge limestone (Pl. I, lPtb; fig. 5, bed 5) and that no "lower Breckenridge limestone" occurs in the subject area. Also, correlation has not been demonstrated of the type Quinn clay in northern Eastland County with the "Quinn clay" mapped by Plummer et al (1949, Pls. II–IV, VII) in northern Stephens County.

D. A. Myers (personal communication, January 1959) stated that the type Breckenridge limestone at Breckenridge correlates with the lower of two limestone beds of the Breckenridge limestone member in southern Stephens County. If these two limestone beds, which are separated by as much as 20 feet of shale in southern Stephens County, correspond to the "upper and lower Breckenridge limestone" of Plummer et al. (1949, Pl. VII) at the type Quinn clay locality in northern Eastland County, several stratigraphic problems are indicated: (1) the "upper Breckenridge limestone" (idem) must disappear north of southern Stephens County; the limestone may be approximately equivalent to sandstone bed *b* and limestone bed *c* (Pl. III); (2) the type Quinn clay in northern Eastland County is probably equivalent only to the upper part of the "Quinn clay" of Plummer et al. (1949, Pl. IV, *Cq*) in northern Stephens County, between beds *b* or *c* and the Crystal Falls limestone (Pl. I).

In this report the clay and clay-shale between the Breckenridge and Crystal Falls limestones are called the Quinn clay member; this usage agrees with that of Plummer et al. (1949, Pl. IV) for the area. The Quinn clay is a useful rock unit in the area, but future work may resolve the correlation problem and indicate a needed re-

vision of the original definition or the present usage.

General features.—The Quinn clay member ranges from 30 to 50 feet thick, with a minimum thickness north of the Clear Fork of the Brazos River; the clay contains several thin sandstone lentils, a limestone lentil, and a sandstone channel deposit.

The upper part of the Quinn clay, between the Crystal Falls limestone and beds *b* or c (Pl. III, A-A′), is plastic and gray to olive, containing purple and red areas of higher iron content. Iron oxide nodules, disseminated gypsum, and thin bands of organic matter are impurities. The clay has conchoidal fracture and no apparent bedding. The outcrop of this part of the member is relatively free of trees or other vegetation, probably because of the gypsum and iron content and the impermeable soil formed on the clay.

The lower part of the Quinn clay or clay-shale, between the Breckenridge limestone and beds *b* or *c,* contains more iron than the clay above; the clay-shale is commonly red with abundant thin fragments (0.1 to 1 inch) of ferruginous claystone. These thin oxidized claystone fragments range from red to yellow orange and are abundant on slopes beneath bed *b* south of the Clear Fork of the Brazos River (Sections 7, 8). The clay-shale has indistinct shaly laminae. North of the Clear Fork this lower interval thins from about 20 to 5 feet. The lower part of the Quinn clay is commonly deeply weathered and covered by rock debris; mesquite trees grow in abundance in these areas. A few live-oak trees grow along the outcrop of bed *c,* and post-oak trees grow on the sandstone channel (bed *d*) south of Breckenridge (B-l, Pl. I).

Limestone and sandstone lentils.—A persistent 1-foot bed of sandstone (bed 6, Pl. I), with 1 or 2 feet of overlying ferruginous shaly sandstone, crops out near the middle of the Quinn clay south of Crystal Falls (Pl. III, A-A′). Near Breckenridge the sandstone unit thickens to 5 feet (Sections 5 and 6), and at many places the bed produces a slight topographic bench and caps several small outliers (D-9, 10, Pl. I). On these topographic benches the soft ferruginous sandstones above the resistant bed 6 weather to small distinctive "mounds" of green and red sandstone. Ripple marks are common. Several discontinuous sandstone lentils are present at about the same level north of the Clear Fork of the Brazos River (Pl. III).

Near Crystal Falls, a limestone (bed *c,* Pl. I) about 3 feet thick is 23 feet above the Breckenridge limestone (fig. 6, bed 4), but northeast of Crystal Falls bed *c* gradually converges with the Breckenridge limestone (Pl. III, A-A′). Bed *c* is the "Cl" limestone of Bradish (1937) and Lee (1938, p. 63). It weathers to hard dense fragments of limestone in a marly matrix; fusulinids are locally abundant. Within a mile, between Sections 9 and 10 (Pl. III), bed *c* changes to a zone of ferruginous nodules grading from claystone containing thin calcite septa to sideritic limestone (Section 9, bed 3). As far south as C-4 (Pl. I) bed *c* is represented by a thin zone of limestone nodules (Sections 5–8), calcareous claystone septaria (locality 214-T-77), or rarely a fossiliferous limestone bed (locality 214-T-67). This zone beneath sandstone bed *6* is the southward pinch-out of bed c; the zone was not mapped south of Section 9.

Sandstone channel deposits.—South of Breckenridge in B, C-l, 2 (PL I), the Breckenridge limestone was removed by a channel that cut through the lower part of the Quinn clay, the Breckenridge limestone, and into the upper part of the unnamed shale (Pl. III, A-A′). The channel extends south of the area; a channel sandstone occurs above the type Breckenridge limestone over a large area between Breckenridge and Cisco (D. A. Myers, personal communication, January 1959). Plummer et al. (1949, fig. 8; Pl. VII, sections 18-21) called the channel deposit a "sandstone lentil."

The sandstone channel, bed *d,* occurs at about the stratigraphic position of the Parks Mountain sandstone in the Colorado Valley (Eargle 1958, p. 50); both sandstones are pre-Chaffin [Crystal Falls?] post-Breckenridge deposits that replaced the Breckenridge limestone. The Parks

Mountain sandstone, however, fills deeper channels than does bed *d*.

The Breckenridge limestone is absent south of an east-west channel "cut-out" line (B, C-2, Pl. I). The limestone was not observed in contact with channel deposits, but the position of the "cut-out" line or contact can be restricted to about 50 yards between the last outcrop of the Breckenridge limestone (Pl. II, B, gully no. 1) and **locality 214-T-113.**

A sandstone bed crops out about 5 feet above the Breckenridge limestone at locality 214-T-112; about 0.25 mile southeast, at Section 2, the same sandstone (Pl. I, bed *d*) occupies the stratigraphic position of the Breckenridge limestone. Bed *d* is well exposed at Section 1 (bed 2) where it is 20 feet thick, and about 2 miles east (E-1, Pl. I) an outlier capped by a sandstone bed may correlate with bed *d*. Not all of the channeled area, however, was filled with sandstone. At locality 214-T-113 and for about 0.3 mile along a north-south line passing through locality 214-T-115, shale and thin sandstone beds occur at the horizon of the Breckenridge limestone, but no channel sandstone (Pl. I, bed *d*) was observed. The channel, therefore, was filled with finer clastics as well as typical channel sandstone. Based on evidence available in this small area, the writer tentatively concludes that shale and thin sandstones were deposited first in the channel (Pl. III, A-A′) with subsequent channeling and deposition of the sandstone (bed *d*). Further study of the channel south of the area may indicate contemporaneous deposition of finer channel clastics and channel sandstone. A channel deposit composed of shale and sandy shale in the upper Graham formation near Graham, Young County, was reported by Lee (1938, Pl. III).

North of the Clear Fork of the Brazos River, a sandstone 4 feet thick, labeled "bed *d*?" (G-17, Pl. I), occurs about 3 feet above the massive bed of the Breckenridge limestone (Pl. III, Section 19). The sandstone bed occurs at the position of limestone bed *c*, which could not be traced across this local area; therefore, the sandstone probably fills a small channel that removed bed *c*.

CRYSTAL FALLS LIMESTONE MEMBER

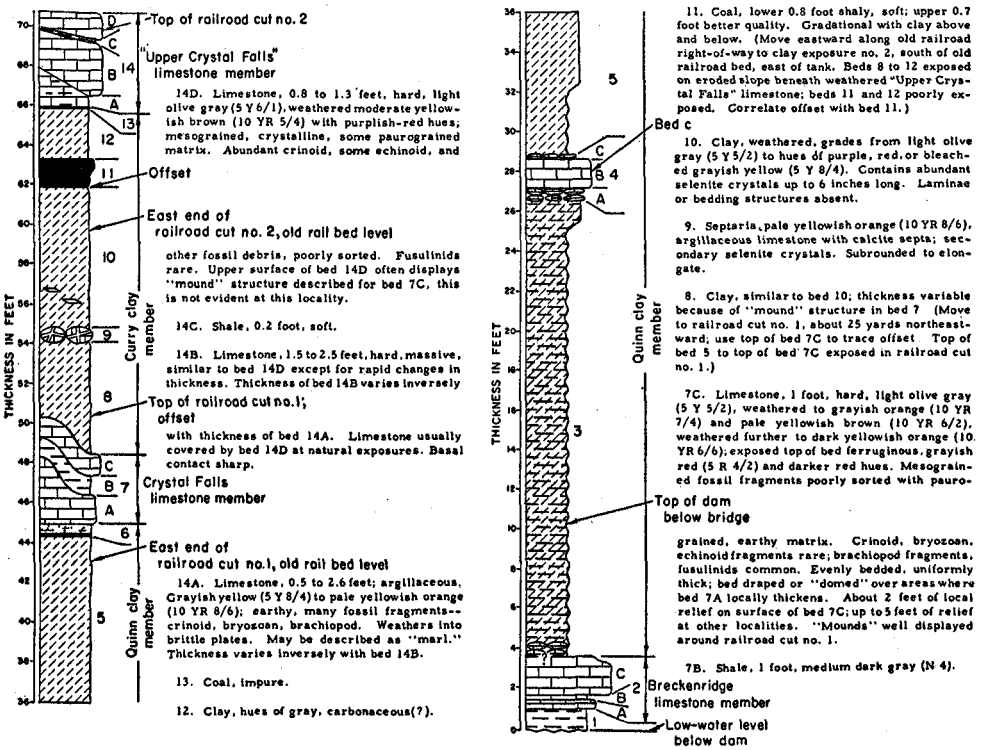
Original type description.—The Crystal Falls limestone (fig. 2) was named by Plummer and Moore (1922, p. 162) ". . . the Crystal Falls lentil, from the town of Crystal Falls in Stephens County . . ." They stated that the limestone ". . . occurs 40 to 80 feet above the base of the Harpersville formation," which is the top of the Breckenridge limestone. The Crystal Falls limestone was described as ". . . yellow or gray limestone, weathering locally red or purple, with an average thickness of 2 or 3 feet." A section accompanying the type description (idem, p. 163) was measured along the Clear Fork of the Brazos River west of Crystal Falls, Stephens County. However, this section does not include an unnamed limestone (Pl. I, bed *c*) 23 feet above the Breckenridge limestone **designated "Cl" by Bradish (1937) and discussed by Lee (1938, p. 63). The** Crystal Falls limestone has been called **"Lower Crystal Falls" by Bradish (1937)** and some other writers.

Plummer et al. (1949) showed sections in the Crystal Falls type area. Differences in interpretation may be noted by comparing the section by Plummer et al. (1949, fig. 18) at the Crystal Falls limestone type locality with figure 6 of this report, and their Sections 23, 24, and 25 (idem, Pl. VII) with Sections 9, 10, and 11, respectively, on Plate III (A-A′) of this report. Plummer was co-author of the original Crystal Falls limestone type description (Plummer and Moore, 1922); thus, it is important to clarify these differences. In general, the present report agrees with Lee's stratigraphic description (1938, pp. 61–67) for the section between the Breckenridge and "Upper Crystal Falls" limestones in northern Stephens County.

New type description.—The type section of the Crystal Falls limestone at the **original type locality (C-13, Pl. I) is re**described. The type section was measured from the shale beneath the Breckenridge limestone to the top of the "Upper Crystal

Falls" limestone. Beds 1–4 of this section (fig. 6 and Pl. II, A) crop out on State land and beds 4–14 on the property of Truman Robertson of Crystal Falls.

The Breckenridge limestone crops out in the bed of the Clear Fork of the Brazos River from the dam beneath the bridge on Farm Road 578, downstream to the first bend. The lower part of the section (fig. 6, beds 1–7C) was measured southwestward from the first bend below the dam (Pl. II, A), across the dam and old bridge road to a good exposure of bed 4 (Pl. I, bed *c*), and upward to the excellent exposure of the Crystal Falls limestone in railroad cut no. 1; the upper part of the Quinn clay (bed 5) is well exposed at clay exposure no. 1. The interval from the top of the Crystal Falls limestone to the coal in the Curry clay (Plummer et al. 1949,



14D. Limestone, 0.8 to 1.3 feet, hard, light olive gray (5 Y 6/1), weathered moderate yellowish brown (10 YR 5/4) with purplish-red hues; mesograined, crystalline, some paurograined matrix. Abundant crinoid, some echinoid, and other fossil debris, poorly sorted. Fusulinids rare. Upper surface of bed 14D often displays "mound" structure described for bed 7C, this is not evident at this locality.

14C. Shale, 0.2 foot, soft.

14B. Limestone, 1.5 to 2.5 feet, hard, massive, similar to bed 14D except for rapid changes in thickness. Thickness of bed 14B varies inversely with thickness of bed 14A. Limestone usually covered by bed 14D at natural exposures. Basal contact sharp.

14A. Limestone, 0.5 to 2.6 feet; argillaceous, Grayish yellow (5 Y 8/4) to pale yellowish orange (10 YR 8/6); earthy, many fossil fragments--crinoid, bryozoan, brachiopod. Weathers into brittle plates. May be described as "marl." Thickness varies inversely with bed 14B.

13. Coal, impure.

12. Clay, hues of gray, carbonaceous(?).

11. Coal, lower 0.8 foot shaly, soft; upper 0.7 foot better quality. Gradational with clay above and below. (Move eastward along old railroad right-of-way to clay exposure no. 2, south of old railroad bed, east of tank. Beds 8 to 12 exposed on eroded slope beneath weathered "Upper Crystal Falls" limestone; beds 11 and 12 poorly exposed. Correlate offset with bed 11.)

10. Clay, weathered, grades from light olive gray (5 Y 5/2) to hues of purple, red, or bleached grayish yellow (5 Y 8/4). Contains abundant selenite crystals up to 6 inches long. Laminae or bedding structures absent.

9. Septaria, pale yellowish orange (10 YR 8/6), argillaceous limestone with calcite septa; secondary selenite crystals. Subrounded to elongate.

8. Clay, similar to bed 10; thickness variable because of "mound" structure in bed 7 (Move to railroad cut no. 1, about 25 yards northeastward; use top of bed 7C to trace offset. Top of bed 5 to top of bed 7C exposed in railroad cut no. 1.)

7C. Limestone, 1 foot, hard, light olive gray (5 Y 5/2), weathered to grayish orange (10 YR 7/4) and pale yellowish brown (10 YR 6/2), weathered further to dark yellowish orange (10 YR 6/6); exposed top of bed ferruginous, grayish red (5 R 4/2) and darker red hues. Mesograined fossil fragments poorly sorted with paurograined, earthy matrix. Crinoid, bryozoan, echinoid fragments rare; brachiopod fragments, fusulinids common. Evenly bedded, uniformly thick; bed draped or "domed" over areas where bed 7A locally thickens. About 2 feet of local relief on surface of bed 7C; up to 5 feet of relief at other localities. "Mounds" well displayed around railroad cut no. 1.

7B. Shale, 1 foot, medium dark gray (N 4).

7A. Limestone, 1.5 to 3.5 feet, massive, medium dark gray (N 4), weathered pale to dark yellowish orange (10 YR 8/6-6/6). Hard when fresh, paurograined, earthy; weathered to a dull earthy texture. Abundant, poorly sorted mesograined crinoid, echinoid, bryozoan fragments; fusulinids. Bed characterized by textural and compositional variations; generally more argillaceous and silty toward base; grades into bed 6. Bed usually covered by bed 7C in natural exposures. Bed rapidly thickens 2 feet to produce "core" over which bed 7C is "draped." Thickening occurs at top, but bed drapes slightly over thickened bed 6.

6. Shale, 0.5 foot or less, calcareous, silty, platy; grayish yellow (5 Y 8/4). Thickest where "mounds" occur in bed 7. Abundant, well-preserved bryozoans, echinoid spines; pelecypods. Thin organic and oxidized iron laminae near base. Grades into coal below. Coal, 0.1 foot, impure, enclosed by medium light gray (N 6) shale. (Beds 3 to 5 crop out northeastward between railroad cut no. 1 and dam.)

5. Clay, covered in line of section, upper 12 feet exposed in clay exposure no. 1. Medium gray (N 5) to light olive gray (5 Y 5/2), some purple and red hues; plastic, no bedding laminae. Lower 4 feet partly covered, red, ferruginous.

4C. Limestone, 0.5(?) foot, ferruginous, nodular; grades upward to calcareous ironstone.

4B. Limestone, 1.4 feet, moderately hard, yellowish gray (5 Y 7/2), weathered to light olive gray (5 Y 6/1) and dark yellowish orange (10 YR 6/6). Paurograined, crystalline with areas of mesograined, secondary(?) calcite and fossil fragments; weathered dull, earthy, slightly argillaceous. Crinoid fragments, abundant fusulinids. Upper surface irregular.

4A. Limestone, 0.6 foot, similar to 4B with increased clay content, poorly bedded to nodular, mottled in upper part. Intercalated shale near base, silty; gradational with bed below. Poorly exposed, fossil fragments rare. (Trace bed 4, 30 yards eastward from fence before continuing traverse to river.)

3. Clay-shale, covered in line of section; partly exposed northwestward for 30 yards. At other localities where well exposed, bed is gray green, weathered red with abundant red, thin, ferruginous claystone laminae. (Bed 2 crops out on south side of Clear Fork of Brazos River at the base of dam under bridge and is well exposed more than 100 yards downstream to point just beyond first bend in river; bed described at the first bend.)

2C. Limestone, 1.9+ feet, hard, light olive gray (5 Y 6/1) weathered to mottled dark yellowish orange (10 YR 6/6) and moderate reddish brown (10 R 4/6). Paurograined, crystalline, some mesograined fossil fragments especially near top; weathered surface mottled; ferruginous, slightly argillaceous(?), earthy matrix surrounds irregularly shaped, less altered areas. Basal 1.3 feet massive, top and base irregular. Fusulinids rare, occasional brachiopod and other fragments. Vertically fractured strongly N. 60° W., N. 35° E.; moderately N. 20° W.; and weakly N. 70° E. Upper 0.6+ foot less resistant, more fossiliferous--brachiopods, bryozoans, crinoid fragments, and fusulinids.

2B. Limestone, 0.2 foot, color and texture similar to bed 2C, not mottled. Intercalated with calcareous shale; weathers to irregular slabs. Less resistant than beds above or below. Abundant fusulinids on surface of slabs; brachiopods locally abundant.

2A. Limestone, 0.4 foot, hard, light gray (N 7), earthy matrix with some mesograined fossil fragments and calcite crystals, moderately resistant, variable clay and silt content. Brachiopods, crinoid fragments; fusulinids at top.

1. Clay-shale, light olive gray (5 Y 5/2), plastic.

Fig. 6. Type section of Crystal Falls limestone.

p. 17) was described at clay exposure no. 2 (beds 7C–11), about 25 yards southwest of railroad cut no. 1; the offset is along bed 7C. The upper part of the section (beds 11–14D) was described in railroad cut no. 2 to the west; offset was correlated with the coal (bed 11).

General features.—The type Crystal Falls limestone is composed of an upper 1-foot limestone bed separated by about 1 foot of shale from a lower limestone bed that is 1 to 3.5 feet thick (Pl. III, A-A′). The limestone weathers from gray to yellowish orange, and its upper surface is ferruginous, commonly dark red or purple. The upper surface is uneven and has wave or "mound-like" undulations with amplitudes up to 5 feet (locality 214-T-60). The vegetation along the outcrop of this limestone is not distinctive, and a low indistinct bench characterizes the topography along its outcrop.

Exposures of the Crystal Falls limestone generally are poor, and only fragments of the more resistant upper bed of the member were found along the outcrop. Large blocks of limestone slide over the incompetent plastic Quinn clay, and the troughs of wave-like undulations on the upper surface of the limestone trap debris from above, obscuring the outcrop. North of the Clear Fork of the Brazos River the lithologic character of the Crystal Falls limestone resembles that of the "Upper Crystal Falls" limestone, which also occurs in a clay, coal, and septarian sequence.

The Crystal Falls limestone was removed at two localities (G-16, 17, Pl. I) by post-Crystal Falls, pre-"Upper Crystal Falls" channels (Pl. III, Sections 17, 18); other localities probably occur in this area where exposures of the Crystal Falls limestone are generally poor. South of U.S. Highway 183 (B-7, Pl. I) a sandstone occurs directly above the Crystal Falls limestone along most of its outcrop and caps most of the small outliers of Crystal Falls limestone east of Gonzales Creek (localities 214-T-77, -94). A sandstone exposed at locality 214-T-97 has a narrow east-west lineation. Description of channel sandstones in the Harpersville formation above the Crystal Falls must await further mapping of that interval.

Mound structures.—Lee (1938, fig. 5 and pp. 64–65) first referred to "mound-like" structures exhibited by the Crystal Falls limestone; he described an exposure in the first abandoned railroad cut northwest of Crystal Falls (Pl. II, A, cut no. 1). These mound features have been observed wherever the upper surface of the limestone is well exposed (localities 214-T-45, -47, -60, -77). The circular to elongate mounds are from 10 to about 50 feet in diameter and range in height from a few inches to several feet.

The locality described by Lee (1938, fig. 5) is the only well-exposed cross section of a mound observed in the subject area. At this locality the lower limestone bed of the Crystal Falls (fig. 6, bed 7A) thickens from 1.5 to 3.5 feet to produce the "core" of the mound. The limestone was deposited over a coal smut and several inches of calcareous, silty shale containing bryozoans, echinoid spines, and pelecypod fragments. The basal part of the lower limestone bed is composed of a mixture of limestone detritus and fossil fragments, clay, and silt. The thin shale and upper 1-foot limestone bed of the member (fig. 6, beds 7B, 7C) drape over the thickened core of the lower limestone bed.

Lee (1938, p. 64) reported (no locality reference) that the lower limestone bed of the Crystal Falls was removed and replaced by a mound of sandstone and pebbles. He also noted coal fragments, probably from beneath the lower limestone, in the shale between the two limestone beds, which is further evidence of erosion. The writer observed questionable mound structures on the upper surface of sandstone bed *b* (p. 22), and the "Upper Crystal Falls" limestone (B-9, 10, 11, Pl. I). At locality 214-T-74 small sandstone mounds occur 25 feet above the "Upper Crystal Falls" limestone at the west end of an isolated hill.

Lee (1938, pp. 64–65) explained the origin of the mounds as the result of nearshore erosion—wave, tidal, or other types

—that produced a hummocky surface on top of the lower limestone bed of the Crystal Falls. The thin shale and the upper limestone bed of the Crystal Falls were then deposited on the eroded surface; subsequent compaction produced the mound structures. The writer generally agrees with this interpretation. An organic or reef origin cannot be discounted without a petrographic study; however, field relations and binocular examination indicate that the mounds are sedimentary structures and not organic "build-ups."

SUMMARY AND CONCLUSIONS

1. The Cisco group of Upper Pennsylvanian age in northern Stephens and southern Young counties, Texas, is composed of shale, clay, and thin beds of coal, limestone, and lenticular or channel sandstone. The section included in this report is slightly more than 100 feet thick and consists of five members—three in the upper part of the Thrifty formation (Blach Ranch limestone, unnamed shale, and Breckenridge limestone members) and two in the lower part of the Harpersville formation (Quinn clay and Crystal Falls limestone members).
2. Three rock units—Blach Ranch, Breckenridge, and Crystal Falls limestones —named by Plummer and Moore (1922) are key mappable beds in the area. The Quinn clay member (Plummer et al., 1949) is a useful stratigraphic unit, but correlation with the type locality has not been demonstrated. The shale between the Blach Ranch and Breckenridge limestone is called the unnamed shale, and no formal name is proposed.
3. The Thrifty and Harpersville formations (Plummer and Moore, 1922) are used with reservation. These formations, and all formations in the upper part of the Pennsylvanian, are arbitrary rock units separated by "contacts" drawn at the top or bottom of key mappable sandstone or limestone beds. These formations are useful in discussing these heterogeneous sections of shale, limestone, and sandstone or in charting them on geologic maps, but recent field studies indicate that the classification needs to be revised in order that contacts will be more mappable. In the writer's opinion, a revision should be a modification of Plummer and Moore's classification, and changes in formation contacts should be based on detailed mapping and stratigraphic study.
4. The term Cisco group has no stratigraphic value but it is an established name useful in discussing the section of rock included in the Graham, Thrifty, and Harpersville formations. The Cisco is not recognized as a time-stratigraphic "series" equivalent to the Virgil series.
5. Type reference sections at Plummer and Moore's (1922) original type localities of the Blach Ranch, Breckenridge, and Crystal Falls limestones were described. These "type" sections and localities help to clarify the stratigraphic relations and lithologic character of the limestone members, but they are not necessarily typical of the members throughout their surface exposure. The section containing these three units was mapped along the outcrop for about 18 miles to include each type locality. Thirty-three measured sections (pp. 30–38) aided stratigraphic interpretation of the interval. This method of describing "type" rock units provides a more reliable description than a single, isolated type section.
6. Upper Thrifty and lower Harpersville rocks were deposited under cyclic, rapidly changing shallow marine to nonmarine conditions. Fossils are associated with the limestones, which mark maximum but shallow marine transgression. Limestone members are separated by clay and shale members containing sandstone beds and channel deposits that mark maximum regression in the area. Minor local calcareous units which are commonly fossiliferous, near-shore deposits, pinch-out laterally and/or change composition abruptly.
7. The general stratigraphy is as follows:
   (a) The Blach Ranch limestone member is a persistent unit of relatively uniform lithology and thickness in the area. Abundant fossils occur locally, and the limestone is well exposed except where removed by channeling at several localities.

(b) The unnamed shale member thins southward and contains several thin beds of lenticular sandstone, a channel sandstone that locally cuts the Blach Ranch limestone, and two calcareous beds. The calcareous beds are discontinuous; the upper one grades from a slightly fossiliferous sandstone to clastic limestone containing abundant fossils.

(c) The Breckenridge limestone member is a very persistent mappable unit in the area. However, near the type locality are three limestone units that are not typical of the member elsewhere in the area. One of these units is very fossiliferous, and the basal part of the more typical widespread massive mottled Breckenridge limestone bed contains abundant fusulinids. A channel cuts the limestone member at one locality.

(d) The Quinn clay member of this report thins north of the Clear Fork of the Brazos River. The member is divided into upper clay and lower clay-shale units by a thin sandstone south of the Clear Fork of the Brazos River and by a limestone north of the river. A channel that removed the Breckenridge limestone originated near the middle of the Quinn clay member.

(e) The Crystal Falls limestone member is not well exposed in the area. It exhibits "mound" structures that are interpreted as near-shore erosional features with subsequent compaction of overlying shale and limestone. Abundant fossils at the base of the limestone were observed at several localities. The Crystal Falls limestone member was removed by small channels in the northern part of the area.

8. Paleontology was not treated in this project, but this omission does not minimize the need for a thorough biostratigraphic and paleoecologic investigation. The accumulation of stratigraphic information is a prerequisite for paleontologic or other more specialized studies. Clay mineralogy, geochemistry, and sedimentary petrology, which show promise of solving many problems involving environment of deposition, cannot be initiated until adequate stratigraphic data are available.

9. This report provides detailed stratigraphic facts in this small but critical area and interval and also provides an anchor for future regional stratigraphic studies in the Cisco of the Brazos and Trinity River valleys. It is hoped that this type of study will stimulate other basic projects that are vitally needed in solving problems in the surface Pennsylvanian rocks of north-central Texas.

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APPENDIX

Measured Sections

Section 1 (B-1)[2]

Measured from base of massive sandstone on south side of county road, westward along road to crossroads, then north to top of Crystal Falls limestone in north-south road.

	Thickness Feet
Harpersville formation—	
Curry clay member—	
7. Sandstone, resting on Crystal Falls limestone; occurs in this position throughout area	1.0+
Crystal Falls limestone member—	
6. Limestone, upper bed, exposed in road	0.8+
Quinn clay member—	
5. Clay, upper 6 to 8 feet covered, exposed in ditches along east-west road and at old well site north of road	17.0(?)
4. Sandstone, can be traced northward to type section (fig. 5) of Breckenridge limestone; bed *b* (Pl. I) may correlate with this sandstone rather than with bed 2C, below	1.0+
3. Clay	5.8
2. Sandstone and shale, channel deposits	19.8
2C. Sandstone and shale, interbedded, 3.5 feet. Sandstone from 0.2 to 0.5 foot; lower 1.5 feet mainly shale. Unit is mapped as bed *b*(?) (Pl. I), but correlation is questionable (see bed 4, above).	
2B. Sandstone and shale, interbedded, 4.5 feet, upper sandstone bed 1.5 feet, lower sandstones thin.	
2A. Sandstone, 11.8 feet, with thin intercalated shales in upper 4.3 feet; lower 7.5 feet massive, base irregular. Bed occurs at stratigraphic position of Breckenridge limestone, which is absent. Mapped as bed *d* (Pl. I).	
1. Shale, 2 feet exposed at base of bed 2A along road; 10 to 15 feet exposed 30 yards north of road	2.0+
Total	47.4+

Section 4 (C-2)

Measured on east side at south end of railroad cut from level of tracks to top of excavation.

	Thickness Feet
Thrifty formation—	
Breckenridge limestone member—	
7. Limestone and shale	5.6
7E. Limestone, 0.7 foot, crinoidal, severely weathered; brachiopods and bryozoans. Unknown thickness of limestone above this bed removed. Correlates with bed 5B, Breckenridge limestone type section (fig. 5).	
7D. Shale, 1 foot.	
7C. Limestone, 0.3 foot, weathered to fragments.	
7B. Shale, 0.3 foot.	
7A. Limestone, 3.3 feet, massive, mottled. Correlates with bed 5A at Breckenridge limestone type section (fig. 5).	
Bed 7 not in place; about 5 feet below proper position.	
Unnamed shale member—	
6. Shale, 3.7 feet exposed, estimated 5 feet covered by bed 7	3.7
5. Sandstone, soft, bored, irregularly bedded, approximately equivalent to bed *e* (Pl. I) present less than half a mile east at Section 32	1.5
4. Shale, similar to bed 6	1.3
3. Sandstone, slightly calcareous; pelecypod casts and bryozoan impressions present at top	1.0
2. Shale	1.5
1. Sandstone, upper 1 foot massive, slightly cross-bedded; base covered. Sandstone grades downward into sandy shale and more sandstone. Only 1.3 feet of sandstone exposed in this cut, but bed can be traced westward 150 yards to abandoned railroad cut where 4 feet of sandstone is exposed	1.3+
Total	15.9+

[2] Coordinates, Plate I.

Section 5 (C-4)

Measured eastward from Breckenridge limestone to top of isolated hill ("Donkey Mountain").

	Thickness Feet
Harpersville formation—	
Curry clay member—	
7. Sandstone, severely weathered; rests directly on Crystal Falls limestone	2.0+
Crystal Falls limestone member—	
6. Limestone and shale	2.4+
6C. Limestone, 0.7 foot, crinoidal, severely weathered.	
6B. Shale, 1.0+ foot.	
6A. Limestone, 0.7+ foot, base covered, rare exposure of lower bed.	
Quinn clay member—	
5. Clay, partly covered	18.0(?)
4. Sandstone and shale	4.5
4D. Sandstone, 1.5 feet, produces slight topographic terrace, weathers green.	
4C. Sandstone, 1.5 feet, partly covered, soft, calcareous(?).	
4B. Shale, 1 foot, partly covered, sandy.	
4A. Sandstone, 0.5 foot, resistant; overlies nodule zone (Pl. III, bed *b*).	
3. Limestone nodule zone, 1- to 3-inch nodules interspersed in red clay-shale; thickness of zone estimated. Digging necessary to locate nodules	1.0+
2. Clay-shale, partly covered, better exposed on north side of outlier, south of tank; many thin ferruginous claystone fragments	28.0
Thrifty formation—	
Breckenridge limestone member—	
1. Limestone	3.2
1C. Limestone, 0.6+ foot, weathers into irregular beds, nodular.	
1B. Limestone, 1.8 feet, massive, mottled.	
1A. Limestone, 0.8 foot, slabby, less resistant than above	
Total	59.1+

Section 7 (C-7)

Measured from near creek bank, east of fence on east side of U.S. Highway 183, westward across old railroad bed and highway to top of isolated hill.

	Thickness Feet
Harpersville formation—	
Curry clay member—	
7. Sandstone, severely weathered, rests directly on bed 6. Bed occurs at similar position throughout most of this area	1.0+
Crystal Falls limestone member—	
6. Limestone, only top exposed, weathered	0.5+
Quinn clay member—	
5. Clay, partly covered	18.5
4. Sandstone (Pl. I, bed *b*), greenish, produces topographic bench; badly weathered sandstone occurs as small mounds. Base covered; probably grades downward into sandy shale	1.8(?)
3. Limestone nodule zone, 1- to 3-inch nodules interspersed in matrix of green to red clay-shale. Occurs directly below sandstone; considerable digging necessary to locate nodules	1.0+
2. Clay-shale, abundant small ironstone fragments on weathered surface. Road level is approximately 7 feet above base	22.7
Thrifty formation—	
Breckenridge limestone member—	
1. Limestone	2.9
1C. Limestone, 0.6 foot, less resistant than bed 1B.	
1B. Limestone, 1.6 feet, massive, mottled.	
1A. Limestone, 0.7 foot, thin, irregular beds, fusulinids.	
Total	48.4+

Section 8 (C-9)

Measured northeastward to top of small Crystal Falls limestone outlier; section is 30 to 40 yards east of and parallel to railroad.

	Thickness Feet
Harpersville formation—	
Crystal Falls limestone member—	
7. Limestone and shale	2.7
7C. Limestone, 0.6 foot, severely weathered. Massive sandstone occurs above bed 7C on larger outlier to east.	
7B. Covered, shale, 0.5 foot estimated.	
7A. Limestone, 1.6 feet, massive, poorly exposed beneath bed 7C.	
On northeast side of larger outlier to east, bed 7A occurs as talus blocks 3 feet thick.	
Quinn clay member—	
6. Clay, partly covered, exposed on northeast side of larger outlier to east	14.0+
5. Sandstone (Pl. I, bed *b*), severely weathered, green to dark red, base not exposed	0.5+
4. Covered, shale, probably sandy	1.9(?)
3. Limestone nodule zone, 1- to 3-inch nodules interspersed in green and red clay; some calcareous claystone nodules with limestone septa; thickness of bed approximate; gradational. To the east on south side of larger outlier, 0.8 to 1 foot of limestone occurs approximately at top of bed 3. Fossils are present at this position at outlier to north (locality 214-T-67)	1.5+
2. Clay-shale, well exposed at west end of outlier beside railroad; many thin oxidized claystone fragments	27.9
Thrifty formation—	
Breckenridge limestone member—	
1. Limestone	2.5
1C. Limestone, 1 foot exposed, very crinoidal, some brachiopod fragments.	
1B. Limestone, 1.5 feet exposed, massive, mottled, base not exposed.	
1A. Limestone, covered at this locality, exposed elsewhere in vicinity.	
Total	51.0+

Section 9 (B, C-12)

Measured from Breckenridge limestone at head of small north-south gully 30 yards east of north bridge abutment on Hubbard Creek, northward across highway to ridge on east side of small lake.

	Thickness Feet
Harpersville formation—	
Crystal Falls limestone member—	
5. Limestone, lower bed exposed, upper bed covered. Well exposed in small gully. Limestone is below top of hill where "Upper Crystal Falls" limestone debris occurs; "Upper Crystal Falls" in place in ridge to the north	1.6+
Quinn clay member—	
4. Clay, better exposed on west side of hill, red near base	20.4
3. Nodules, septate; composition grades from limestone to silty calcareous claystone. Bed is best exposed along fence, north side of highway, immediately east of curve to bridge. Inclusions of clay within limestone nodules, and septa of claystone nodules are calcareous. Nodules are interspersed in red and green clay, exact thickness cannot be determined. This bed and clay directly above and below are ferruginous. Bed is at stratigraphic position of bed *c* (Pl. I), which occurs 1 mile to the north (fig. 6)	2.5+
2. Clay-shale, only upper 3 feet exposed along section; better exposed westward at spillway, west end of dam of small lake	23.3
Thrifty formation—	
Breckenridge limestone member—	
1. Limestone, massive, mottled bed. Talus blocks of bed 1 occur in bed of Hubbard Creek below and east of bridge; bed is in place in gully 30 yards east of north bridge abutment	1.0+
Total	48.8+

Section 11 (D-14)

Measured eastward from road crossing over Breckenridge limestone at north-south creek to ridge capped by Crystal Falls limestone.

	Thickness Feet
Harpersville formation—	
Crystal Falls limestone member—	
7. Limestone, outcrop severely weathered, top of bed exposed	0.5+
Quinn clay member—	
6. Covered, clay, exposed north in gullies and south along road	19.4
5. Sandstone, partly exposed, in place (?)	1.7
4. Covered, clay-shale, exposed in vicinity	9.3
3. Limestone (Pl. I, bed *c*), weathered, massive, indistinct bedding	2.5
2. Clay-shale, weathered, red, well exposed in gullies and along road directly east of creek crossing	12.0
Thrifty formation—	
Breckenridge limestone member—	
1. Limestone	2.0+
1C. Covered, limestone.	
1B. Limestone, 1.5 feet, massive, mottled, serves as floor for creek crossing.	
1A. Limestone, 0.5 foot exposed, irregularly bedded, fusulinids.	
Total	47.4+

Section 16 (F-16)

Measured from road crossing east-west creek on top of Breckenridge limestone, generally westward to "Upper Crystal Falls" limestone; offsets noted in section.

	Thickness Feet
Harpersville formation—	
"Upper Crystal Falls" limestone member—	
13. Limestone, partly covered, severely weathered, characterized by large crinoid columnals	1.0+
Curry clay member—	
12. Clay, partly covered	1.5
11. Coal, weathered, shaly	0.5
10. Clay with large selenite crystals, abundant iron concretions, weathered septaria near base	9.8
Offset 20 to 30 yards east to Crystal Falls outcrop.	
Crystal Falls limestone member—	
9. Limestone, partly exposed, severely weathered, top heavily stained by oxidized iron, upper surface of limestone exhibits prominent "mounds." Lower bed not exposed	1.0+
Interval above and below Crystal Falls limestone varies several feet in short distances because of "mound" structures.	
Quinn clay member—	
8. Clay, covered	12.8
7. Sandstone and shale	3.6
7C. Sandstone, 1 foot, top of topographic terrace below Crystal Falls limestone. Bed is heavily stained red with iron oxide.	
7B. Covered, 1(?) foot, shale.	
7A. Sandstone, 1.6 feet, resistant.	
6. Shale, partly covered, ferruginous	3.4
5. Sandstone, thin bedded, basal 0.5 foot red, ferruginous	1.5
4. Covered, shale	4.0(?)
Offset eastward to top of limestone (bed 3) in ditch on west side of north-south road.	
3. Limestone (Pl. I, bed *c*), severely weathered, distinctive bedding absent	3.0
2. Clay-shale, partly covered	6.6
Thrifty formation—	
Breckenridge limestone member—	
1. Limestone	2.8
1C. Limestone, 0.5 foot exposed.	
1B. Limestone, 1.6 feet, massive, mottled.	
1A. Limestone, 0.7 foot, irregular 2-inch beds with abundant fusulinids.	
Total	51.5+

Section 17 (G-16)

Measured westward up steep bluff above Clear Fork of Brazos River; top of section at abandoned oil well location.

	Thickness Feet
Harpersville formation—	
"Upper Crystal Falls" limestone member—	
Beds 11 to 15 exposed at well site excavation on crest of bluff.	
15. Limestone	1.3
Curry clay member—	
14. Clay	5.2
13. Coal, shaly	0.5
12. Clay with thin sandstones	1.8
11. Sandstone, channel deposit (Pl. I, bed *a*), with interbedded sandy shale	7.8
Crystal Falls limestone member—	
Crystal Falls limestone absent at proper stratigraphic position which coincides with base of bed 11; limestone is present to the west. Limestone was removed and replaced by bed 11.	
Quinn clay member—	
10. Clay, partly covered, upper part exposed in old mud pit 25 yards southwest	32.3
Limestone (Pl. I, bed *c*), covered (?), exposed southwestward along outcrop.	
Thrifty formation—	
Breckenridge limestone member—	
9. Limestone	3.6
9C. Limestone, 1.5 feet exposed, grades upward into bed 10.	
9B. Limestone, 1.3 feet massive, mottled, fusulinids.	
9A. Limestone, 0.8 foot, poorly bedded to nodular, fusulinids.	
Breckenridge limestone produces topographic bench.	
Unnamed shale member—	
8. Shale	8.9
7. Sandstone, partly covered	1.6
6. Shale	3.1
5. Sandstone, ripple marked, massive	1.0
4. Shale, weathered, partly covered	6.8
3. Sandstone, partly covered, cross-bedded	2.0
2. Shale	26.2
Blach Ranch limestone member—	
1. Limestone and shale	2.9
1C. Limestone, 0.6 foot.	
1B. Shale, 0.5 foot.	
1A. Limestone, 1.8 feet, massive.	
Total	105.0

Section 22 (E-3)

Measured from water level at base of concrete pier, southwestward along road to top of Breckenridge limestone, south end of dam, Lake Grand.

	Thickness Feet
Thrifty formation—	
Breckenridge limestone member—	
4. Limestone, top exposed in ditches along road to Lake Grand, basal part covered	1.0+
Unnamed shale member—	
3. Covered, shale	14.0(?)
2. Sandstone and shale, partly covered, top is at 90-degree turn in road	6.5(?)
1. Sandstone, channel deposit, massive, cross-bedded, well exposed along edge of Lake Grand east of concrete pier. Top of massive sandstone dips northeastward. Base is below water level; large blocks of sandstone cover slope west of dam (Pl. I, bed *f*)	12.8+
Total	34.3+

Section 23 (E-4)

Measured in east-west Lake Grand spillway, north end of dam.

	Thickness Feet
Thrifty formation—	
Unnamed shale member—	
6. Sandstone, channel deposit, (Pl. I, bed *f*), massive, cross-bedded, irregular base. Rests on or cuts Blach Ranch limestone at east end of spillway	6.0+
5. Shale, cut by sandstone	0–2.0
Blach Ranch limestone member—	
4. Limestone and shale, produces waterfall at west end of spillway	3.3
4C. Limestone, 1 foot, weathers into two equal beds; bed is floor of spillway at west end.	
4B. Shale, 0.7 foot.	
4A. Limestone, 1.6 feet, massive.	
Unnamed shale member between Ivan and Blach Ranch limestones—	
3. Shale, with thin intercalated ferruginous sandstones, some organic laminae	7.0
2. Coal, 1 inch hard, remainder shaly	0.3
1. Clay-shale, shaly laminae indistinct	5.0+
Total	23.6+

Section 24 (G-4, 5)

Measured westward to top of Breckenridge outlier, east of State Highway 67; base of section east of salt-water tank.

	Thickness Feet
Thrifty formation—	
Breckenridge limestone member—	
7. Limestone, top of massive bed exposed, outlier is severely weathered	1.0+
Unnamed shale member—	
6. Covered, shale	7.2
5. Sandstone, forms secondary topographic bench below Breckenridge limestone	1.6
4. Shale, altered by salt water	16.6
3. Sandstone, cross-bedded, relatively thin bedded (6 to 8 inches) with intercalated sandy shale. Bed is at head of gully at northeast corner of salt-water pit	5.1
2. Shale, excellent exposure in gully; small iron oxide concretions	14.0
Blach Ranch limestone member—	
1. Limestone and shale	3.0
1C. Limestone, 1 foot.	
1B. Shale, 0.5 foot.	
1A. Limestone, 1.5 feet, upper 0.7 foot, massive; 0.8 foot of badly weathered limestone at base.	
Total	48.5+

Section 25 (H-8, 9)

Measured from pond east of ranch road, southward to top of Breckenridge outlier (oil storage tank at top).

	Thickness Feet
Thrifty formation—	
Breckenridge limestone member—	
9. Limestone, top of massive bed exposed	1.0+
Unnamed shale member—	
8. Shale, upper 3 feet covered	5.3
7. Sandstone	1.0+
6. Shale	8.0
5. Concretions, limestone, 1 to 6 inches in diameter in red shale. Occur within interval 2 or 3 feet thick	0.5
4. Shale	8.6
3. Sandstone, upper 1.5 feet well exposed	4.7+
2. Shale, upper 9 feet covered	20.5
Blach Ranch limestone member—	
1. Limestone and shale, base covered	2.4+
1C. Limestone, 0.7 foot.	
1B. Shale, 0.5 foot.	
1A. Limestone, 1.2 feet exposed, massive.	
Total	52.0+

Section 26 (E-13)

Measured southeastward up southwest extension of Breckenridge limestone outlier.

	Thickness Feet
Thrifty formation—	
Breckenridge limestone member—	
7. Limestone, upper part of massive, mottled bed	1.0+
Unnamed shale member—	
6. Shale, upper 4 feet partly covered	8.4
5. Sandstone, produces no prominent topographic bench at this locality but is responsible for such a feature throughout much of area	2.0+
4. Shale, weathered, predominantly red	12.4
3. Sandstone, massive, ripple marked, weathering to three equal beds. Sandstone produces topographic terrace at south end of outlier. Base covered; may be thicker than observed. Bed thickens at base to become the channel deposit in railroad cut (Section 27) to the northeast	4.0+
2. Shale, exposed except for 2 or 3 feet near top and base	19.7
Blach Ranch limestone member—	
1. Limestone and shale, well exposed	2.9
1C. Limestone, 0.5+ foot, grades upward into shale.	
1B. Shale, 0.5 foot, covered.	
1A. Limestone, 1.9 feet, massive. Bed 1A is thickest at this locality.	
Total	50.4+

Section 27 (F-13)

Measured from base of Blach Ranch limestone exposed on south side of tracks, east end of sandstone railroad cut, westward to top of massive sandstone exposed in railroad cut.

	Thickness Feet
Thrifty formation—	
Unnamed shale member—	
3. Sandstone (Pl. I, bed *f*), massive, cross-bedded, wedges, channel deposit. Approximate top of bed at top of railroad cut; base not exposed	22.5
2. Shale, covered	5.8(?)
Blach Ranch limestone member—	
1. Limestone, lower bed, massive (upper bed not exposed)	1.4+
Total	29.7+

Section 29 (F-15)

Measured up north wall of very narrow east-west canyon, east of Clear Fork of Brazos River.

	Thickness Feet
Thrifty formation—	
Breckenridge limestone member—	
9. Limestone, massive, mottled, fusulinids, base covered, upper bed removed	1.5+
Unnamed shale member—	
8. Covered, shale	5.7
7. Sandstone, massive, slightly calcareous with trace of fossil fragments	2.0
6. Covered, shale	3.8
5. Sandstone, irregular base, may not be in place	2.0
4. Covered, shale	6.5
3. Sandstone, ripple marked, bored, cross-bedded, base very irregular; crinoidal limestone fragments at base	4.0
2. Shale, partly covered, exposed northwest at point of bluff	26.1
Blach Ranch limestone member—	
1. Limestone and shale	2.9
1C. Limestone, 0.6 foot, poorly exposed, weathered.	
1B. Covered, shale, 0.5 foot.	
1A. Limestone, 1.8 feet, massive, fractured.	
Total	54.5+

Section 30 (H-17)

Measured from point where ranch road crosses creek on top of Blach Ranch limestone, westward to top of Breckenridge escarpment.

	Thickness Feet
Thrifty formation—	
Breckenridge limestone member—	
9. Limestone, upper part massive, mottled bed exposed	1.0
Unnamed shale member—	
8. Covered, shale	5.1
7. Sandstone, top of secondary topographic bench below Breckenridge limestone	1.5
6. Covered, shale	1.3
5. Sandstone, partly exposed	0.6
4. Covered, shale	5.5
3. Sandstone, partly exposed	1.0+
2. Shale, partly covered along line of section	34.0
Blach Ranch limestone member—	
1. Limestone, top of massive lower bed exposed in creek bed; better exposures down creek	0.5+
Total	50.5+

Section 31 (C-2)

Measured northward along east side of private road from fossiliferous sandstone to top of Breckenridge limestone.

	Thickness Feet
Thrifty formation—	
Breckenridge limestone member—	
5. Limestone	8.0(?)
5C. Limestone, 3.0+ feet, nodular; base covered.	
5B. Limestone, 2.0(?) feet, 0.3 foot exposed beneath bed 5C. Bioclastic, crinoid fragments, brachiopods, other fossils.	
5A. Limestone, 3.0(?) feet, upper 1 foot exposed, massive.	
Unnamed shale member—	
4. Covered, shale; limestone fragments in calcareous soil	11.6(?)
3. Sandstone, bored, variable thickness, irregular bedding surfaces, weathered into 2- to 6-inch rounded to elongate fragments; approximately equivalent to bed *e* (Pl. I) exposed at Sections 32 and 33	0.7(?)
2. Covered, shale	1.8
1. Sandstone, fossil fragments along top bedding surface. Pelecypods, rare crinoid fragments	0.8
Total	22.9

Section 32 (D-2)

Measured southeastward from "floor" to top of recently opened "caliche" pit, Stoker farm.

	Thickness Feet
Harpersville formation—	
Quinn clay member—	
5. Sandstone, weathered debris and sandy soil, resting on bed 4 throughout most of this area. Weathered sandstones in the lower part of the Quinn clay member have obscured outcrop of bed 4 for over a mile. Bed 1 (Pl. I, bed *e*) is mapped in this area because of difficulty in tracing the Breckenridge limestone.	
Thrifty formation—	
Breckenridge limestone member—	
4. Limestone	7.8
4C. Limestone, 0.5 foot exposed beneath bed 5, mesograined, crystalline, crinoidal with other fossil fragments; ferruginous at top. Correlates with bed 5B at type section of Breckenridge limestone.	
4B. Limestone, 3.3(?) feet, paurograined, fairly massive, slightly mottled. Correlates with bed 5A, type section of Breckenridge limestone.	
4A. Limestone, 4(?) feet, texture similar to bed 4B; massive at top, becomes thin bedded toward base. Weathering produces mottled, "fragmental" appearance; massive part of bed is upper limit of workable "caliche"; lower part of unit can be broken into road ballast by drag line. Base of unit grades into shale, bed 3. It is possible that secondary precipitation of carbonate has occurred in the lower part of bed 4A.	
Unnamed shale member—	
3. Shale, very calcareous, marly, with abundant irregular limestone beds and nodules; good road material, grades upward into bed 4A. Secondary precipitation of carbonate may have occurred in this bed	3.0(?)
2. Shale, partly covered, calcareous with some limestone inclusions	2.0(?)
1. Limestone (Pl. I, bed *e*), crinoidal, generally mesograined, crystalline, only top exposed. Varies from 0.5 to 1.0+ foot. Bed is floor of "caliche" pits southeast of Breckenridge. Limestone is mapped since the Breckenridge limestone is difficult to trace. An extremely fossiliferous, argillaceous limestone less than 0.4 foot thick occurs nearby below the crinoidal bed (locality 214-T-108). This fossiliferous limestone contains abundant, well-preserved brachiopods, bryozoans, solitary corals, and crinoid columnals, spines, and plates	0.5
Total	13.3

Section 33 (E-2)

Measured northwestward from top of Blach Ranch limestone in shallow gully several yards east of ranch road, to point where road cuts bed 7.

	Thickness Feet
Thrifty formation—	
Unnamed shale member—	
7. Limestone (Pl. I, bed *e*), white to pink, mesograined, very crystalline, crinoid and other fossil fragments	1.0
6. Covered, shale	1.0+
5. Sandstone, 1 to 2 feet thick, exposed in road cut; blocks removed from cut on west side of road	2.0
4. Shale, covered along section, better exposed several yards east in gully and along section of abandoned ranch road. A poorly exposed, red sandstone approximately 1 foot thick occurs 2 feet above base	11.5(?)
3. Sandstone, massive, best exposed in gully about 20 yards east of abandoned section of ranch road	1.5
2. Shale, severely weathered, upper 6 feet partly covered	14.1
Blach Ranch limestone member—	
1. Limestone, only top of upper bed exposed	0.5
Total	31.6+

LOCALITIES

Stephens County, Texas

214–T–37 (F–17).[3] "Upper Crystal Falls" limestone exposed in gully southwest of Crystal Falls limestone outcrop (Pl. I).

[3] Coordinates, Plate I.

214–T–38 (G–17). "Upper Crystal Falls" limestone fragments and underlying coal exposed east and southeast of oil well site.

214–T–39 (G–17). "Upper Crystal Falls" limestone on small outlier east of road; coal occurs below. Crystal Falls limestone mound structures exposed on south and southwest sides of outlier.

214–T–40 (F, G–16, 17). Sandstone at fork in road; bed rests upon and may replace(?) Crystal Falls limestone 10 to 20 yards east of road. Sandstone may be equivalent to bed *a* (Pl. I) but also may be post-"Upper Crystal Falls." Sandstone has a northwest-southeast lineation(?). Undisturbed "Upper Crystal Falls" limestone occurs 30 to 40 yards north of this locality on west side of road and at locality 214-T-39.

214–T–41 (G–16). Interval from Crystal Falls limestone to "Upper Crystal Falls" limestone on west side of canyon; exceptional exposure for this area; septaria, coal, and clay exposed.

214–T–42 (G–16). "Upper Crystal Falls" limestone at head of canyon, north side of topographic saddle.

214–T–43 (F–16). "Upper Crystal Falls" limestone, east side of ranch road near fence; coal exposed below.

214–T–44 (F–16). "Upper Crystal Falls" limestone with septaria and coal below; this limestone is exposed east and northeast almost to road 40 to 50 yards southwest of swinging gate. The "Upper Crystal Falls" limestone is better exposed and may be confused with the Crystal Falls limestone, especially from this point northeastward into Young County. The Crystal Falls limestone is not exposed between the creek bed north of Section 16 and localities 214-T-39, -40, -41, except at a few places just west of Section 17 (G–16).

214–T–45 (F–16). Crystal Falls limestone with several mound structures exposed west of road; "Upper Crystal Falls" limestone outcrops in vicinity.

214–T–46 (E, F–16). "Upper Crystal Falls" limestone exposed along low bench.

214–T–47 (E–16). Crystal Falls limestone mound structures exposed.

214–T–48 (G–15). Ivan limestone in ranch road at creek crossing; also present northeast in next creek.

214–T–49 (K–16). Ivan(?) limestone at top of outlier. Calcareous sandstone (Avis?) 10 to 15 feet below; similar relationship in area west of Farm Road 701 (J, K–15) where Ivan(?) crops out around large Blach Ranch outlier.

214–T–50 (J–15). Ivan limestone at head of deep gully.

214–T–51 (H–14). Sandstone exposed on escarpment, east side of Clear Fork of the Brazos River; Avis(?) sandstone.

214–T–52 (E–15). "Upper Crystal Falls" limestone.

214–T–53 (E–14). "Upper Crystal Falls" limestone; occurs about 15 feet above Crystal Falls limestone in most of the area north of Clear Fork of the Brazos River where the interval is not covered by weathered overlying sandstone or has not been removed by channeling.

214–T–54 (F–13). Quaternary high terrace deposits at old pit; typical of deposits along Clear Fork of the Brazos River in this area. Composed of gravel and limestone fragments with calcite cement.

214–T–55 (C–14). Interval above "Upper Crystal Falls" limestone containing clay, coal, sandstone, and limestone concretions exposed in abandoned railroad cuts northwest of Crystal Falls.

214–T–56 (C–13). "Upper Crystal Falls" limestone crops out around northeast side of cemetery.

214–T–57 (B–13). Interval exposed between Crystal Falls and "Upper Crystal Falls" limestone, and clay, coal, limestone concretions, and sandstone above "Upper Crystal Falls" exposed in small northeast-branching canyon.

214–T–58 (B–12). Limestone, fossiliferous, 1 foot thick; occurs 10 to 15 feet above "Upper Crystal Falls" limestone exposed at locality 214-T-59.

214–T–59 (B–12). "Upper Crystal Falls" limestone exposed above Crystal Falls limestone on west side of north-south canyon.

214–T–60 (B–12). Crystal Falls limestone mound structures on west side of north-south canyon.

214–T–61 (B–12). "Upper Crystal Falls" limestone on east side of north-south canyon at base of small bluff; clay, coal, septaria, and sandstone exposed above the limestone.

214–T–62 (D–12). Breckenridge limestone; good reference section. Entire unit exposed in railroad cut; fossiliferous.

214–T–63 (G–12). Ivan limestone containing abundant coral at top exposed in creek; small folds occur about 200 yards upstream in overlying sandstones. Interval from Ivan to Blach Ranch limestone exposed.

214–T–64 (H–12). Ivan limestone at creek crossing.

214–T–65 (B–11). "Upper Crystal Falls" limestone exposed near base of high steep bluff, east of fence; Crystal Falls covered by alluvium.

214–T–66 (B–11). "Upper Crystal Falls" limestone on west side of road; septaria present below limestone.

214–T–67 (D–10). Limestone, fossiliferous, about 0.2 foot thick, impure, 5 feet below sandstone bed *b* (Pl. I); correlates with bed *c* (Pl. I). Contains abundant brachiopods.
214–T–68 (H–10, 11). Ivan limestone at creek crossing.
214–T–69 (G–10). Coal a few feet below Blach Ranch limestone.
214–T–70 (L–11). Ivan limestone exposed along ranch road. Exposures of the limestone are poor or missing between this vicinity and the area in K-15.
214–T–71 (A, B–10). "Upper Crystal Falls" limestone at tank dam.
214–T–72 (B–10). "Upper Crystal Falls" limestone on south side of road.
214–T–73 (A–10). "Upper Crystal Falls" limestone, crops out along prominent escarpment on east side of Hubbard Creek.
214–T–74 (B–9). Limestone, post-"Upper Crystal Falls," pre-Saddle Creek(?), fossiliferous; occurs several feet below sandstone at top of outlier. Clay, coal, and a concretionary limestone exposed below limestone.
214–T–75 (B–9). "Upper Crystal Falls" limestone crops out along low bench.
214–T–76 (C, D–9). Limestone, about 1 foot thick, fossiliferous, occurs about 2.5 feet below green sandstone (Pl. I, bed *b*); limestone is at top of nodular limestone zone and correlates with bed *c* (Pl. I) present north of Clear Fork of the Brazos River.
214–T–77 (D–9). Crystal Falls limestone mound structures. Base of a sandstone 6 feet thick occurs about 10 feet above limestone. Zone of claystone septaria, 1 foot thick, occurs beneath bed *b* (Pl. I), about 700 feet north of locality near cross fence.
214–T–78 (H, J–9). Ivan limestone crops out extensively in area along creeks (J–9, 10, 11) which breach a local positive structure.
214–T–79 (L–9). Ivan limestone in road cut, State Highway 67.
214–T–80 (B–8, 9). "Upper Crystal Falls" limestone at fence corner, north side of road.
214–T–81 (C–8). Sandstone below Breckenridge limestone exposed in several railroad cuts south of this point; local dip reversals observed in sandstone in area.
214–T–82 (C–8). Blach Ranch limestone exposed in Gonzales Creek; several exposures north and south in creek.
214–T–83 (D–8). Quaternary stream deposit; composed mainly of limestone fragments cemented with calcite.
214–T–84 (C–7). Quaternary high terrace deposit in abandoned railroad cut; composed mainly of limestone fragments cemented with calcite ("caliche"). Contains fragments of many rocks exposed in the region.
214–T–85 (F, G–7). Blach Ranch limestone; top of unit exposed in creek for one-fourth mile.
214–T–86 (H–7, 8). Sandstone above Blach Ranch limestone with east-west lineation; can be traced 1,000 yards. Pattern on aerial photograph shows that it may be small channel(?) deposit.
214–T–87 (D–7). Small folds in sandstone below Breckenridge limestone.
214–T–88 (E–6). Small folds in sandstone below Breckenridge limestone; several occur downstream in creek.
214–T–89 (J–6). Ivan limestone along prominent escarpment (see locality 214-T-93).
214–T–90 (E, F–5, 6). Quaternary channel deposit along road east of bridge; channel cuts into sandstone below Breckenridge limestone and contains fragments of sandstone and limestone.
214–T–91 (C–5). Quaternary terrace deposit in road cut; mainly limestone fragments and unsorted quartz particles cemented with calcite ("caliche"). Fragments of many other rock types represented.
214–T–92 (C–5). "Upper Crystal Falls" limestone crops out around small salt-water tanks.
214–T–93 (H–5). Ivan limestone in road cut; limestone crops out north and south along prominent escarpment which is continuous from vicinity of locality 214-T-79 south to U.S. Highway 180.
214–T–94 (D–4). Sandstone, may be channel deposit; Crystal Falls limestone, if present, is covered by sandstone.
214–T–95 (B–4). Crystal Falls limestone mound structures exposed in bed of creek.
214–T–96 (B–4). "Upper Crystal Falls" limestone crops out along low ridge.
214–T–97 (C–4). Sandstone in road cut occurs directly above Crystal Falls limestone and has east-west lineation. Sandstone can be traced for 1 mile; easily distinguished on aerial photographs. Probably post-"Upper Crystal Falls" (?) channel deposit.
214–T–98 (C–3, 4). Breckenridge limestone, bioclastic bed, exposed in creek; massive bed exposed north and south in creek bed (Pl. I). Beds correlate with beds 5B and 5A (fig. 5), respectively.
214–T–99 (D, E–4). Fossil locality in north-south gully; upper bed of Blach Ranch limestone contains abundant gastropods, bryozoans, and other fossils.
214–T–100 (F–4). Sandstone below Breckenridge limestone; westward to Lake Grand area, the sandstone thickens and the interval between the sandstone and Blach Ranch limestone thins.
214–T–101 (F–3). Interval between the Breckenridge and Blach Ranch limestone exposed northwestward from the point on the south and southwest side of creek; top of Blach Ranch is covered by stream sediment in creeks in this area. Sandstone between the two limestones contains trace of fossil fragments in this vicinity; probably correlates with fossiliferous sandstone below bed *e* (Pl. III, C–C') about 2 miles southwest.
214–T–102 (C–3). Breckenridge limestone, bioclastic bed (fig. 5, bed 5B) exposed at rear of American Legion Hall and southeast in next north-south street.

214–T–103 (E–2). Breckenridge limestone, bioclastic bed, exposed above massive bed, on north side of east-west road at gate to Stoker farm. Correlates with beds 5B and 5A (fig. 5), respectively.

214–T–104 (F–3). Thin sandstone directly above Breckenridge limestone with north-south lineation; feature can be traced 1 mile. Pattern on aerial photographs suggests a thin channel(?) deposit below bed *b* (Pl. I) at position of bed *d* in B, C–1.

214–T–105 (G–2). Sandstone at junction of U. S. Highway 180 and Farm Road 207; bed replaces Blach Ranch limestone 0.3 mile south.

214–T–106 (B, C–2). Sandstone below Breckenridge limestone exposed in creek; sandstone correlates with bed 3 (fig. 5).

214–T–107 (C–2). Sandstone below Breckenridge limestone in abandoned railroad cut. Correlates with bed 3 (fig. 5).

214–T–108 (D–2). Fossil locality in road material pit, 100 yards south of Humble warehouse; occurs at base of thin crinoidal limestone (Pl. I, bed *e*).

214–T–109 (D–2). Similar to locality 214-T-108. Other localities exposed in similar road material pits to the east at same stratigraphic position.

214–T–110 (E–2). Crinoidal limestone (Pl. I, bed *e*) with sandstone directly below; sandstone contains fossil fragments. Similar exposures along outcrop of bed *e*.

214–T–111 (G–2). Limestone below Blach Ranch limestone in creek bed; Ivan(?) limestone.

214–T–112 (B–2). Sandstone, 5 feet above Breckenridge limestone, exposed on east side of road; mapped as bed *d* (Pl. I) where it replaces Breckenridge limestone to the south. Exposure is near north limit of post-Breckenridge, pre-Crystal Falls channel area.

214–T–113 (C–2). Breckenridge limestone absent in gully; limestone is present about 40 yards north at gully no. 1 (Pl. II, B). Limestone replaced with shale and thin sandstone.

214–T–114 (B–1). Sandstone directly above Crystal Falls limestone; bed may locally replace limestone in this area.

214–T–115 (B–1). Breckenridge limestone absent at proper stratigraphic position south of type section; east-west gullies in this area expose shale and thin sandstones at Breckenridge horizon. Channel sandstone, bed *d*, absent in this vicinity (Pl. I).

214–T–116 (D–1). Limestone below Blach Ranch limestone in oil-field road; Ivan(?) limestone,

214–T–117 (D, E–1). Limestone below Blach Ranch limestone; Ivan(?) limestone.

214–T–118 (F–1). Limestone below Blach Ranch limestone in creek bed; Ivan(?) limestone.

214–T–119 (F–1). Limestone below Blach Ranch limestone in creek bed; Ivan(?) limestone.

Young County, Texas

251–T–51 (H–18). Interval from coal and septaria below "Upper Crystal Falls" limestone to limestone above "Upper Crystal Falls" bed. Crystal Falls limestone covered.

251–T–52 (G–18). "Upper Crystal Falls" limestone west of road; Crystal Falls limestone covered. Both limestones covered near north-south road and Farm Road 1974.

251–T–53 (G–18). Post-"Upper Crystal Falls" limestone and fragments of another limestone above this bed occur in small clearing near crest on east side high north-south ridge.

251–T–54 (G–18). "Upper Crystal Falls" limestone crops out east of tributary of Wagon Timber Branch.

251–T–55 (G–18). "Upper Crystal Falls" limestone crops out along prominent bench north of Wagon Timber Branch; outcrop passes on north side of tank.

251–T–56 (F–18). "Upper Crystal Falls" limestone crops out along prominent bench south of Wagon Timber Branch.

251–T–57 (F–18). "Upper Crystal Falls" limestone exposed in creek bank; fossiliferous.

251–T–58 (G–17). "Upper Crystal Falls" limestone a few feet south of fence.

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