Permian Stratigraphy, North-Central Texas
Report No. 5
W. John Nelson - December 11, 1998

SUMMARY

This year's field season in Texas covered 14 days (October 2 through 16), which were spent on varied activities (Table 1). For six days I measured sections of Wolfcampian and Leonardian rocks with Neil Tabor, who is investigating Permian paleosols of Texas and their paleoclimatic implications. The rest of the season was devoted to studies of uppermost Clear Fork, San Angelo, and Blaine Formations (Leonardian and Guadalupian), focusing on fossil plant deposits of the upper San Angelo and basal Blaine Formations. These plant deposits occur in small, sandy channel-fill deposits that may be tidal channels, and are closely associated with copper mineralization. The association with copper is fortunate, because the copper deposits have been prospected extensively and prospect sites are recorded in the literature.

I regard this as an unproductive season, due to a lack of focused effort and advance planning. My future research in Texas needs to be structured more carefully in view of short-term and long-range goals, and logistics need to be worked out before entering the field.

Activities with Neil Tabor

For six days of this field season I measured sections with Neil Tabor in Archer, Jack, Wichita, Baylor, and Wilbarger Counties; in strata that ranged from the Markley Formation (basal Wolfcampian) through the lower Clear Fork Formation (Leonardian). Localities where we worked are listed in Table 1 and shown on a map in Figure 1. The sections measured were principally mudstones, wherein paleosols are developed. These sections were measured in greater detail than is customary for stratigraphic studies, and Neil collected many samples for laboratory analysis. The purpose of Neil's study is to interpret changes in climate, vegetation, and landscape through time, as indicated by the character of ancient soils.

Stratigraphic Studies

My stratigraphic studies this season encompassed the uppermost Clear Fork, San Angelo, and lower to middle Blaine Formation. The focus of attention was the San Angelo-Blaine transition, where deposits of fossil plants occur. The principal study areas were on the Lyles Ranch in western Knox County and the 6666 Ranch in eastern King County. Reconnaissance visits were made to several other areas.

Clear Fork Formation (uppermost part)

Excellent exposures of uppermost Clear Fork strata were examined at three widely separated localities (Fig. 2):

1. Maverick Flats: near mouth of unnamed canyon leading to South Fork of Wichita River on the Maverick Flats Quadrangle, western Knox County
2. Truscott: roadcuts on FM 1756 on the east side of Bluff Creek, 3.5 miles west of Truscott in northern Knox County
3. Copper Breaks State Park: bluffs on the north side of the Pease River in southern Hardeman County.

Rocks at these sites closely resemble the uppermost Clear Fork seen previously near McFaddin Lane in southwestern Knox County. Brownish-red, blocky to massive, silty mudstone is the dominant lithology. Light gray to greenish-gray siltstone and very fine sandstone occurs as lenses and tabular beds a few inches to 3 feet thick. These rocks show planar lamination, cross-lamination, and ripple marks. Gypsum occurs as veins and stringers of satin spar and selenite, as nodules (commonly in distinct horizons), and as beds less than 1 foot thick. Silty, micritic dolomite occurs as widely traceable beds a few inches thick and as bands of ovate lenses.

Because the three sections are each separated by many miles, correlation of marker beds among them is not feasible. The most noteworthy difference among the sections is that no gypsum is present in the roadcuts west of Truscott.

Neil Tabor and I observed that mudstones in the uppermost Clear Fork contain weakly developed paleosols. Soil features include angular blocky structure, peds with clay skins (uncommon), small slickensides (uncommon), and silt-filled mud cracks. No fossils were found, and no beds likely to be fossiliferous were observed.

San Angelo Formation

Duncan Sandstone Member. Beede and Christner (1926) correlated the San Angelo Formation of Texas with the Duncan Sandstone in southwestern Oklahoma. Smith (1974) divided the San Angelo into two members, the lower Duncan Sandstone Member and the upper Flowerpot Mudstone Member.

I observed the Duncan Member in the same three areas where I described uppermost Clear Fork strata (Fig. 2). Outcrops near Maverick Flat include the Kahn Quarry, which is the most significant fossil vertebrate locality in the San Angelo (Olson, 1962). The roadcuts west of Truscott display the contact to the Clear Fork beautifully. Extensive outcrops of the Duncan are found in Copper Breaks State Park.

Most early geologists, such as Beede and Bentley (1918), Beede and Christner (1926), and Patton (1930), described the contact of the San Angelo with the Clear Fork as unconformable. Smith (1974) interpreted the contact as generally conformable, but locally erosional due to scouring in channels at the base of the Duncan Member. My observations support Smith's finding. The variable nature of the contact is shown best in the two roadcuts west of Truscott. In the eastern roadcut, sandstone of the San Angelo fills a channel scoured into the Clear Fork. The channel truncates color banding in the Clear Fork, cutting downward toward the east and showing about 11 feet of erosional relief. In the western roadcut, thin lenticular beds of sandstone alternate with red to green siltstone and silty mudstone through an interval 8 to10 feet thick. Placement of the formation contact within this interval is arbitrary. Similar observations were made at Copper Breaks, where the contact is gradational in some places, erosional in others. Erosional channels are shallow and their margins gently sloping. Local erosional relief in the park is less than 5 feet; maximum total relief is about 15 feet.

At Maverick Flat, a tabular unit of laminated, shaly sandstone about 2 feet thick conformably overlies Clear Fork mudstones. The sandstone is overlain by 6 feet of strata that coarsen upward from claystone at the base to shaly sandstone at the top. These rocks in turn are overlain with scoured contact by thick, ledge-forming sandstone forming the main body of the Duncan Member. Whether the tabular shaly sandstone and upward-coarsening unit are assigned to the Clear Fork or the San Angelo appears to be mapper's choice.

At all sites visited this year the Duncan Member consists of sandstone with interbeds of siltstone and silty mudstone and small lenses of conglomerate (mainly near the base). The sandstone is very fine to fine-grained quartz arenite to sublitharenite that generally lacks the muddy matrix typical of sandstones in the Clear Fork. The bedding is thin to thick, lenticular, and shows abundant shallow scour surfaces. Common sedimentary structures are planar lamination, cross-lamination, ripple cross-lamination, and small to large-scale trough crossbedding. Lateral accretion sets, which are so prevalent in the Clear Fork, are uncommon in the Duncan. Accretion sets were observed in the upper part of the large channel-fill sequence in the eastern Truscott roadcut and at the top of the Duncan at and near the Kahn Quarry.

Mudstone and siltstone in the Duncan are greenish gray, reddish gray, and brownish gray, and massive to weakly laminated. These rocks form fining- and coarsening-upward sequences a few feet thick and in most cases are lenticular, commonly being scoured by overlying sandstones.

Lenses of conglomerate occur in the channel phase of the lower Duncan Member. Clasts are mainly granule-size fragments of mudstone, siltstone, and carbonate rock probably derived from the Clear Fork. Larger rounded, flat pebbles of light gray, micritic dolomite occur in conglomerate at Copper Breaks and Truscott. Dolomite chips as large as 3 inches across can be seen in the ditch on the south side of the road opposite the eastern Truscott roadcut. Because no similar dolomite occurs in underlying Clear Fork strata, these dolomite pebbles evidently were transported from afar. Possibly they were derived from the Merkel Dolomite Member of the Clear Fork, which crops out in Stonewall County and southward. At field station #8 in Copper Breaks, transported (?) gypsum nodules as large as 6 inches in diameter lie along an inclined sandstone bed near the base of the San Angelo. If these are transported clasts, they are probably of local origin; similar nodules are common in underlying Clear Fork beds.

Considering conglomerates, Beede and Christner (1926) reported that conglomerates of large, rounded chert and quartz pebbles are common in southern outcrops of the San Angelo. The pebbles become smaller and less numerous northward, and disappearing in southern Stonewall County. These conglomerates imply a southeastern source of sediments, probably either in the Llano Uplift or the now-buried Ouachita orogenic belt.

Some Duncan outcrops contain gypsum in the form of interstitial cement in sandstones, and as small nodules, stringers, and veins in all rock types. There are no distinct gypsum beds or bands of nodules, as in the Clear Fork. Copper mineralization, in the form of malachite, was rare in the areas where I worked.

The only fossils I observed in the Duncan Member are trace fossils that were found in sandstone at the top of a bluff next to the east abutment of the dam at Lake Copper Breaks. They consisted of vertical cylindrical burrows 5 to 7 mm in diameter and less than 20 mm long, and straight to gently sinuous, gutter-stacked horizontal burrows of the same diameter. The horizontal burrows resemble *Teichichnus*, a common trace in Carboniferous rocks. Roger Burkhalter of the Oklahoma State Museum collected a tetrapod trackway at or near the same site. The ranger at Copper Breaks State Park showed to R.W. Hook and me a large slab of sandstone collected by Burkhalter. This slab, however, contained nothing that we could identify as a trackway.

The contact of the Duncan to the overlying Flowerpot Member is gradational, intertonguing, and difficult to map consistently in the areas visited.

Kahn Quarry

The Kahn Quarry, located on the west side of a north-flowing drainage near Maverick Flat, yielded the largest and most diverse vertebrate collection discovered in the San Angelo (Olson, 1962). A pit approximately 60 feet square and 12 feet deep was excavated into the hillside to uncover the fossil-bearing layer. The strata consist of variegated, banded accretion sets of silty mudstone, siltstone, and very fine sandstone, fining upward overall (Fig. 4). These strata gradationally overlie a sandstone interval more than 25 feet thick exposed along the ravine. Along with vertebrate remains (Hook, 1998), we collected poorly preserved plant axes and roots from this site (Smithsonian collection 1995-03; USNM 40965). The fossil-bearing unit is about 6 feet thick and is overlain with erosional contact by upward-fining sandstone and mudstone.

Kahn Quarry illustrates the difficulties of applying Olson's lithologic descriptions and environmental interpretations. Although the rocks at Kahn Quarry are well exposed, I have difficulty matching Olson's measured section (1962, p. 115) with my own. Some difficulties center around Olson's terminology, such as "evenly bedded shales" for what I might describe as "massive mudstones with well defined color banding". Other problems surround Olson's lack of mention (or recognition) of sedimentary structures such as accretionary bedding and ripple cross-lamination. At the time of Olson's work, terminology for many such features was not standardized and the environmental significance of many structures was not appreciated.

Flowerpot Mudstone Member

The Flowerpot Mudstone Member of the San Angelo Formation (Smith, 1974) was examined in three areas: ridges south of Kahn Quarry near Maverick Flat on the Lyles Ranch, near the head of Smelter Canyon on the Lyles Ranch, and near Snake Den Tank on the 6666 Ranch (Figs. 3 and 4). Plant fossils were collected from three sites near the top of the Flowerpot, and scrappy plant remains were observed elsewhere in this unit, all in close association with copper mineralization.

The Flowerpot is very similar in lithology to the upper Clear Fork. Brownish red mudstone prevails, with thin interbeds of greenish gray siltstone and sandstone and abundant nodules, stringers, veins, and thin interbeds of gypsum. The principal difference between the upper Clear Fork and the Flowerpot is that only the latter contains common small, shallow channel-fill deposits of shale and sandstone in which plant fossils are found.

Snake Den dolomite bed

As discussed in last season's report (Nelson, 1998) the Snake Den dolomite is a thin unit of dolomite and calcareous shale that crops out in easternmost King and westernmost Knox Counties. The bed is named for Snake Den Tank on the Buzzard Peak quadrangle, eastern King County. The dolomite has been traced through outcrops and boreholes 6 miles south to the East Taylor Pasture (Hump) plant-collecting area.

Depending on how the formation contact is defined, the Snake Den is either in the uppermost San Angelo or basal Blaine Formation. Smith (1974) defined the formation contact as the base of the lowest gypsum bed that is 1 foot or thicker. Using this definition, the Snake Den bed is in the San Angelo near Snake Den Tank (on the north) and in the Blaine at East Taylor Pasture (Fig. 4). Gypsum beds in this area are known to be discontinuous and vary in thickness, whereas the Snake Den dolomite is consistent and probably represents a time line.

In most of its mapped extent the Snake Den dolomite contains, at the top, a single bed of silty, micritic dolomite that is 3 to 6 inches thick. This overlies 2 to 3 feet of calcareous to dolomitic, bluish to greenish-gray, laminated silty shale, siltstone, and very fine-grained sandstone. These rocks coarsen upward and contain numerous lenses and discontinuous beds of micritic dolomite that generally are less than 4 inches thick. Malachite is finely disseminated along the bedding planes of the shale and occupies small vugs in the dolomite. The Snake Den dolomite overlies a thick interval of deep brownish-red mudstone that contains numerous gypsum "buns" or nodules that commonly are more than a foot in diameter.

Lithology of the Snake Den bed changes abruptly along the north shore of Snake Den Tank and the gullied, north-facing escarpment that stretches west of the tank, south of Little Croton Creek. The upper dolomite layer thickens to 3 feet and consists partly of crossbedded peloidal grainstone and conglomerate of dolomite intraclasts. In places the lower part of the dolomite becomes very sandy, grading to calcareous or dolomitic sandstone. These lithologies suggest a channel fill, yet the thick dolomite appears to intergrade laterally with the bluish-green shales rather than being scoured into them.

Pastel mudstone

A unit of mudstone that is 7 to 10 feet thick and banded in pastel colors is conspicuous at the top of the San Angelo in Smelter Canyon and near Maverick Flat (Fig. 4). The pale pinks, greens, buffs and grays of this unit contrast with the deeper and brighter reds of the rest of the Flowerpot Member beneath. The mudstone is silty, grading in part to siltstone; and much of it is laminated although some layers are blocky to massive. Features indicative of soil formation are generally lacking. The pastel mudstone is bounded at top and base by thin bands of gypsum nodules, and is overlain by thicker gypsum layers and poorly exposed mudrocks of the lower Blaine Formation. The Snake Den dolomite bed is absent in this area.

Pastel banded mudstone also was observed in badland gullies east of Snake Den Tank, directly overlying the Snake Den dolomite bed (Fig. 4). Evidence strongly indicates that the pastel mudstone near Snake Den Tank is the same as that found to the north. The evidence includes occurrence of copper- and plant-bearing channels immediately above the pastel mudstone in both areas, and deep-red mudstone containing abundant large gypsum "buns" a short distance below (Fig. 4).

Olson (1962, p. 109-110 and fig. 53) described pastel banded rocks at the San Angelo-

Blaine transition zone in eastern King County. He attributed these rocks to deposition in "offshore" or "basinal" settings, in lateral facies with brightly colored beds onshore. My observation that the pastel mudstone immediately overlies a marine carbonate bed and is largely laminated, lacking soil features, suggests that it formed on a lower tidal flat under conditions that alternated from reducing to moderately oxidizing.

Shooting Range plant locality

The Shooting Range plant locality is located near an informal shooting range 1/4 mile southeast of Snake Den Tank on the 6666 Ranch (UTM 3,710,100N, 406,650E). The site was discovered in September, 1997 on the basis of a USBM copper sampling site reported by Smith (1974). Cuprified logs and abundant blade-shaped plant remains, possibly conifers, occur within channel-filling claystone, siltstone, and sandstone. Two channel storeys are exposed, the lower striking N65W with accretion to the northeast and the upper striking N80W with accretion to the southwest (Hook, 1997). My own measurements and a measured section by Hook (1997) indicate that the base of the plant-bearing channel cuts within less than 1 foot of the top of the Snake Den dolomite and the top is 8 to 10 feet above the dolomite (Fig. 5).

Logjam plant locality

The Logjam site (TX-1998-12) is located in gullies along a gentle west-facing slope about 1,000 feet southwest of the Shooting Range site. The Logjam site was discovered by 6666 Ranch manager Mike Gibson, who observed cuprified logs while riding through the area. In addition to cuprified logs, this deposit contains a variety of other plant fossils in fair to good states of preservation, as well as palaeoniscoid fish remains (Hook, 1998).

Fossils at the Logjam are found within channel deposits that closely resemble those at the Shooting Range, and in the field we presumed that the two form a contiguous deposit. My measured section (Fig. 5), however, reveals that the Logjam channel is younger than the Shooting Range channel. The top of the Logjam channel is about 20 feet above the Snake Den dolomite, and the base of the channel is 12 to 14 feet above the dolomite.

Pyron plant locality

The Pyron Prospect or Smelter Mine represents attempts to mine copper on the west side of Smelter Canyon on the Lyles Ranch, western Knox County (UTM 3,718,200 N, 411,350 E). Stroud et al. (1970) report that mining took place between 1880 and 1945 and that 1,000 tons of crude ore were produced. Two collapsed adits with small tailings piles, the remains of a smelter, and narrow-gauge rails mark the site today. The adits are about 300 feet apart near the base of a steep slope on the south side of a small draw. Outcrops are poor at the eastern adit, which is marked "prospect" on the Cedar Mountain 7.5-minute topographic sheet. Rocks are well exposed at the western adit, where we collected plant fossils from mineralized siltstone that was the target of mining.

The fossiliferous ore zone is greenish-gray siltstone to very fine, shaly sandstone that is about 11 feet thick. The rock has thick planar lamination and contains abundant stringers of satin spar gypsum. Malachite occurs as small irregular blebs and masses throughout the deposit, along with abundant fusain and coalified logs. Most plant remains are fragmentary and unidentifiable, although a number of collectible specimens, including *Wattia*, were recovered.

The plant-bearing siltstone at Pyron differs from other San Angelo plant deposits in being a tabular, plane-bedded unit as opposed to a channel deposit. The siltstone was traced laterally on both sides of Smelter Canyon through an area on nearly one square mile without finding its termination. The siltstone reaches its maximum observed thickness at Pyron Prospect, and nowhere else were plant fossils or significant copper mineralization found within it. This unit was not identified at Maverick Flat to the north or in the Snake Den area to the south.

The plant-bearing unit directly overlies the pastel-banded, variegated mudstone that is the best marker unit in the area, and occurs a few feet below the lowest thick gypsum bed that defines the base of the Blaine Formation (Fig. 4). This would place the plant-bearing unit about 10 feet above the position of the Snake Den dolomite. The Pyron plant deposit thus is correlative with the Logjam plant locality, slightly younger than Shooting Range, and slightly older than Squire Mine.

Other localities

A broad paleochannel trending N60W was observed on the east side of Smelter Canyon 1.0 mile ESE of the Pyron Prospect. It is filled with greenish-gray siltstone and very fine-grained sandstone that form well-developed accretion sets. The paleochannel lies directly beneath the pastel variegated mudstone. No copper mineralization was observed. While prospecting, Bob Hook found fragments of conifers and calamites within the paleochannel, but no formal collecting was attempted.

Blaine Formation

Buzzard Peak traverse. Neil Tabor and I made a traverse from Snake Den Tank (map, Fig. 3) to the top of Buzzard Peak, obtaining a rather rough section of the lower 280 feet of the Blaine Formation (Fig. 6). In making the traverse, special attention was paid to carbonate beds, which are the most reliable marker units in the Blaine. The outcrop section is partially supplemented by the log of USBM borehole A-5 (from Stroud et al., 1974), which was drilled 0.5 mile east of the peak.

Five dolomite beds were observed on the outcrops. A 5-foot-thick dolomite caps Buzzard Peak, and another 5-foot dolomite occurs 30 feet below the summit. Dolomite layers less than 2 feet thick were encountered at 1750, 1700, and 1640-foot contours along the ravine that trends NNE from the peak. Three of the five dolomites contain large amounts of gypsum in the form of interstitial crystals, vug-fillings, and laminations.

Identifying the dolomites observed on Buzzard Peak is not easy. Carbonate beds of the Blaine are marked on the Lubbock GAT sheet (Eifler et al., 1993), but the traces of the beds on the map are so thin and so poorly labeled that they cannot be followed in many areas of the map even under magnification. The line labeled as the Mangum Dolomite Member appears to be at about 1700 to 1750-feet elevation near Buzzard Peak. Roth (1945) measured his published section of the lower part of the Blaine along Little Croton Creek, not far from Buzzard Peak.

Roth uses the name Medicine Lodge dolomite for bed of oolitic and fossiliferous limestone and dolomite that is 2.5 feet thick and about 250 feet above his "chalcocite dolomite" (my Snake Den dolomite). Among dolomite beds between the Snake Den and Medicine Lodge on Roth's measured section, the thickest is 8 inches. Therefore, Roth's Medicine Lodge dolomite probably corresponds with dolomites at the 1850- and/or 1880-foot levels on Buzzard Peak (Fig. 5). Jones (1971) suggested that the Medicine Lodge dolomite of Roth is the Mangum Dolomite Member, a suggestion that is consistent with placement of the Mangum on the relevant GAT sheets (Eifler et al., 1993; Hentz and Brown, 1987).

My tentative conclusion is that one, or both of the thick dolomites near the top of Buzzard Peak is the Mangum Dolomite Member. A more definitive conclusion will require further study.

Volcanic ash(?) bed. In his composite measured section of the Pease River Group, Roth (1945) described a 5-foot layer of "volcanic ash" in the middle part of the Blaine Formation along the South Fork of the Wichita River in the Bateman Oil Field. Because of the potential for obtaining absolute geologic age from volcanic minerals, we determined to trace out and sample the reported ash bed this season.

Dan Chaney and Neil Tabor visited the Bateman Oil Field this spring, and sampled the bed indicated by Roth. As they reported to me, analysis showed that volcanic materials are present, but the sample lacked minerals suitable for radiometric dating.

This season I investigated the ash beds at four sites: (1) bluff of South Fork of Wichita River just east of road crossing in Bateman Oil Field, (2) along Newman Creek, about 2.5 miles east-southeast of Bateman locality, (3) along Willow Creek south of ranch road crossing 2.0 miles northeast of Bateman locality, and (4) at Pouring Spring on the Middle Fork of the Wichita River, 13 miles northeast of Bateman locality.

Measured sections from the first three localities are closely correlative (Fig. 7). The dolomite capping the highest benches is the Guthrie Dolomite Member, as identified both by Jones (1971) in his measured section and by Eifler et al. (1993) on their GAT sheet. These identifications are probably reliable, because the Guthrie stratotype is nearby and the trace of this bed is legible (under magnification) on the GAT sheet. Below the Guthrie in descending order are the Masterson dolomite bed of Jones, the thick and prominent Acme Dolomite Member, an unnamed dolomite, and the Willow Creek dolomite bed of Jones. The Masterson and Willow Creek dolomite beds both were named by Jones for localities in the immediate area and are identified in his measured section #20, which was made at my Willow Creek site.

The ash bed exposed at Bateman was identified and sampled at Willow Creek. This bed apparently is just below drainage at the exposures I observed along Newman Creek.

Where I observed it, the volcanic ash reported by Roth is thinly to thickly laminated silty shale or siltstone that is greenish to olive-gray in fresh exposures and buff to light grayish-orange on weathered surfaces. It is soft and erodes to a recessive notch at the base of thick, massive, cliff-forming gypsum. Hand samples from Bateman have a low density and resemble water-laid volcanic tuff, although no volcanic minerals or textures are macroscopically evident. Samples from Willow Creek appear to be ordinary siliciclastic siltstone, although the color and lamination are unusual for the Blaine.

Pouring Spring "ash"

The fourth possible ash locality is at Pouring Spring in northeastern King County (Fig. 3). Dan Chaney reported ash-like material along a ranch road just east of the bridge across the Middle Fork of the Wichita River. Bob Hook and I found the material beside the road and also in vertical banks on the west side of the river. In these banks is at least 10 feet of extremely porous, low-density silt that is light gray to grayish-orange. The silt lacks bedding or lamination but exhibits color banding. It is strongly calcareous and laden with gypsum crystals, which locally form a travertine-like crust near the base of the bank. Downward the material becomes denser, clay-rich, and grades to brownish-orange.

In the small area where we observed it, the ash-like silt underlies a level to gently sloping terrace that stands 15 to 20 feet above the Middle Fork. The silt overlies Permian bedrock but no bedrock was found overlying it. Although readily erodable, it stands in vertical banks with no protective caprock. This material is markedly different from the ash bed in the Bateman-Willow Creek area.

My opinion is that the ash-like material at Pouring Spring is Quaternary alluvial silt that owes its porous, fluffy texture to large quantities of interstitial gypsum.

Conclusions and Recommendations

This field season produced little in the way of new discoveries or insights on the Permian strata of North-Central Texas. My data base for the San Angelo and Blaine Formations expanded, and our prospecting model for plant fossils was confirmed: plants occupy small channels near the formation contact and are associated with copper mineralization. The search for additional fossil sites therefore will concentrate on reported copper mines and prospects in these strata. Known copper mineralization extends northward from Stonewall County, Texas into several counties of southwestern Oklahoma (Johnson, 1976). In addition to published sources, landowners commonly are aware of copper deposits on their properties. More leads on plant fossils of the San Angelo may be found in reports on the vertebrates, such as Olson and Beerbower (1953) and Olson (1962).

Reconnaissance should be made of San Angelo outcrops south of Stonewall County, where previous geologists report conglomeratic and presumably more terrestrial facies of this unit.

Although most of the Blaine Formation appears unlikely to yield plant or vertebrate fossils, this unit may provide keys to understanding regional stratigraphy. Although its marine carbonate beds are excellent, widespread mapping horizons, existing maps are largely unreliable due to miscorrelations and cartographic problems. No two authors agree on the positions of named limestone and dolomite members in the Blaine. As a minimum, we need to assemble reliable composite sections, based on marker beds that are traced to type or reference sections. Unpublished work maps that are more usable than published maps may exist at the Bureau of Economic Geology or elsewhere. An effort should be made also, to tie the outcrop to the subsurface through study of well logs. Exploration of the Blaine may yield unexpected dividends, such as **(1)** new fossil localities, **(2)** fusulinids or other invertebrates useful for biostratigraphic zonation, and **(3)** volcanic ash beds that can be dated radiometrically. Further effort should be made to trace out the ash bed reported by Roth (1945) and to obtain samples for dating. If outcrop samples are too badly weathered, we should consider core-drilling to obtain fresh samples. Regional field and subsurface studies of the San Angelo and Blaine can enhance our understanding of plant fossils, environments, and paleoclimate.

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Table 1. Activity log (see map, Fig. 1)

October 2- to Archer County with Neil Tabor, measuring sections of the Archer City Formation at the Archer City bonebeds and Anarene.

October 3- to Jack County with Neil Tabor, measuring sections of the Markley Formation at Bloodworth (Hog Farm), Cooper lease, and Malone Ranch.

October 4- to southwestern Wichita County with Neil Tabor, measuring a section of the uppermost Petrolia Formation on the Bradley JS Ranch near Kadane Corner.

October 5- return to southwestern Wichita County with Neil Tabor, measuring another section of uppermost Petrolia Formation near the stratotype, in the KMA Oil Field.

October 6- to Lyles Ranch in Knox County with entire party, examining upper San Angelo and lower Blaine Formations at and near the Pyron copper prospect.

October 7- continue work from previous day on Lyles Ranch.

October 8- to eastern King County with Dan Chaney and Neil Tabor, examining exposures of the middle part of the Blaine Formation including the volcanic ash reported by Roth (1945).

October 9- to western Archer County with Neil Tabor, observing Nocona-Petrolia formation contact at "Parkey's oil patch"; then to Grayback in Wilbarger County, where we measured sections of the Lueders Formation.

October 10- return to the Grayback area with Neil Tabor in the morning and measured sections in the lower Clear Fork Formation, then in the afternoon to Moonshine Creek south of Lake Kemp in Baylor County, where we measured sections of the Waggoner Ranch and Lueders Formations.

October 11- to Maverick Flat on the Lyles Ranch in western Knox County with the entire party, measuring sections from uppermost Clear Fork through basal Blaine Formations.

October 12- to Snake Den Tank on the 6666 Ranch in eastern King County with the entire party, examining the San Angelo-Blaine transition at and near the new Shooting Range and Logjam plant localities.

October 13- continue studies around Snake Den Tank, including a traverse to the top of Buzzard Peak with Neil Tabor.

October 14- to Hardeman County with Bob Hook, examining uppermost Clear Fork and lower San Angelo Formations in Copper Breaks State Park. We also checked out property ownership and road access to a reported copper prospect near Medicine Mound.

October 15- through Knox and King Counties with Bob Hook, checking out a possible volcanic ash deposit on the Lowrance Ranch at Pouring Spring, examining middle Blaine strata including possible volcanic ash at Willow Creek on the JY Masterson Ranch, and examining the San Angelo-Clear Fork contact in roadcuts west of Truscott.

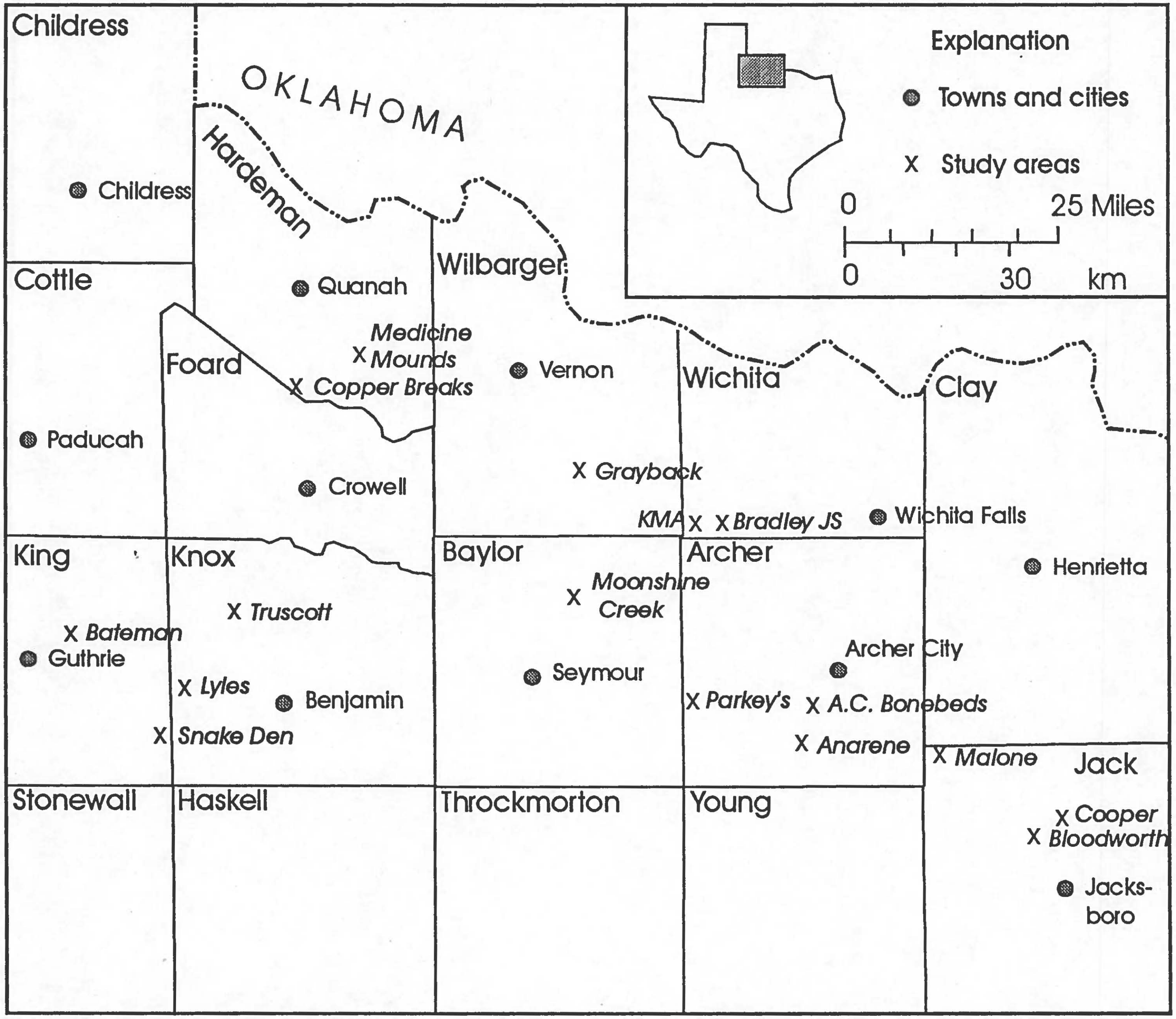
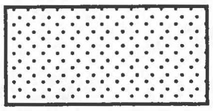
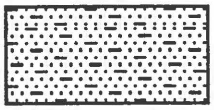
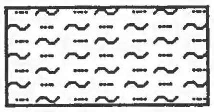


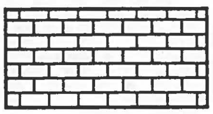
Figure 1. Map of North-Central Texas, showing study areas mentioned in this report.

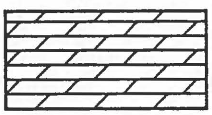
Explanation of symbols used on graphic columns

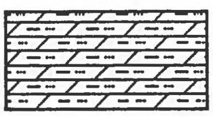

Sandstone


Shaly sandstone

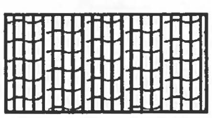

Siltstone or silty mudstone

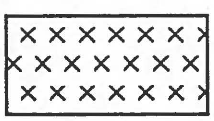

Limestone


Dolomite


Silty dolomite


Gypsum


Shaly gypsum


Volcanic ash


Fossil plants


Fossil vertebrates


Interval coarsens upward


Interval fines upward

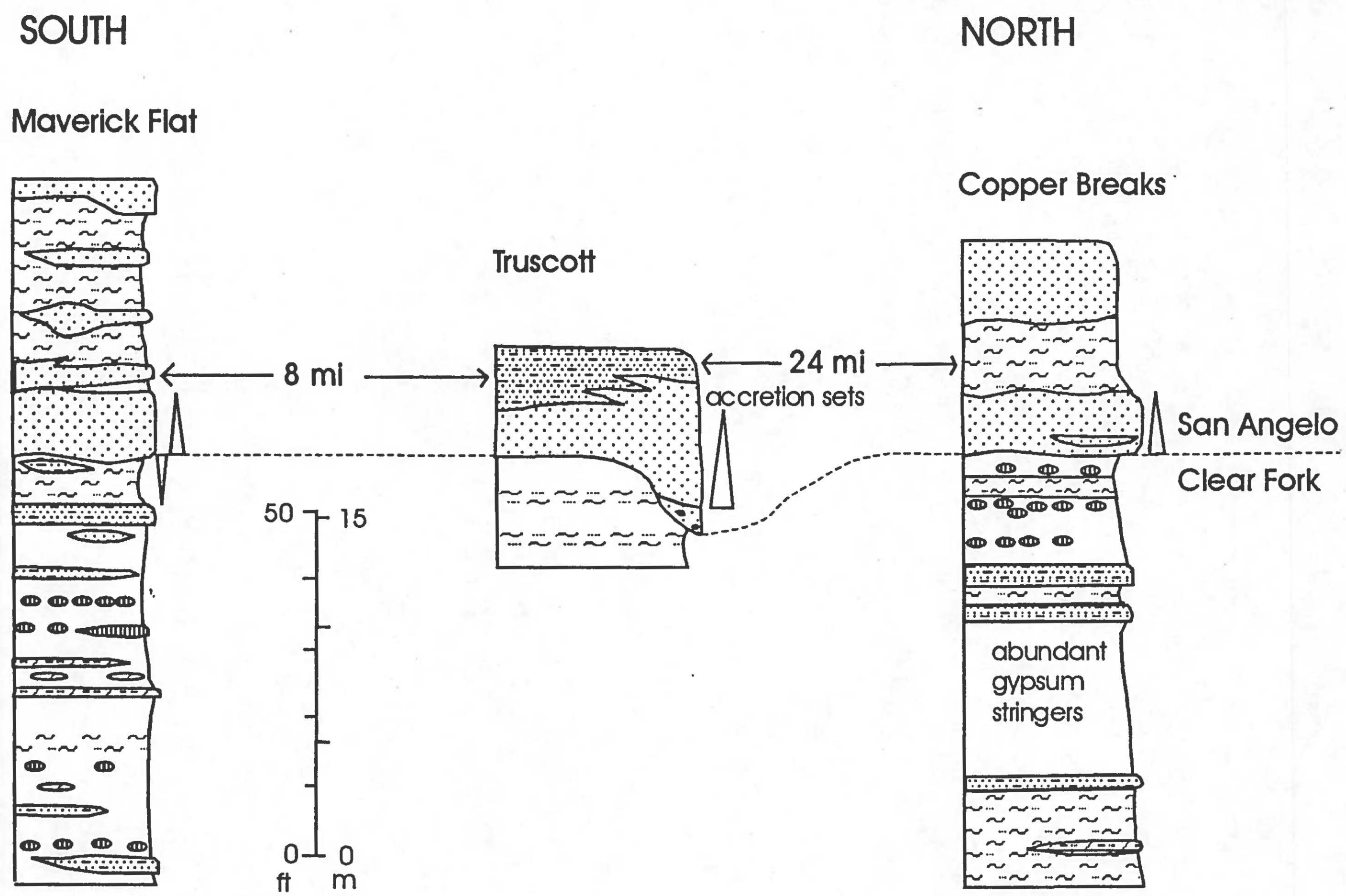


Figure 2. Graphic sections of uppermost Clear Fork and lower San Angelo formations.

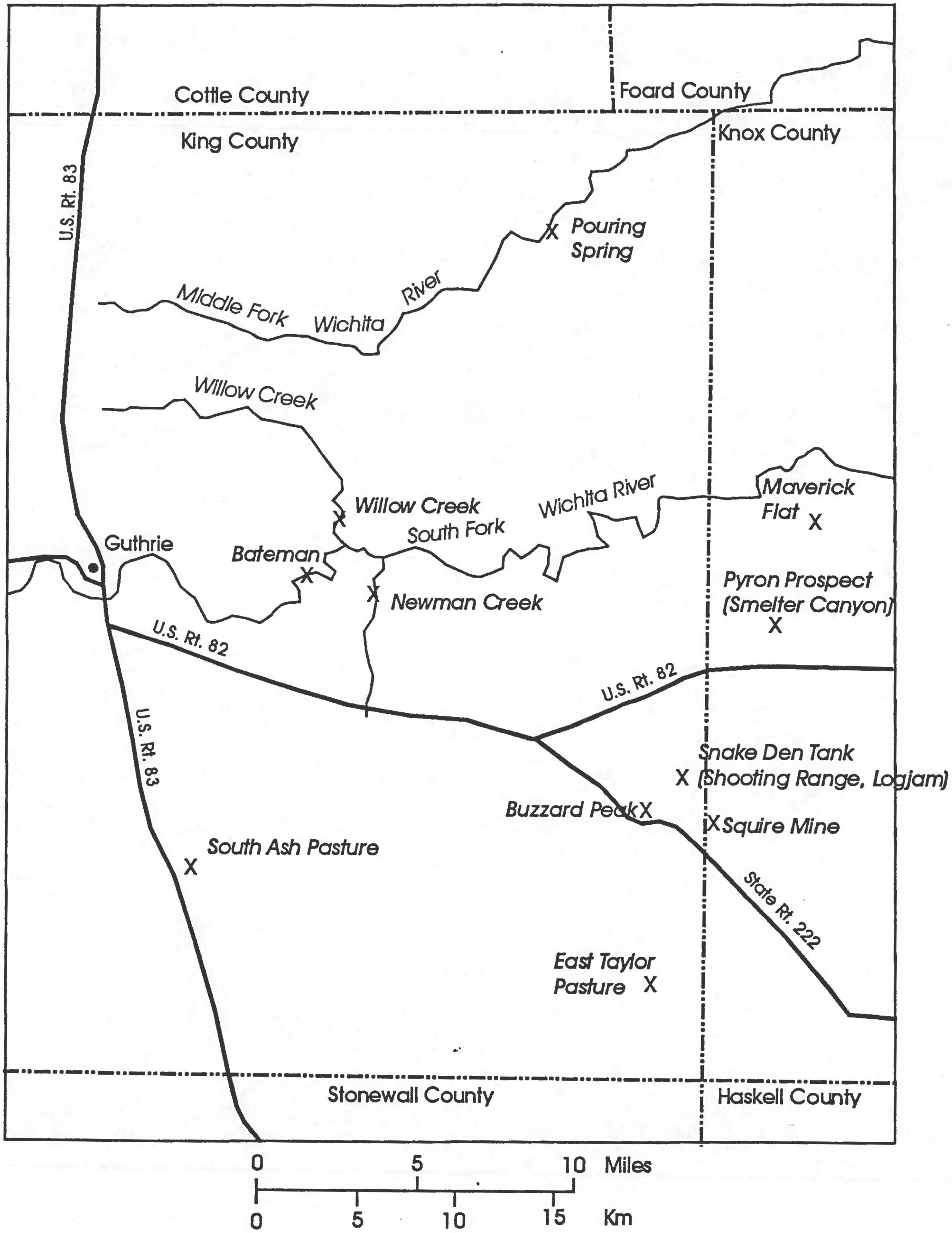


Figure 3. Map of eastern King and western Knox counties, showing localities mentioned in text.

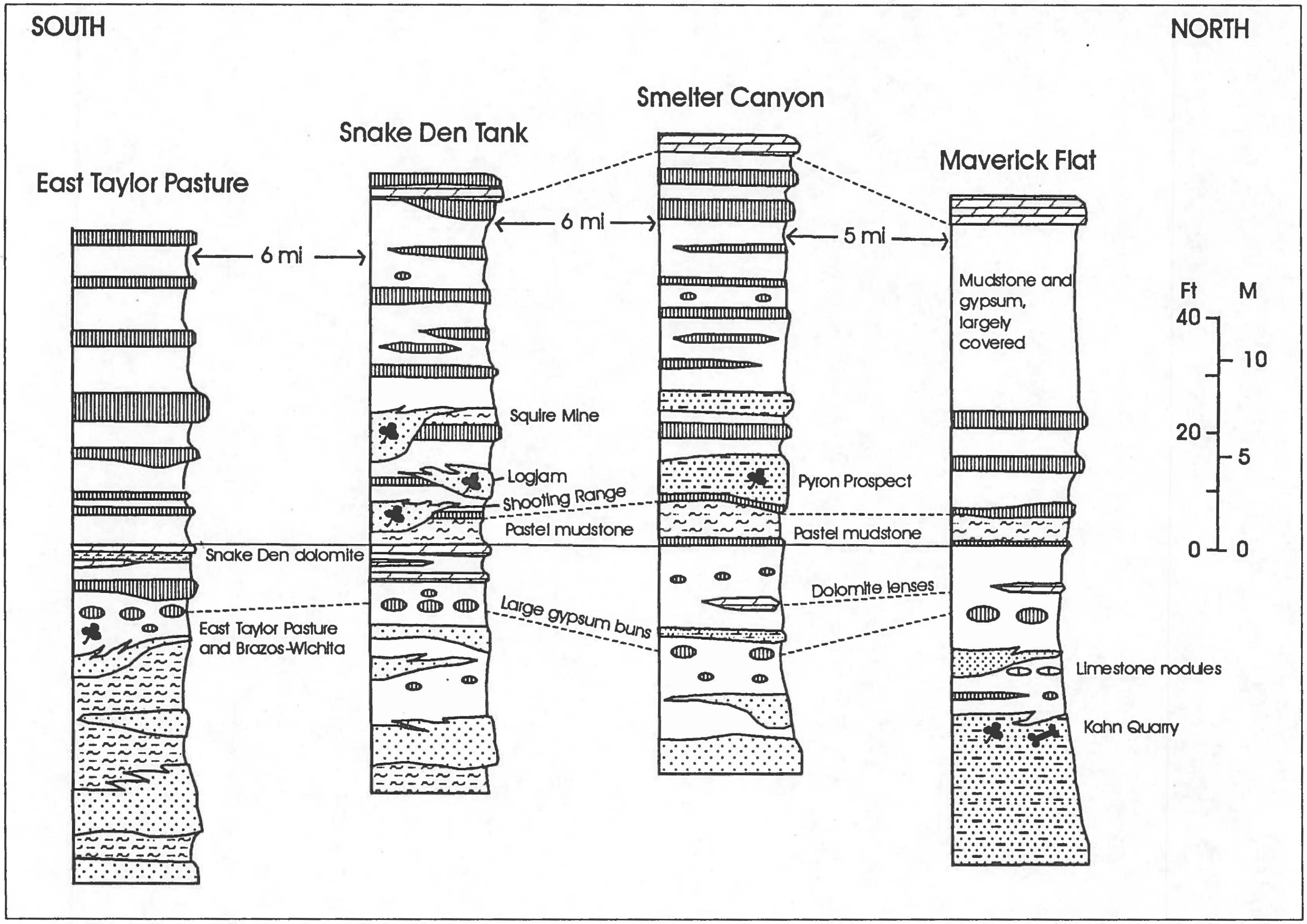


Figure 4. Graphic sections of the upper San Angelo and lower Blaine formations. Datum is top of Snake Den dolomite bed or its inferred position. See Fig. 3 for locations.

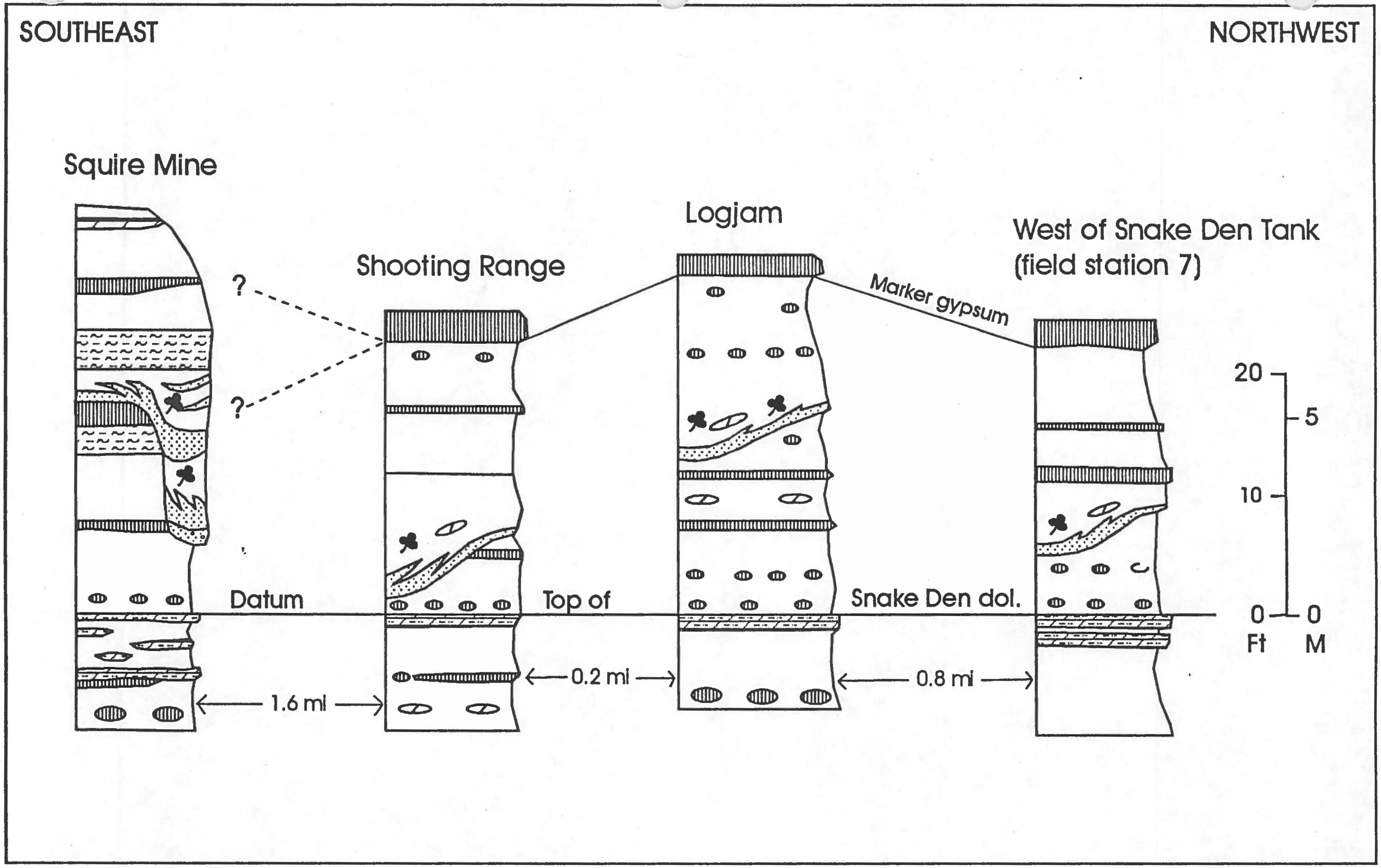


Figure 5. Graphic sections of upper San Angelo and basal Blaine Formation at four plant-collecting localities.

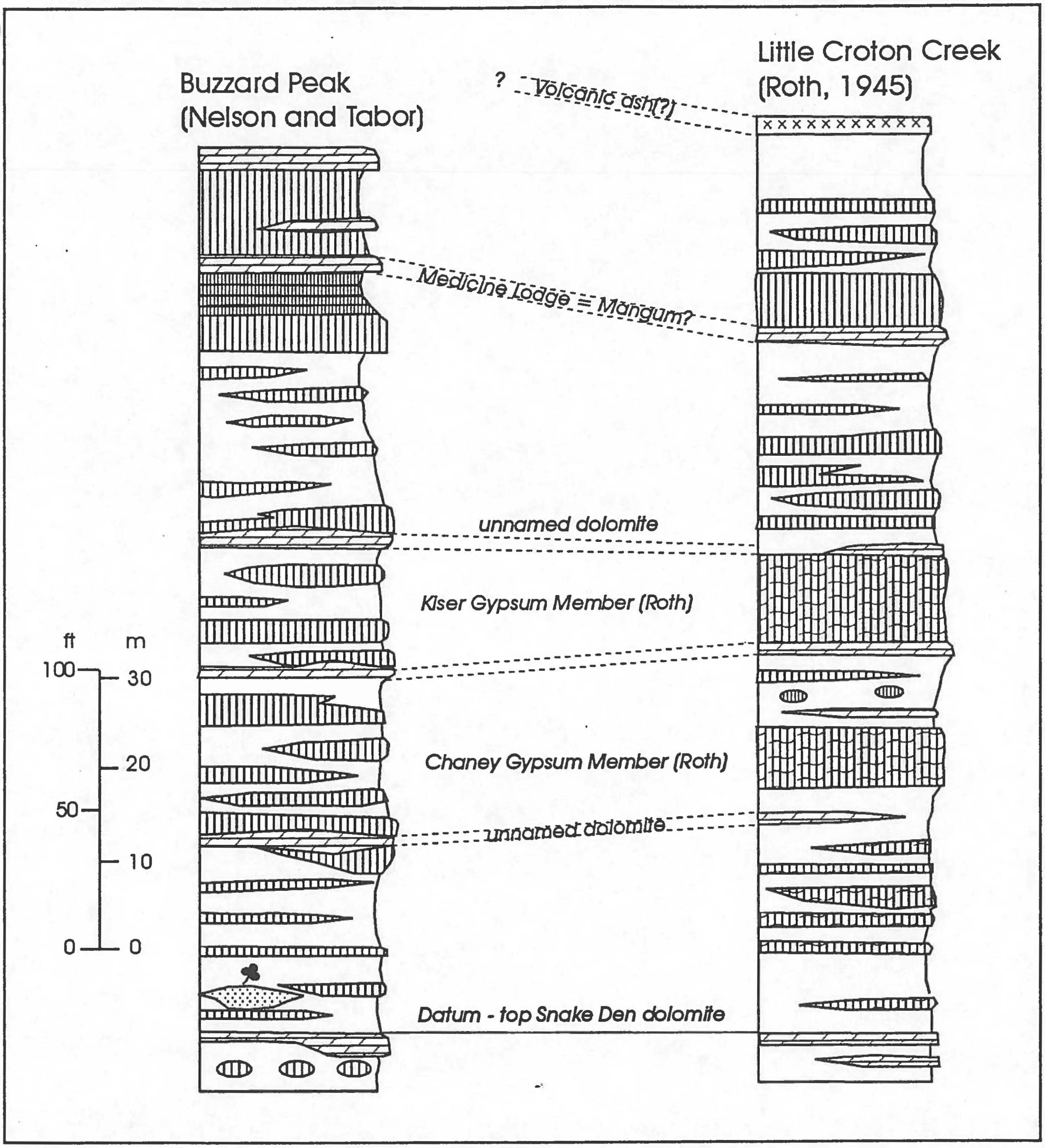


Figure 6. Graphic sections of lower and middle part of Blaine Formation near Snake Den Tank and Buzzard Peak.

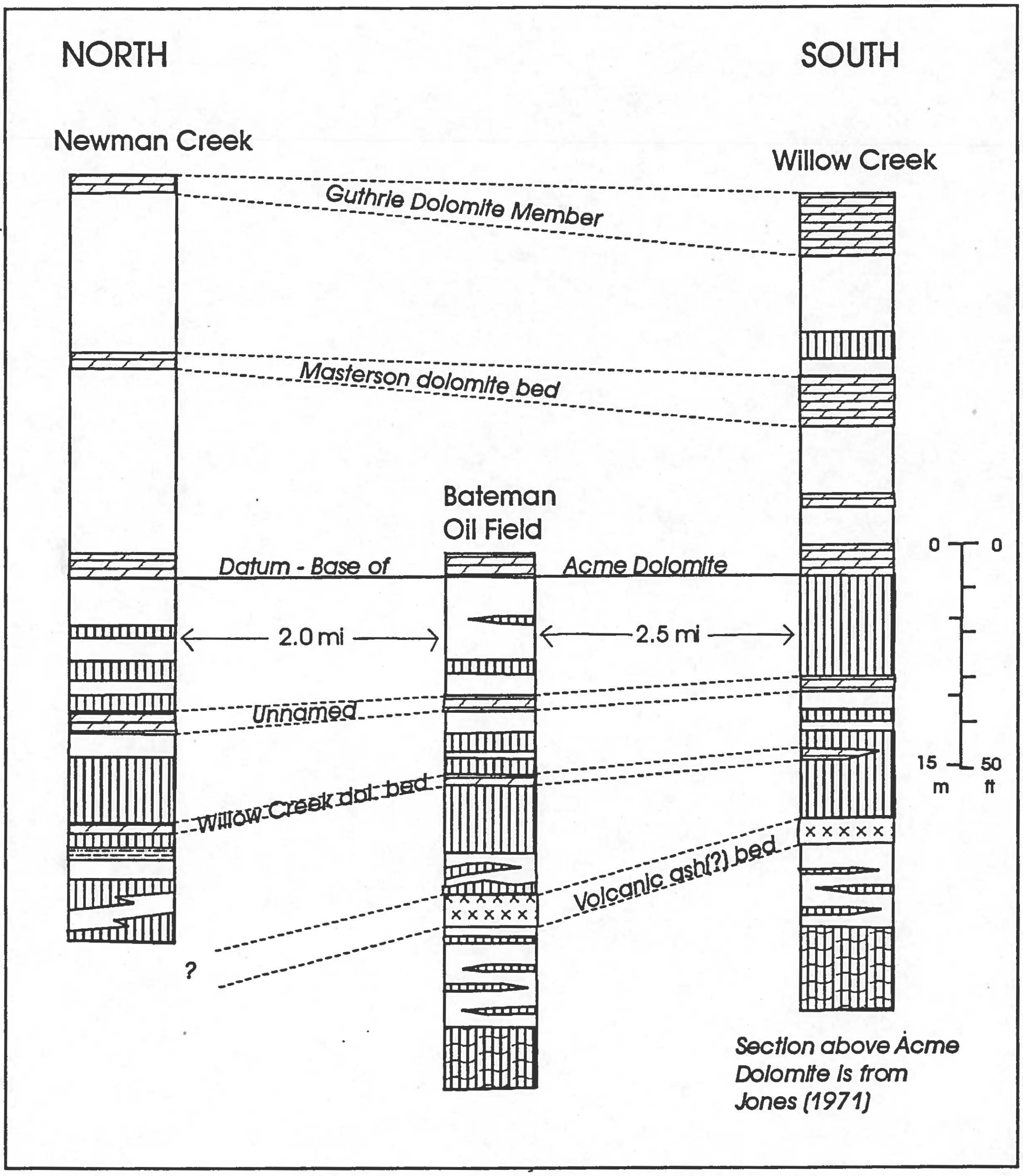


Figure 7. Graphic sections of middle and upper parts of Blaine Formation. See Fig. 3 for locations.