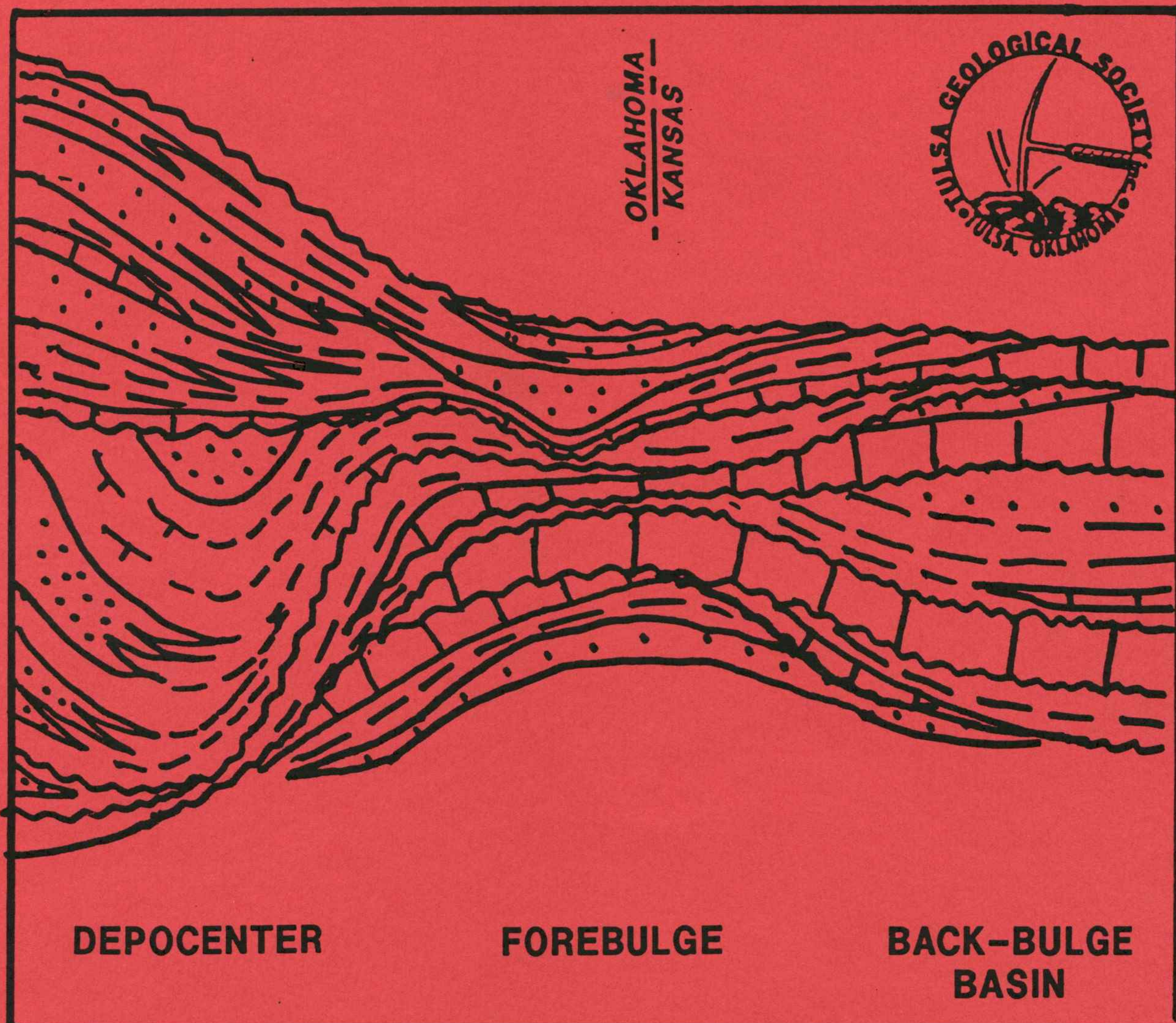

TGS SPRING GEOLOGIC FIELD TRIP AND CONFERENCE - APRIL 20, 1996

UNCONFORMITIES, HIATUSES AND PALEOSOLS IN MIDCONTINENT SEQUENCES

KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 96-61

UNCONFORMITIES, HIATUSES AND PALEOSOLS IN MIDCONTINENT SEQUENCES

Tulsa Geological Society
Geologic Field Trip and Conference
April 20, 1996

Field Trip Leaders
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Missing Figures #1, 10 and 11

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1996, TGS SPRING FIELD TRIP
GUIDEBOOK

ROLE OF UNCONFORMITIES, HIATUSES AND PALEOSOLS IN MIDCONTINENT SEQUENCES

LEADERS

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ACKNOWLEDGEMENT

Although the following text and interpretations are largely those of the undersigned, he is deeply indebted to Philip Heckel, Darwin Boardman, Lynn Watney, their associates and students, and numerous other Midcontinent stratigraphers for developing many of my current concepts. even though they may have different versions from the outcrop evidence. Also, this guidebook was made possible through the help of the Tulsa Geological Society officers, especially the field trip chairman, Douglas Cook and the Helmerich and Payne geological draftsman, Don Naugle.

Allan P. Bennison

TGS FIELD TRIP

INTRODUCTION

This field trip will probe rock outcrops from Tulsa to the Parsons area of southeastern Kansas to learn more, under actual field conditions, about the bases for sequence and sequence set boundaries. These involve stratal interruptions and anomalies, such as unconformities, fossil soil horizons, hiatuses, condensed sections and clastic wedges. Because these represent an interplay of tectonism, paleogeography, and sea level eustatism within a space-time continuum, sequence scenarios show varying, often chaotic patterns, sometimes difficult to fit into standard stratigraphic sequence models.

The area of investigation is an outcrop belt of Middle Pennsylvanian beds, that trends almost at right angles to their depositional strike across the northwest corner and ramp of the Arkoma Basin, the Chautauqua Arch and the Cherokee Basin, fig 1. These respectively represent a retro-foreland basin, a fore-bulge or peripheral arch and back-bulge basin, fig 2, according to the developing terminology for the setting of foreland basins such as recorded in SEPM special bulletin 52.

Stratigraphers seeking sequence boundaries should concentrate, whenever possible, on core and outcrop data, where

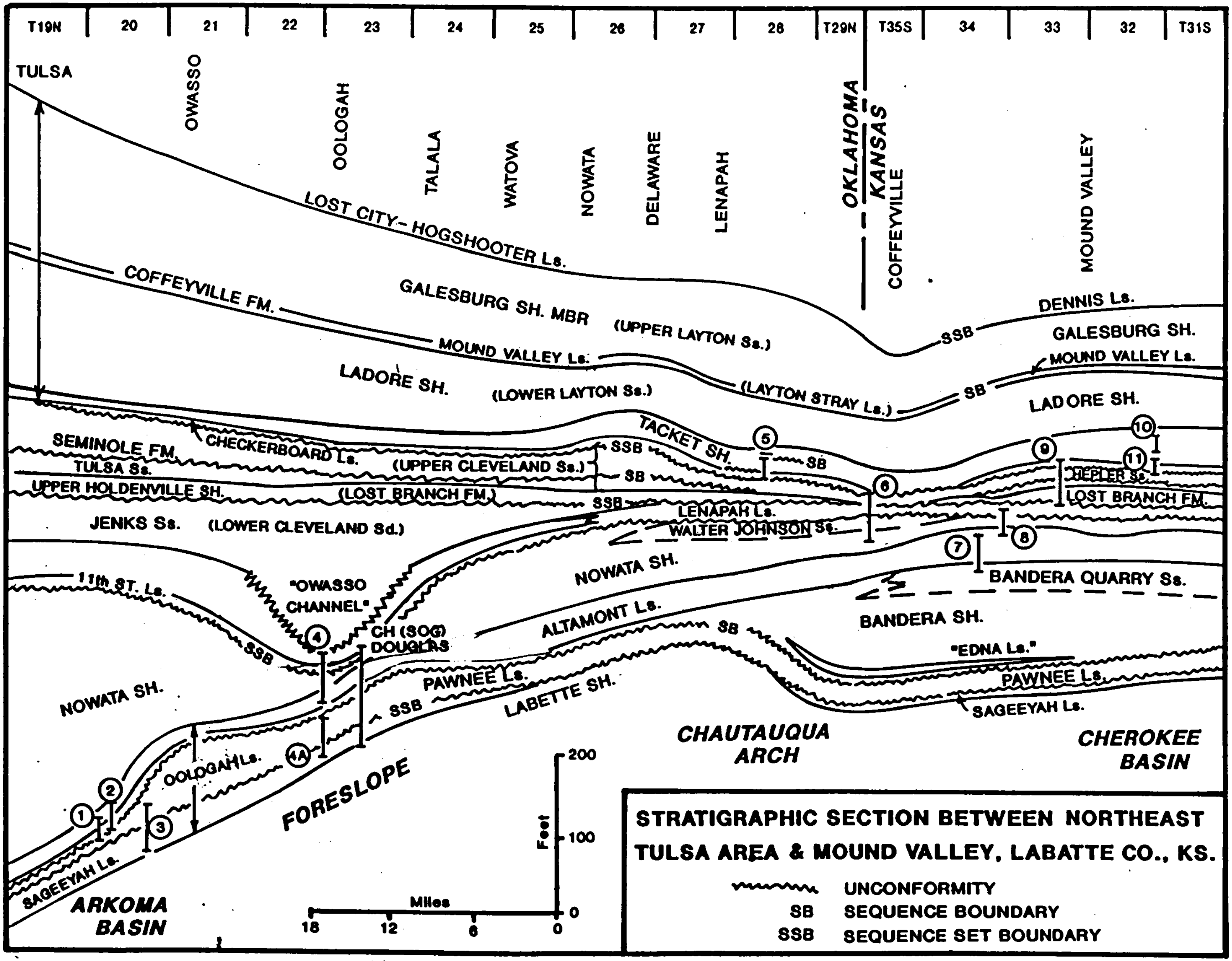

Fig. 2 Stratigraphic intervals of field stops.

resolution is frequently at the millimeter scale. Resolution on most mechanical logs is usually at several centimeters and seismogram imaging generally exceeds a meter.

The basal unit in our area is the cyclothem, which corresponds to the sequence as defined by the Exxon group. Parasequences and parasequence sets are very difficult to delineate, owing to the lack of continuous outcrops. However, a higher order of cyclicity is apparent from the stacking of sequences in packages of about 3 to 6 in which each succeeding sequence usually represents a shallower and more restrictive depositional environment until the basin is full. This is usually followed by some emergence and erosion prior to renewed abrupt subsidence. Such sequence packages are now known as sequence sets, fig 3.

Because Pennsylvanian time presents an earth somewhat similar to that of our own time, we should expect that catastrophism commonly follows gradualism, such as revealed from the Greenland ice cores.

In foreland and back-bulge basinal settings, regional tectonism is commonly out of phase with eustatic sea level fluctuations. This results in unconformities at any position within a sequence, with a preference for the base of the transgressive system tract. The lowstand or shelf margin system tract commonly represents the final filling phase of a sequence or cyclothem. Another anomaly usually not apparent on seismic profiles and mechanical logs is the increment of offlapping of shallower sediments shelfward within the transgressive system tract. This seems the opposite of the transgressive onlap of the passive marginal model. These supposed anomalies are quite explicable. They are closer to sedimentary provenances.

To the resident biota, an abrupt lithogenetic break represents more of an environmental disaster than simply a flooding event or a sea level fluctuation. Tidal zone and biohermal life perished over vast areas. Marine waters and muds drowned marshes and their inhabitants. However, some marine and onshore species filtered in to replace dying populations. Increasing aridity in rain shadows, resulting from mountain uplifts, probably led to explosive evolution of its lizard-like fauna, eventually leading to dinosaurs, birds, mammals and people.

Environmental and climatic changes, evolutionary adaptation, extinction and migration drive this evolutionary pump. Therefore, paleontology is still an important adjunct to stratigraphy.

We hope that the attendees of this field conference will find it stimulating and informative.

SEQUENCE SETS	SEQUENCES (CYCLOTHEMS)
DENNIS-DEWEY	Quivira Slick-Westerville? Stark
CHECKERBOARD-COFFEYVILLE	Cedar Bluff Mound Valley Hushpuckney Mound City Last Chance Checkerboard
UPPER HOLDENVILLE (LOST BRANCH)- SEMINOLE	South Mound Tulsa (Hepler) coal Nuyaka Creek
PAWNEE-NOWATA	Nowata flags Laredo coal Lake Neosho Mulberry Joe Anna
FORT SCOTT-LABETTE	Sageeyah Wimer School Little Osage Excello

Fig 3 Provisional sequences and sequence sets of Labette to Dewey succession, northeast Oklahoma and southeast Kansas

TGS FIELD TRIP - SPRING 1996

Theme: Role of unconformities and fossil soil horizons in Midcontinent sequences.

0.0 Lv AAPG parking lot.

0.2 Turn left on 13th St.

0.3 Turn right onto OK 51.

0.8 Veer left for US 75.

2.0 Turn right for I-244 east. Here excavation for the traffic interchange pylons yielded an excellent Seminole megaflora, dominated by several species of Neuropteris.

2.6 Ahead is dip slope underlain by the massive Tulsa Sandstone. This sandstone is now interpreted by the Oklahoma Geological Survey to be the uppermost member of the Desmoinesian Holdenville Formation.

8.9 Veer left to exit onto US 169. This area is underlain by the Altamont Limestone Formation of the Oologah Limestone (subgroup).

9.6 Turn right onto Pine Street. Amoret Limestone Member of the Altamont crops out in ditches at intersection and along Pine Street.

STOP 1. We stop briefly on west side of Garnett Road to examine the wavy contact between the overlying Bandera Shale and the underlying Laberdie Limestone; both are members of the Oologah Limestone, fig 4.

The hummocky top of the Laberdie Ls. is typical of both modern and ancient bioherms. A thin oxidized crust may reflect some subaerial weathering. Visible fossils, especially the large productids, indicate probable tidal to shallow water subtidal conditions. A precipitous drop in sea level probably terminated this thick shelf-edge carbonate bank. A soil zone then formed over it. Farther north this paleosol is thicker and is locally

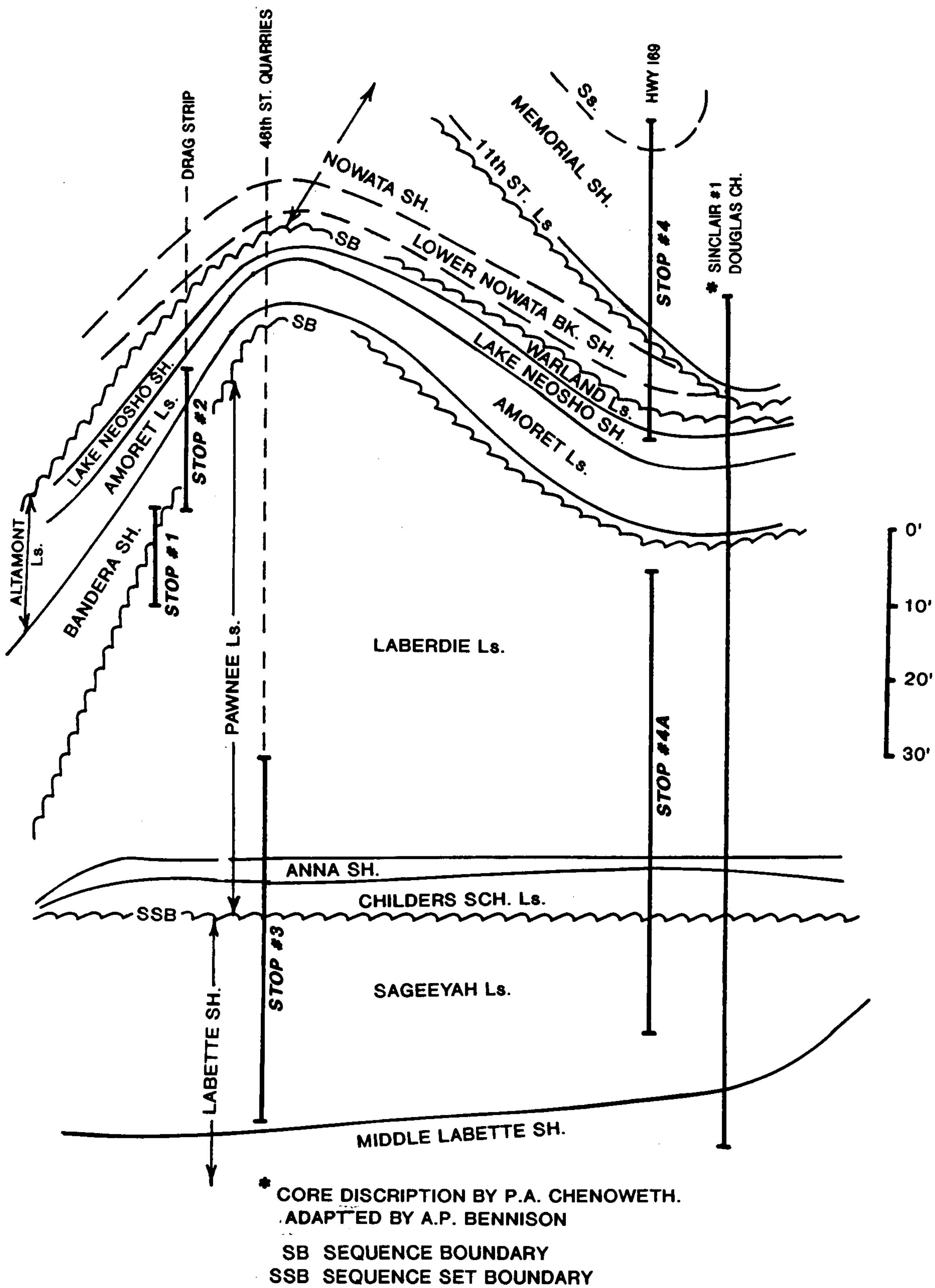

Fig. 4 Stratigraphic sequence of the Oologah beds northeast of Tulsa to Oologah.

overlain by the Mulberry coal, which represents spreading wetland deposits preceding a major influx of marine muds. In the Kansas-Oklahoma border area, the Bandera commonly exceeds 100 feet in thickness and the marine mudrock and commonly associated calcareous mudstone are succeeded by silty clays grading up into lenticular sandstones of its Bandera Quarry Sandstone member. Brenner and Brownfield of the University of Iowa conjecture the westward encroachment of a deltaic complex with sediments derived from the erosion of earlier Pennsylvanian clastics that once bordered or covered the Ozark Uplift.

10.7 Crossing railroad tracks.

11.1 Crossing Apache Street.

11.3 Amoret Limestone ledges in east ditch of Garnett Road.

11.4 Amoret Limestone.

11.5 STOP 2. Fossil brachiopod shells littered this outcrop of Bandera Shale in great profusion, fig 4. Throughout the Tulsa area, the Bandera Shale is usually a fossiliferous green gray marly clay shale, varying in thickness from 3 to 30 feet, and separates the overlying Altamont Limestone from the underlying Pawnee Limestone. Contacts are sharp and regional correlations suggest discordancy. Two miles south the Bandera Shale overlaps much of the Laberdie Limestone.

In Nowata and Craig Counties Amoret Limestone apparently offlaps the upper shoaling silty shale and sandstone facies of the Bandera Shale where the formation locally exceeds 120 feet in thickness.

11.6 Passing entrance to drag strip. Slight rise ahead is south dipping ramp of the Laberdie algallimestone bank.

12.1 Stop for E. 36th St. North and continue north on Garnett Road.

13.2 Stop and then turn right onto E. 46th St. N. Crossing N 129 E. Ave. Note on right deep excavation of the Oolagah Limestone. Here it justifies its name, Big Lime. The relatively thin black band is the Anna

Shale. Actually the Big Lime (Oologah Limestone) consists of 8 distinctive lithic units, that involve 4 different formations in the Oklahoma-Kansas border area. These formations in upward order are the upper Labette Shale, Pawnee Limestone, Bandera Shale and Altamont Limestone.

14.6 Anna Shale in road cut. Bank mergers such as current in the news are not new. A form of bank merger occurred during Pennsylvanian time in the Tulsa area, when 6 banks merged to become the giant carbonate bank known as the Big Lime. Its depositors consisted of countless trillions of shell and carbonate secreting organisms from microbes to algae, and still larger life forms.

14.7 STOP 3. Near entrance to former quarry on south side of highway. Fig 4 &5 Here is revealed, in a relatively small area 3 OolOgah limestone banks. Of special interest is the unconformity of the basal transgressive Pawnee Limestone (Childers School Limestone) on the upper Labette Shale limestone member. (Sageeyah Limestone). Calcarenite of the Childers School Limestone fills burrows for several inches deep in the underlying calcareous mudstone of the Sageeyah Limestone.

The Childers School Limestone, about 4 feet thick, grades up into the black phosphatic nodular shale of the core shale of the Pawnee Limestone, which, in turn, is overlain by the locally very thick Laberdie Limestone. This limestone thins abruptly to southeastern Tulsa, where it commonly is less than a foot in thickness.

14.7 Return along 46th Street to highway US 169 N.

16.2 Turn right on US 169 N.

17.3 Crossing 56th Street.

17.6 Bird Creek Bridge. Note Laberdie Limestone cutbanks on right.

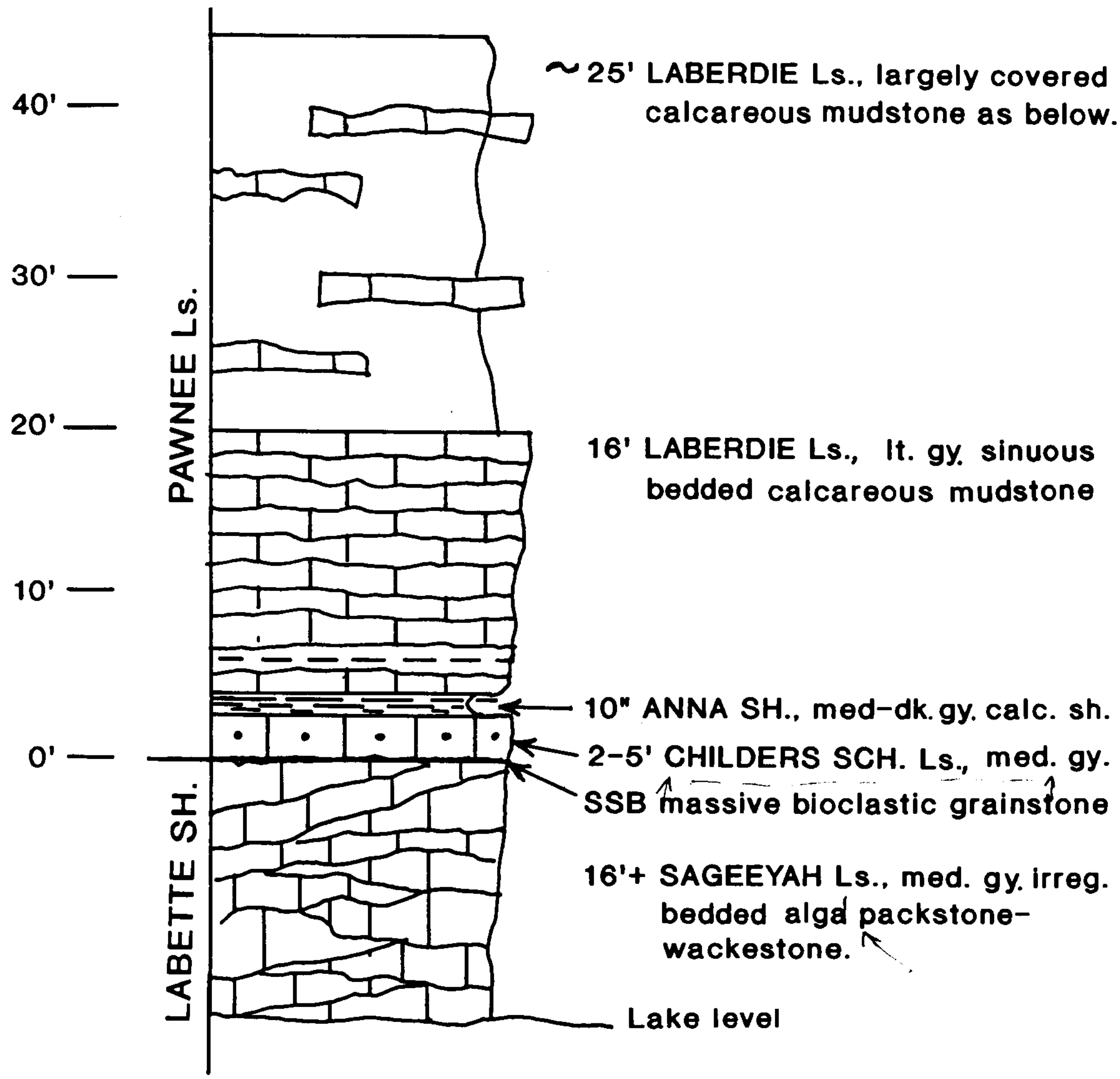

Fig. 5 Stop 4A Cliff section at southwest dam site of Oologah Lake revealing 3 limestone members of the Oologah Limestone.

19.3 Crossing 76th Street in Owasso. Flat area is underlain by Holdenville and Nowata Shales.

20.3 Crossing 86th St., in Owasso.

20.6 Climbs up on Owasso Sandstone channel (subsurface Lower Cleveland Sand). This sandstone locally exceeds 100 ft. in thickness.

24.1 Crossing Oklahoma highway 20 E.

27.1 Crossing Oklahoma highway 20 W.

29.2 Caney Creek bridge.

30.6 Enter Rogers County.

31.7 Hilly area ahead largely composed of great thickness of the Jenks Sandstone (lower Cleveland sand).

35.0 STOP 4. In ditch and ravine on south side of US 169 near nursery is a sequence of Memorial Shale truncating basal black shale bed of the Nowata Shale that rests disconformably on the upper Altamont Limestone member (Worland Limestone).

35.3 Just south (right) of highway was a borrow pit revealing an unusual sequence of basal Altamont Limestone (Amoret Limestone) on a thin 1.5 to 2.0 foot interval of the Bandera Shale. A 2 inch thick coal (Mulberry coal?) with underclay (fossil soil) rests disconformably on the weathered Laberdie member of the Pawnee Limestone.

Unfortunately, this informative exposure is now a victim of progress.

35.5 Four Mile Creek bridge.

36.4 Turn right at OK hwy 88.

38.2 Entering Oologah Lake Park.

39.2 Turn left into picnic area.

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38.2 Entering Oologah Lake Park.

39.2 Turn left into picnic area.

39.3 STOP 4A. From parking lot walk down to cutbank of Oologah Lake, fig 6, where 3 distinctive types of limestone are exposed, composing the Oologah Limestone, as illustrated on figs 4 and 6. Section very similar to that in the Tulsa quarries, except for thinner Anna Shale. Note signs of weathering at base of Pawnee Limestone.

This stop provides another glimpse of the contact between the base of the Pawnee Limestone and the truncated and northward thinning Sageeyah Limestone and other variegated beds of the underlying Labette Shale. Bennison interprets this contact to be the base of the Pawnee to Nowata sequence set. The Pawnee Limestone is approximately the Anna Cycle.

The Sageeyah Limestone has no well defined core shale. South of Oologah Lake the middle interval of thicker Sageeyah Limestone contains black cherty shales that seemingly represent deeper water facies than the algal calcilutites and calcarenites both above and below. Therefore, the Sageeyah Limestone may be regarded as a true cyclothem or sequence, closing the Fort Scott to Lagette sequence set.

42.2 Return to intersection of US hwy 169 and OK 88 and turn right (north).

42.3 Entering town of Oologah, stratotype of Oologah Limestone that crops out extensively in this area. The Oologah Limestone results from the convergence of several shelf edge limestone banks belonging to 4 distinct formations in the Oklahoma-Kansas border area: Labette, Pawnee, Bandera and Altamont.

43.5 Oologah public school recently reconstructed after disastrous tornado.

44.3 Crossroads w/Texaco station on left (west). About 300 feet west and 300 feet north of E-W section line road is the location of the Sinclair O&G Corehole Douglass described by P.A. Chenoweth.

REVISED AND CONDENSED DESCRIPTION OF CORE DATA
RECORDED BY THE LATE DR. PHILIP A CHENOWETH

Sinclair Core Hole No. 1 Douglass, SE/4 sec 16, T23N,R15E, 1 mi N of Oologah, and 300' W of US 169 Hwy.

0 - 17	Surficial deposits.
17 - 25.5	Probable Memorial Shale; medium dark gray calcareous with fossils.
25.5-26.3	Probable Eleventh Street Limestone; fossil hash, glauconitic, fossiliferous with sharp upper and lower contacts.
26.3-28	Possible truncated Nowata Shale; medium to dark gray, foraminiferal with fragmental larger fossils.
28 - 29.5	Worland Limestone; medium light fossiliferous calcilutite, algal and crinoidal.
29.5-33.5	Lake Neosho Shale; dark gray to gray black, blocky with phosphate nodules. Contacts sharp and uneven.
33.5-41.4	Amoret Limestone; light gray to medium light gray calcilutite, unevenly bedded, fossiliferous with patches and streaks of calcareous shale, fine calcarenite and calcisiltite.
41.4-42.8	Bandera Shale; medium gray to dark gray calcareous, fossiliferous with abundant brachiopods. Thin siltstones near base.
42.8-84	Laberdie Limestone; light to medium gray or yellow gray interbedded calcilutite and calcisiltite, with shale partings, fossiliferous.
84 - 85	Anna Shale; medium to dark gray, calcareous, fossiliferous with some calcilutite.
85 - 90.8	Childers School Limestone; basal Oologah, interbedded calcareous siltstone, shale and calcarenite, medium to dark gray and brown gray, fossiliferous.
90.8-112.5	Sageeyah Limestone, uppermost Labette Shale; light olive gray to medium gray, interbedded calcilutite, calcarenite and calcarudite with calcareous shale parting and a thin band of chert, fossiliferous.
112.5-118.5	Labette Shale; medium to medium dark gray calcareous silty shale with small limestone concretions.

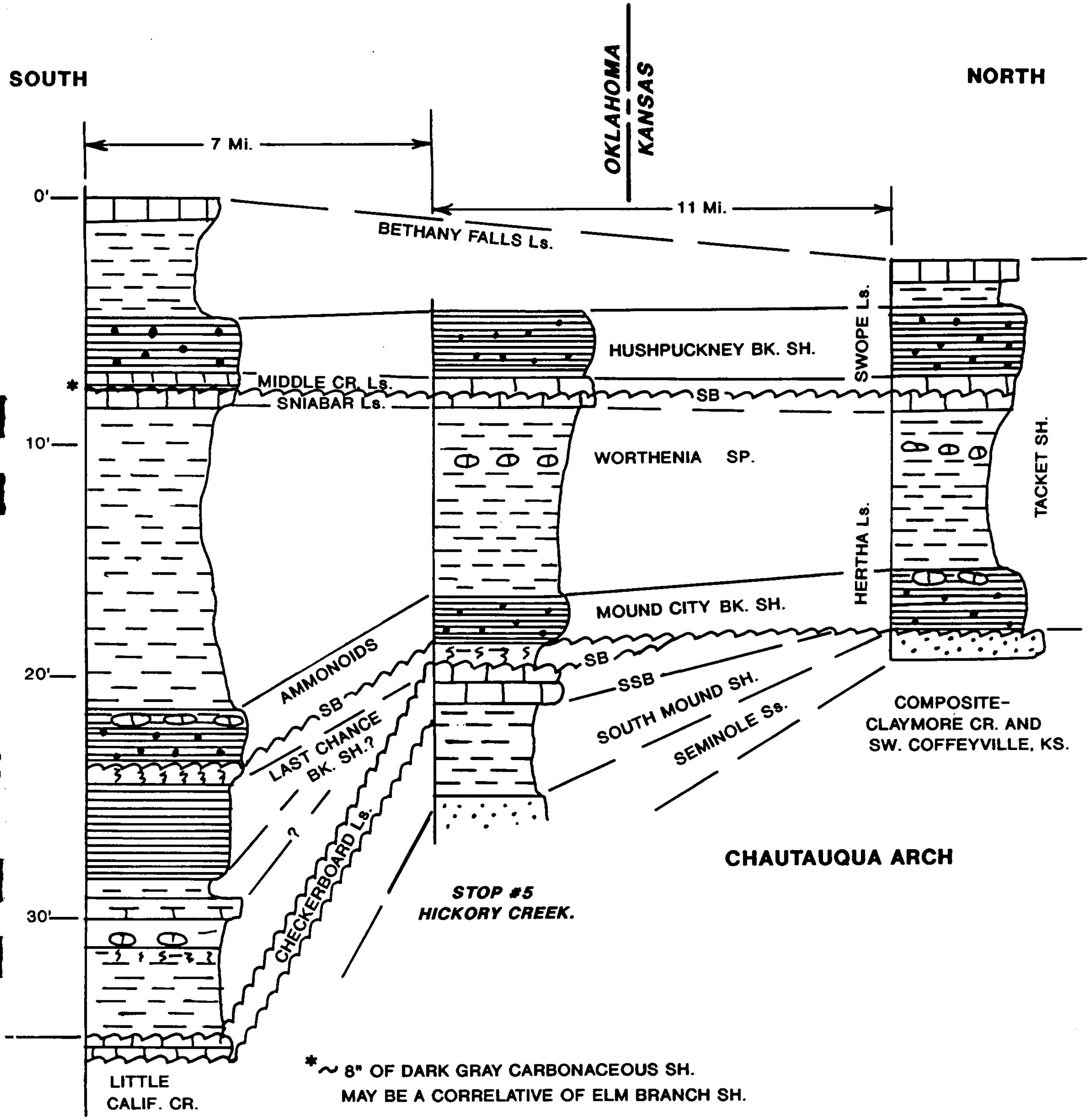


Fig. 6 Stratigraphic section through through field-stop 5, showing multiple unconformities in the Checkerboard-Coffeyville interval

112.5 - 118.5 <u>Labette Shale</u>; medium to medium dark gray calcareous silty shale with small limestone concretions.

45.8 Nowata flagstones on low road cut.

48.4 Crossing EW 34 road and entering town of Talala.

55.2 Entering village of Watova.

58.0 Crossing South Double Creek.

58.7 Crossing North Double Creek.

59.1 Viaduct over Burlington Northern RR.

60.3 Entering city of Nowata.

61.1 Traffic light for US 60 in Nowata. Continue on US 169.

64.5 Bridge over California Creek

66.5 Town of Delaware on right (west).

71.5 Intersection of OK Hwy 10. Town of Lenapah on right (west). Continue on US 169.

73.5 Quarry on left mining Lenapah Limestone for aggregate.

74.3 Excellent outcrop of Lenapah Limestone on Nowata Shale.

74.4 Hickory Creek bridge.

75.0 Turn left (west) on road 8.

76.2 STOP 5. Hickory Creek ford, an accessible locality, fig 6. for the Checkerboard-Tacket succession is well exposed. This exposure has much significance. Two major hiatuses are indicated. The upper one involves extreme stratigraphic thinning of the Hushpuckney and Mound City cyclothems and the probable non-deposition of the intervening Elm Branch Shale. This hiatus accounts for the loss of 50 feet or more of sediments present in Linn and Bourbon Counties of east-Central Kansas. Also, the thin transgressive limestone probably related to the Middle Creek Limestone of the Hushpuckney cyclothem rests with a sharp break upon the equally thin probable Sniabar Limestone, the regressive unit of the Mound City cyclothem.

The lower hiatus involves even a greater loss of stratigraphic section. At this Hickory Creek locality accompanying figure reveals that the 1.5' thick shale interval between Checkerboard Limestone and the Mound City black shale bed is in contrast to the 10 feet of mixed lithology only miles to the south along Little California Creek. Here a 10 foot interval consists of green gray to dark gray and black shale, concretionary limestone zones and fossiliferous marls, and may represent several beds and members composing the Pleasanton Group of Kansas. In east-central Oklahoma near Okemah this interval consists of about 100 feet of offshore marine shale with a thin basal coal bed and paleosol.

76.2 Return to US 169.

77.4 Turn left (north) on US 169.

80.9 Crossing Opossum Creek.

82.3 Crossing Vinegar Creek.

83.3 Cross road 2. About 1.5 miles west there is an exceptional outcrop of black anoxic shale forming the core shale of the Mound Valley cyclothem. According to Watney and French (oral communication) this is one of the hottest (high gamma ray reading) shale in the Midcontinent, and yet is has only a known 2 mile outcrop length. Presumably, it occurred as a black anoxic organic muck in a narrow but deep seafloor depression. Normally, its core shale is lacking or only thin and slightly disoxic, fig 7.

The Mound Valley Limestone in Oklahoma has an erratic development near the middle of the Coffeyville Formation. It is probably the Layton Stray Limestone of the subsurface.

[redacted]

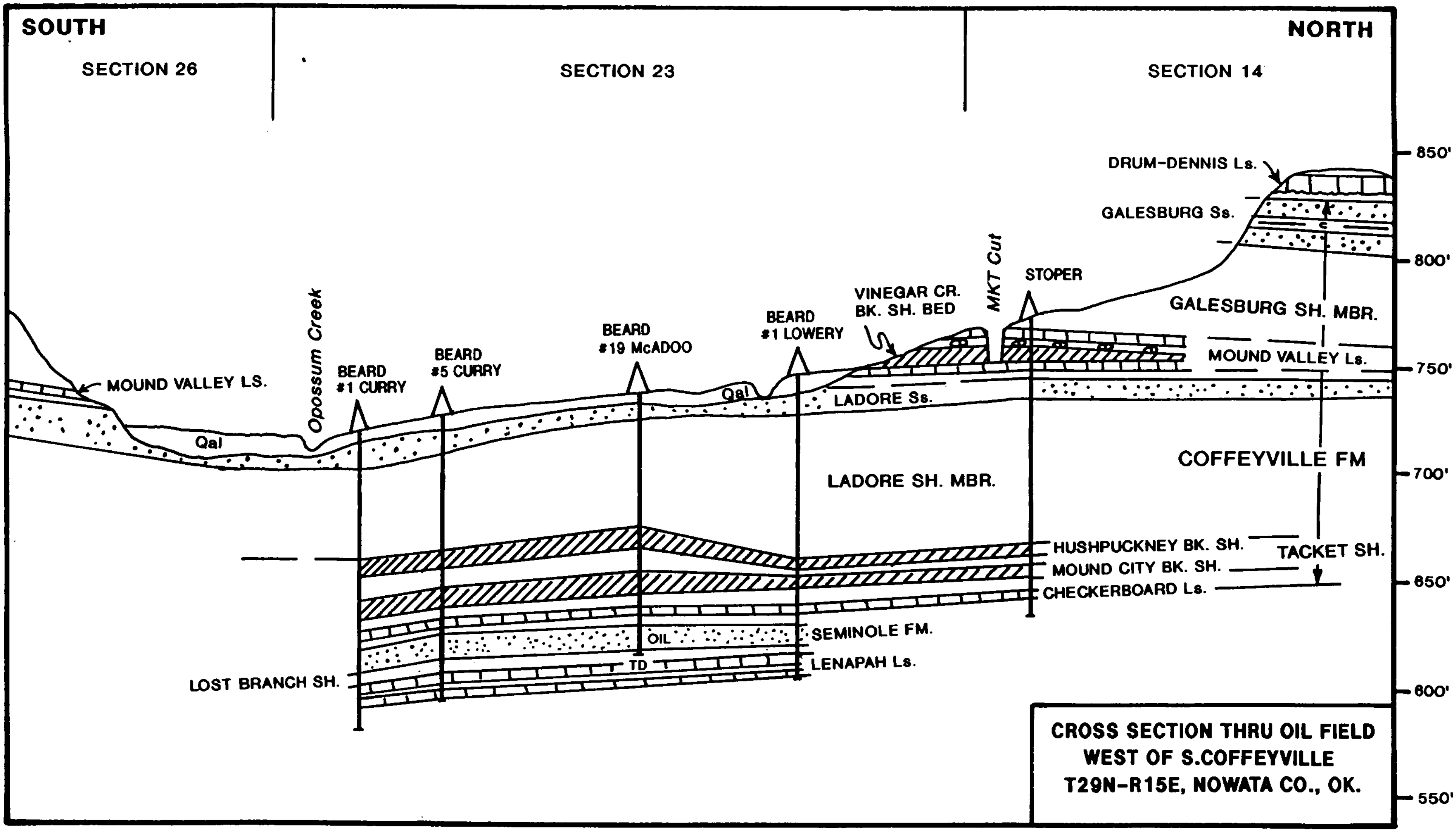


Fig. 7 Cross section through small oil field west of South Coffeyville showing unusual black anoxic shale forming core shale of Mound Valley Limestone.

Alternative Route.

84.3 Entering Kansas. On east side of highway US 169 there was once a good outcrop of Checkerboard Limestone, but it has become a victim of progress.

85.3 Entering the city of Coffeyville.

86.3 On east of US 169 notice large abandoned quarry in Nowata Shale capped by the Lenapah Limestone. This straddles the Coffeyville Anticline that was the site of a now largely produced and abandoned oil field. South reversal between South Coffeyville and Coffeyville is about 50 ft.

86.8 Turn left (west) onto US 166 in downtown Coffeyville.

90.8 STOP 6A. Excellent exposure of Coffeyville to Chanute Formation in crossroad area. Watch out for traffic. This is near the approximate axis of the Chautauqua Arch, a major feature not familiar to many Midcontinent stratigraphers. Bennison interprets this to be a forebulge, a commonly developed uplift linked to a foredeep and coextensive orogen. Evidence for episodic uplifts and erosional intervals abounds in its many unconformities and associated hiatuses throughout Lower to Middle Pennsylvanian beds. Stratigraphic mapping along the outcrop belt from Tulsa County to the Coffeyville area reveals several major discontinuities, fig 8.

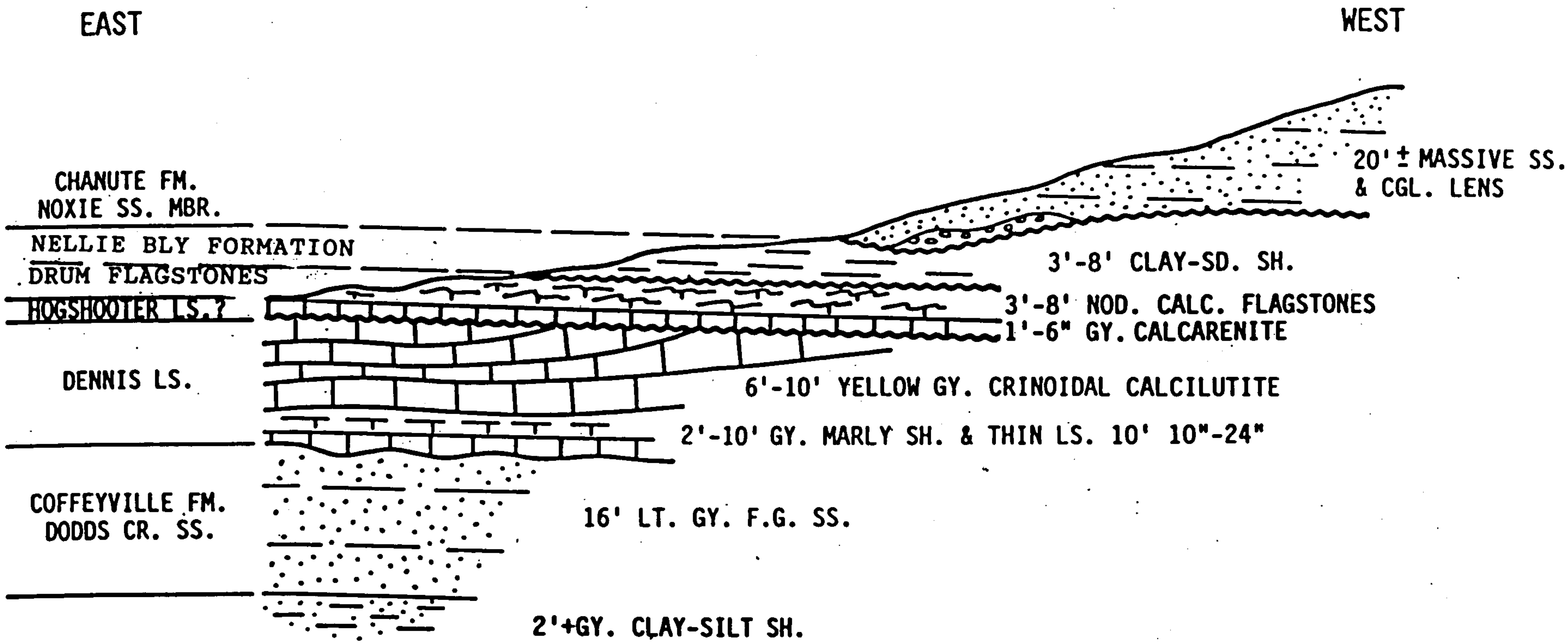
1. Upper Dennis (Winterset Limestone) truncation of of the uppermost Coffeyville Formation (upper Layton sand), the Canville Limestone (the transgressive limestone of the Dennis or Lost City limestone), and the Stark Shale (black phosphatic shale of the Dennis Limestone).

2. Lower Hogshooter or Drum Limestone (Block Limestone) truncation of the uppermost beds of the Dennis Limestone and the Cherryvale Shale that exceeds 60 feet in thickness in its type area a few miles north of Coffeyville.

3. Nellie Bly Formation of the upper Hogshooter or Drum Formation, which , at Independence locally exceeds 50 feet.

4. Chanute Shale truncation of the Dewey Limestone and all but the lower few feet of the normally thick (25 to 50 feet) Nellie Bly Formation in southern Kansas.

These 4 unconformities and hiatuses and many others recur throughout the Desmoinesian and Missourian beds of the southeastern Kansas and Oklahoma border area, incicating that this was a major forebulge zone at that time, probably distantly related to the Oachita, Wichita and Arbuckle orogenies of southern Oklahoma. This is superposed on a much greater forebulge, the earlier Chautauqua Arch, along which the Late Devonian Chatanooga Shale rests directly on Early Ordovician carbonates and associated clastics. Many of the Arbuckle wells have been very productive along this trend. Missing sections amount to thousands of feet of Late Ordovician, Silurian and early to Middle Devonian strata.



INTERPRETED BY: A. Bennison 4/84

INTERPRETATIVE SKETCH OF STRATIGRAPHY EXPOSED ALONG SOUTH SIDE
OF U.S. HWY. 166 CUT 3.5 MILES WEST OF COFFEYVILLE, KANSAS
(NE CORNER OF SEC.5, T35S, R16E)

Fig. 8 Stratigraphic Section 3 miles west of Coffeyville showing multiple unconformities.

84.3 Oklahoma-Kansas state line. On east side of highway 169 there was once a good outcrop of Checkerboard Limestone.

84.9 Turn right (east) on county road.

85.9 Verdigris River on left.

86.4 STOP 6. Verdigris River Bridge, fig 9. This is a fine vertical section, exposing a condensed section of the Missourian-Desmoinesian boundary interval. The lower clastic interval belongs to the Nowata Shale and the protruding ledges represent the Walter Johnson (Wayside) Sandstone. Above this is the Lenapah Limestone with its 3 members, that, in upward order, are the Norfleet Limestone, Perry Farm Shale and Idenbro Limestone. These members thicken southward in Oklahoma, owing to an increase of clastic wedges, and are known as the Eleventh Street Limestone, Memorial Shale and Jenks Sandstone.

Truncating the Lenapah Limestone is the Seminole Formation with a thin basal shale bed that may be a depositional remnant of the uppermost Holdenville or Lost Branch Shale. Joints in the Lenapah Limestone have an infilling of the overlying shale and thin sandstones.

Truncating all these Pennsylvanian beds in this area are the upland terrace deposits, consisting of water-worn chert pebbles in an oxidized soil. Some authorities interpret these deposits to be of fluvial origin and derived from the Flint Hills of south central Kansas. Isolated exposures of similar chert gravel are found as far south as the high ridge northwest of Sand Springs, about 150 feet above the Arkansas River.

87.4 Turn left (north) at cross-roads.

88.8 Railroad crossing.

89.0 Stop for CR 1800 and continue north.

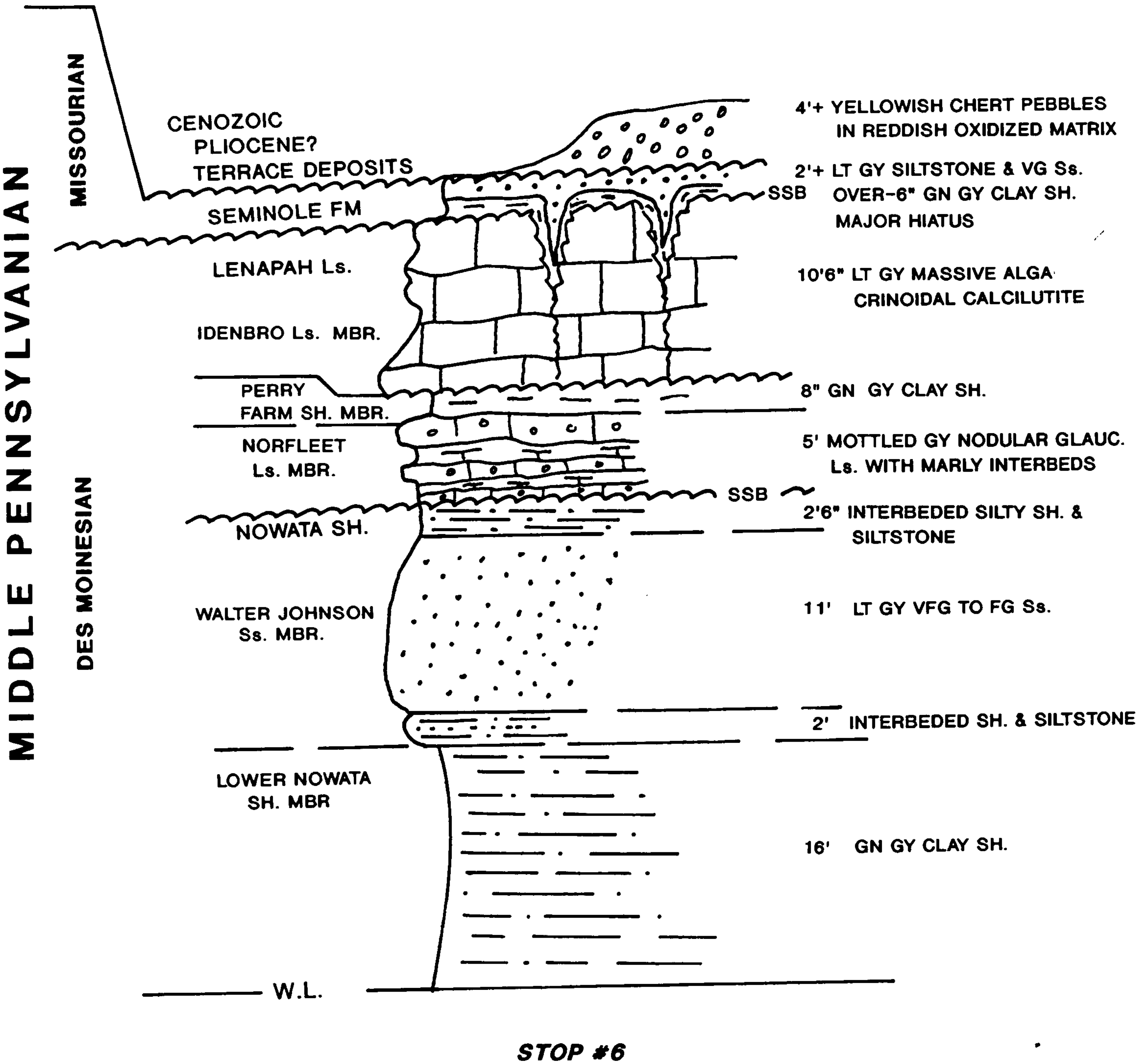


Fig. 9. Stratigraphic section of stop 6 at Verigris River bridge southeast of Coffeyville. Kansas.

89.1 Pumpkin Creek Bridge. Note contact of Lenapah Limestone on Nowata Shale.

89.3 To right are abandoned quarries in the Lenapah Limestone.

89.6 Stop for US Hwy 166 and turn right (east).

90.6 Good Lenapah outcrops.

91.2 Pumpkin Creek Bridge.

91.3 In ravine on right is thin outcrop of Laredo coal at base of the Nowata Shale.

92.0 Nowata interbedded shales and sandstones on south side of highway.

92.2 Entrance to Midwest Minerals quarry in the Altamont Limestone.

92.6 Entering Labette County.

93.3 Occasional outcrops of Altamont Limestone.

94.6 Good contact of Idenbro Limestone on Perry Farm Shale. Fossils are abundant, especially the moderate depth *Leiorhynchus* sp.

96.4 Altamont Limestone exposure.

96.8 Crossing Antola-Valeda road.

98.8 Turn left at intersection of Gray Road.

99.4 Railroad tracks.

100.4 STOP 7 Good exposure of Amoret Limestone Member of Altamont Limestone resting on upper interbedded sandstones and shale beds of very thick Bandera Shale measuring about 120 feet thick in this area, in contrast to the 8 foot section of Bandera Shale at the stops in the northeast Tulsa area. Contact here may be conformable.

100.4 Continue north on Gray Road.

102.9 Crossing county road 8000.

104.0 STOP 8. Left (west) of road good exposure of a very thin Nowata Shale on Altamont Limestone, fig 10. Basal Nowata Shale contains the thin Laredo coal with thick paleosol on the Worland Limestone. Walk with care on account of resident rattlesnakes and a water moccasin in area. This is one of the best examples of a sequence boundary. Here the basal beds of the Nowata Shale rest unconformably on the hummocky top of the Worland Limestone Member of the Altamont Limestone, fig. 4. These basal beds are correlated with the Laredo coal and its underclay of northern Missouri. The Laredo coal is in turn capped by a thin carbonaceous wackestone and dark clay shale of the Nowata Shale. Still stratigraphically higher is a calcareous siltstone, that is tentatively correlated with the Norfleet Limestone, the basal member of the Lenapah Limestone. The Norfleet Limestone is the correlative of the Eleventh Street Limestone of Tulsa County, where it truncates more than 100 feet of the underlying Nowata beds, including its Walton-Johnson Sandstone Member, which is the productive Wayside sand of the subsurface.

104.8 Crossing county road 10,000.

107.8 Crossing county road 13,000. hill to west capped by Checkerboard limestone.

108.1 Dawson coal in ravine on left (west).

108.7 Pumpkin Creek Bridge.

108.9 STOP 9 Stratotype of Lost Branch Shale named by P.H. Heckel for uppermost Holdenville Shale, previously known as Memorial Shale in kansas. Note the sharp contact between Dawson coal and overlying Nuyaka Creek. In the Tulsa area the contack is more transitional. The Dawson paleosol in Washington County contains pebbles of the Lenapah Limestone, indicating a major straigraphic sequence boundary, Fig 11.

These outcrops along Lost Branch near the village of Mound Valley reveal a condensed section involving several cyclothems, unconformities and hiatuses. Lowest bed is the truncated Idenbro Limestone, the upper member of the Lenapah Limestone, above which is the paleosol of the Dawson coal.. Up to 100 feet of clastic strata that include the subsurface lower Cleveland sane (Jenks Sandstone of the surface outcrops) are missing. Above the coal is the Nuyaka creek black shale bed, which is an offshore moderate depth anoxic shale, which has a prominent gamma ray spike recognizable on logs from southeastern Oklahoma to Nebraska and Iowa. This is the basal bed of the Lost Branch Formation proposed by P. Heckel, 1994. However, Bennison prefers the base of the Dawson paleosol for the base of the Lost Branch Formation and a sequence set.

Overlying the Lost Branch Formation and possibly its regressive deposit is the thin Hepler Sandstone, a name frequently used by Midcontinent stratigraphers, although the type Hepler is much older. Part of this thinness may be attributed to truncation by the Early Missourian colloquial Hepler coal and its thin paleosol. The base of this Hepler paleosol may represent the Desmoinesian-Missourian boundary and another sequence boundary. This coal is succeeded by thin carbonaceous shale and siltstone and an overlying gray shale with siderite nodules. This is interpreted to be the South Mound Shale Member of the Seminole Formation.

Highest exposed bed is the Checkerboard Limestone, a relatively thin gastropod-rich wackestone and a major sequence set boundary.

108.9 Turn right (east) on K 69 highway.

109.05 Turn left (north) on K 222 highway.

109.5 Entering village of Mound Valley.

111.9 Crossing county road 17,000

113.8 At Y-intersection turn right.

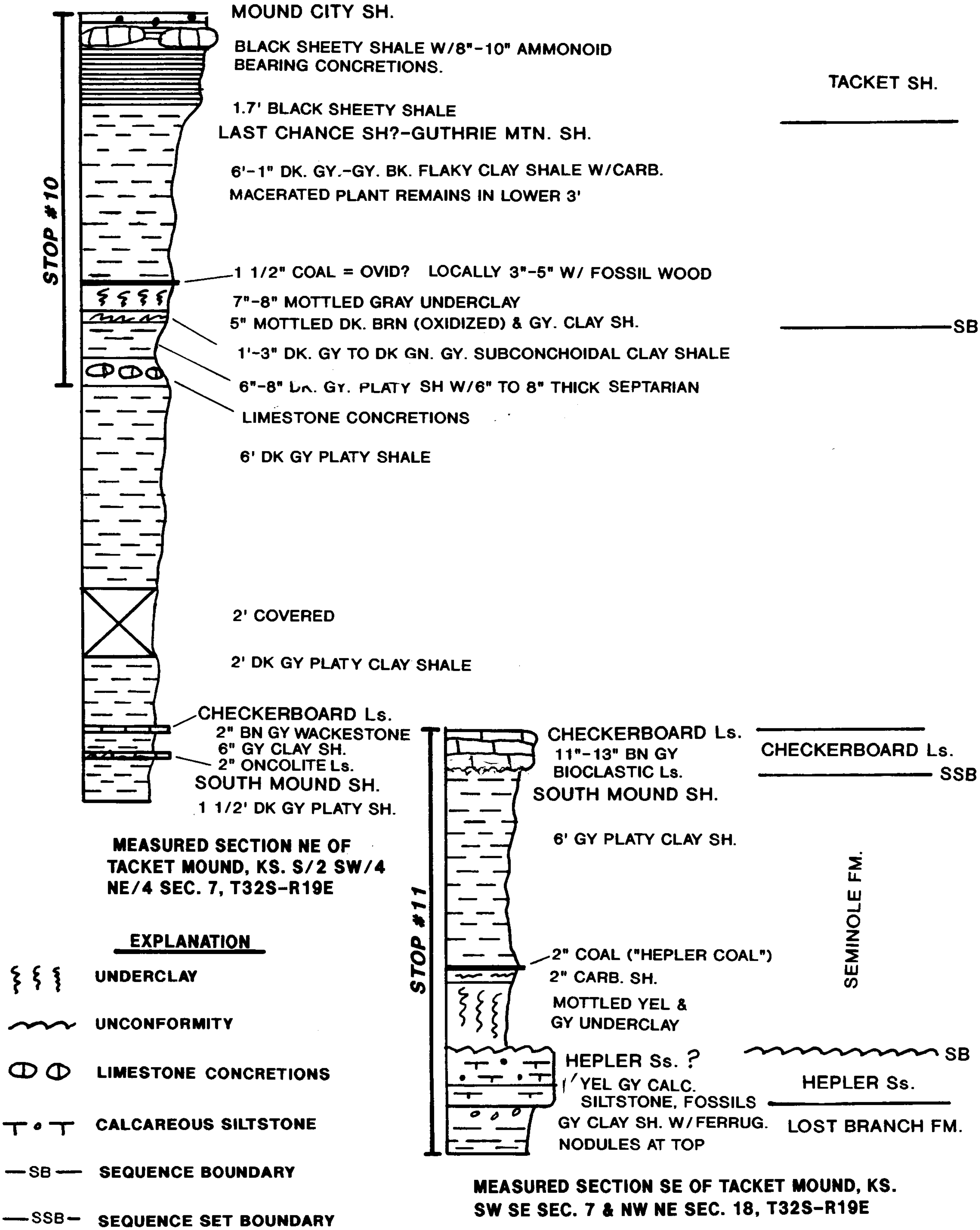


Fig. 12. Measured sections on south side of Tacket Mound, Labette Co.,KS

113.9 Turn right (east) on county road 19,000.

115.3 STOP 10. Outcrops in ravine on north side of road expose the base of the Mound City sequence, which rests discordantly on the Checkerboard sequence, fig 12.

115/4 Crossing Irving Road.

116.1 STOP 11. Ravine on north side of road has excellent exposure of Checkerboard Limestone on shale of the Seminole Formation, Fig 12. On south side of road and short distance down the ravine, the Seminole has a well developed coal bed and paleosol on thin shallow marine siltstone, that may correlate with the Hepler Sandstone of Kansas and Tulsa sandstone of Oklahoma. The coal is informally called the Hepler coal and bears early Missourian palynomorphs. This coal and its paleosol bearing soil nodules may represent the base of the Missourian stage. In contrast, the underlying calcareous siltstone of the Hepler sandstone rests with only a minor break upon the Desmoinesian Lost Branch Shale.

116.1 Continue east to road intersection.

116.4 Turn left.

117.2 Nearby is the location of the KGS corehole No. 1 Tanner, drilled by Lynn W. Watney into the top of the Tacket Shale and bottomed in the Amoret Limestone Member of the Altamont Limestone at about 152 feet. An annotated gamma ray-resistivity log is included, fig 13.

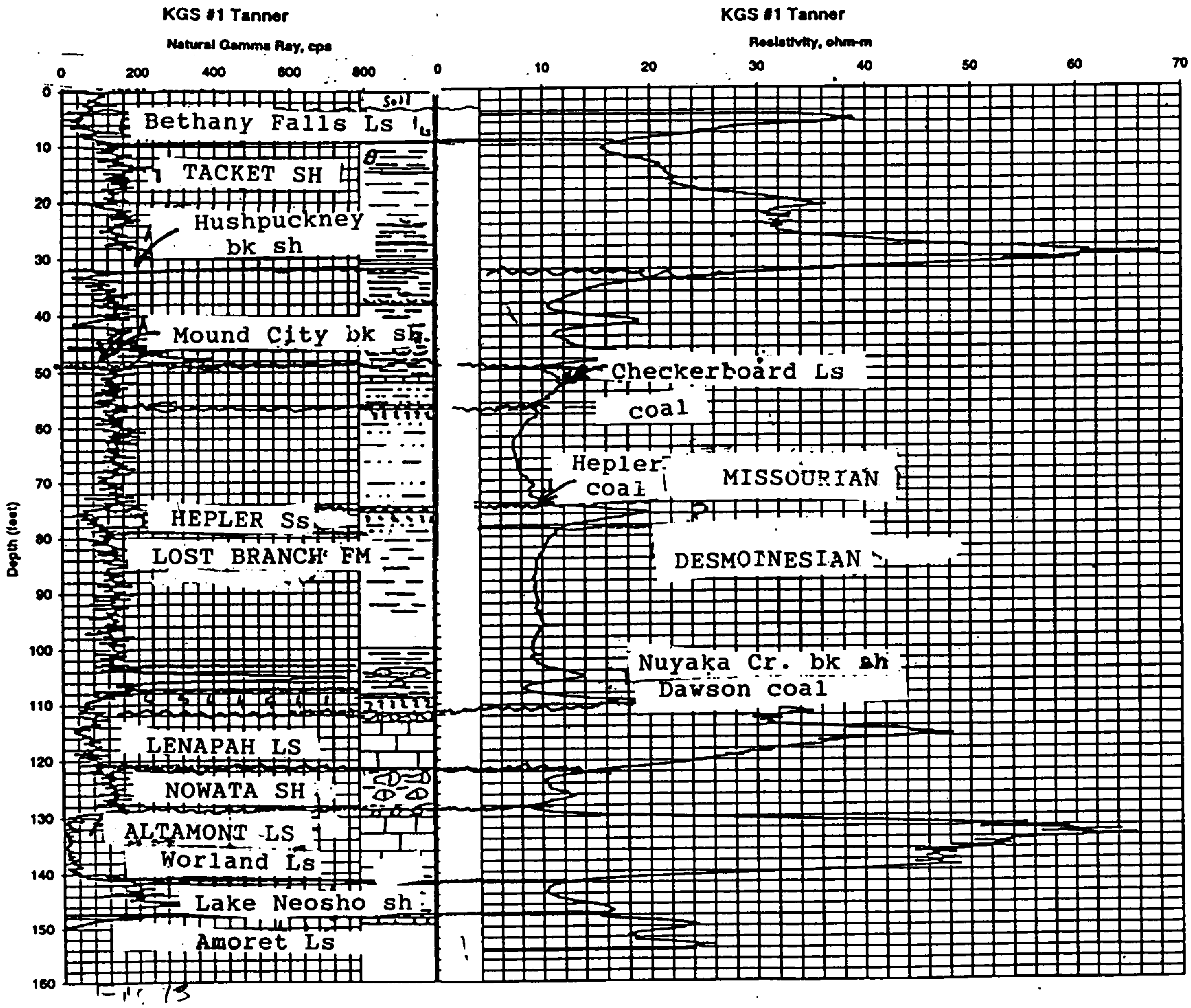


Fig. 13. Gamma Ray and Resistivity log of KGS C.H. No. 1 Tanner just east of Tacket Mound.