Report No. 9 - Spring 2000 Field Season
Permian Strata of North-Central Texas

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1.0 Summary

The Spring 2000 field season was devoted to stratigraphic work and fossil prospecting in the upper Clear Fork, San Angelo, and Blaine Formations. The upper Clear Fork was examined in breaks of the South Wichita River of eastern Knox County, between Vera and Benjamin. Also we visited Castle Peak, a site in Taylor County where vertebrate trackways from the Choza (upper Clear Fork Group) have been described. Outcrops of the San Angelo Formation were prospected in southeastern King County and near Oak Creek Reservoir in Coke and Runnels Counties. Dolomite beds of the Blaine were mapped in King County, tying together composite sections in that area. Blaine outcrops in Hardeman and Stonewall Counties also were visited.

Three new fossil plant localities were discovered in the Clear Fork on the Thompson property, about 2 to 3 miles west of Vera. Fossils occur in abandoned-channel facies of an extensive sandy channel-belt complex that is correlated with the Ignorant Ridge member. Higher in the Clear Fork, channels are shallow, isolated, and silt-dominated; thus far, these have yielded only scattered unidentifiable fragments of fossil plants. Fossil plants reported from Castle Peak were not verified; we suspect they were misidentified trace fossils. Scattered plant fragments and bits of fusain, but no collectible fossils were found associated with several copper prospects in the San Angelo of southern King County. The San Angelo of Oak Creek Reservoir, and all Blaine outcrops we observed, were barren of fossils.

A chart (Table 1) shows the stratigraphic positions of 60 fossil plant localities in the Clear Fork and Pease River Groups. The interval separating each fossil site from the base of the Clear Fork was determined on the basis of borehole data. The chart shows that the intervals separating key fossiliferous members are generally consistent across large areas. Most notably, San Angelo plant localities that span a lateral distance of 45 miles cluster within a 50-foot vertical interval. This evidence indicates that thickness variations of these rocks within the study area are slight. Further support for the same conclusion was obtained in Knox County, where structural dips measured on outcropping upper Clear Fork and San Angelo are nearly identical to dips on the base of the Clear Fork determined by subsurface mapping.

2.0 Clear Fork Group

2.1 Benjamin-Vera area

We spent several days prospecting for fossils and examining outcrops of the upper part of the Clear Fork between Benjamin and Vera in Knox County. E.C. Olson, Gary Johnson, and other previous vertebrate workers have not examined this area. The breaks south of the South Wichita River provide many good exposures that are, for the most part, easily accessible. Property contacts were arranged through Don Gregg of Seymour, and all landowners we contacted were cooperative (see Appendix).

Data collected this season, combined with sections measured at Maverick Flat in 1998, provide the basis for a nearly complete composite section of the upper Clear Fork (Fig. 1). The only significant gap is about 50 feet thick and near the top of the Clear Fork. Thicknesses determined in the field are supplemented by well data, to provide accurate intervals between key beds and the base of the Clear Fork.

2.1.1 Ignorant Ridge member. The oldest rocks observed (Fig. 1) include a complex of cross-cutting and stacked paleochannels filled with siltstone and sandstone. Individual channels form upward-fining sequences 5 to 10 feet thick, and display accretionary bedding that represents point-bar deposits (Fig. 2). The channel-bearing interval is 30 to 40 feet thick; well records indicate that it is 660 to 700 feet above the base of the Clear Fork. In overall lithology, this channel complex closely resembles other middle Clear Fork fossiliferous units, such as the Ignorant Ridge and Rt. 1919 members of previous reports.

Well-preserved plant fossils were found at three sites within this channel complex on the Thompson property 2 to 3 miles west of Vera. At Thompson 1 (UTM location 14SMN 4400 2266) gigantopterids and other plant remains, along with fragmentary fish remains, were collected from interbedded claystone and siltstone in the bank of a dry wash. Inclined bedding in the fossil deposit indicates a channel, but exposure is poor. Thompson 2 (UTM 14SMN 4389 2285), a short distance down the same stream, is definitely in a channel, having a conglomerate or mudstone and dolomite clasts at the base overlain by interbedded limonitic claystone and siltstone. Fossils are mainly large strap-like elements, believed to be *Cordaites.* The Thompson 3 site (UTM 14SMN 4293 2245) is west of the first two localities and lower in elevation, within a tract of badland hillocks west of the main stream. Here a "pond deposit" roughly 100 feet in diameter contains laminated, variegated siltstone and silty mudstone, in which limonite bands and nodules are common (Fig. 3). The deposit is saucer-shaped, having a sharp lower contact and generally fining upward. Plant axes replaced by limonite and black iron/manganese oxide are the most common fossils, but we also collected foliage of *Taeniopteris, Comia,* and *Calamites*, seeds, and coprolites.

We did not explore the Thompson area thoroughly, and many large, promising outcrops were not prospected. The Thompson fossil localities are at the same structural elevation as the Nichols Roadcut plant locality (USNM 40663) located 2 ½ miles northeast (Table 1). The Thompson and Nichols sites in turn are correlative to the Ignorant Ridge member, which has yielded a prolific flora on both sides of the North Wichita River.

2.1.1 Burnet dolomite member. Moving westward and about 90 feet stratigraphically above the Thompson plant localities is a distinctive dolomitic zone. The zone consists of one to three thin (a few inches) layers of hard, gray, microgranular dolomite, or lenses of dolomite, interbedded with dolomitic shale and siltstone and with reddish-brown mudstone. The entire zone is approximately 10 feet thick. Individual dolomite layers are not continuous, but the zone was followed more than two miles without finding a lateral termination.

This zone is closely similar in lithology and directly on line of strike with the Burnet dolomite bed, mapped north of the South Wichita in previous field seasons. Well records indicate the Burnet to be approximately 760 feet above the base of the Clear Fork along the South Wichita (Fig. 1). Three-point construction using outcrops on both sides of the river yields a strike of N 25 E and a dip of 40 feet per mile toward the northwest. These values agree closely with those indicated on our 1997 subsurface map of structure on the base of the Clear Fork Group, which indicates a strike of N 30 E and a dip of about 37 feet per mile northwest.

Shallow paleochannels filled with siltstone and shaly sandstone are common a short distance below and especially a short distance above the Burnet dolomite (Fig. 4). These single-story channels are shallow (typically about 5 feet, not over 10 feet) and do not represent a mappable channel belt such as the Ignorant Ridge member. We prospected for fossils, but found only unidentified fragments of plants. The youngest known Clear Fork fossil plants are from the same stratigraphic level on the Montgomery Ranch, about 16 miles north.

2.1.3 Narrows couplet. A distinctive and widely traceable pair of gypsum and dolomite layers that we call the Narrows couplet crops out in the vicinity of The Narrows, a few miles east and northeast of Benjamin. We traced the Narrows couplet continuously for more than 2 miles, and identified it at additional locations that span a map distance of more than 4 miles. The couplet comprises an upper unit of interlaminated dolomite, gypsum, and shale a few inches to 3 ½ feet thick; a middle unit of mudstone 3 to 6 ½ feet thick, and a lower unit of interlaminated dolomite and gypsum a few inches to 1 ½ feet thick (Fig. 5). Toward the northwest, the gypsum content increases and the middle mudstone unit thins. Well records indicate the Narrows couplet is about 900 to 910 feet above the base of the Clear Fork. The average dip, determined from outcrop data, is approximately 25 feet per miles toward the west-northwest.

Isolated, shallow paleochannels filled with siltstone and sandstone occur both above and below the Narrows couplet. Two types of channels were observed. One type is 5 to 10 feet deep and contains inclined, accretionary beds of light gray sandstone or siltstone and reddish-brown silty mudstone. The other type of channel is only 2 to 3 feet deep, and is filled with weakly laminated siltstone or silty mudstone (Fig. 6). Both types of channels yielded no identifiable fossils.

2.1.4 Benjamin and Bisbee dolomites. Laterally persistent beds of gray dolomite a few inches thick are a common feature in the upper part of the Clear Fork. Two such beds are exposed in roadcuts along State Rt. 6 north of Benjamin, and are identified on the column (fig. 1) as the Benjamin and Bisbee dolomites [Bisbee is a triangulation point mapped approximately 1.5 mi north of Benjamin]. The Benjamin consists of interlaminated dolomite and gypsum and is continuous for several hundred feet along the highway. The Bisbee dolomite, about 80 feet higher in the section, is a single dolomite bed and also traceable for hundreds of feet. The Benjamin may correspond to one of several thin dolomite layers observed along the Beavers Ranch road about 2 miles east of Rt. 6. Extent of the Bisbee away from Rt. 6 is unknown.

This portion of the Clear Fork is predominantly deep reddish-brown mudstone, which contains thin but extensive tabular layers of bluish-gray siltstone to very fine sandstone. Channel deposits are uncommon, and those we saw are isolated and shallow. None contained fossils.

2.1.5 Uppermost Clear Fork. We did not examine any new exposures of the uppermost Clear Fork during this field season. The upper Clear Fork shown on the column (Fig. 1) is based on observations in previous field seasons in the Maverick Flat area on the Lyles Ranch, west of Benjamin. A thin dolomite bed observed in that area, 30 feet below the top of the Clear Fork, is identified as Maverick dolomite on Fig . Similar, thin dolomite beds have been observed near the top of the Clear Fork at widely scattered localities, including McFaddin Lane, Copper Breaks State Park, and the Double Mountain Fork near Devil's Canyon. At the latter locality, a 3-foot-thick dolomite bed, possibly the Merkel Dolomite, is at the top of the Clear Fork and partially truncated by basal San Angelo Sandstone. Whether dolomite beds observed at such far-flung locations are correlative cannot be determined.

2.1.6 Structure. Nelson estimated the surface dip of the San Angelo-Clear Fork contact, based on limited outcrop data and topographic expression in the western part of the Truscott South Quadrangle and in the Maverick Flat area. In unmapped areas, the contact was assumed to lie at the midpoint of the steep slope on topographic maps, representing the escarpment formed by resistant San Angelo sandstone overlying nonresistant Clear Fork mudstones. The dip determined for Truscott South is N 25 E strike, 25 feet per mile northwest. This compares to a dip of about 20 feet per mile toward the west-northwest on the base of the Clear Fork from our 1997 map. For Maverick Flat, the dip of the San Angelo-Clear Fork contact is 15-20 feet per mile west-northwest. The base of the Clear Fork also dips west-northwest at a rate of 10 to 15 feet per mile here.

Such close correspondence of structural dip between base and top (or upper part of) the Clear Fork indicates that original thickness of the Clear Fork, and of marker-defined intervals therein, does not vary greatly in the area of interest.

We observed one small fault during this field season. It is a thrust fault that has an apparent dip of about 15 degrees westward, 3 to 4 feet of heave, and about 1 foot of throw (Fig. 4). The fault offsets sandstone layers near the top of a vertical cut bank and is not directly accessible. This is the only thrust fault we have observed in North-Central Texas, and its origin is problematic.

2.2 Bullwagon Dolomite Reconnaissance and Castle Peak

Exposures of the Bullwagon Dolomite, which forms the base of the Choza Formation as described by early workers, were sought at five localities shown in the type area of Taylor and Jones Counties on the Abilene GAT sheet (Brown and Goodson, 1972) and earlier AAPG-BEG cooperative maps from the 1930s. On the east side of Anson North Lake, thin dolomitic siltstones and very fine-grained sandstones form a modest ledge that is mapped as Bullwagon. The unit appears to thicken southward and becomes more prominent in the vicinity of Bull Wagon Creek. The best exposures occur on private land and were not accessed. Frank Brown (written communication, 2000) reports that they did not use any subsurface data in mapping the Abilene sheet and mainly relied upon projections based upon regional dip to identify the Bullwagon.

On April 24 we visited the well-known vertebrate trackway locality of Castle Peak, located about 6 miles south of Merkel in Taylor County. Tetrapod trackways and other trace fossils from Castle Peak have been described by Moodie (1929 and 1930), Sarjeant

(1971). Unconfirmed reports of fossil plants brought us to Castle Peak in company of David Allen, a fossil collector who lives in Merkel and knows the landowner. We were taken to a site on the north flank of the mountain (UTM 14SMN 0587 8164) where the trackway-bearing layer is well exposed.

Trace fossils are confined to a thin bed of fissile, very fine-grained sandstone at about the 2040-foot contour line. The trackway layer has a maximum thickness of about 1 foot and pinches out laterally within the exposure (Fig. 7). In spite of frequent past collecting here, we found numerous examples of well-preserved vertebrate footprints and partial trackways, along with several kinds of invertebrate trace fossils, including small myriapod tracks. A number of sedimentary features, including raindrop impressions and straight-crested current ripples, also are preserved. Trace fossils also occur in a deeply gullied area on the steep west face of Castle Peak at about the same elevation as on the north flank. They occur in a thin, lenticular, fissile sandstone that appears identical to the one on the north flank of the peak.

A section measured in the northern collecting area (Fig. 8) shows about 65 feet of strata, dominantly reddish-brown mudstone, containing several thin and discontinuous layers of light gray siltstone and sandstone. Siltstone layers commonly are dolomitic; dolomite also occurs as small, irregular nodules and veinlets. Gypsum nodules are present near the base of the exposure. Referring to the Abilene and Big Spring GAT sheets (Brown and Goodson, 1972; Eifler et al., 1994), these rocks are in the upper Clear Fork (Choza Formation). The overall lithology at Castle Peak is closely similar to that of the upper Clear Fork in other areas where we have worked.

The significance of the Castle Peak trackways is that they indicate a tetrapod fauna that is otherwise unrepresented in the upper half of the Clear Fork Group. All the tracks were made by small terrestrial animals, such as dissorophoid amphibians and varanopseid pelycosaurs. This occurrence clearly impeaches any paleoclimatic suggestions that the evaporite-bearing upper Clear Fork was a hostile, uninhabitable setting.

Reports of plant fossils at Castle Peak remain enigmatic. We found none in several hours collecting at the site, or among fossils in David Allen's personal collections. A gutter-stacked horizontal feeding trace, rare among the fossils we examined, resembles a conifer and could be mistaken for a floral remain. David White (in Moodie, 1929, p. 356) identified a specimen from Castle Peak as a lycopsid, *Rhytidolepis*, but his description ("The central rib is partly covered by compressive overlap of the adjacent ribs…") is similar to the feeding trace that David Allen thought was a plant. A similar specimen is on exhibit at the Texas Memorial Museum, misidentified by C. Durden as *Lebachia*. The Moodie specimen is said to be at the Yale Peabody Museum.

3.0 San Angelo Formation

We visited several sites in southeastern King County that are reported as copper-sampling localities of Stroud et al. (1970). All sites proved to be in the upper part of the San Angelo Formation or in beds transitional from the San Angelo to the Blaine Formation, the level where fossil plants commonly accompany copper mineralization. We found malachite and azurite at most of the sampling localities, and in some cases bits of mineralized fusain, but none of the sites yielded identifiable fossil plants. Both stratiform and channel-fill deposits were observed.

The most interesting area is approximately 1 mile northeast of the East Taylor Pasture plant-collecting sites in a badland area near the head of an east-trending drainage (UTM 14SMN 0560 0140). Abundant malachite occurs within a series of shallow, cross-cutting channels that are filled with interbedded sandstone and gypsum(!). The channels are about 5 feet deep and their accretionary beds dip steeply, locally being slumped. Overlying the sandstone/gypsum are local "pockets" of laminated dark gray to greenish-gray shale that looked promising for plant fossils; none were found. The occurrence of gypsum in channels, along with sandstone, suggests "tidal" channels that connected with a nearby evaporite basin.

A short field day was spent near Oak Creek Reservoir, near the northeastern corner of Coke County; and at roadcuts in adjacent Runnels County. Outcrops of the San Angelo Formation occur on public land near the lake shore and in roadcuts along U.S. Rt. 277 southeast of the lake. Most of the area is thickly vegetated; manmade exposures and natural outcrops are small and widely separated. Outcrops near the lake reveal alternating layers of fine-grained crossbedded sandstone and reddish-brown massive siltstone to silty mudstone. Lenses of mud-chip conglomerate are present in some of the sandstones. Roadcuts on Rt. 277 show the same lithologies, and also pebbly sandstone and quartz-pebble conglomerate (Fig. 9). Quartz pebbles are generally well rounded and less than 1 inch in diameter, the largest are about 1 inch in diameter. Granules or pebbles of other minerals, principally chert, comprise roughly 10% of the total. The only fossils we found were a single tetrapod footprint (cf. *Dromopus*) in sandstone float near the lake, and a variety of horizontal burrows or feeding traces in the upper part of a channel sandstone along the highway. To summarize, San Angelo facies near Oak Creek Reservoir are similar to those we have seen in larger outcrops to the south in Coke and Tom Green Counties.

4.0 Blaine Formation

We spent several days in King County tracing out dolomites and other key beds between North Croton Creek, Buzzard Peak, and East Taylor Pasture. Brief visits also were made to an area along the Salt Fork in Stonewall County and to the Acme area in Hardeman County. This field work confirmed tentative correlations made earlier, verified correlations and mapping by other authors, and filled in gaps in the stratigraphy of the lower half of the Blaine. Correlations within the Blaine in Stonewall and King Counties now are considered firm, and the identity of several key units in Hardeman County appears well established.

The most impressive Blaine exposure we saw is in a cut bank of the Salt Fork of the Brazos just west of the bridge carrying FM 1835 across the river in northeastern Stonewall County. The vertical cliff, more than 3,000 feet long and 100 to 150 feet wide (Fig. 10), was featured in the GSA Centennial Field Guide (Jones and Hentz, 1988). This cliff illustrates great continuity and regularity of the interbedded gypsum, mudstone, and dolomite comprising the Blain, and illustrates that the weathering of gypsum beds along less-well-exposed stream outcrops tends to mask the exposure of other rock types in such sections. The chief exceptions to stratal continuity we have observed are the result of the local dissolution of evaporite layers and collapse of overlying rocks.

After the field season, Nelson integrated our data on the Blaine with the 45 measured sections in Jones (1971). The GAT sheets (Eifler et al., 1992 and 1993; Hentz and Brown, 1987) were examined carefully, comparing mapped traces of members in the Blaine with their identifications in Jones' measured sections. This work enables regional correlation of most named members and beds in the Blaine from Stonewall County northward into Oklahoma, where Johnson (1990) has published reference sections for the Blaine. Regional correlations are presented on a chart (Fig. 11), which is keyed to a map (Fig. 12).

Stratigraphic work in the Blaine is incomplete because of gaps and inconsistencies in the sections by Jones (1971). Difficulties with his data include:

1. Long distances between measured sections
2. Interval thicknesses in Jones' sections are known to be in error by as much as 30% at sites where we have control from topographic maps and our own measurements.
3. Jones' identifications of named members frequently are at odds with the GAT sheets, and also internally inconsistent.
4. Jones' sections do not overlap completely, leaving gaps or questionable identification, particularly in the vicinity of the Mangum Dolomite.

Taking these uncertainties and difficulties into account, several important conclusions can be stated:

1. The Guthrie and Acme Dolomites are continuous from Stonewall County, Texas, into southwestern Oklahoma.
2. The Hollis Dolomite Bed, formally named by Johnson (1990), extends into Texas and is identical to the Masterson dolomite bed of Jones (1971). The Hollis is midway between the Guthrie and Acme Dolomites, and is mapped but not named on GAT sheets from Childress County (within 6 miles of the Hollis type section in Oklahoma) to southern Stonewall County (Eifler et al., 1992 and 1993).
3. Below the Acme Dolomite the following units extend from Stonewall County to southwest Oklahoma. Directly below the Acme is a cliff-forming gypsum unit commonly 20 to 25 feet thick. Next lower is the Willow Creek dolomite bed of Jones (1971), which is 2 to 6 feet thick and typically has thin planar bedding, Directly below the Willow Creek is another 20- to 25-foot-thick massive gypsum unit, which is mined commercially at Acme.
4. The Mangum Dolomite appears to be continuous in the Texas outcrop belt, and in most places is a shaly dolomite 2 to 5 feet thick. The dolomite identified as Flat Top in Stonewall County (Nelson 1999) is the Mangum.
5. According to Jones (1971), multiple dolomite beds, having a net thickness as great as 15 feet and occupying an interval as thick as 50 feet, are in the middle-lower Blaine of Hardeman County. We tentatively correlate these dolomites with the Mangum, but we have not observed them in the field, so further study is required.
6. Below the Mangum in Texas are several thin dolomite beds, normally a few inches to about 2 feet thick. Our field work in Stonewall and King Counties, along with comparison of Jones' measured sections, indicates that some of these beds are traceable for miles, but none are continuous across the region.
7. Thin dolomite beds and dolomitic or calcareous siltstone in the basal Blaine and

uppermost San Angelo are not regionally continuous. The Snake Den dolomite, which underlies plant deposits north and east of Buzzard Peak, is not correlative with a similar carbonate zone that overlies the plant deposits of East Taylor Pasture. In fact, all fossil plants of East Taylor Pasture and the Buzzard Peak area are 160 to 170 feet below the Mangum Dolomite. The fossil plants and "marker" dolomite of Devil's Canyon, in southern Stonewall County, are younger than those of King County.

5.0 Stratigraphic Distribution of Clear Fork and Pease River Plant Localities

A subsurface map of the top of the Lake Kemp Limestone, which is the base of the Clear Fork Group, is the basis for evaluating the regional stratigraphic distribution of fossil plant localities in North-Central Texas. The map was constructed from 320 well logs in Baylor, Knox, Foard, Wilbarger, King, and Stonewall Counties. An earlier version of this map was distributed in 1997. Most of the logs are from the 1950s and consist of SP and resistivity curves; unlike more recent wells, these early wells were cased only to approximately 200 ft. The top of the Lake Kemp Limestone was identified from a distinctive resistivity response at the top of the Albany Group, some 890 to 970 ft above the base of the Coleman Junction, which is represented by a highly characteristic SP response.

Subsurface limestone elevations were contoured by hand at 20 ft intervals at a scale of 1:100,000. Plant localities were plotted on the same base maps on the basis of UTM coordinates (Table 1), and their stratigraphic positions were determined by subtracting the elevation of the limestone from the ground elevation of the fossiliferous deposit. Given the variability of well data and accuracy of map locations, the stratigraphic positions probably are accurate to ±10 ft. Greater variation is apparent near the northeastern limit of present well control in the case of plant localities near the Craddock dolomite. Whereas subsurface data indicate these localities to be 74 to 105 feet above the Lake Kemp Limestone, outcrop sections show the interval to be approximately 45 to 60 feet.

A total of 60 localities was determined (Fig. 13). These include some localities that have not been collected adequately (numbers 13, 14, 19, 41, 42, 54), and exclude a few "plant shows" that have not been assessed. The two localities in East Taylor Pasture, King County, are not included because they are outside the area of present well coverage. Likewise, plant localities in the Haskell, Abilene, and San Angelo areas are excluded.

An absence of Clear Fork localities above the level of the Montgomery Ranch deposits is conspicuous but not entirely proven. Most of the upper 250 feet of the Clear Fork has been covered only in reconnaissance, and a gap of about 50 feet near the top of the member has not been visited at all.

The results confirm some observations we have made in the field and raise some points for further consideration. The "Red Tank Sandstone" member localities, all of which represent abandoned channel deposits, span an interval of 90 ft. This is greater than the observed thickness of the unit in any one field area, and suggests that the Red Tank may represent a series of overlapping and stacked channel deposits. The "Cedar Top Sandstone" member localities are more constrained stratigraphically (and geographically), spanning an interval of less than 30 ft. Localities within the "1919 Sandstone" and "Ignorant Ridge Sandstone" members both fall within ranges approximately 70 feet thick.

The San Angelo localities (numbers 2-7) are clustered within a 50 ft interval; it is remarkable that the southern- and northern-most San Angelo sites, which are approximately 45 mi apart, occur within 10 ft of each other stratigraphically. All in all, the data indicate that the thicknesses of intervals within the Clear Fork are surprisingly consistent across the study area.

Figure 13 includes tracings of two electric logs that were accompanied by sample descriptions. Log 216 is from the Bateman Oilfield in east-central King County, and log 239 is from northeast Stonewall County, about 16 mi to the south. Both include the base of the San Angelo and, more importantly, thin but persistent carbonate beds in the Clear Fork. Three carbonate zones are present: a lower zone starting at about 100 ft above the Lake Kemp Limestone, a middle at about 400 ft, and an upper at 800 ft. These zones are present in nearly all logs from Stonewall, King, western Knox, and southwestern Foard Counties. The uppermost zone is identified provisionally as the Bullwagon Dolomite, which is exposed in Haskell, Jones, Taylor, and Runnels Counties and which marks the Vale-Choza contact. The base of the Bullwagon zone appears to be correlative with the Burnet dolomite as we mapped it in Knox County, and the upper part of the zone may include the "Narrows Couplet." The middle and lower zones may be correlative to the Standpipe Limestone and named Arroyo carbonate beds of the same area, but much additional subsurface work is required to establish certain correlations.

6.0 Conclusions and Recommendations for Future Work

6.1 Subsurface Mapping

The combination of detailed surface mapping and regional subsurface mapping provides a high-resolution stratigraphic framework for evaluating Lower Permian plant occurrences in North-Central Texas. This framework exceeds the resolution of any other Late Paleozoic plant-bearing sequences that are not coal bearing and was entirely unexpected during our early years of work in the Clear Fork and Pease River Groups.

In order to integrate important Lower Permian plant records that occur in the general area of Abilene, it will be necessary to acquire well logs in southern Baylor and Knox Counties, and all of Haskell, Jones, and Taylor Counties. This work also will clarify the relationship between formal Clear Fork carbonate units mapped in the Abilene area and those that have been named informally in our field area. Approximately four months of full-time work will be required by Hook to complete this subsurface study. An estimated $700 is required to cover the cost of duplicating logs at the BEG and 7.5' quadrangle-scale base maps at the Texas Railroad Commission. This work would be undertaken in July and completed before the end of 2000 if funds are available.

Two additional subsurface projects are proposed here. The first regards extending Clear Fork, San Angelo, and Blaine control in the subsurface through Fisher, Nolan, Runnels, Coke, and Tom Green Counties. This would provide much-needed data to assess the relationship between northern and southern facies of these units. The facies relationships, little discussed in the literature, are critical to understanding the regional distribution of plant and vertebrate fossils in the Clear Fork and Pease River Groups.

The second project entails placing Wichita/Albany and Bowie/Cisco plant deposits in stratigraphic context, as we have done here for Clear Fork plant deposits. The Coleman

Junction Limestone, readily identified on wireline logs, provides the regional datum. This proposed study would encompass part or all of Archer, Clay, Montague, Throckmorton, and Young Counties. Combined, these projects would require approximately nine months of work and $2,300 in duplication and map charges to complete.

6.2 Surface Mapping

Surface mapping in the Clear Fork Group is practically complete. A small (roughly 50 feet) gap in coverage is near the top of the group, and data on the interval above the Narrows couplet is sparse. One to two days in the field north and northwest of Benjamin, where property contacts are already established, could fill these gaps. Given the apparent absence of fossils and demonstrated continuity of marker beds above and below, priority is lower than for field work in the Pease River Group.

In the San Angelo Formation, several copper mines and prospects reported by Smith (1974) have not been visited. These include the Gibbs prospect near Medicine Mounds in Hardeman County, the McClellan Mine near Copper Breaks State Part in Foard County, the Pyron or Craig Ranch mine in northern King County, and the "true" Buzzard Peak Mine in King County. Visiting the first two named, which are northernmost, would extend our area of coverage the most. Property access may be difficult, but the chances of finding fossils appear good. An early start on requesting property access to these sites appears to be in order. Also, we should not give up on trying to gain access to the Panther Canyon site and adjacent areas in Stonewall County.

To work out regional stratigraphy of the Blaine Formation, field work is needed in several areas. One objective is to sort out the stratigraphy of the dolomite beds between King County and southwestern Oklahoma, where Johnson (1990) established a standard section. By far the best unvisited exposures are along the Pease River in southwestern Hardeman and northeastern Cottle Counties. Jones (1971) measured several long sections in the river bluffs, but his identification of keys beds is not consistent with the GAT sheets. Another area of interest is along the North Wichita River near the Cottle-Foard county border, where Jones measured a long section and a fault is shown on the GAT sheet. Extensive mapping and section measurement are not required; mainly we need to identify carbonate beds mapped on GAT sheets and tie them into Jones' measured sections.

A second area of interest for Blaine studies is in northwestern Stonewall County, specifically the falls of Salt Croton Creek. This area probably provides the best exposures in Texas of the upper Blaine, including the Aspermont Dolomite, the unit that yields fossil plants at South Ash Pasture. Both the Aspermont and Salt Croton dolomites are unusually thick and fossiliferous (invertebrates) near the falls, a situation unexplained in any published report. Visiting this area should yield insights into deposition of the Aspermont and similar carbonate units.

The third Blaine topic to address is the southern sandy facies. Old county reports and our own limited work in Tom Green and Coke Counties show that the rocks called Blaine here are totally different from those of Stonewall County and north. Interbedded gypsum, dolomite, and mudstone on the north change to sandstone and siltstone on the south. No previous author addressed this facies change or its possible causes. In addition, the southern sandy facies might yield fossils. The most promising area for outcrop work is in Coke County, northeast and east of Robert Lea. We briefly visited roadside exposures in 1998; access to private property will be required for additional study.

Depending on our success in making property contacts, all of the above work might require two to three weeks in the field.

6.3 Fossil Collecting

The three plant deposits found on the Thompson Ranch extend the geographic range of the Ignorant Ridge sandstone member. Preservation is best at localities 1 and 3, and locality 3 is particularly well exposed and rather extensive. These deposits were accessed through the Coulton property to the east, but may be reached more easily by driving through the Galen Scott property, which adjoins Coulton to the east and north.

6.4 Integration of Data and Reports

This project would benefit greatly from a single database that includes all paleontological, stratigraphic, subsurface, and geographical data related to our work in North-Central Texas. These data are currently reside as largely uncollated handwritten notes, sketches, and field maps, distributed between Austin, Champaign, and Washington, D.C. Unless we integrate and simplify this mass of data, it is in danger of becoming unusable. The ISGS currently is using ArcView software to produce publication-quality geologic quadrangle maps. ArcView can be used to produce a unified data base on topographic maps of 1:24,000 scale. Topographic base maps are available digitally from the USGS for all of North-Central Texas and adjoining parts of Oklahoma at a cost of approximately $200, and John Nelson is available to conduct the digitizing.

We envision a detailed paper on our stratigraphic work in the Clear Fork. A target journal has not been identified; either a vertebrate paleontology theme or paleobotany venue is possible. Unfortunately, data-laden stratigraphic studies such as these are not very marketable in these days. We believe a shorter "high-profile" paper to the likes of *Geology* is appropriate if an overview of the plant data is available; such a paper could be written now and certainly would be appropriate. It seems likely that monographic works are in order, and because CD-ROMs are replacing monographs, it is appropriate to investigate such options at the Smithsonian.

7.0 References

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APPENDIX

Property-Access Contacts

The following individuals facilitated or allowed property access during our field work. Because of past difficulties, we would like to see all such contacts compiled in a similar manner in the future.

Don Gregg, Manager, Tri-County Electric Co-op, Seymour. 940-888-3441. Since the 1970's, Don has been the Smithsonian's "life line" for property access in Baylor and Knox Counties. **Pete Winn**, Don's assistant at Tri-County, also has been helpful in the past, particularly in Knox County.

Stanton Brown, Chief Appraiser, Knox County Appraisal District, P.O. Box 47, Benjamin, TX 79505, 940-454-3891. Don introduced us to Stanton, who has lived in Knox County all his life and knows property owners and leaseholders. He contacted the following individuals by phone on our behalf:

> **Larry and Cindy Thompson** – own most of old Burnett Ranch north of US 82 and roughly between FM 267 and Colton property west of Vera. Live in Munday.
>
> **Lamond Patterson** and son **Kynn Patterson** (home 940-454-2871; mobile 940-256-2360). After Stanton called Lamond, who is retired, we met Kynn in his pasture. This property is north of US 82 between the Thompson property and The Narrows.
>
> **Tom and Becky Morehouse** – holds lease on old Beavers Ranch northeast of Benjamin. This is the same Morehouse that we contacted for property access in the King-Knox County line area in the past. Stanton indicated that they also lease the Alexander Ranch, which includes an old copper mine (Pyron) that we have not visited.

Buddy Tolson -- owns small parcel immediately north of The Narrows rest area. Wife runs general store in Benjamin.

Carl Coulton – owns small ranch that adjoins east side of Thompson property west of Vera. Property is leased by **David Scott** (home: 940-888-2295; mobile 940-733-5355), who turns wild hogs out on the land for hunting.

Mike Sheddy – foreman, Spike Box Ranch (940-454-3581; home 940-454-2102; mobile 940-256-2387). Mike gave access to land west of State Route 6 north of US 82.

Mike Gibson – foreman, 6666 Ranch (806-596-4457).

Dolan Brinson – visited at ranch near Falls of Salt Croton area. Former oil man. Said that old Lloyd and Winters land near falls is leased by **Danny Spraberry** of Anson (home 915-823-3640; mobile 915-668-0411 and 0361). No contact made.

Allene Riddel – P.O. Box 874, Aspermont, 989-3347. Owns land that includes large cutbank along Salt Fork west of FM 1835 in King County. Granted property access over phone.

David Allen – 401 South 8th, Merkel, 915-928-5553; email loudavidallen@cs.com. Arranged access to Castle Peak.

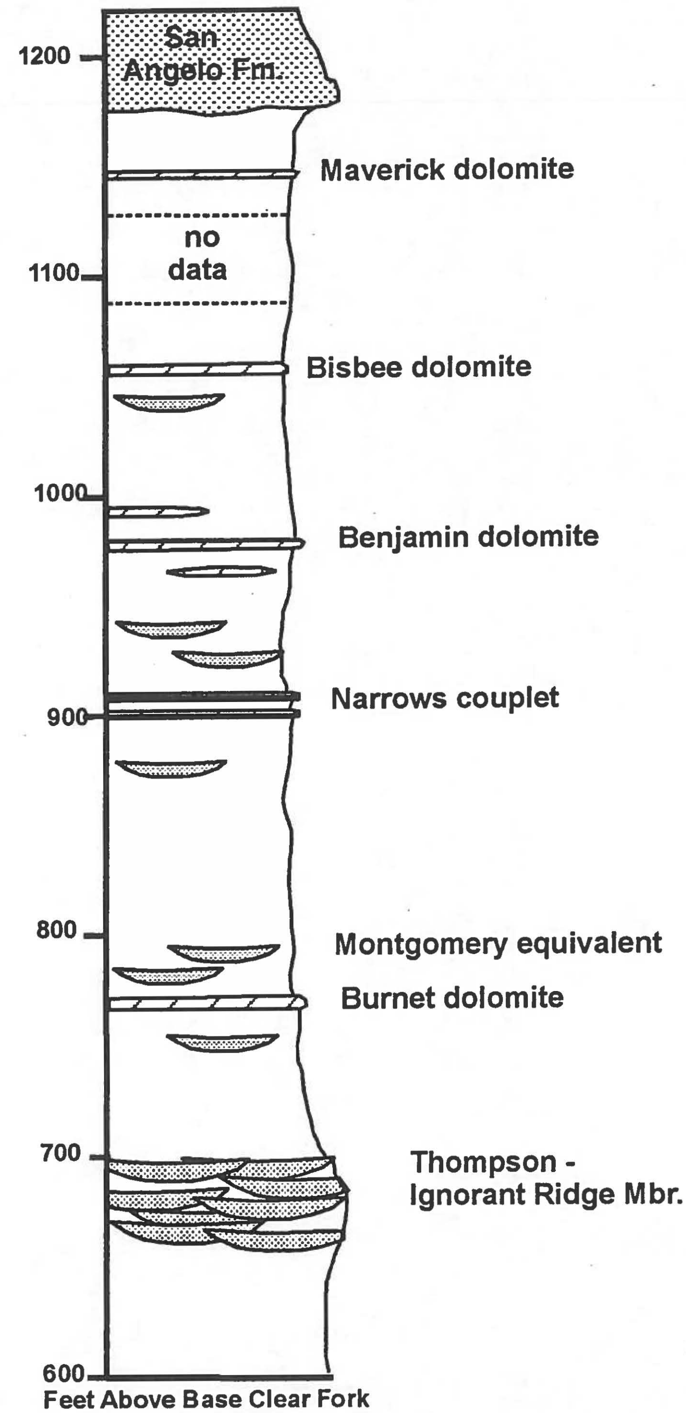

Figure 1. Composite section of upper Clear Fork in Knox County.

Figure 2. Cut bank on Thompson property (14SMN 4363 2180, Vera Quadrangle) showing superimposed channel-fill sequences that contain plant fossils and are correlated with the Ignorant Ridge member.

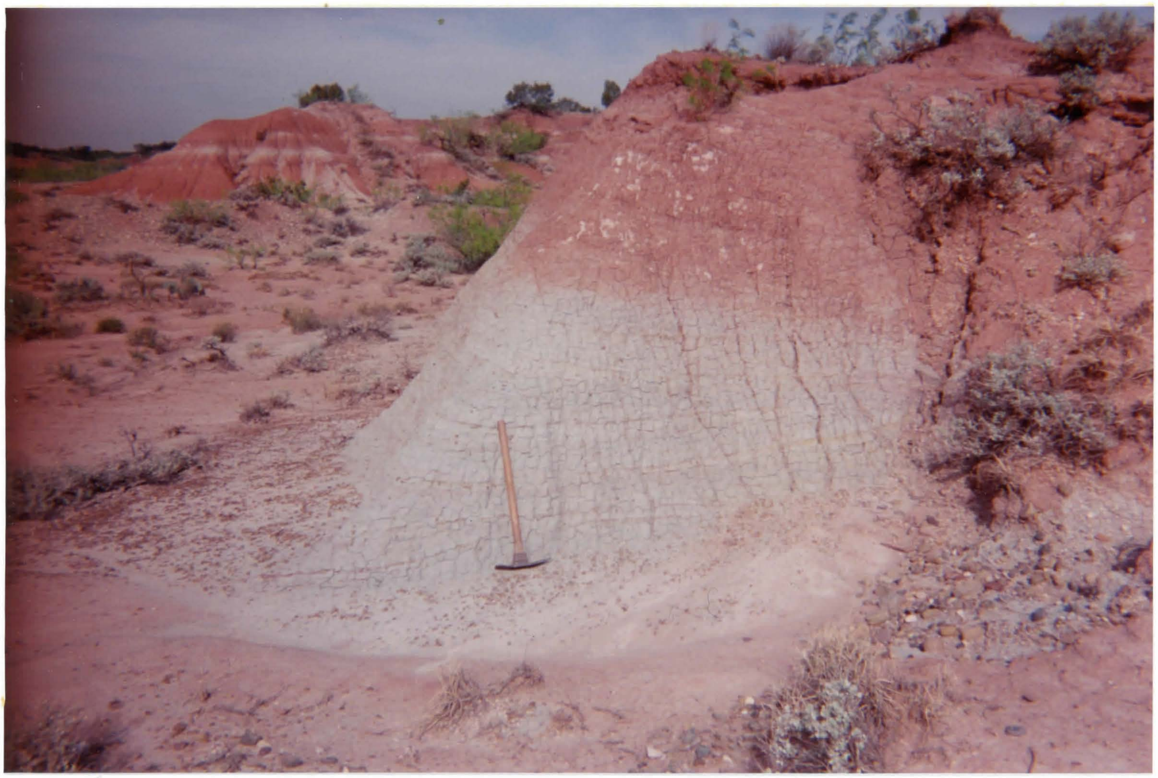

Figure 3. Part of "pond" or abandoned channel deposit that yielded fossil plants at Thompson 3 locality.

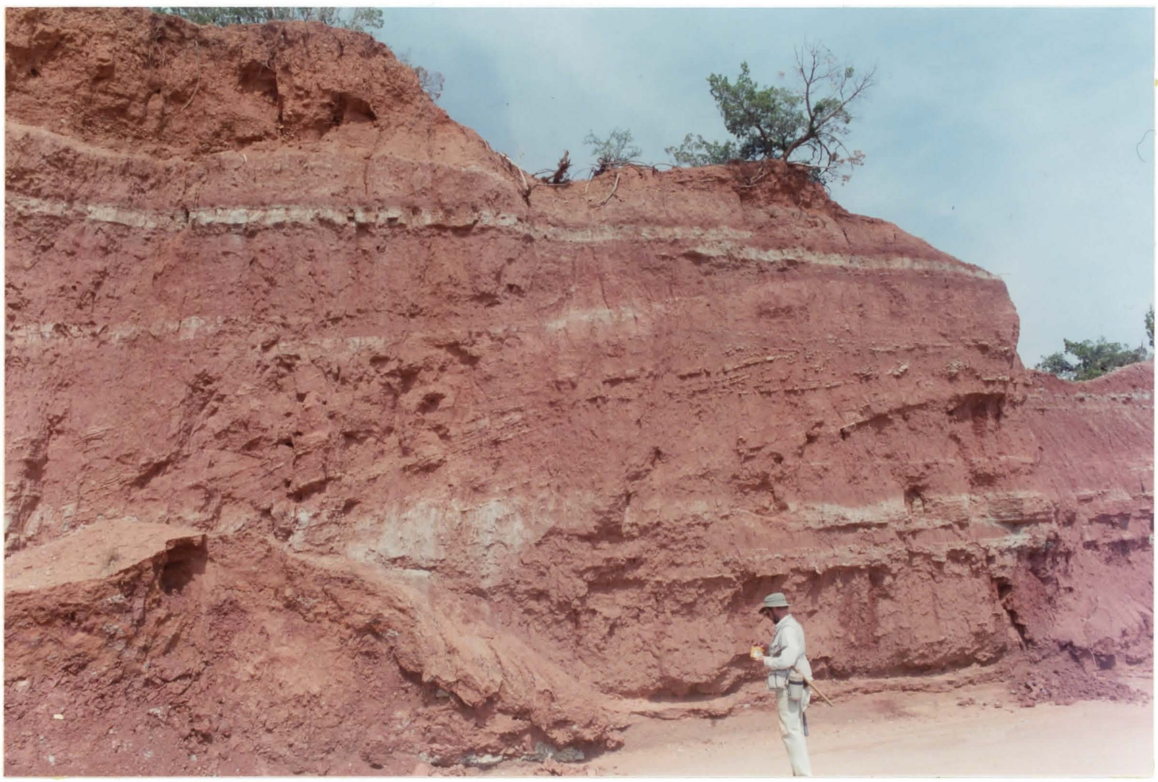

Figure 4. Strata a short distance below Burnet dolomite on Thompson property, west of plant localities (14SMN 3942 1975, Rhineland Quadrangle), showing the edge of a paleochannel, at left. At top of bank directly above Bob Hook a small thrust fault offsets a light gray sandstone layer.

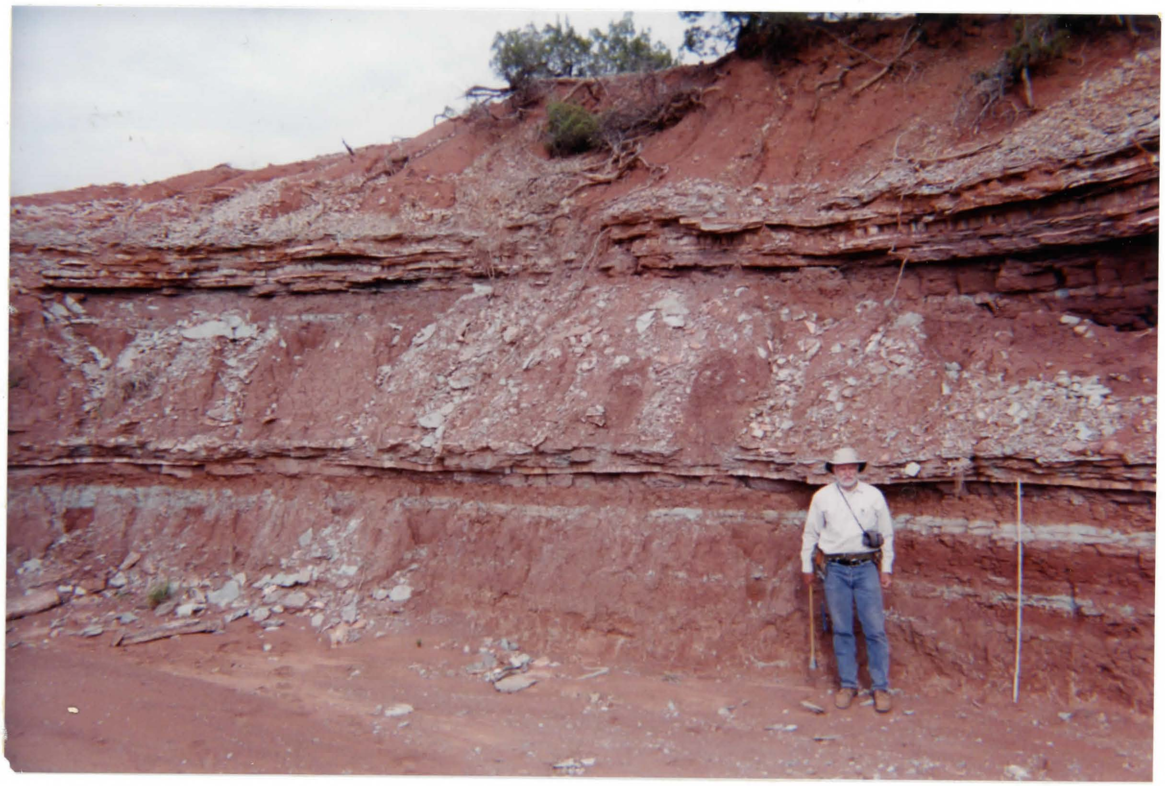

Figure 5. The "Narrows couplet", a pair of bench-forming gypsum and dolomite beds that can be traced for miles. Locality is about 2 miles northwest of The Narrows, 14SMN 3162 1920, Rhineland Quadrangle.

Figure 6. Shallow channel filled with bluish-gray siltstone, below Benjamin dolomite. The siltstone has climbing ripples and low-angle accretionary bedding. Locality is a stream just east of Beavers Ranch Road, 14SMN 2898 1934, Benjamin Quadrangle.

Figure 7. The trackway-bearing sandstone in the primary collecting area on the north side of Castle Peak. Sandstone pinches out near left margin of photograph.

Figure 8. Graphic section of Choza Formation at Castle Peak.

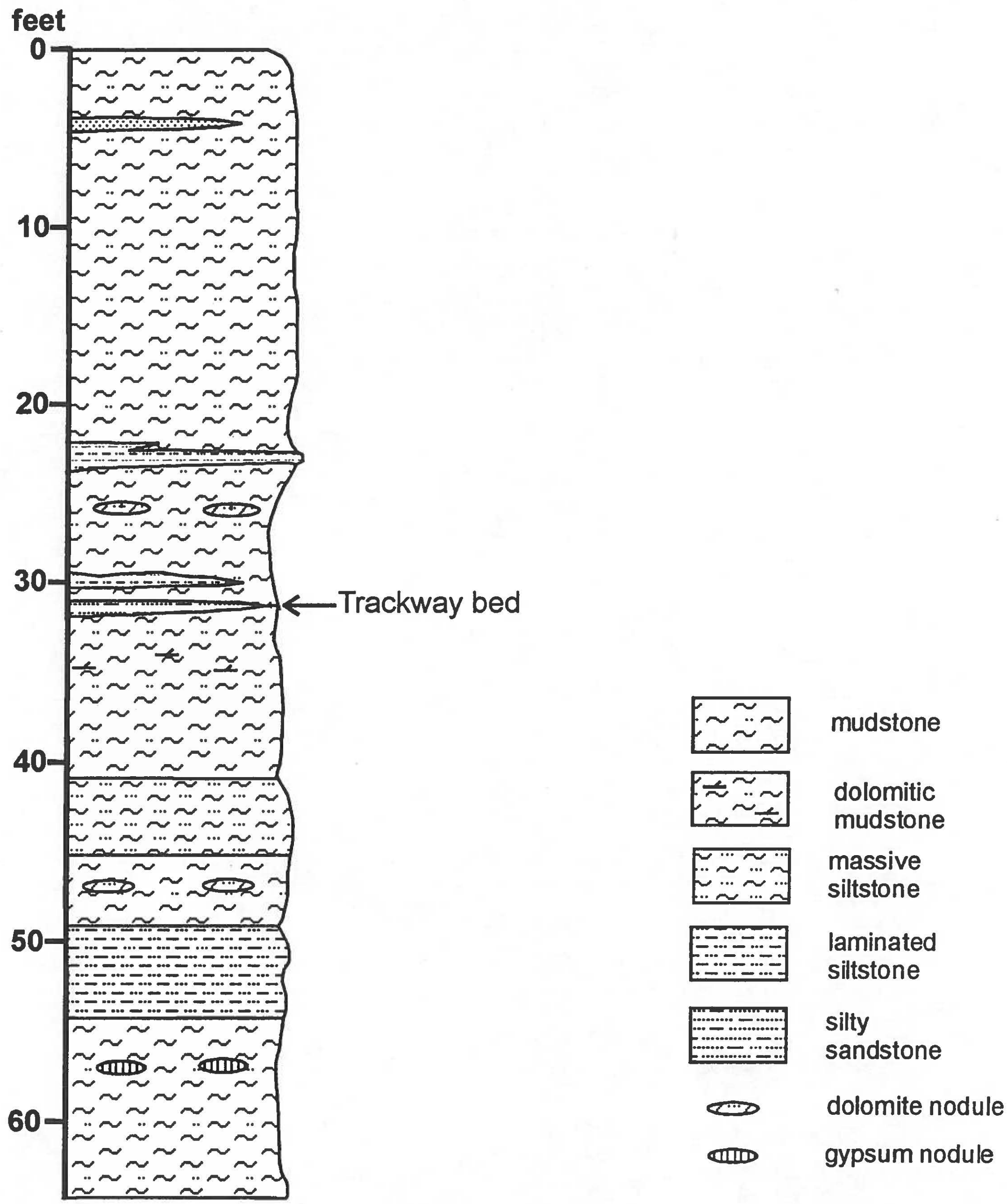

Figure 9. Quartz-pebble conglomerate and pebbly sandstone of the lower San Angelo Formation in roadcut southeast of Oak Creek Reservoir, northwestern Runnels County.

Figure 10. Big cut bank on Salt Fork of the Brazos in Stonewall County displays lateral continuity of gypsum, dolomite, and mudstone beds in the mid-lower part of the Blaine Formation.

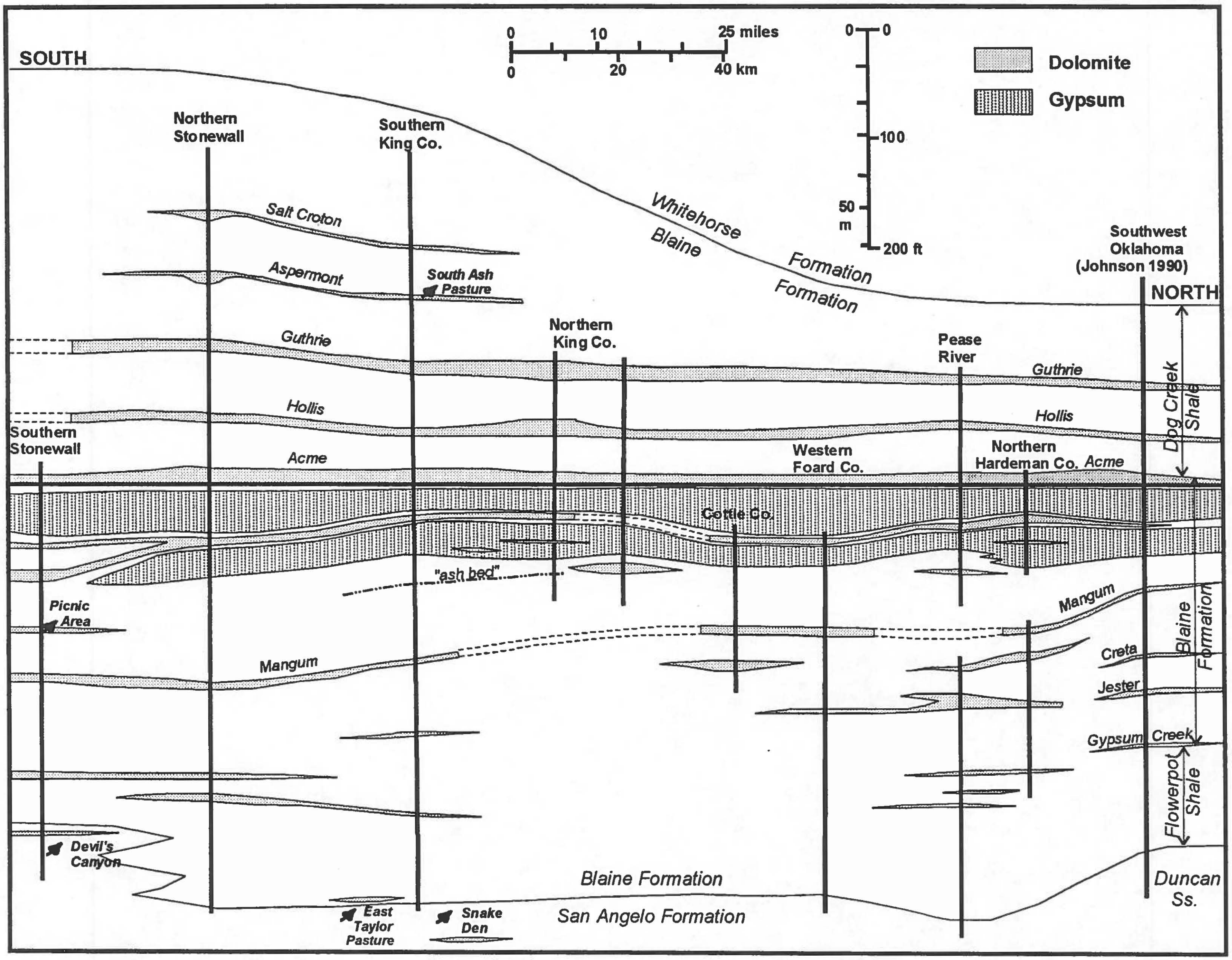

Figure 11. Preliminary regional cross section of Blaine Formation from Stonewall County to southwestern Oklahoma, based on Jones (1971), Johnson (1990), and our field work.

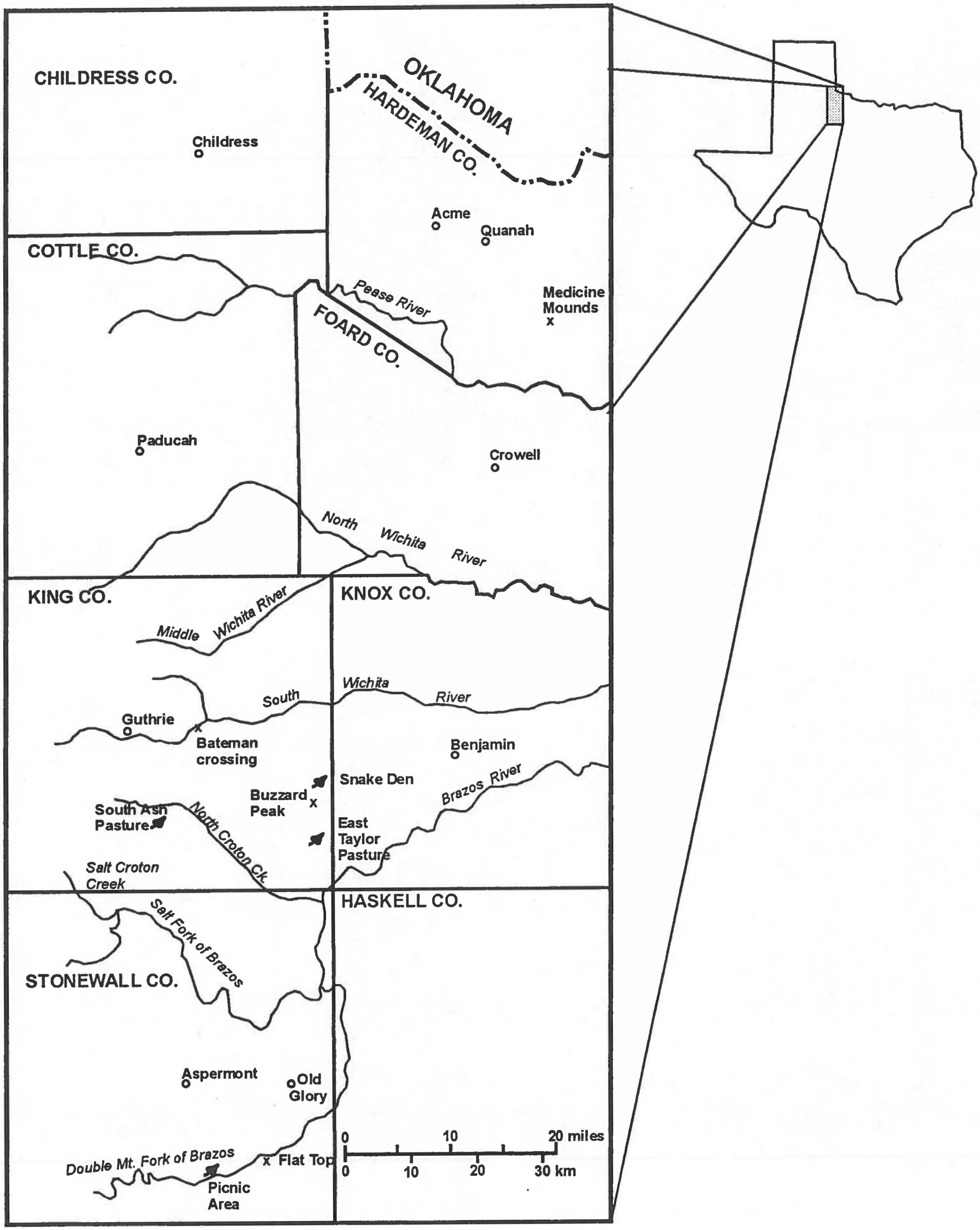

Figure 12. Map showing area of Blaine Formation outcrops.

Figure 13 (next page). Stratigraphic distribution of Clear Fork and Pease River Groups plant localities, North-Central Texas, and representative electric logs. Left, plant localities of Table 1 and formal and informal stratigraphic divisions. Right, electric logs from east-central King County (No. 216) and northeastern Stonewall County (No. 239) with provisional stratigraphic picks; vertical scale same as left-hand column. Sample logs accompanied these logs; horizontal lines represent resistivity "kicks" that are regionally persistent. Psa = base of San Angelo Formation, Pbw = base of ?Bullwagon Dolomite, Plk = top of Lake Kemp Limestone, base of Clear Fork Group.

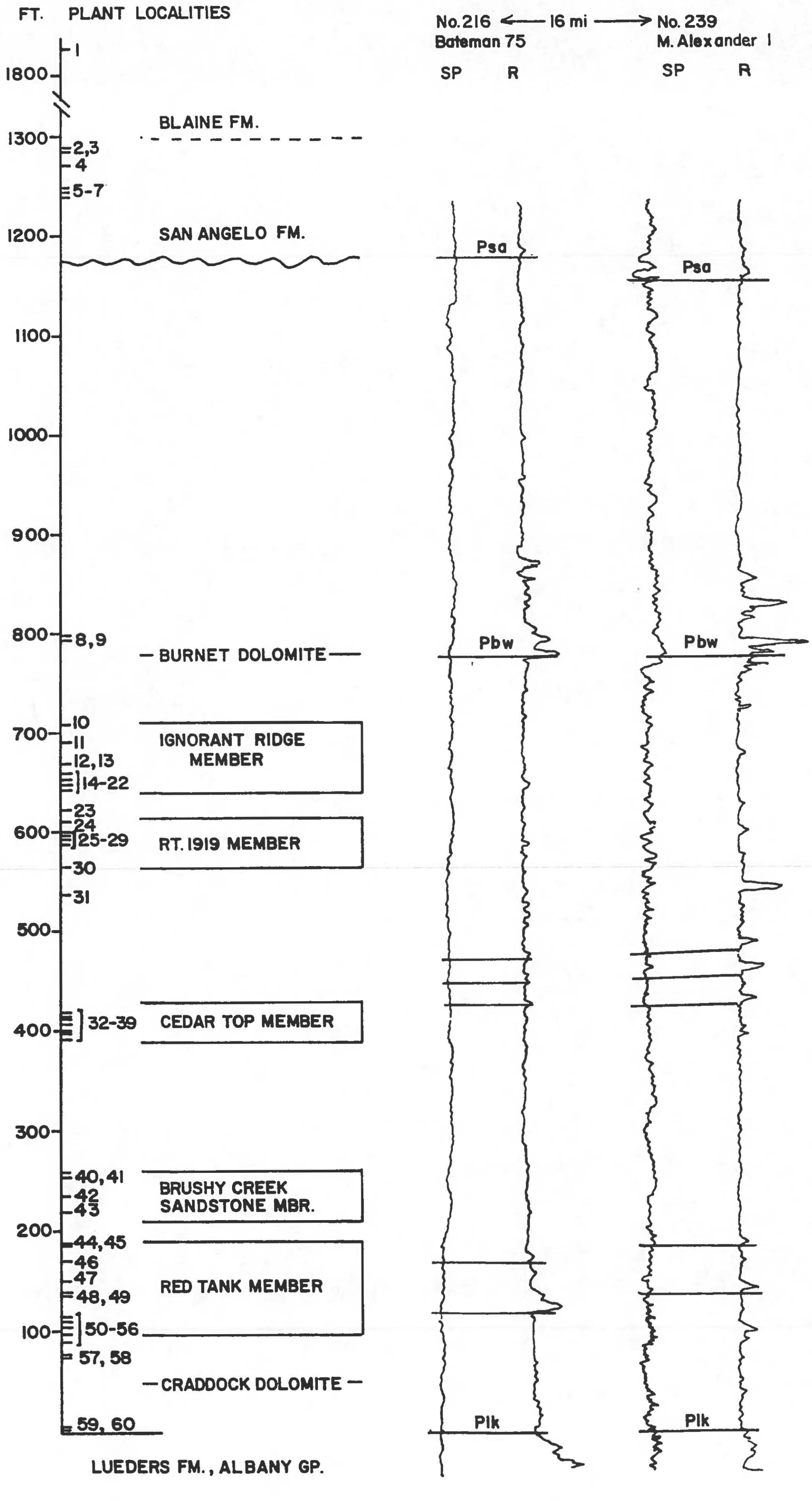
FT. PLANT LOCALITIES
No. 216 ← 16 mi → No. 239
Bateman 75
M. Alexander 1
SP R
SP R
1800
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
1
2,3
4
5-7
8,9
10
11
12,13
14-22
23
24
25-29
30
31
32-39
40,41
42
43
44,45
46
47
48,49
50-56
57,58
59,60
BLAINE FM.
SAN ANGELO FM.
BURNET DOLOMITE
IGNORANT RIDGE MEMBER
RT. 1919 MEMBER
CEDAR TOP MEMBER
BRUSHY CREEK SANDSTONE MBR.
RED TANK MEMBER
CRADDOCK DOLOMITE
LUEDERS FM., ALBANY GP.
Psa
Pbw
Plk

Figure 13.

Table 1. Stratigraphic distribution of plant localities in Pease River and Clear Fork Groups. Pcf bs = elevation (ft) of base of Clear Fork, Intrvl = interval (ft) between plant locality and base of Clear Fork.

No.	Name	Coll. #	USNM #	Quadrangle	UTM ZN	UTM E	UTM N	Elev.	Pcf bs	Intrvl	Stratigraphy
1	SOUTH ASH PASTURE	1995-4		BOB CREEK	14SLN	8139	0620	1778	-50	1828	Aspermont Dolomite
2	SNAKE DEN	1998-12		BUZZARD PEAK	14SMN	0635	1004	1590	300	1290	upper San Angelo
3	SHOOTING RANGE	1997-4		BUZZARD PEAK	14SMN	0667	1010	1592	304	1288	upper San Angelo
4	SQUIRE MINE	1997-2		CEDAR MNTN	14SMN	0811	0805	1615	342	1273	upper San Angelo
5	DEVILS CANYON	1999-?		FROG MNTN	14SLM	9866	5774	1645	393	1250	upper San Angelo
6	LYLES	1998-9		CEDAR MNTN	14SMN	1269	1767	1610	365	1245	upper San Angelo
7	SMELTER CANYON	1998-7		CEDAR MNTN	14SNN	1190	1819	1600	360	1240	upper San Angelo
8	MONTGOMERY RNCH	1997-6		HALSELL RANCH	14SMN	4214	4337	1348	550	798	above Burnet dol.
9	MONTGOMERY RNCH	1998-9		HLSLL RNCH	14SMN	4211	4337	1345	550	795	above Burnet dol.
10	KH		40660	HALSELL RANCH	14SMN	4862	3461	1400	690	710	Ignorant Ridge mbr.
11	I.R. GIGANTOPTERID		40661	COLWELL CREEK	14SMN	4849	3438	1380	688	692	Ignorant Ridge mbr.
12	NICHOL'S ROADCUT		40663	VERA	14SMN	4690	2506	1410	740	670	Ignorant Ridge mbr.
13	THOMPSON 1	2000-1		VERA	14SMN	4400	2266	1390	720	670	Ignorant Ridge mbr.
14	THOMPSON 3	2000-3		VERA	14SMN	4293	2245	1350	690	660	Ignorant Ridge mbr.
15	KNOW WHERE 2		40657	COLWELL CREEK	14SMN	5115	4109	1330	670	660	Ignorant Ridge mbr.
16	KNOW WHERE 1		40656	COLWELL CREEK	14SMN	5130	4101	1330	675	655	Ignorant Ridge mbr.
17	KNOW WHERE 4	1995-12		COLWELL CREEK	14SMN	5163	4099	1335	680	655	Ignorant Ridge mbr.
18	KNOW WHERE 3	1995-11		COLWELL CREEK	14SMN	5183	4090	1335	684	651	Ignorant Ridge mbr.
19	THOMPSON 2	2000-2		VERA	14SMN	4389	2285	1365	715	650	Ignorant Ridge mbr.
20	IR NORTH ROAD		40662	COLWELL CREEK	14SMN	4929	3533	1345	696	649	Ignorant Ridge mbr.
21	KI	1995-18		VERA	14SMN	4589	3122	1310	663	647	Ignorant Ridge mbr.
22	KE POND		40650	VERA	14SMN	4689	3127	1325	682	643	Ignorant Ridge mbr.
23	KD		40672	VERA	14SMN	4529	2960	1295	670	625	below Ignorant Ridge
24	NORTH FORK PENS 3	1995-9		COLWELL CREEK	14SMN	5265	3995	1312	700	612	Rt. 1919 member
25	NORTH FORK PENS 1		40651	COLWELL CREEK	14SMN	5216	4031	1290	690	600	Rt. 1919 member
26	1919 AMPHITHEATER		40052	SNT RS LK SW	14SMN	5548	3892	1340	740	600	Rt. 1919 member
27	FOUR HILLS		40659	VERA	14SMN	4940	2679	1355	758	597	Rt. 1919 member
28	NORTH FORK PENS 2		40652	COLWELL CREEK	14SMN	5239	4000	1290	695	595	Rt. 1919 member
29	1919 PECOPTERIS		40051	SNT RS LK SW	14SMN	5548	3887	1328	740	588	Rt. 1919 member
30	JOHN'S POND	1995-22		COLWELL CREEK	14SMN	5026	3727	1260	695	565	Rt. 1919 member
31	1919 EAST		40649	SNT RS LK SW	14SMN	5642	3866	1292	754	538	Below Rt. 1919 mbr
32	DON'S DUMP 4		40655	SOAP CREEK	14SMN	5840	3335	1270	850	420	Cedar Top member
33	DON'S DUMP 5	1995-5		SOAP CREEK	14SMN	5859	3379	1270	850	420	Cedar Top member

34	CONRAD'S FISH CRK	1995-20		SNT RS LK SW	14SMN	6301	3963	1290	875	415	Cedar Top member
35	DON'S DUMP 6	1995-6		SOAP CREEK	14SMN	5848	3317	1270	857	413	Cedar Top member
36	CEDAR TOP	1995-8		SOAP CREEK	14SMN	5890	3232	1290	882	408	Cedar Top member
37	DON'S DUMP 3		40654	SOAP CREEK	14SMN	5863	3317	1260	860	400	Cedar Top member
38	DON'S DUMP 2		40653	SOAP CREEK	14SMN	5899	3356	1260	862	398	Cedar Top member
39	HEAD OF FISH CRK	1995-19		SNT RS LK SW	14SMN	6526	4041	1290	897	393	Cedar Top member
40	OLSON'S Baa AREA		40666	NW LAKE KEMP	14SMN	7026	3655	1260	1000	260	above Brushy Creek
41	CROOKED CREEK	1996-?		SW LAKE KEMP	14SMN	6618	3262	1215	960	255	Brushy Creek Ss.
42	N. BANK WICHITA R.	1996-?		SW LAKE KEMP	14SMN	6546	3063	1200	965	235	Brushy Creek Ss.
43	DEADMAN CREEK		40670	SW LAKE KEMP	14SMN	6644	2863	1220	1000	220	Brushy Creek Ss.
44	WEST BRUSHY CRK		38908	SW LAKE KEMP	14SMN	7200	2590	1265	1077	188	Red Tank member
45	UPPER BRUSHY 2		40048	SW LAKE KEMP	14SMN	7348	2634	1280	1096	184	Red Tank member
46	UPPER BRUSHY 1		38901	SW LAKE KEMP	14SMN	7356	2618	1270	1100	170	Red Tank member
47	CRADDOCK R.T. 2	1996-3		SW LAKE KEMP	14SMN	7442	2752	1250	1100	150	Red Tank member
48	CRADDOCK R.T. 3	1996-4		SW LAKE KEMP	14SMN	7453	2750	1240	1100	140	Red Tank member
49	CRADDOCK R.T. 1		38903	SW LAKE KEMP	14SMN	7441	2705	1240	1102	138	Red Tank member
50	LOWER BRUSHY CRK		38907	SW LAKE KEMP	14SMN	7184	2962	1197	1082	115	Red Tank member
51	STERNBERG BNYRD	1996-?		NE LAKE KEMP	14SMN	7725	3913	1180	1070	110	Red Tank member
52	HOG CREEK		40665	SW LAKE KEMP	14SMN	7077	3060	1165	1055	110	Red Tank member
53	W OF PONY CK GATE	1996-12		SW LAKE KEMP	14SMN	7609	2966	1205	1100	105	near Craddock dol.
54	WEST COFFEE CRK		no coll.	NE LAKE KEMP	14SMN	7729	3985	1180	1082	98	Red Tank member
55	WAG-CRAD SLUMP	1996-15		SW LAKE KEMP	14SMN	7533	2833	1190	1100	90	near Craddock dol.
56	WAG-CRAD FUSAIN		40605	SW LAKE KEMP	14SMN	7525	2833	1190	1100	90	near Craddock dol.
57	BC LAKE FRONT 1	1996-11		SW LAKE KEMP	14SMN	7334	3063	1160	1082	78	near Craddock dol.
58	BC LAKE FRONT 2	1996-13		SW LAKE KEMP	14SMN	7315	3069	1155	1081	74	near Craddock dol.
59	PONY CREEK		38904	SE LAKE KEMP	14SMN	7876	2467	1238	1230	8	basal Clear Fork
60	HARMEL TANK		40050	SE LAKE KEMP	14SMN	8178	2329	1310	1305	5	basal Clear Fork