SURFACE AND SHALLOW SUBSURFACE INVESTIGATION OF THE NELLIE BLY FORMATION IN NORTHEASTERN OKLAHOMA

By

DAVID MICHAEL FILGAS

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NORTHEASTERN OKLAHOMA

Thesis Approved:

Arthur W. Cleaves
Thesis Adviser

Gary F. Stewart

Zuhair Al-Shaieb

Norman N. Durham
Dean of the Graduate College

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CHAPTER I

ABSTRACT

The Missourian Series Nellie Bly Formation in northeast Oklahoma is a clastic unit composed of shales, siltstones, and sandstones. An investigation was conducted to ascertain the distribution of the Nellie Bly Formation, its depositional environment(s), and regional stratigraphic relationships in northeast Oklahoma. The Nellie Bly Formation was studied on the surface and in the shallow subsurface. The study area encompassed portions of Osage, Tulsa, Washington, Pawnee, and Creek Counties in Oklahoma. Surface data from outcrops was incorporated to aide and facilitate interpretations of wireline logs used in the subsurface study. Approximately 360 well logs were utilized in the construction of structure, isopach, and gross sand maps of the Nellie Bly Formation. A network of loop and tie cross sections was constructed to study lateral changes of the Nellie Bly Formation.

Interpretations based upon outcrop observations, well log signatures, and isopach/gross sand maps indicate the Nellie Bly Formation was deposited in shallow marine shelf and deltaic environment. The Nellie Bly Formation is composed primarily of shales with lesser amounts of siltstones and sandstones.

Southward, the formation thickens and sandstone beds increase in thickness and abundance. Deltaic facies observed in the Nellie Bly Formation include prodelta, delta front, and stream-mouth bar. The Nellie Bly Formation is predominantly a regressive clastic deposit bounded by two transgressive limestones - the Hogshooter Limestone below and the Dewey Limestone above.

CHAPTER II

INTRODUCTION

Rocks of the Missourian Series of the Pennsylvanian System are exposed throughout much of the midcontinent region. Outcrops composed of cyclic limestone, shale and sandstone are present in Iowa, Nebraska, Missouri, Kansas and Oklahoma. The midcontinent Missourian Series is characterized by four major facies belts (Heckel, 1968, 1977). The northern portion of the outcrop belt is composed of open marine and northern shoreward facies. The extensive phylloid-algal mound facies in southeastern Kansas changes to a terrigenous detrital facies in northeastern Oklahoma (Figure 1). The Missourian Series Nellie Bly Formation, located in northeastern Oklahoma, is one of several units comprising the terrigenous detrital facies belt. The Nellie Bly Formation is a clastic unit consisting mostly of shales, siltones, and sandstones and the formation is bounded by two thin algal limestones.

Purpose of Study

The purpose of this investigation is to study the Nellie Bly Formation using shallow subsurface data to aid in better understanding the distribution of the Nellie Bly

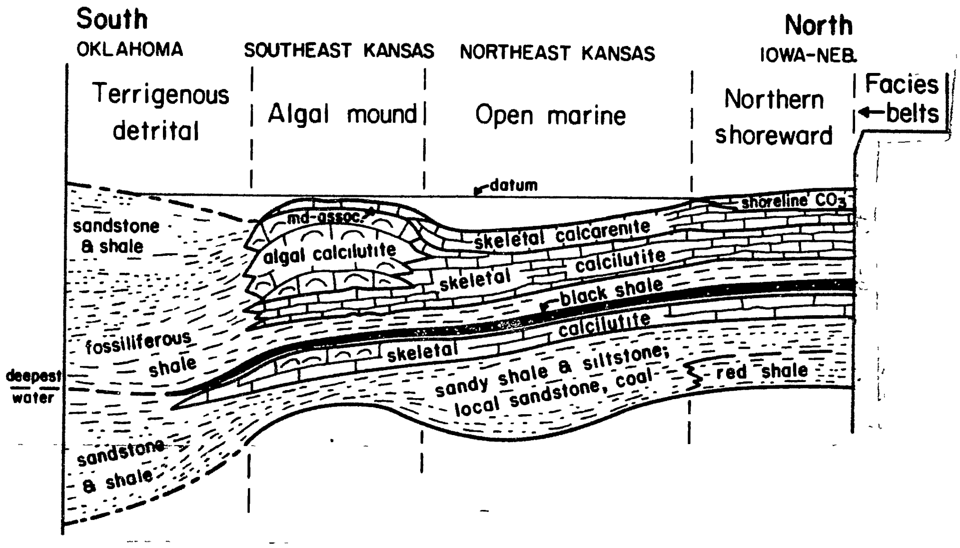

Figure 1. Cross section along outcrop of Upper Pennsylvanian Midcontinent facies belt (from Heckel, 1977).

Formation, its depositional environment(s), and regional stratigraphic relationships. The area under study involves the subsurface portion of the Nellie Bly and the adjacent outcrop. In addition to subsurface mapping, other sources of data, such as outcrop observations, core data, paleontology and petrography, are incorporated in the study of this Missourian unit.

Location

The study area encompasses portions of Osage, Tulsa, Washington, Pawnee, and Creek counties in Oklahoma (Figure 2). The Nellie Bly was studied in all or parts of Township 19 North to Township 21 North, Range 9 East to Range 12

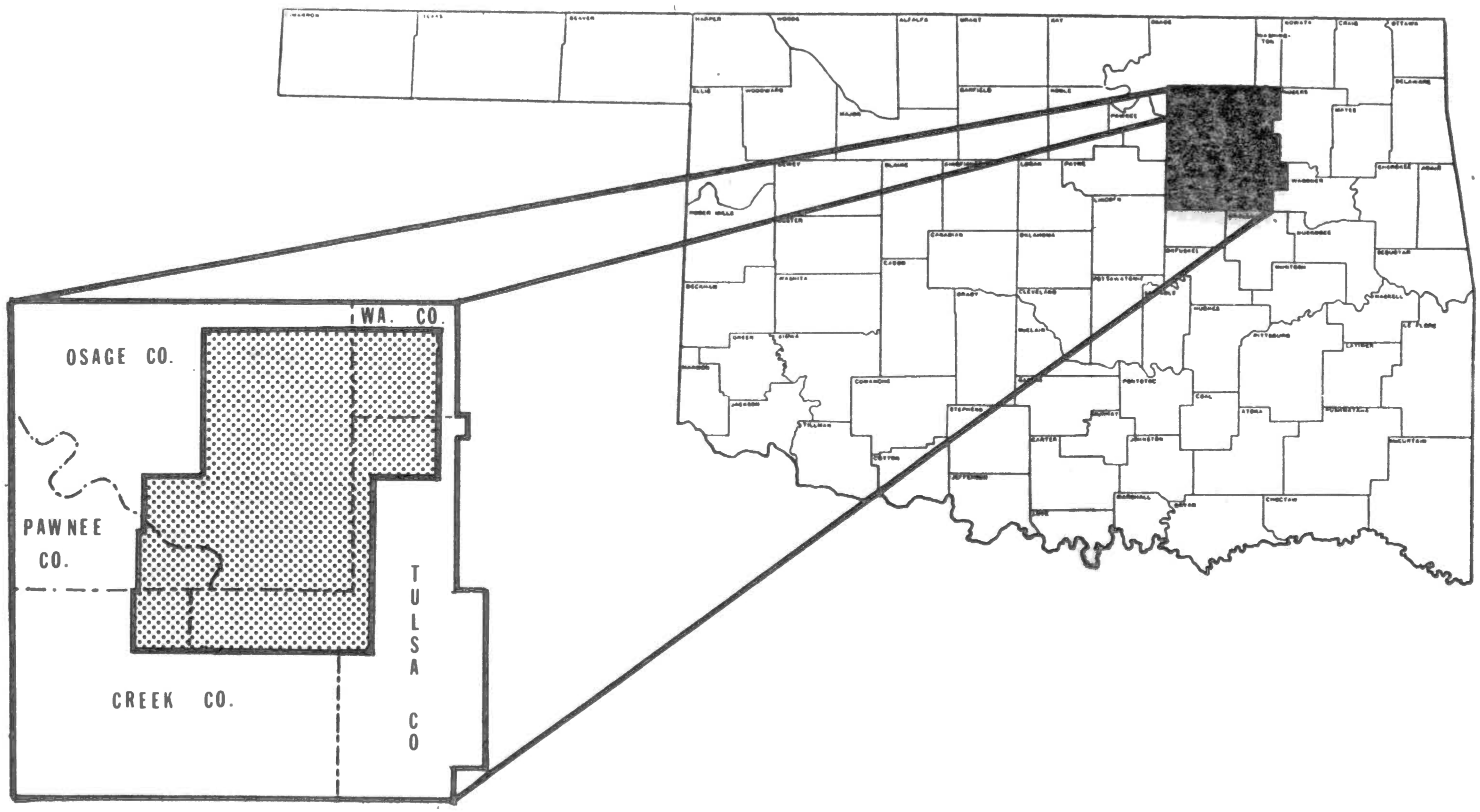

Figure 2. Location map of study area.

East, and Township 22 North to the Southern 1/2 of Township 24 North, Range 10 East to Range 13 East (Figure 2). The subsurface study area covers approximately 430 square miles and the Nellie Bly outcrop covers approximately 110 square miles. The topography of the outcrop belt changes in response to the bedrock geology of the area. The northern portion of the thesis area lies in the Claremore Cuesta Plains geomorphic province (Curtis and Ham, 1972). This province is characterized by resistant Pennsylvanian limestones and sandstones that form low, gently westward dipping cuestas with broad shale plains in between. The southern portion of the study areas lies in the Eastern Sandstone Cuesta Plains (Curtis and Ham, 1972), composed predominantly of sandstone cuestas with shale plains between. This area consists of many sandstone and limestone-capped hills.

Previous Investigations

Many geologists have contributed to the knowledge of the rocks which crop out in northeastern Oklahoma. Reconnaissance work in the late 1800's and early 1900's provided the foundation upon which subsequent studies have built; in some cases previous work has been revised. A review of relevant geologic studies (Table 1) was necessary to determine the current status of knowledge about the Nellie Bly Formation and enable the author to decide upon areas where further investigations were needed.

TABLE I

SUMMARY OF PREVIOUS INVESTIGATIONS

Date	Author(s)	Summary of Work
1897	N.F. Drake	Published a reconnaissance map of the Indian Territory coal field and proposed divisions of Pennsylvanian rocks.
1903	G.I. Adams, et al.	Conducted a preliminary study of northeastern Oklahoma while working on the Upper Carboniferous geology of Kansas.
1904	J.A. Taff	Observed that north of the Arkansas River, sandstones decrease in thickness and shales thicken. Also noted that there are fewer limestones in northern Oklahoma than in southern Kansas and that the limestones die out south of the Arkansas River.
1907	C.E. Siebenthal	Reconnaissance work and observations added to the knowledge of the stratigraphy and structure of the region.
1910	Gould, Ohern, and Hutchison	Proposed four groups of Pennsylvanian rocks in Eastern Oklahoma. Although not addressed directly, rocks of the Nellie Bly were included in the Sapulpa Group. Areal extent of Hogshooter and Dewey Limestones was mentioned.
1910	D.W. Ohern	The Copan Member name was proposed for rocks lying between the Hogshooter and Stanton Limestones. The lithology of what was later to become the Nellie Bly is discussed in general and discussion of the Dewey Limestone Lentil was given. The Hogshooter Limestone Member name was proposed.

TABLE I (Continued)

Date	Author(s)	Summary of Work
1914	D.W. Ohern	In his unpublished manuscript, Geology of the Nowata and Vinita Quadrangles, Ohern proposed and named the Nellie Bly Formation. The type section and stratigraphy were discussed as well as that of the bounding formations.
1922	White, et al.	Mapped Osage County for the USGS. The Nellie Bly was interpreted to be deltaic in origin.
1925	C. N. Gould	First published map of the Nellie Bly Formation.
1928	Beckwith	Described the Nellie Bly Formation in Osage County.
1928	Carpenter	Described the Nellie Bly formation in Washington County.
1930	Cloud	Described briefly the Nellie Bly Formation in Tulsa County.
1934	Miller and Cline	First major faunal study of the Nellie Bly was published. Fossils from an outcrop west of Sand Springs were described in detail.
1936 1937	Oklahoma Geological Survey	As part of the WPA Project No. 65-65-538, shales and sandstones of the Nellie Bly were studied for their economic benefits and applications.
1937	Moore, et al.	During the 11th Annual Field Conference of the Kansas Geological Society, the definition and classification of the Missourian subseries of the Pennsylvanian Series in northeastern Oklahoma was studied. The Skiatook name was raised to group status and the Hogshooter, Nellie Bly, and Dewey were correlated (miscorrelated?) with formations in Kansas.

TABLE I (Continued)

Date	Author(s)	Summary of Work
1940	M. C. Oakes	In OGS Bull. 62 - Washington Co., the Nellie Bly was studied, mapped, and outcrops are listed.
1952	M. C. Oakes	In OGS Bull. 69 - Tulsa Co., the Nellie Bly was studied and mapped. Its geometry throughout the county was discussed.
1954	H. D. Miser	Mapped the Nellie Bly on the state geologic map.
1954	W.E. Gardner	In his master of science thesis on the Barnsdall area, Gardner mapped and described the Nellie Bly in portions of Osage County.
1957	J.B. Carl	In his master of science thesis on the Black Dog area, Carl mapped and described the Nellie Bly in portions of Osage County.
1959	M. C. Oakes	In OGS Bull. 81 - Creek Co., the Nellie Bly was studied and mapped.
1959	L.D. Perry	Studied the petrography of the Nellie Bly Formation in northeastern Oklahoma.
1962	A. G. Unklesby	In OGS Bull. 96 - Pennsylvanian Cephalopods, fauna of the Nellie Bly were mentioned.
1965	Cronoble and Mankin	In their study of the Hogshooter Limestone of Washington and Nowata counties, they noted the lateral geometry of the Hogshooter and that down dip shales assigned to the Nellie Bly are probably Hog-shooter equivalents.
1972	A. P. Bennison	Tulsa's Physical Environment. The Nellie Bly Formation was discussed and mapped.
1974	Cocke and Strimple	In their study of algae and corals in Missourian Rocks, they

TABLE I (Continued)

Date	Author(s)	Summary of Work
		discussed the Nellie Bly and mentioned the possible miscorrelation of the upper Nellie Bly by Oakes (1940).
1984	A. P. Bennison	Discussed recent field work and possible miscorrelations of the Nellie Bly Formation. Also, discussed were interpretations of Oklahoma clastics in view of midcontinent cyclothems.
1985	A. P. Bennison	The early Missourian Skiatook Group trough-to-shelf sequence in Oklahoma and Kansas was discussed.

CHAPTER III

GEOLOGIC SETTING

"The cyclic..Pennsylvanian..rocks of the Midcontinent are the product of complex and intricate interaction between tectonism and sedimentation" (Rascoe and Adler, 1983).

Stratigraphic Framework of the Missourian Series Skiatook Group

Pennsylvanian age rocks constitute a significant portion of the stratigraphic record in northeastern Oklahoma. In trying to study this thick sequence of rocks, geologists have found it necessary to divide the Pennsylvanian System in the midcontinent area into five series. These include:

Virgilian Series (youngest)
Missourian Series
Desmoinesian Series
Atokan Series
Morrowan Series (oldest)

The Missourian Series of northeastern Oklahoma is divided into the Ochelata Group (younger) and the Skiatook Group (older).

The Skiatook Group, as defined by Ohern (1914) and modified by Moore (1937), includes beds from the base of the Missourian Series to the base of the Chanute Shale. The formations which make up the Skiatook Group include:

Dewey Limestone (youngest)
Nellie Bly Formation
Hogshooter Limestone
Coffeyville Formation
Checkerboard Limestone
Seminole Formation (oldest)

Seminole Formation

Taff (1901) proposed the Seminole name for rocks exposed in the southeastern portion of the Seminole Nation (County). Originally called the Seminole Conglomerate, the Seminole Formation is applied to rocks lying above the unconformity at the base of the Missouri Series and below the base of the Checkerboard Limestone.

Checkerboard Limestone

The Checkerboard Limestone was defined by Gould (1925) for its exposure along Checkerboard Creek in Okmulgee County, Oklahoma. The Checkerboard is a thin limestone with a large areal distribution. Its distinctive log characteristics have made it a very useful marker bed in subsurface studies.

Coffeyville Formation

The Coffeyville Formation was named by Schrader and

Hayworth (1906) for exposures near Coffeyville, Kansas. The Coffeyville is underlain by the Checkerboard Limestone and overlain by the Hogshooter Limestone. The Coffeyville is a clastic unit composed of shales, siltstones, and sandstones.

Hogshooter Limestone

The Hogshooter Limestone was named by Ohern (1910) for exposures along Hogshooter Creek in Washington County. It is bounded below by the Coffeyville Formation and above by the Nellie Bly Formation. Four members constitute the Hogshooter Limestone. They are:

Winterset Limestone Member
Stark Shale Member
Canville Limestone Member
Lost City Limestone (restricted to type locality near Sand Springs, Ok)

From its type locality proceeding southward, the Hogshooter becomes thin to discontinuous making it hard to recognize on the surface and in the shallow subsurface. Cronoble and Mankin (1965) studied the Hogshooter in great detail in Washington and Nowata Counties, Oklahoma. The Lost City Limestone Member was named by Ohern (1910) for a thick algal mound near Lost City (Sand Springs, Oklahoma) and this member crops out for approximately 14 linear miles across parts of Creek, Osage and Tulsa Counties.

Nellie Bly Formation

The type section for the Nellie Bly Formation, as defined by D.W. Ohern (1914), is along Nellie Bly Creek located just southwest of Ramona, Oklahoma in Sections 28, 29, 31, 32, T. 24 N., R. 13 E. Ohern's original description (unpublished manuscript) of the formation follows:

> The Nellie Bly formation lies between the top of the Hogshooter limestone and the base of the Dewey limestone and underlies the Dewey with local unconformities in the northern part of the Nowata quadrangle...The Nellie Bly formation consists of alternating shales and hard gray to brown sandstones, the latter ranging in thickness from a few inches to several feet.

Dewey Limestone

Named by Ohern (1910) for exposures in a quarry near Dewey, Oklahoma, the Dewey Limestone is an algal mound limestone. The Dewey is underlain by the Nellie Bly Formation and overlain unconformably by the Chanute Formation.

Tectonic Framework and Paleogeography

The Pennsylvanian Period in Oklahoma was a time of major tectonic activity. Tectonism during the Mid-Pennsylvanian Wichita Orogeny created several features which influenced subsequent depositional patterns. Collision of the North American plate with the South American plate during the Early Pennsylvanian time produced the Quachita foldbelt. This collision was also responsible for increased subsidence of the Arkoma Basin. The Quachita foldbelt in Arkansas and southeastern Oklahoma provided a source of clastic material during Missourian time (Figure 3). The Arkoma Basin provided a major depocenter for thick clastic deposits.

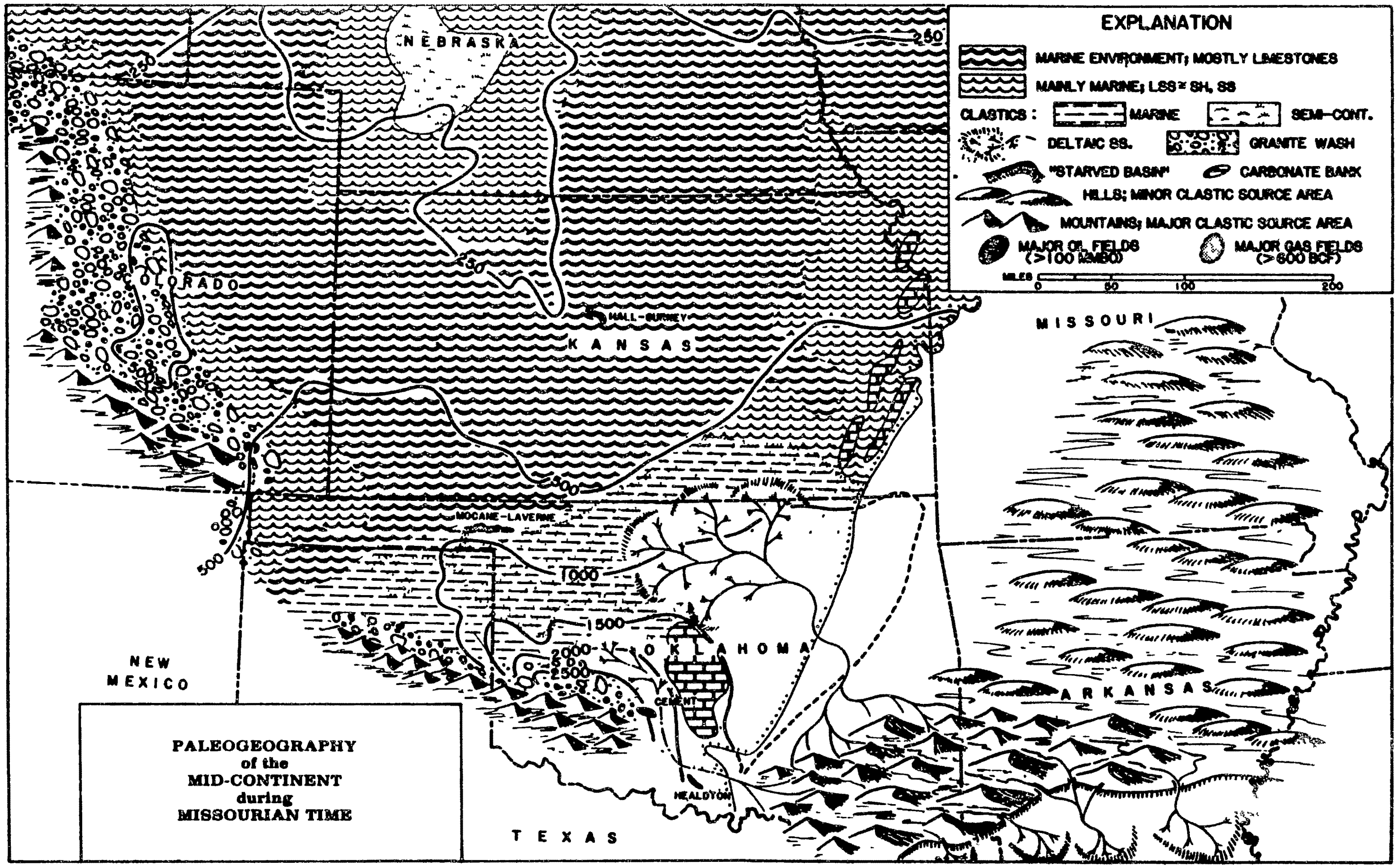

Figure 3. Missourian Paleogeography of the midcontinent region (from Rascoe and Adler, 1983).

CHAPTER IV

SURFACE GEOLOGY

Methods and Problems

The surface investigation was conducted to assist the author in understanding the geology of the Nellie Bly Formation. In studying the geology and characteristics of the Nellie Bly outcrop, valuable information was gained and used to interpret the subsurface portion of the Nellie Bly. Observations made at the surface allow the geologist to examine details too minute to be detected by subsurface methods, yet extremely vital in facies analysis. Lateral changes on an outcrop can provide information about bed geometry which cannot be seen in a borehole. Field observations by this author and surface geologic maps prepared by others have been studied to facilitate knowledge about the Nellie Bly Formation as it applies not only to the study area, but also to the surrounding area (Figure 4).

The study of the Nellie Bly on the surface was hindered by a several problems. Owing to the relatively low relief in the northern area, outcrops are generally found in stream beds, drainage ditches or rare roadcuts. The only continuous exposure of the Nellie Bly Formation is found in

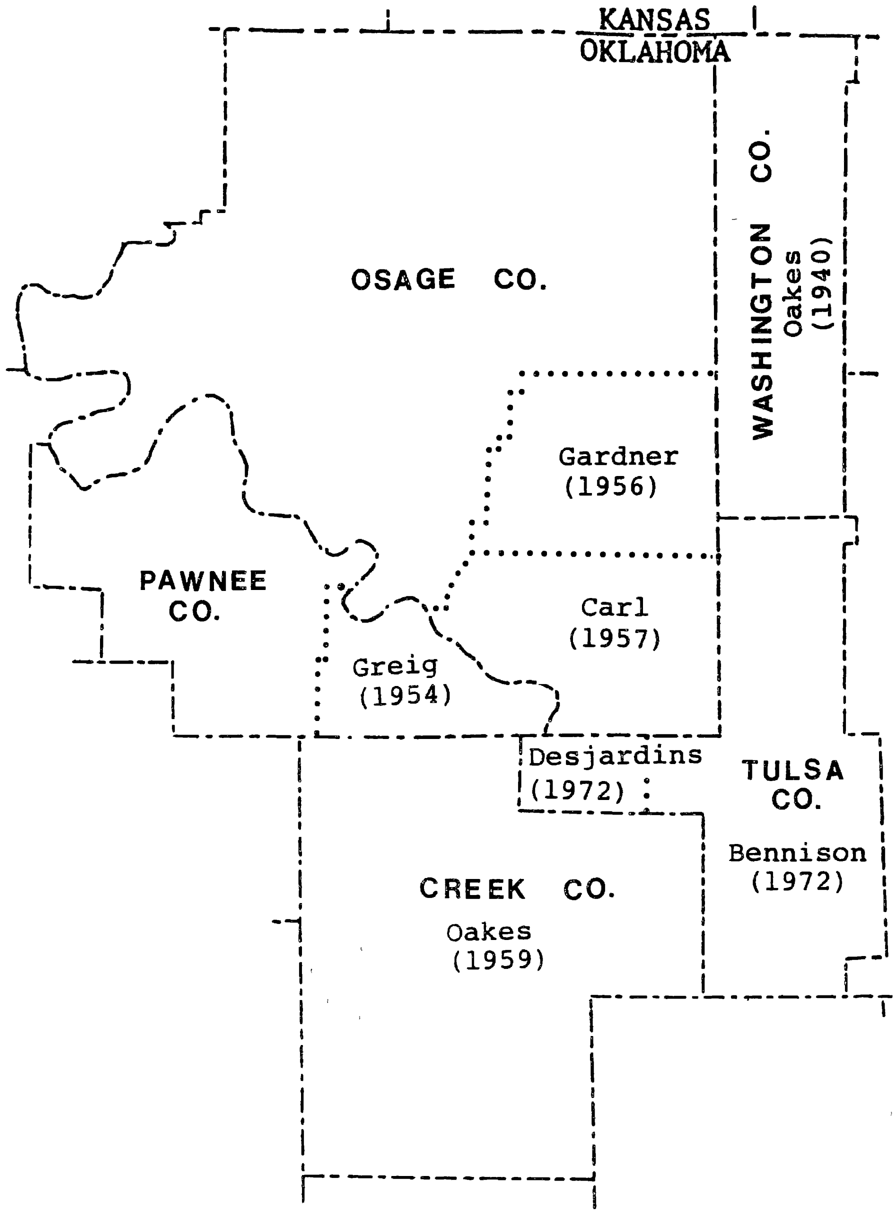

Figure 4. Index to authorship of surface geologic maps in study area.

the vicinity of the type section. In the southern portion of the study area, outcrops are better, yet limited in number. Due to high relief and distances between exposures, correlation is difficult.

Surface Stratigraphy

In northeastern Oklahoma, the outcrop of the Nellie Bly Formation varies in width from less than one kilometer up to several kilometers. The outcrop belt (Figure 5) extends southwestward from the Kansas-Oklahoma border through Washington County, the southeastern portion of Osage County, the western portion of Tulsa County, and into Creek County. Figure 6 is a schematic surface cross section of the Nellie Bly Formation in northeastern Oklahoma.

Along the Kansas - Oklahoma border, the Nellie Bly was almost completely removed by pre-Chanute erosion. Only about 4.5 m (15 feet) of shale separate the Hogshooter Limestone from the Dewey Limestone (Ohern, 1914).

Oakes (1940) reported a complete section of the Nellie Bly along the south side of Sec. 19, T. 28 N., R. 15 E. where it is 24 m (80 feet) thick. The lower 8 m (25 feet) is clayey shale. The next 14 m (45 feet) grades from a shale below to a sandstone above. The top 3 m (10 feet) is a fine to medium grained, reddish brown, moderately thick-bedded sandstone. In the NW 1/4, Sec. 28, T. 29 N., R. 15 E. the formation is approximately 20 m (60 feet) thick and consists entirely of a clay shale.

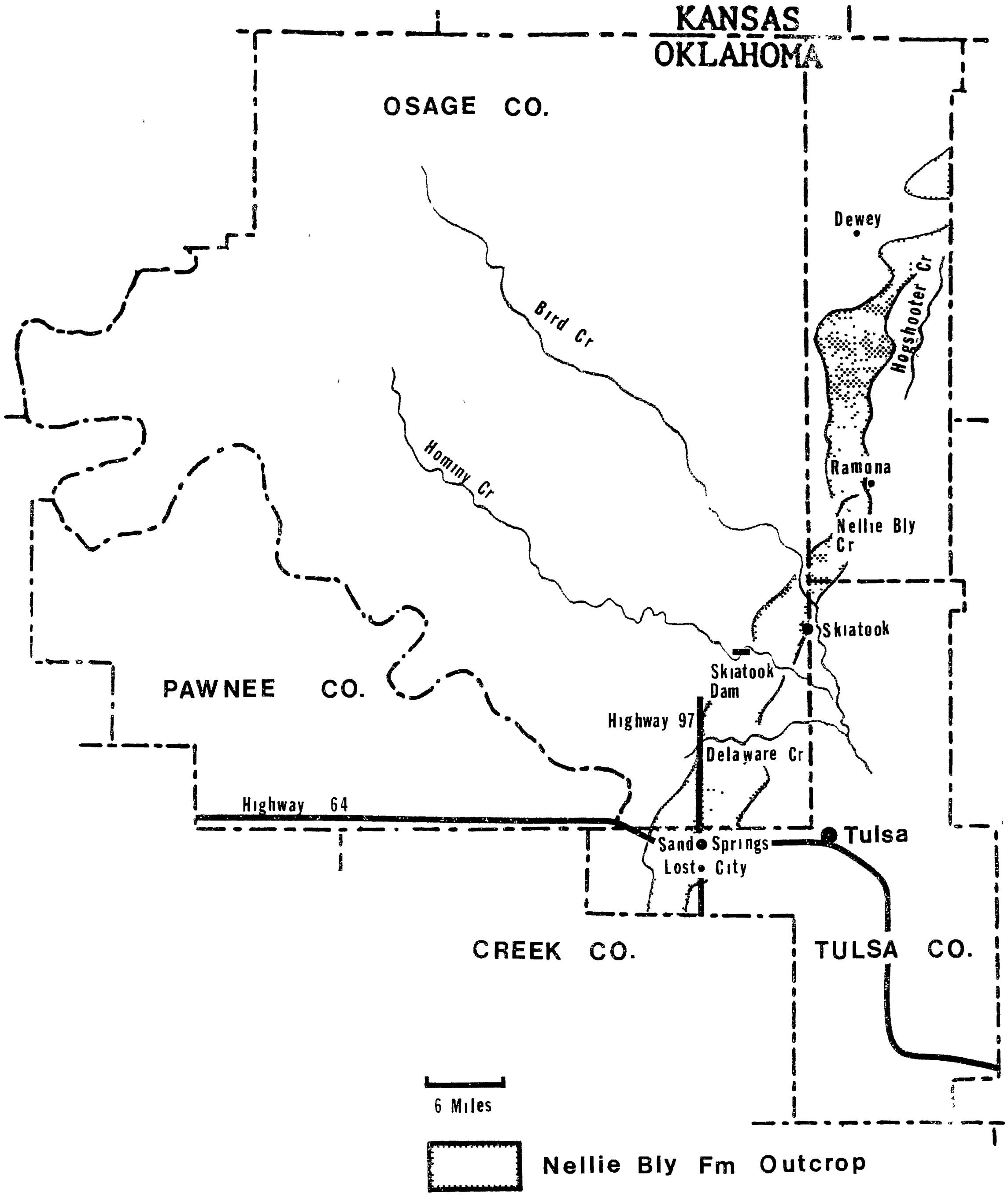

Figure 5. Outcrop belt of the Nellie Bly Formation in northeastern Oklahoma.

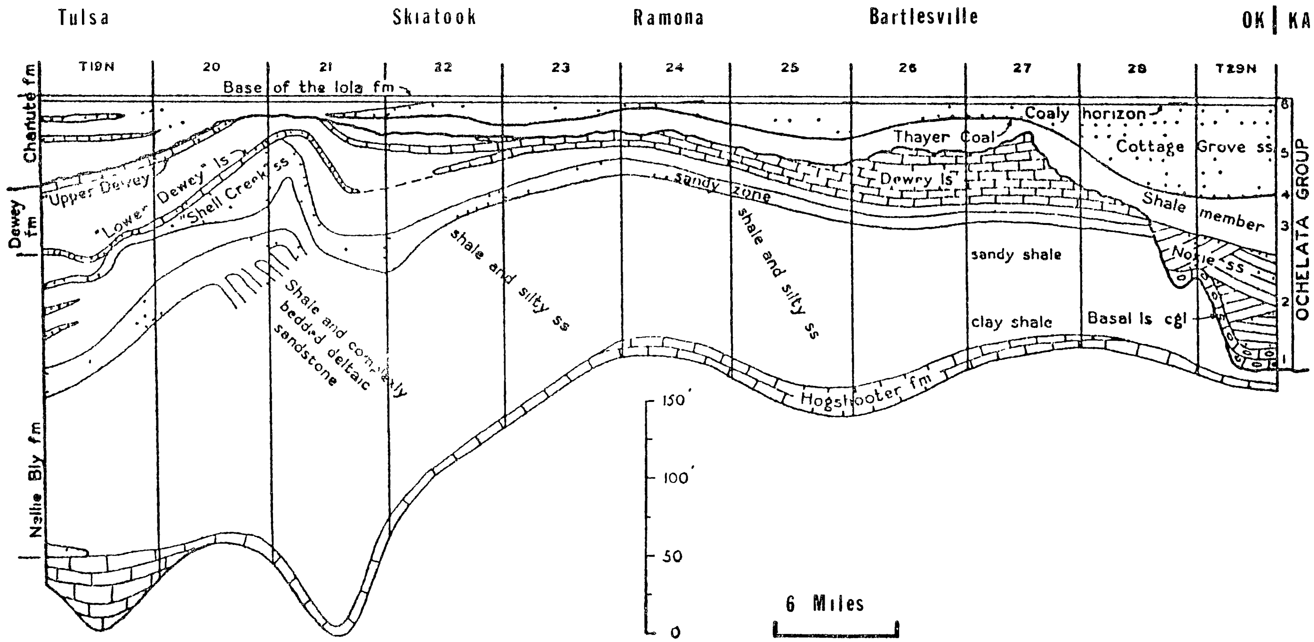

Figure 6. General Surface North-South Cross Section of the Nellie Bly through Iola Interval in Northeastern Oklahoma (modified from Oakes, 1952).

The Nellie Bly thickens to about 30 m (100 feet) in T. 27 N., R. 14 and 15 E. The lower part is clay shale which changes upward to a sandy shale, with thin silty sandstone beds. Bloesch (1935) reported that the Dewey Limestone rests on black, fissile, carbonaceous shale of the Nellie Bly Formation in Sec. 10, 11, and 15, T. 27 N., R. 14 E.

In Township 26 North, Oakes (1940) reported that the formation is 35 m (115 feet) thick, on the average. It is sandy and silty with thin-bedded, silty sandstones in the upper part.

The Nellie Bly Formation is estimated to be 43 m (140 feet) thick in T. 25 N., R. 13 E. and is composed of sandy, silty shale with minor amounts of thin-bedded, fine-grained to silty sandstone (Oakes, 1940).

Township 24 North

In the central portion of Township 24 North, alluvium covers the Nellie Bly Formation. Thickness of the Nellie Bly Formation in this area is 35 m (115 feet). The lower 12 m (40 feet) and upper 6 m (20 feet) are silty shale; the middle part, about 17 m (55 feet), is silty to sandy shale and thin bedded, silty sandstone (Oakes, 1940). The type locality has rather limited and poor exposures. However, 8 m (26 feet) of the Nellie Bly is well exposed, approximately 1.6 km (1 mile) north of the type section along the road west of Ramona (West 1/4 Corner, Sec. 28, T. 24 N., R. 13 E.). Along the north side of the road (in pit) are noncalcareous clay shales interbedded with thin sandstones (Figure 7). The contact between the two is very sharp but non-erosional (no shale clasts were observed in the overlying sandstones). No macro-fossils were observed on the outcrop. Basal Parts of all the sandstones were heavily burrowed (Figure 8). The sandstone beds average 5 cm (2 inches) thick and are laterally continuous. Upper surfaces of sandstones are ripple marked and have minor amounts of trace fossils. Evidence of a small channel is in the upper portion of the outcrop (Figure 9). The upper portion of this outcrop grades into a silty-shale to a shale.

Township 23 North

The contact between the Nellie Bly and the underlying Hogshooter is poorly exposed south of the type section along the east-west road 1/2 km (0.3 miles) west of the SE 1/4 Corner, Sec. 21, T. 23 N., R. 13 E. At this location, the Hogshooter has been reduced in thickness to 15 cm (6 inches). The reduction and near disappearance of the Hogshooter at this latitude makes it extremely difficult to locate this unit.

The contact between the Nellie Bly and the overlying Dewey Limestone is well exposed 1.6 km (1 mile) to the west (SE 1/4 Corner, Sec. 20, T. 23 N., R. 13 E.), (Figure 10). At this locality, the upper Nellie Bly consists entirely of non-calcareous clay shale. Approximately 3 m (9 feet) of shale are exposed. The lower 1.5 m (4.5 feet) of the

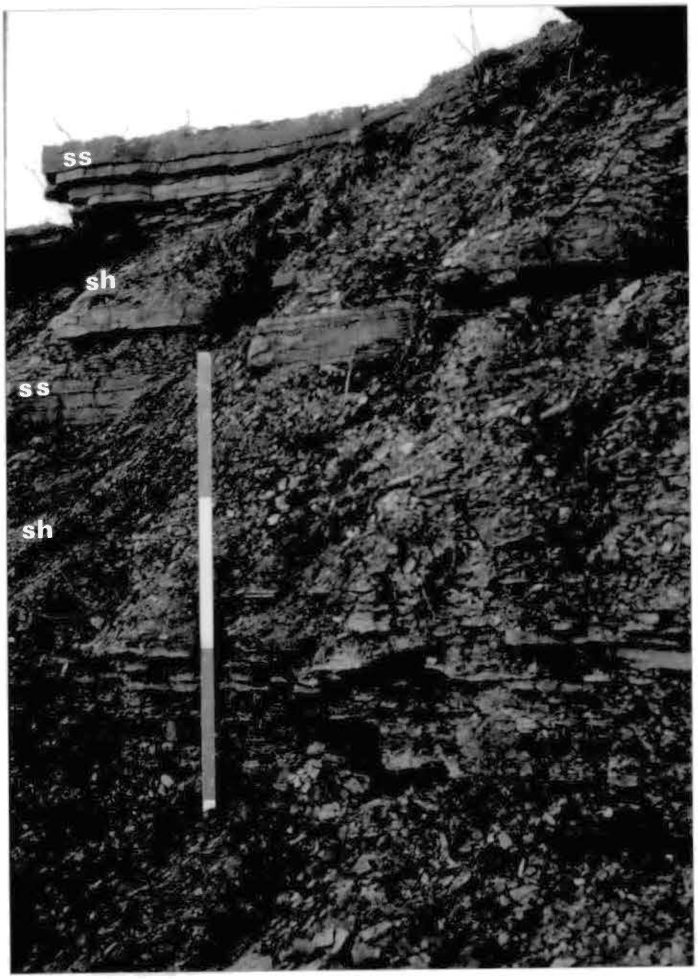

Figure 7. Outcrop of Nellie Bly Shale with Thin Interbedded Sandstones - West 1/4 Corner, Sec. 28, T. 24 N., R. 13 E. (Jacob Staff 1.5 m).

Figure 8. Trace fossils on base of Nellie Bly sandstone bed - West 1/4 Corner, Sec. 28, T. 24 N., R. 13 E.

Figure 9. Small channel sandstone in Nellie Bly Formation - West 1/4 Corner, Sec. 28, T. 24 N., R. 13 E. (Jacob Staff 1.5 m).

Figure 10. Upper Nellie Bly shale and overlying Dewey Limestone - SE 1/4 Corner, Sec. 21, T. 23 N., R. 13 E. (Jacob Staff 1.5 m).

outcrop consists of a gray to dark gray, non-macrofossiliferous, non-calcareous clay shale. The shale grades upward to tan, non-macrofossiliferous, non-calcareous shale. The contact between the Nellie Bly shale and the Dewey Limestone is sharp.

Township 22 North

Alluvium from Hominy and Bird Creeks covers much of T. 22 N. and thus obscures any exposure of the Nellie Bly except for the uppermost parts in contact with the Dewey Formation. Skiatook Dam was constructed on the Hominy Creek floodplain and was built upon the uppermost shales of the Nellie Bly. Corehole data obtained from the U.S. Army Corps of Engineers (Figure 11) indicates that the upper 40 feet of the Nellie Bly consist mainly of shale with a few thin sandstones. Corehole data was used to calculate the structural dip of beds in the area. From Skiatook southward, the outcrop of the Nellie Bly widens considerably.

Township 21 North

In Township 21 North, a distinct change in topographic expression is the first indication of a major change in the Nellie Bly Formation. Southward, there is an increase in the abundance and thickness of sandstone beds. One outcrop, located along Highway 97 and Delaware Creek (NE 1/4, Sec. 33, T. 21 N., R. 11 E.), exhibits depositional

GEOLOGICAL LOG HOLE NO. 121

SKIATOOK DAM SITE	SHEET 1 OF 3 SHEETS
LOCATION Sta 35+46, Tangent Line	SIZE OF CORE NX
ELEV SURFACE 724.6	WATER TABLE ELEV. 635.1 (10/15/76)
ELEV TOP OF ROCK 721.8	DRILLED BY C of E
ELEV BOTTOM OF HOLE 528.7	DRILLING DATES 5-12 Oct 76

ELEVATIONS	DEPTH	SCALE	SYMBOL	DESCRIPTION OF MATERIALS	REMARKS
724.6				Surface	
721.8	2.8			TOP OF ROCK	
622.8	101.8			SHALE, as above	
615.9	108.7			LIMESTONE, mod hard to hard, grainy, thin shale partings, gray. Very shaley 101.8' - 104.1', 106.0' - 108.5' Coal seam, brittle, broken, black 108.5'-108.7'.	
602.1	122.5	120		SANDSTONE, mod hard, fine grained, numerous thin, shale streaks & seams, gray. 0.4' Core loss (101.4' - 111.4') dist SHALEY, 121.5' - 122.5'	
582.9	141.7	130, 140		SHALE, mod hard, calcareous with scattered phosphatic nodules, dark gray. 0.3' Coal seam pyritic, black 123.2 - 123.5 1.2' Core loss (123.2' to 130.7') dist Joints, low angle, slickensided 123.7'-135.1' greenish-gray zone, 133.1' - 135.1'	
576.1	148.5			LIMESTONE, hard, shaly, fossiliferous, gray to dark gray.	DEWEY LIMESTONE
536 0	188.6	150, 160, 170, 180		SHALE, hard, massive bedded, dark gray to black. Some scattered phosphatic nodules. Joint, high angle, clean, 56.7' - 57.7' Joints, high angle, clean, 165.4' - 166.3' 168.0' - 169.0'	NELLIE BLY FORMATION
528 7	195.9	190		SANDSTONE, mod hard to hard, numerous shale streaks and bands, gray to dark gray	
				BOTTOM OF HOLE	

Figure 11. Core log of Upper Nellie Bly and Dewey Limestone in vicinity of Skiatook Dam (modified from U.S. Army Corps of Engineers, 1978).

characteristics not observed to the north. The outcrop is composed of alternating dark gray shales and thin-bedded rippled-marked sandstones (Figure 12 and 13). Shales contain abundant small wood and plant fragments not observed in shales to the north. The sandstones are gray to tan, very fine grained. Upper and lower surfaces on many of the sandstones are ripple marked and wavy. The ripples are slightly asymmetrical. The surfaces of the sandstones contain numerous trace fossils. Another feature not observed in outcrops to the north is the curved, nonparallel bedset surfaces (Figure 14). The angle of contact and the lateral width of these discordant units varies.

The Nellie Bly consists of shales, siltstones, and sandstones; however, a thin limestone has been found at one locality. Colloquially called the "Turley Mountain Stray Limestone" (exposed along road on north side of Turley Mountain in Sec. 36, T. 21 N., R. 12 E.), this limestone occurs 7 m (21 feet) above the Hogshooter. The limestone is 0.3 m (1 foot) thick and consists of crinoids and brachiopods.

One other limestone has been reported (Cocke and Strimple, 1974) to occur in the upper Nellie Bly Formation. This limestone, locally known as the "Cowbarn Limestone," crops out in Township 21 North. Confusion has risen over whether it is part of the overlying Dewey Limestone in the upper part of the Nellie Bly Formation. Oakes (1952) included the "Cowbarn Limestone" in the Dewey Limestone.

Figure 12. Alternating dark gray-to-black shales and thin-bedded sandstones - NE 1/4, Sec. 33, T. 21 N., R. 11 E. (Jacob Staff 1.5 m).

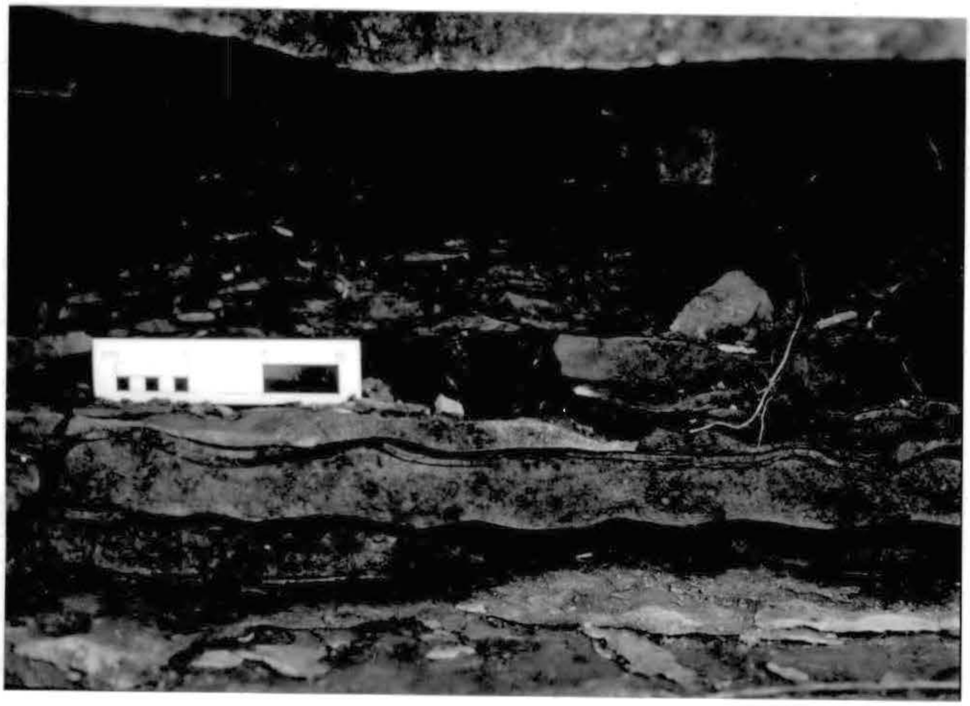

Figure 13. Thin-bedded, ripple-marked sandstone - NE 1/4, Sec. 33, T. 21 N., R. 11 E.

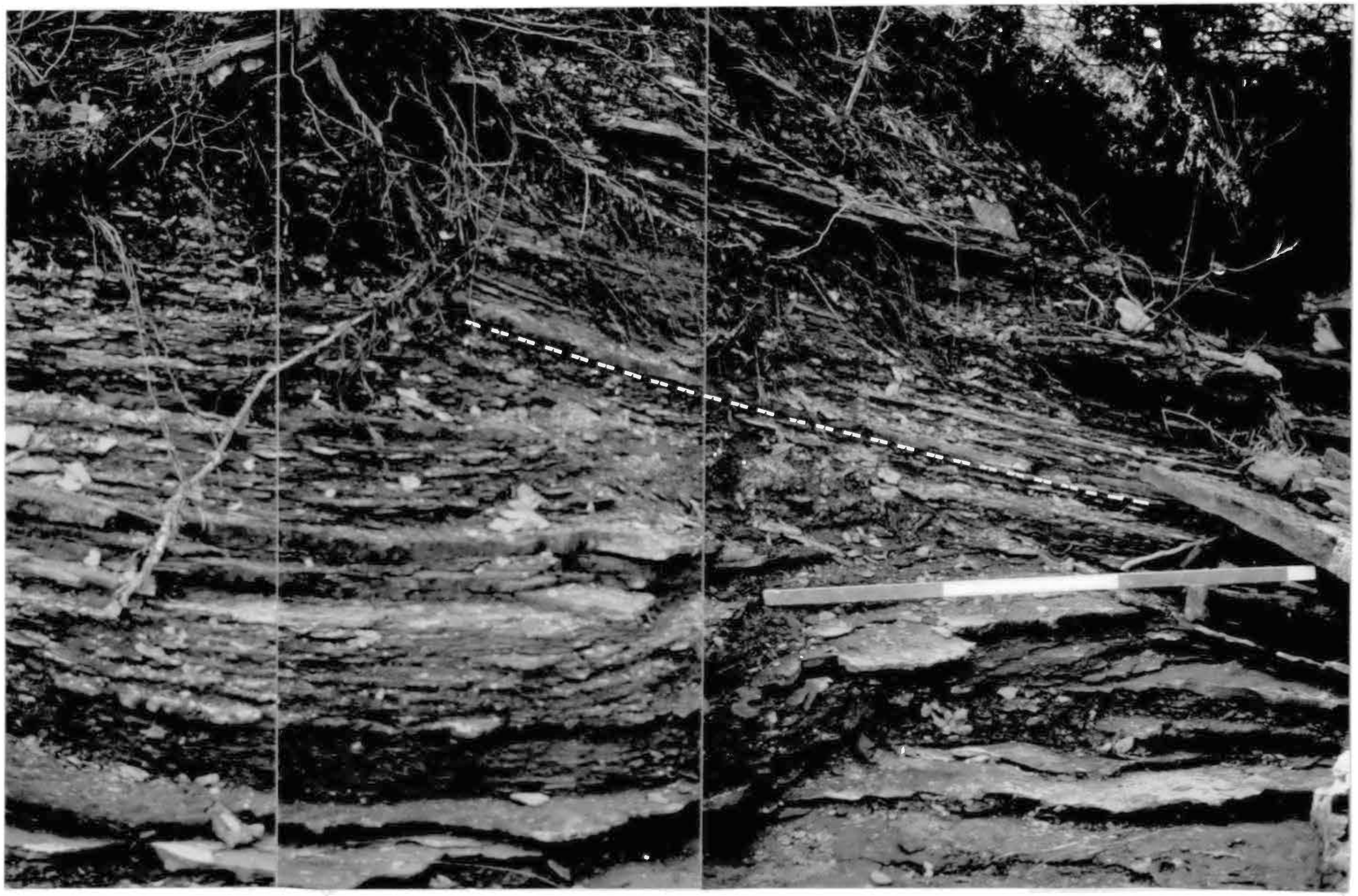

Figure 14. Curved, nonparallel, bedset surface between gray to black thin-bedded siltstones and sandstones - NE 1/4, Sec. 33, T. 21 N., R. 11 E. (Jacob Staff 1.5 m)

However, Cocke and Strimple (1974) believe that the "Cowbarn Limestone" and overlying shale should be assigned to the upper Nellie Bly Formation.

Township 20 North

The outcrops in Township 20 North continue to exhibit the southward increasing abundance and thickening of the sandstone beds. The hills in this region are capped by the sandstones. Correlation is extremely difficult owing to the considerable relief of the area.

Township 19 North

Sandstone deposits of the Nellie Bly Formation are abundant in Township 19 North. Thick sequences of thin to massive bedded sandstones can be observed (Figure 15) in an outcrop located at Highway 64 (SE 1/4, Sec. 5, T. 19 N., R. 11 E.). The beds range from 1 cm (0.4 inch) to greater than 1 m (3 feet) thick. Bedform structures are variable in the outcrop. Convoluted, lenticular sandstones overlie unaltered laminated sandstones (Figure 16). These lenticular beds are, in turn, overlain by laminated sandstone beds with ripple marked surfaces. Most of the sandstone beds in the lower portion of the outcrop are truncated laterally. Plant and wood fragments were observed in the underlying shales.

The contact between the Nellie Bly Formation and the underlying Hogshooter Limestone (= Lost City Limestone) is

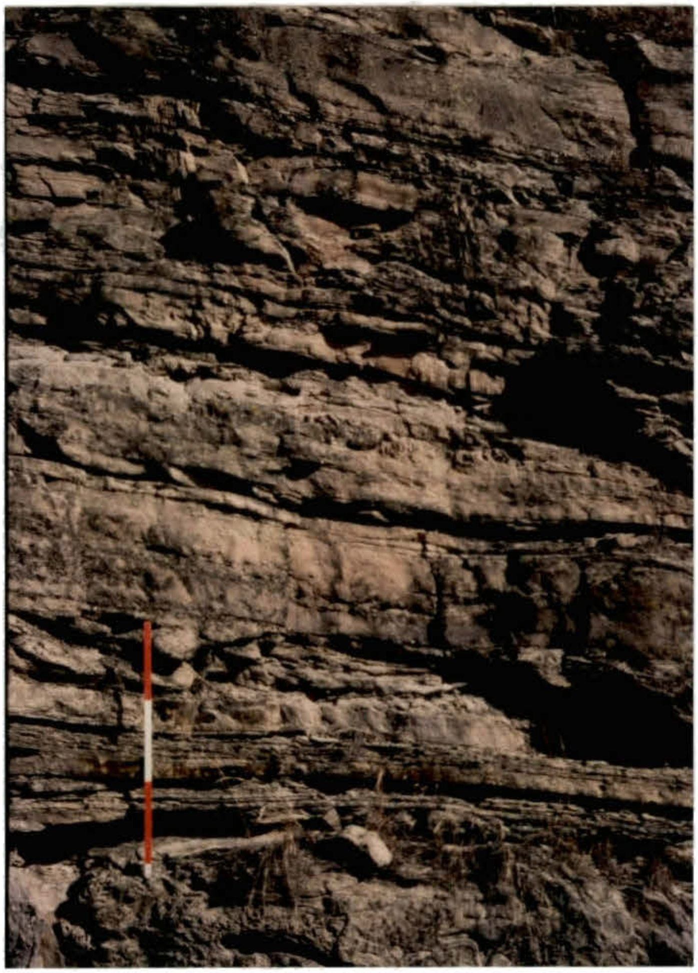

Figure 15. Thin-to-massive bedded sandstones - SE 1/4, Sec. 5, T. 19 N., R. 11 E. (Jacob Staff 1.5 m).

Figure 16. Convoluted, lenticular channel sandstone overlying laminated sandstone beds - SE 1/4, Sec. 5, T. 19 N., R. 11 E. (Jacob Staff 1.5 m)

exposed along the road in the North 1/2 of Sec. 6, T. 19 N., R. 12 E. (Figure 17). At this latitude, the contact between the Nellie Bly Formation and Hogshooter Limestone is easily determined on the surface and in the subsurface.

Figure 17. Base of Nellie Bly Formation and top of Hogshooter Limestone - N 1/2, Sec. 6, T. 19 N., R. 12. E (Jacob Staff 1.5 m).

CHAPTER V

SUBSURFACE GEOLOGY

Method and Problems

The subsurface study was conducted to determine the geometry of the Nellie Bly Formation and to understand better its depositional environments. Although surface observations allowed detailed examination of rocks, there are limitations with which a subsurface study is better suited. Determining lateral extent and geometry of units in the Nellie Bly Formation outcrop is complicated by limited distribution and noncontinuous sections. Subsurface data such as that provided by wells allows the geologist to see complete stratigraphic sections in three dimensions.

Several problems encountered in the mapping and correlation study should be mentioned. In Oakes' study of Creek Co. (1959) problems were encountered in the surface-to-subsurface correlation of strata. Jordan (1959) reported:

> The formations above the Hogshooter consist of lenticular sandstones and shale although locally impure sandy limestone and dolomite strata are present. These formations, Nellie Bly upward .... are difficult to follow on the surface .... and therefore it is not surprising that their projection into the subsurface is complicated

> where electric log and sample logs are used. Normally a recorded electric curve of a formation is two to three miles west of the surface outcrop and the electrical character of the curve may be affected by the presence of fresh water in near surface sandstone.

The problems described above were encountered in varying degrees. The first problem was to find usable well logs close to the outcrop. This problem was partially circumvented by finding wells located at high elevations (i.e. on top of hills) near the outcrop. Log availability presented another problem. While there are many wells located in the thesis area, the number which were logged is considerably less. Of the number which were logged, even fewer had logs released to the state and log libraries.

Approximately 360 logs were used in this study. The logs used in this study consisted of two types: 1) Spontaneous Potential/Electric logs and 2) Gamma Ray Induction logs. The SP/E-log suite is the more common. The SP/E-logs presented several problems. As mentioned by Jordan, fresh water can affect the SP and resistivity curves. Deflection of the SP curve from a shale baseline is used sometimes to infer the presence of sandstone or limestone beds. When the resistivity of fresh water equals the resistivity of mud filtrate, the SP curve will not deflect from the shale baseline.

A closed loop of stratigraphic cross sections was constructed throughout the area of the subsurface study. Two north-south cross sections and six east-west cross sections were constructed (Figure 18) with wells spaced approximately three miles apart. Three wells and one core were used to define upper and lower boundaries in the subsurface. Two type-section logs from the Tulsa Geological Survey were used in defining the interval. The Tulsa Geological Survey Mannford type-section log is included in cross section A-A′ and H-H′. Data obtained from a core hole adjacent to the outcrop and near a subsurface well was used to assist in picking the Dewey contact. At the type locality of the Nellie Bly Formation, the bounding formations are fairly distinct and well developed. However, these bounding formations as well as the Nellie Bly Formation itself, undergo tremendous changes when traced laterally, both on the surface and the subsurface. Where the Dewey Limestone and Hogshooter Limestone are not developed, correlations are tentative and based upon the interval above and below the horizon.

Cross Sections

<u>Cross Section A-A′</u>

Section A-A′ (Plate 1) is one of two North - South stratigraphic cross sections sub-parallel to the outcrop. The southernmost portion is in Township 19 North, Range 9 East and it extends northeastward to Township 24 North, Range 10 East. The southernmost well is the same well used by the Tulsa Geological Society for the North Central Creek County Mannford Area type log. The stratigraphic section is

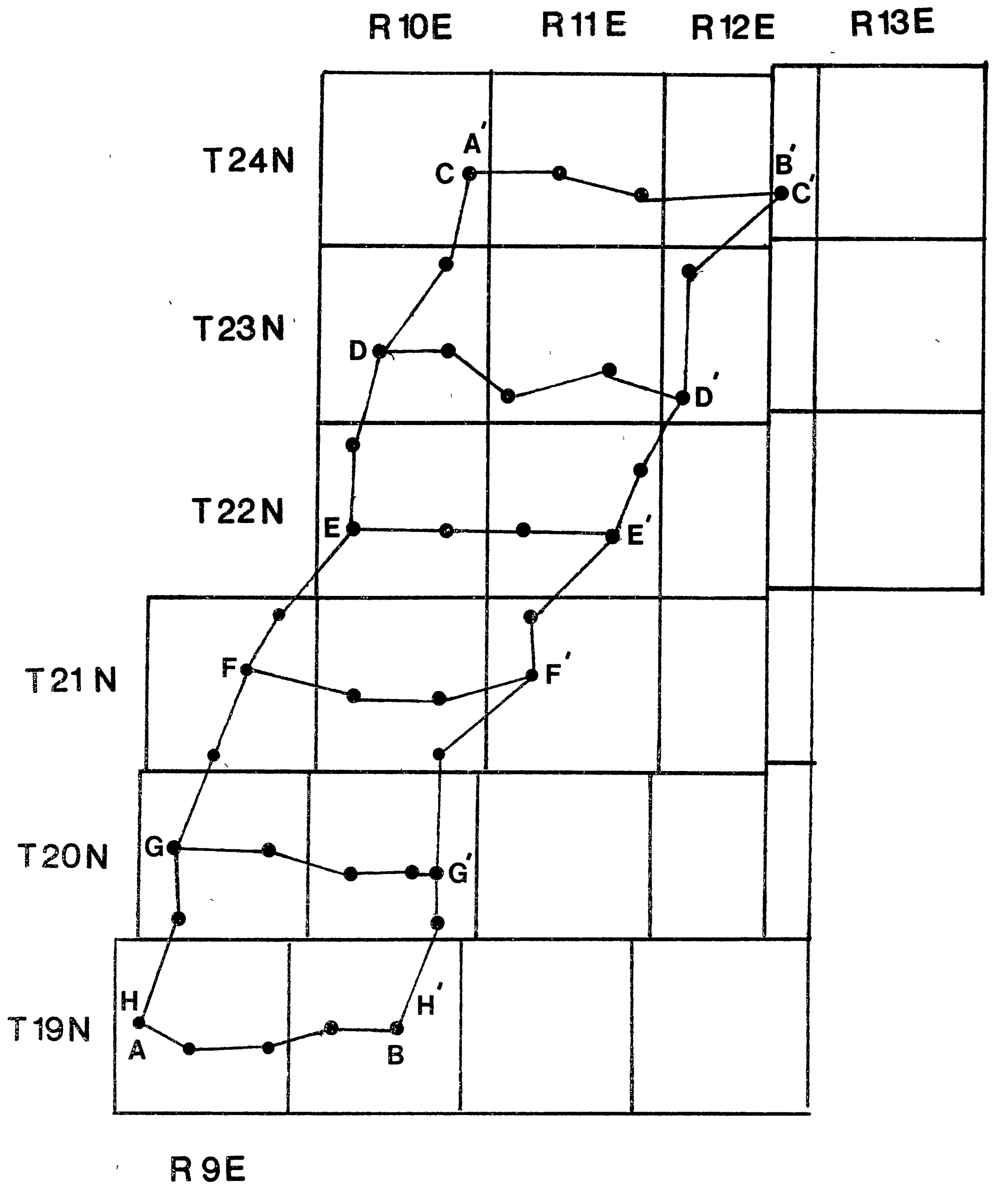

Figure 18. Cross Section Location Map

hung on the base of the Dewey Limestone. The Nellie Bly thickens southward approximately 134 feet thick in Sec. 24, T. 24 N., R. 10 E. to about 170 feet in Sec. 15, T. 21 N., R. 9 E. From this point southward there is an abrupt increase in thickness to approximately 400 feet in Township 19 North.

Cross Section B-B′

Section B-B′ (Plate 1) parallels A-A′ and the outcrop of the Nellie Bly. It lies approximately 7 miles to the east of A-A′ and 5 miles to the west of the outcrop. This section was the first major correlation with which any connection to the outcrop could be made. The B-B′ section shows trends of thickening similar to Section A-A′ and the outcrop (Figure 6). The northernmost well is closest to the type locality of the Nellie Bly Formation. The Dewey Limestone and the Hogshooter Limestone, which are recognizable in the area, are easily detected on the logs. The formation is approximately 160 feet thick in this area. The formation thickens to Sec. 17, T. 21 N., R. 11 E. where it is 180 feet thick. From this point southward, there is a dramatic thickening in both the outcrop and subsurface. The Nellie Bly Formation is 340 feet thick in Sec. 35, T. 20 N., R. 10 E. and thins slightly more to the south.

The upper portion of the Nellie Bly Formation in the southern part of the study area contains the thickest sandstone developments. The sandstone zones are thicker than 100 feet. The thick sandstones thin to the north and are still present to the west. The Hogshooter Limestone is developed quite well in the northern portion of the study area and at the very southern edge of the study area (as the Lost City Limestone). However, its occurrence is somewhat vague to sporadic in the central portion of the study area.

Cross Section C-C′

Section C-C′ (Plate 2) is one of six east-west cross sections, the end wells of which tie in with the two north-south cross sections. This section and other east-west sections show similar stratigraphic thickness in an east-west direction as opposed to the increase from north to south. The Nellie Bly is 130 to 160 feet thick along Township 24 North. The Hogshooter and Dewey Limestones form good boundaries. The base of the Nellie Bly is basically a shale while the upper part is more silty.

Cross Section D-D′

Section D-D′ (Plate 2) is located along Township 23 North. It is approximately 6 miles south of C-C′. The Nellie Bly is 150 feet thick. The basal portion of the section is a shale that grades upward to a silty/sandy zone in the upper portion. Section D-D′ is very similar to C-C′. Sandy/silty zones are a little better developed in the east than they to in the west.

Cross Section E-E′

Section E-E′ (Plate 2) trends across Township 22 North. Thickness of the formation varies from 140 to 180 feet thick. The Dewey Limestone is well developed along the eastern portion of the cross section. Data from nearby core holes provided positive identification of the Dewey in Northwest #23 NE SE SW, Sec. 23, T. 22 N., R. 11 E. The basal portion of Nellie Bly Formation in this well is a sand zone while the middle portion of the log is a shale. The formation grades upward to a silty/sandy zone with a distinct sandstone zone. The uppermost zone consists of shale with a few sandstone stringers.

Cross Section F-F′

Section F-F′ (Plate 3) traverses across Township 21 North. The formation ranges from 200 feet in the East to 170 feet in the west. The formation gradually increases in thickness from north to south. This township is an approximate dividing line with log signatures and characteristics in the north, differing from those to the south.

Cross Section G-G′

Section G-G′ (Plate 3) crosses Township 20 North. This cross section shows the dramatic increase in thickness. The Nellie Bly is approximately 346 feet thick in Sec. 14, T. 20

N., R. 9 E. The western edge of the cross section shows a sandstone free section. Eastward, several sand zones are encountered possibly indicating closer proximity to source areas. The Univ. of OK #1-22 contains thick sequences of non-shale beds.

Cross Section H-H

Section H-H′ (Plate 3) is the southernmost East-West cross section in the study area. The thickest single sand zones encountered in the study are shown on the easternmost log. This sand zone is approximately equivalent to the "Shell Creek Sandstone" of surface usage. The base of the Nellie Bly Formation is at the contact with the Lost City Limestone. The limited areal distribution of the Lost City Limestone can be seen in the cross section; the limestone wedges out between Sec. 21 and Sec. 18, T. 19 N., R. 9 E.

Maps

Structural Contour Map Top of Nellie Bly Formation

A structural contour map (Plate 4) shows the configuration of the top of the Nellie Bly Formation. Beds dip approximately 0.5 to 1.5 degrees (50 to 150 feet per mile) to the northwest. The dominant structural features present include minor domal structures which are also recognized on the surface. Domal structures can be observed in Sec. 32, T. 24 N., R. 11 E., Sec. 9, T. 22 N., R. 11 E., and in Sec. 18, T. 20 N., R. 10 E.

Isopach Map Nellie Bly Formation

The isopach map (Plate 5) of the Nellie Bly was constructed utilizing a well density of 1 well per square mile. Only wells penetrating the whole interval were used. The top of the Hogshooter Limestone defines the base of the Nellie Bly and the base of the Dewey Limestone marks the top of the Nellie Bly Formation. Where either of the bounding formations is not present or indistinguishable, interval correlation was used to approximate the boundary. A contour interval of 10 feet was used. The isopach map reveals the three dimensional geometry of the formation. The study area encompasses a transitional zone of the Nellie Bly Formation. In the northern part of the study area, the Nellie Bly Formation is relatively consistent in thickness with a gradual increase in thickness to the south. The isopach map reveals a zone located in the southern portion of Township 21 North, where the Nellie Bly greatly increases in thickness. From here, the formation increase even more to the southwest. There is a relative thinning of the formation in the southeastern portion of the study area.

The isopach map of the Nellie Bly can also be viewed as a tentative paleostructure map. Several assumptions made allow the validity of this interpretation. Assuming that the Checkerboard Limestone and Hogshooter Limestone were deposited on relatively flat surfaces, the inference can be drawn that the southern portion of the study area subsided more than the northern area. Another assumption is that the Dewey Limestone was also deposited on a relatively flat surface. Consequently, at the end of Nellie Bly Formation time, there was a depositional trough in the south. If the isopach map is viewed with a negative perspective, the upper surface assumed to be flat and thicker sections of the Nellie Bly as being deeper, the shelf area can be seen to the north with a southward dip. A break in the shelf area to a deeper trough can be seen along Township 21 North.

Interpretative Gross Sand Map
Nellie Bly Formation

Mapping the sandstones of the Nellie Bly Formation proved to be a problem. Criteria normally used to map sands were not extremely useful. Shallow fresh water made the SP curve useless to attempt using cutoff values. The relatively few number of GR logs run did not allow widespread use of this tool. The use of resistivity tools to determine gross sand thickness provided some help but were not very effective in discerning thin bedded sandstones. Gross sand values are interpretative.

The gross thickness of sandstones (Plate 6) increases southward. In Townships 23 and 24 North, the gross sand value range from 15 to 30 feet. A local thin occurs along the southern edge of Township 23 North, Range 10 East where the sand disappears. Sand values average 20 to 30 feet in the central portion of the mapped area of Township 22 North. Two areas of thin sand deposits are on either side of the local thick trending northwest to southeast. Township 21 North shows the dramatic southward increase in sand thicknesses. Values exceeding 50 feet occur in a northeast to southwest trend. There continues to be thinning to complete disappearance of sands to the west. Continuing into Township 20 North, the isopach values continue to increase. Township 20 North, Range 10 East has sand values exceeding 70 feet, while 6 miles to the west in Township 20 North, Range 9 East, the values have decreased to only 7 feet. Thick isopach values predominate throughout Township 19 North with values exceeding 100 feet. A localized thin occurs along the township line between Township 19 North, Range 9 East and Range 10 East and Township 19 North and Range 10 East.

CHAPTER VI

DISCUSSION OF SURFACE AND SUBSURFACE FINDINGS

Information obtained from studying the subsurface reveals many things about the Nellie Bly Formation's geometry and depositional setting. Outcrop information reveals similar trend. General characteristics of outcrops were observed and noted to more effectively interpret well log signatures. The north to south increasing thickness of the Nellie Bly Formation was observed in both the subsurface and surface. While potential thickening and thinning could not readily be determined in an east-west direction on the outcrops, subsurface data show an overall equal thickness along east-west traverses. Stratigraphic correlations tend to indicate a structurally low area in the south portion of the thesis area which accommodated a thicker section of rocks.

The region where there is a dramatic increase in the Nellie Bly Formation thickness serves as a demarcation line which separates varying log signature in the subsurface and varying depositional units observed in outcrop. In the northern area, the Nellie Bly Formation is dominated by shales with thin, ripple marked sandstone beds. The beds are laterally continuous on outcrop, and in the subsurface. In the southern area, sandstones exhibit entirely different characteristics than those in the northern area. The sandstones in Townships 19 and 20 North are highly variable in thickness and lateral extent. The beds range from a few centimeters to several millimeters thick. Individual beds are extremely lenticular in nature and truncate other sandstone beds. The noticeable change in sandstone bed/unit geometries coincides at approximately the same latitude where this is a rapid increase in the Nellie Bly Formation isopach (along the southern edge of Township 21 North). The rapid thickening of the Nellie Bly Formation roughly coincides with the increased gross sand trend.

It appears that two dominant depositional environments characterize the Nellie Bly Formation in the study area. A quiet, shallow marine shelf, depositional environment appears to have reigned over the northern portion of the study area. The predominate lithology is gray to tan shales with thin-bedded siltstones and sandstones. The shales are clayey and very micaceous. the presence of: 1) bioturbated and burrowed shales and sandstones, 2) abundant detrital mica, and 3) ripple-marked sandstones with trace fossils on the surfaces is interpreted to represent a low energy depositional environment. Log signatures from wells in the northern portion of the study area also indicate a predominance of shale sequences containing thin sandstone beds (Plate 2 - Cross Section C-C′ Osage, Stapleton #1-M, Cross Section D-D' Messick #2-B, Cross Section E-E' Northwest #23-1). Interpretative gross sand values (Plate 6) are less than 35 feet in Townships 22, 23, and S/2 24 North, Ranges 10, 11, and 12 East.

The southern portion of the study area was the sight of clastic influxes. The sandstone beds are thicker than in the north. Log signatures in Township 19 North indicate an influx of clastics from east to west. The Peoples #1 Sec. 15, T. 19 N., R. 10 E., (SE NE NW) on cross section H-H' shows thick channel sandstone development. Westward, the Lashly #1 Sec. 21, T. 19 N., R. 9 E. on cross section H-H' shows thinner sandstone beds near the top recording periodic impulses of clastics. Farther west, wells such as the Rigsby #1 Sec. 17, T. 20 N., R. 9 E. on cross section G-G' record little or no influx of clastics to this area. Evidence tends to indicate a deltaic environment with prograding channels over prodelta shales and silts. Outcrops reveal dark carbonaceous (plant and wood fragments) shales to be overlain by sandstone beds containing soft-sediment deformation features. Coarsening upward log signatures (Plate 3 - Cross Section G-G', University of Oklahoma #1-22) and slump structures observed in the outcrop are interpreted to represent progradation delta front deposits over prodelta clays and shales.

CHAPTER VII

CONCLUSIONS

The Missourian Nellie Bly Formation in northeastern Oklahoma is composed mainly of shales, siltstones, and sandstones. The formation thickens southward. This trend is also reflected on the outcrop. Stratigraphic correlations indicate the presence of a local depocenter for the Nellie Bly Formation in Townships 19 and 20 North. The structural dip of the Nellie Bly Formation is less than two degrees to the northwest. The quality of shallow subsurface data available necessitated general interpretative analysis of the gross sand values in the Nellie Bly Formation. Two different environments of deposition are interpreted for the Nellie Bly Formation. In the northern area it appears that quiet deposition of shales and sandstones in a shallow marine shelf environment dominated. To the south, depositional environments included prodelta shales, delta front sandstones and siltstones, and stream-mouth bar deposits. Prograding delta front deposits are interpreted from well log signatures and outcrop observations. The Nellie Bly Formation is a regressive clastic unit bounded by two thin transgressive limestones, the Hogshooter Limestone below and the Dewey Limestone above.

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VITA

David Michael Filgas

Candidate for the Degree of

Master of Science

Thesis: SURFACE AND SHALLOW SUBSURFACE INVESTIGATION OF THE NELLIE BLY FORMATION IN NORTHEASTERN OKLAHOMA

Major Field: Geology

Biographical:

Personal Data: Born in Tulsa, Oklahoma, February 17, 1961, the son of Robert J. and Betty Filgas.

Education: Graduated from Charles C Mason Senior High School, Tulsa, Oklahoma, in May, 1979; received Bachelor of Science Degree in Geology from Oklahoma State University at Stillwater, Oklahoma in July, 1986; completed requirements for the Master of Science degree at Oklahoma State University in May, 1991.

Professional Experience: Geotech, Diamond Energy Operating Company, Tulsa, Oklahoma, January, 1989 to May, 1990.

PLATE 1

STRATIGRAPHIC CROSS-SECTIONS

A–A′

B–B′

D.M. Filgas

M.S. Thesis 1991

PLATE 2

STRATIGRAPHIC CROSS-SECTIONS
C–C′ D–D′ E–E′

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PLATE 3

STRATIGRAPHIC CROSS-SECTIONS

F–F′ G–G′ H–H′

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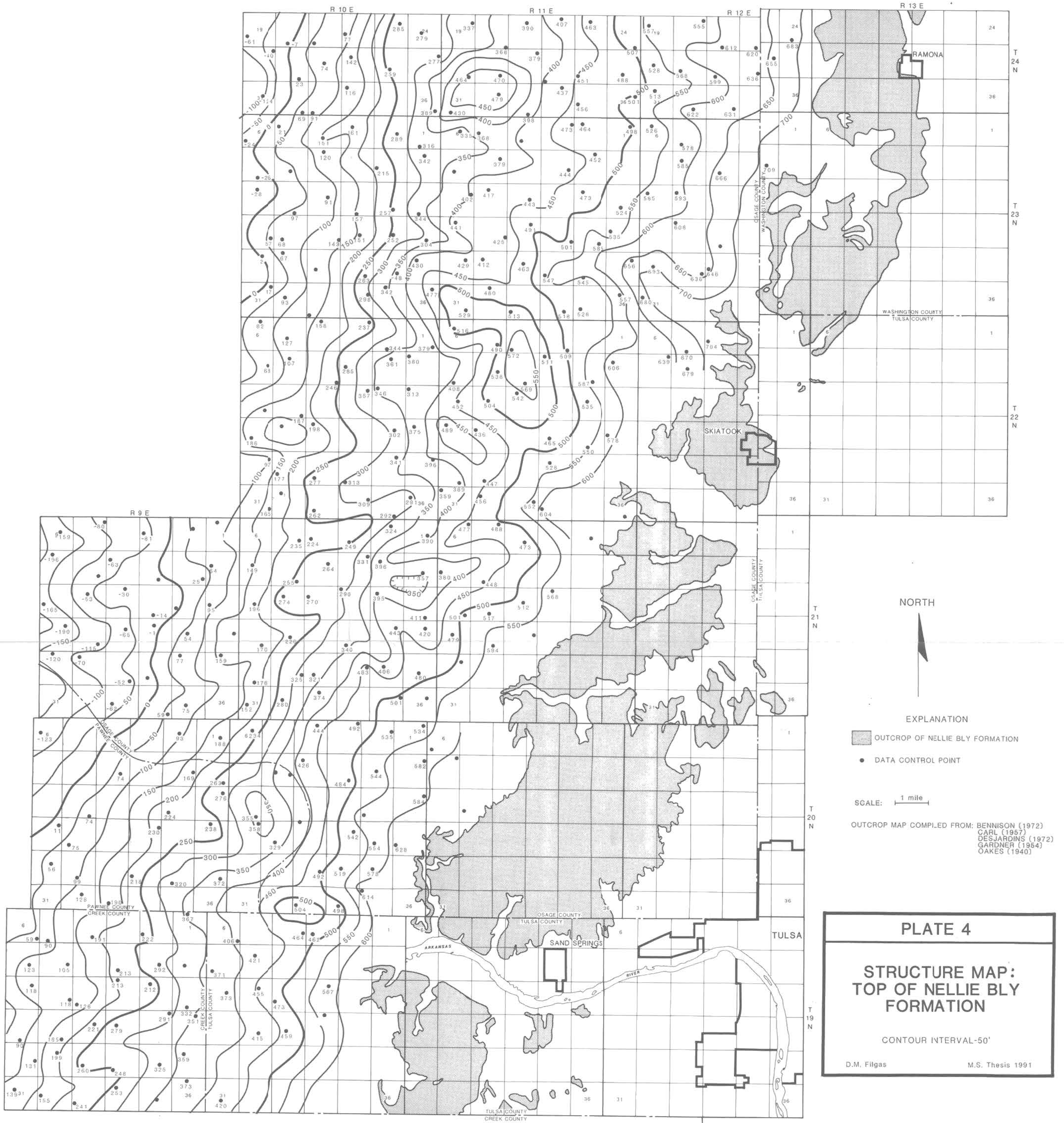

R 9 E
R 10 E
R 11 E
R 12 E
R 13 E
T 24 N
T 23 N
T 22 N
T 21 N
T 20 N
T 19 N
RAMONA
SKIATOOK
SAND SPRINGS
TULSA
ARKANSAS
RIVER
OSAGE COUNTY
WASHINGTON COUNTY
TULSA COUNTY
PAWNEE COUNTY
CREEK COUNTY
NORTH
EXPLANATION
OUTCROP OF NELLIE BLY FORMATION
DATA CONTROL POINT
SCALE: 1 mile
OUTCROP MAP COMPILED FROM: BENNISON (1972)
CARL (1957)
DESJARDINS (1972)
GARDNER (1954)
OAKES (1940)
PLATE 4
STRUCTURE MAP: TOP OF NELLIE BLY FORMATION
CONTOUR INTERVAL-50'
D.M. Filgas
M.S. Thesis 1991

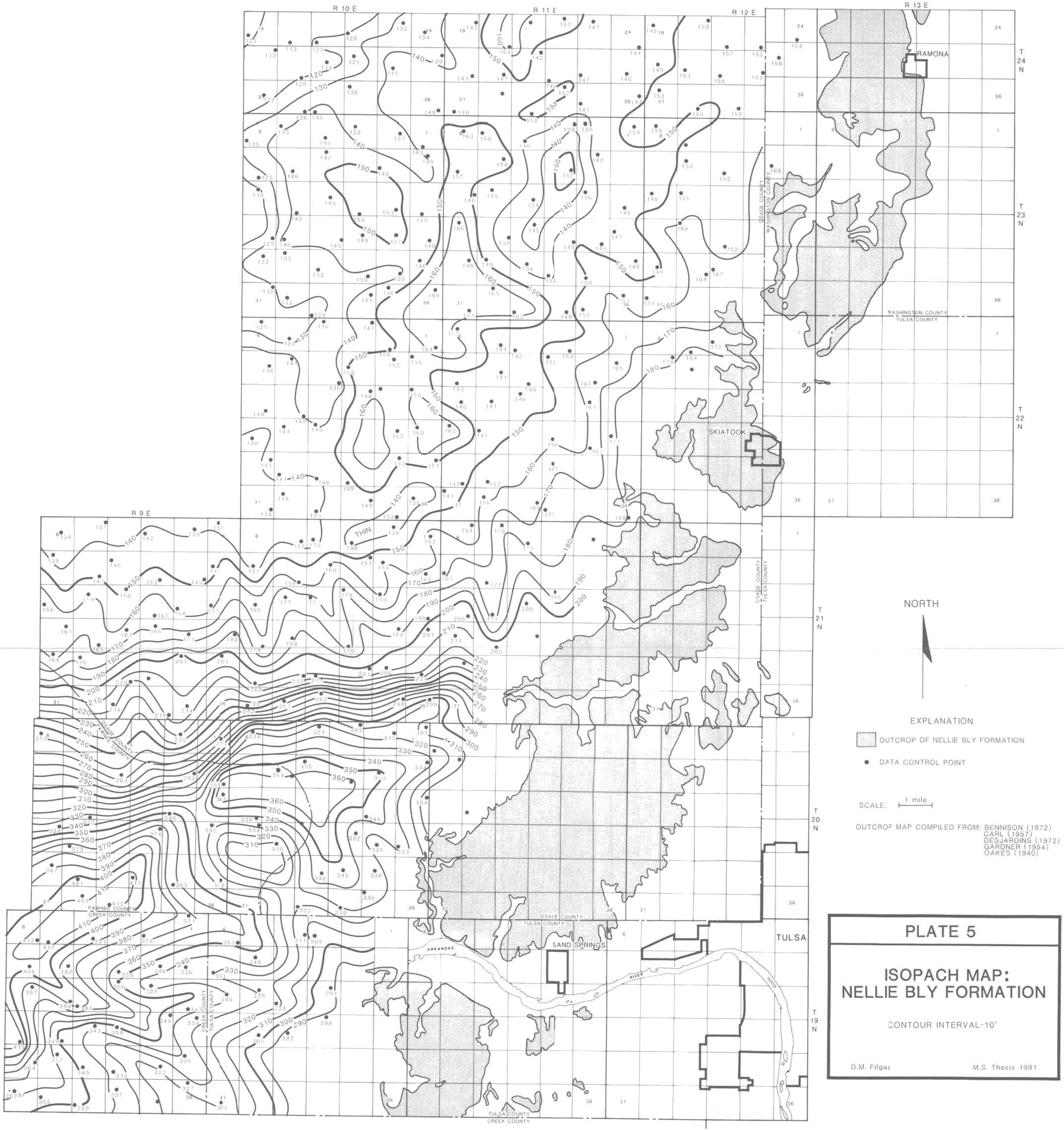


PLATE 5
ISOPACH MAP:
NELLIE BLY FORMATION
CONTOUR INTERVAL-10'
D.M. Filgas
M.S. Thesis 1991
EXPLANATION
OUTCROP OF NELLIE BLY FORMATION
DATA CONTROL POINT
SCALE: 1 mile
OUTCROP MAP COMPILED FROM: BENNISON (1972)
CARL (1957)
DESJARDINS (1972)
GARDNER (1954)
OAKES (1940)
NORTH
R 9 E
R 10 E
R 11 E
R 12 E
R 13 E
T 24 N
T 23 N
T 22 N
T 21 N
T 20 N
T 19 N
RAMONA
SKIATOOK
SAND SPRINGS
TULSA
ARKANSAS
RIVER
THIN
OSAGE COUNTY
WASHINGTON COUNTY
TULSA COUNTY
PAWNEE COUNTY
CREEK COUNTY

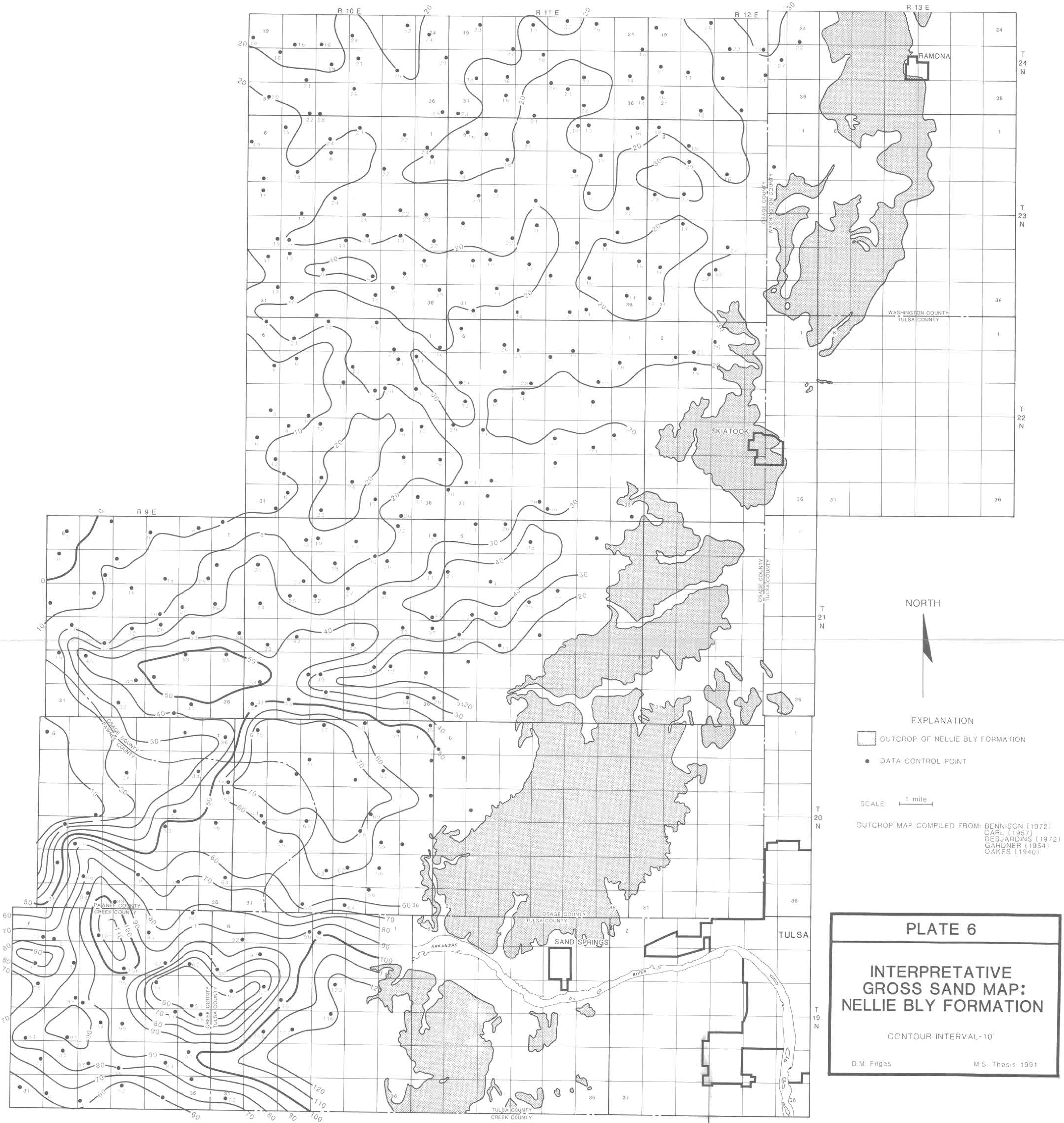
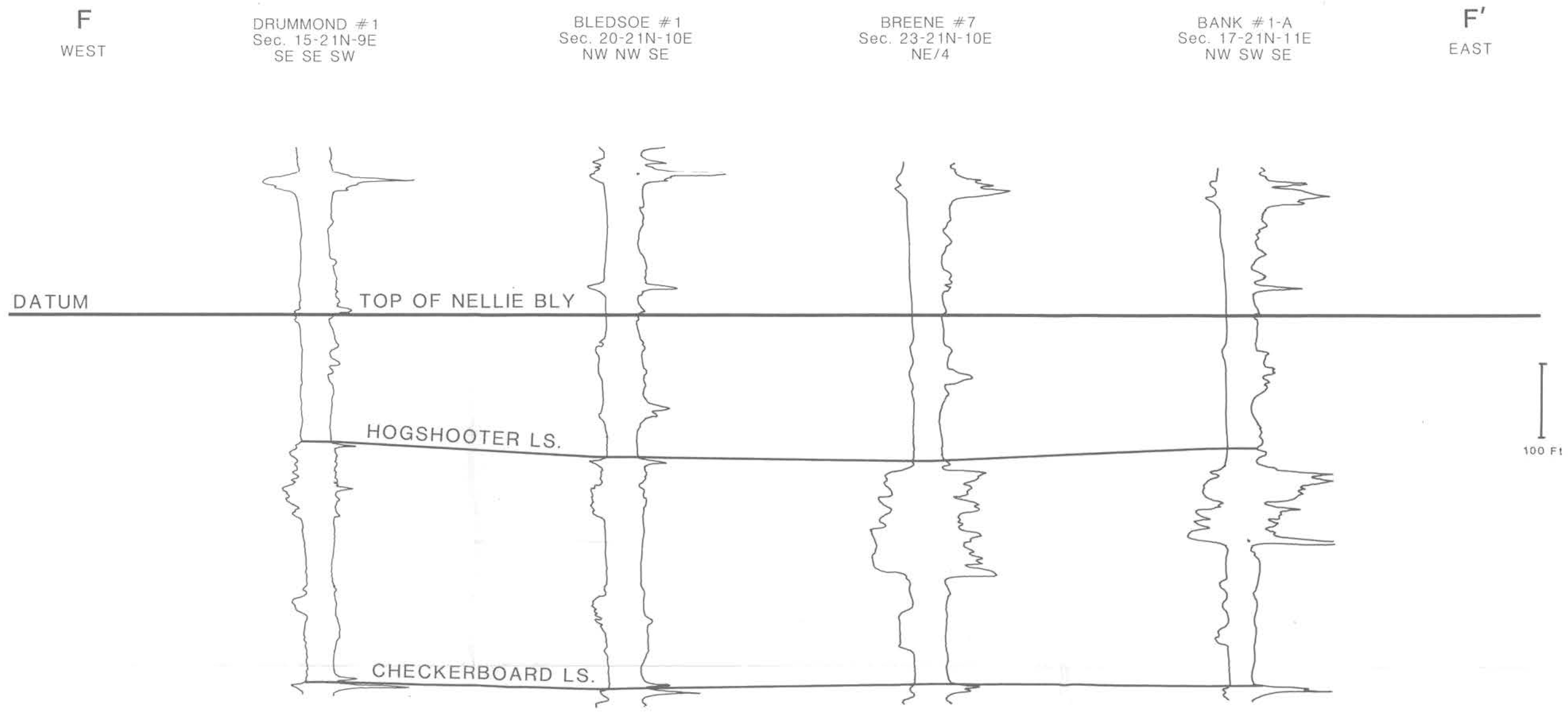

R 9 E
R 10 E
R 11 E
R 12 E
R 13 E
T 24 N
T 23 N
T 22 N
T 21 N
T 20 N
T 19 N
RAMONA
SKIATOOK
SAND SPRINGS
TULSA
ARKANSAS
RIVER
OSAGE COUNTY
WASHINGTON COUNTY
TULSA COUNTY
PAWNEE COUNTY
CREEK COUNTY
NORTH
EXPLANATION
OUTCROP OF NELLIE BLY FORMATION
DATA CONTROL POINT
SCALE: 1 mile
OUTCROP MAP COMPILED FROM: BENNISON (1972)
CARL (1957)
DESJARDINS (1972)
GARDNER (1954)
OAKES (1940)
PLATE 6
INTERPRETATIVE GROSS SAND MAP: NELLIE BLY FORMATION
CONTOUR INTERVAL-10'
D.M. Filgas
M.S. Thesis 1991

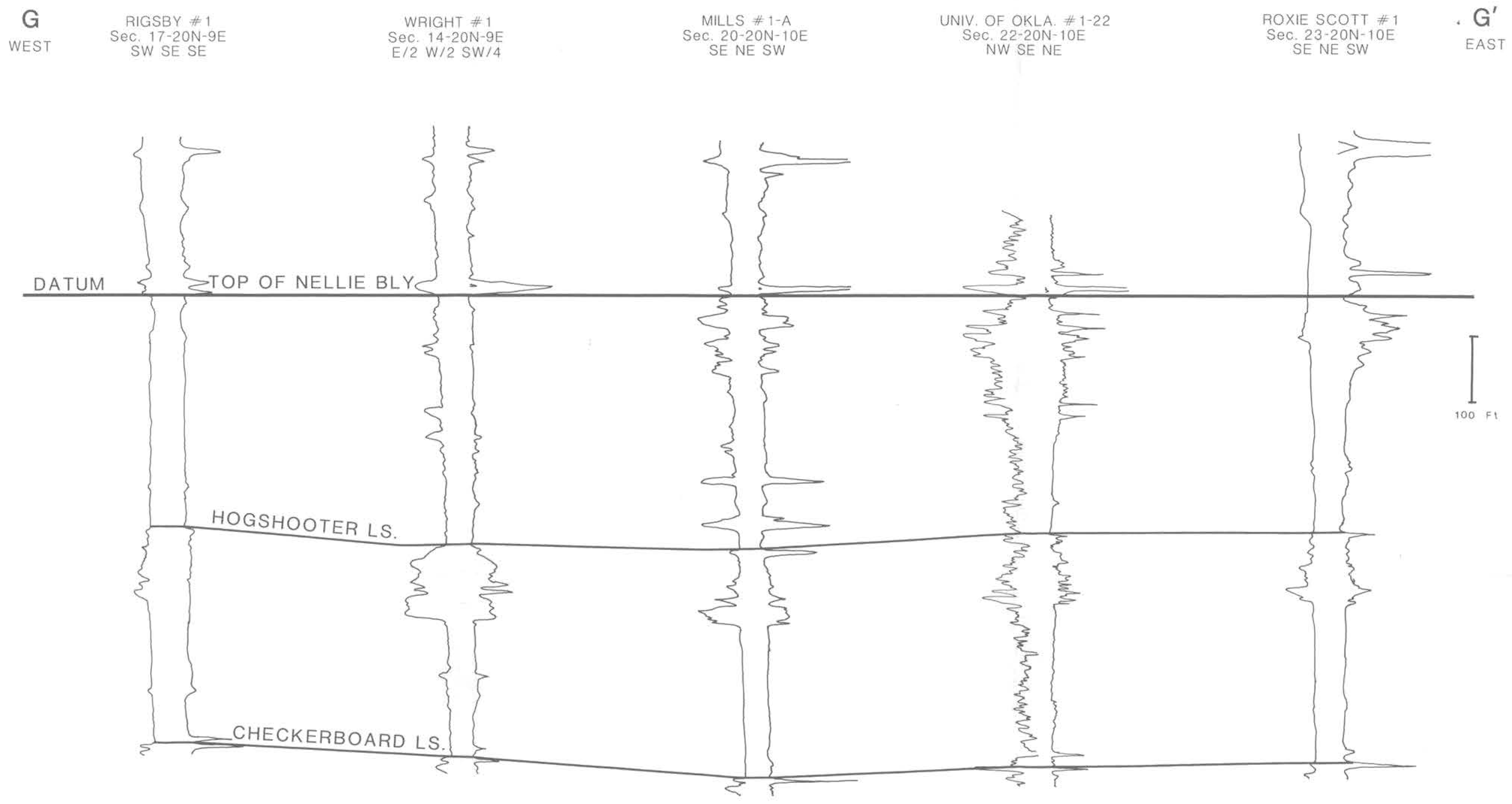
PLATE 1

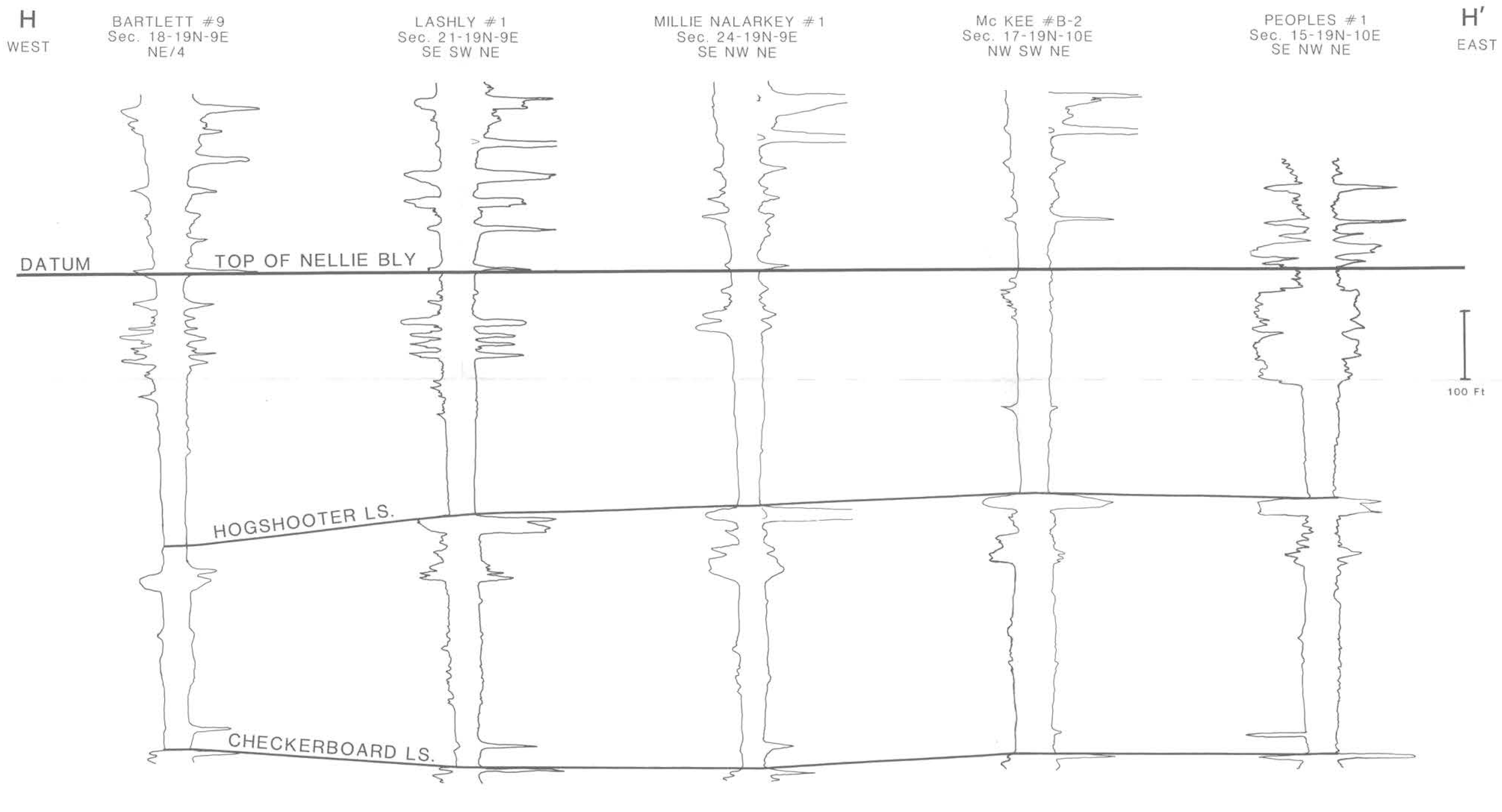
STRATIGRAPHIC CROSS-SECTIONS
A-A′
B-B′

D.M. Filgas M.S. Thesis 1991

C
WEST
BARNSDALL #1
Sec. 24-24N-10E
SW/4
OSAGE-STAPLETON #1-M
Sec. 21-24N-11E
SW NW NE
AVANT UNIT WELL #25-4
Sec. 25-24N-11E
SE NE SW
SHELL #1-A
Sec. 26-24N-12E
SW SE NE
C′
EAST
DATUM
TOP OF NELLIE BLY
HOGSHOOTER LS.
CHECKERBOARD LS.
D
WEST
CANYON #1
Sec. 21-23N-10E
SE NE SE
SUNDOWN UNIT TRACT
97-92 WELL #4
Sec. 23-23N-10E
NW NW SE
STUART #10
Sec. 30-23N-11E
NE/4
STUART ESTATE #5
Sec. 26-23N-11E
SW/4
MESSICK #2-B
Sec. 30-23N-12E
SE NW
D′
EAST
DATUM
TOP OF NELLIE BLY
HOGSHOOTER LS.
CHECKERBOARD LS.
E
WEST
TRUMBLEY #20-1
Sec. 20-22N-10E
NW/4
DILDINE #15
Sec. 23-22N-10E
NE SW NE
YORK #1
Sec. 20-22N-11E
NW SW NW
NORTHWEST #23-1
Sec. 23-22N-11E
NE SE SW
E′
EAST
DATUM
TOP OF NELLIE BLY
HOGSHOOTER LS.
CHECKERBOARD LS.
100 F'
SCALE
VERTICAL: 1"-100'
100'
HORIZIONAL: NO SCALE
PLATE 2
STRATIGRAPHIC
CROSS-SECTIONS
C-C′ D-D′ E-E′
D.M. Filgas
M.S. Thesis 1991







SCALE

VERTICAL: 1"=100' 100'

HORIZIONAL: NO SCALE

PLATE 3

STRATIGRAPHIC CROSS-SECTIONS

F–F' G–G' H–H'

D.M. Filgas M.S. Thesis 1991

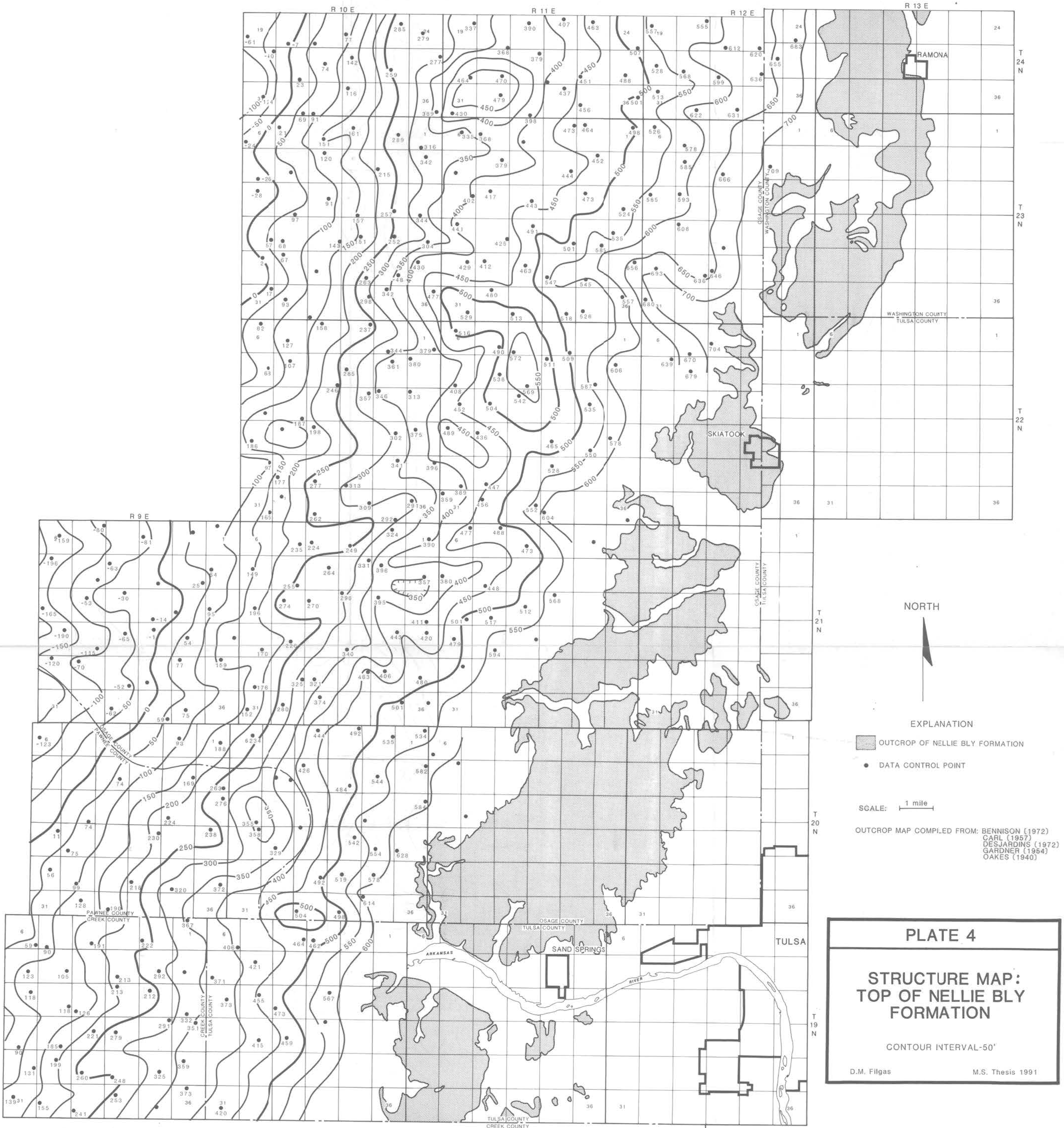


PLATE 4

STRUCTURE MAP: TOP OF NELLIE BLY FORMATION

CONTOUR INTERVAL-50'

D.M. Filgas M.S. Thesis 1991

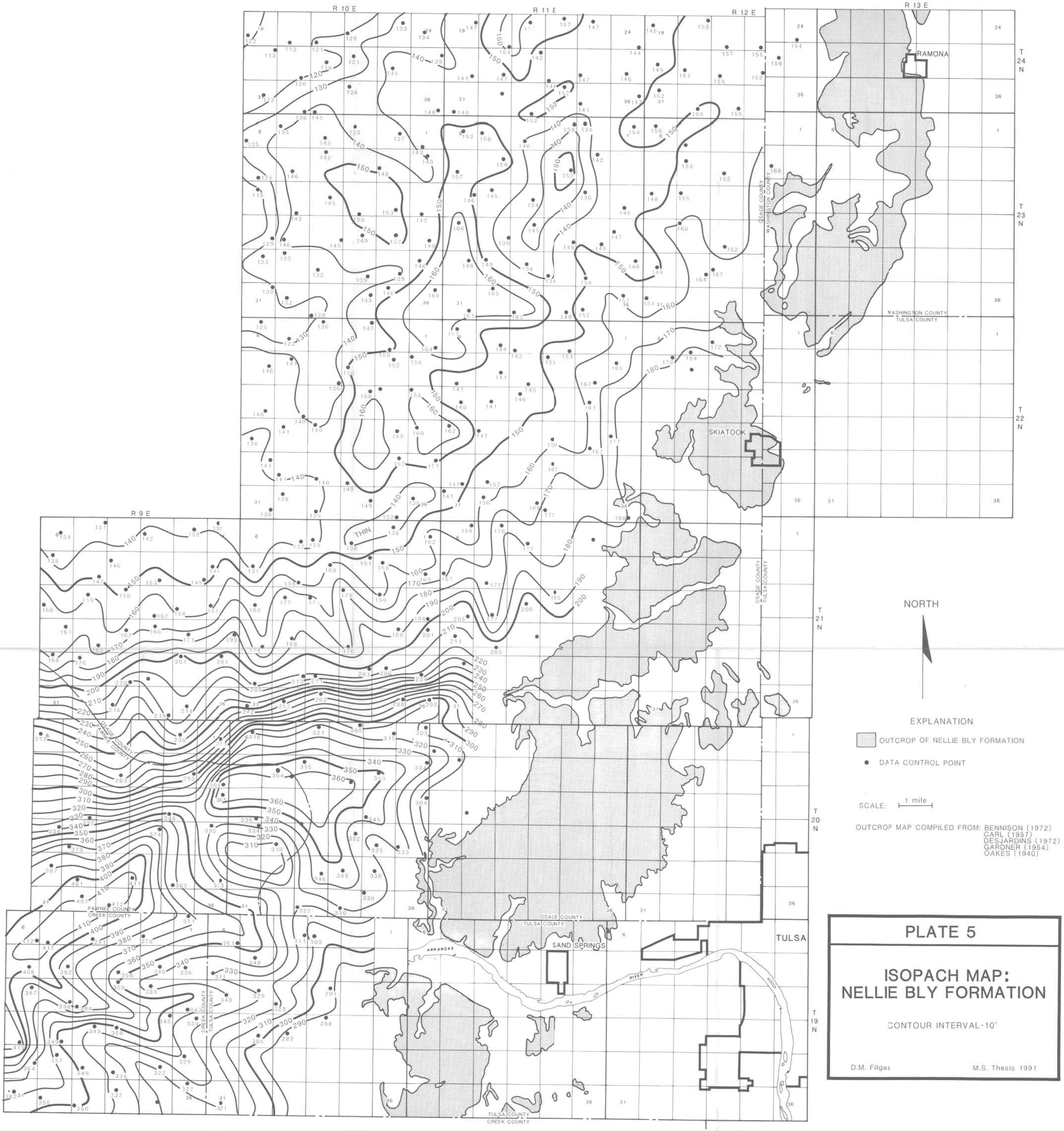


PLATE 5

ISOPACH MAP: NELLIE BLY FORMATION

CONTOUR INTERVAL-10'

D.M. Filgas

M.S. Thesis 1991

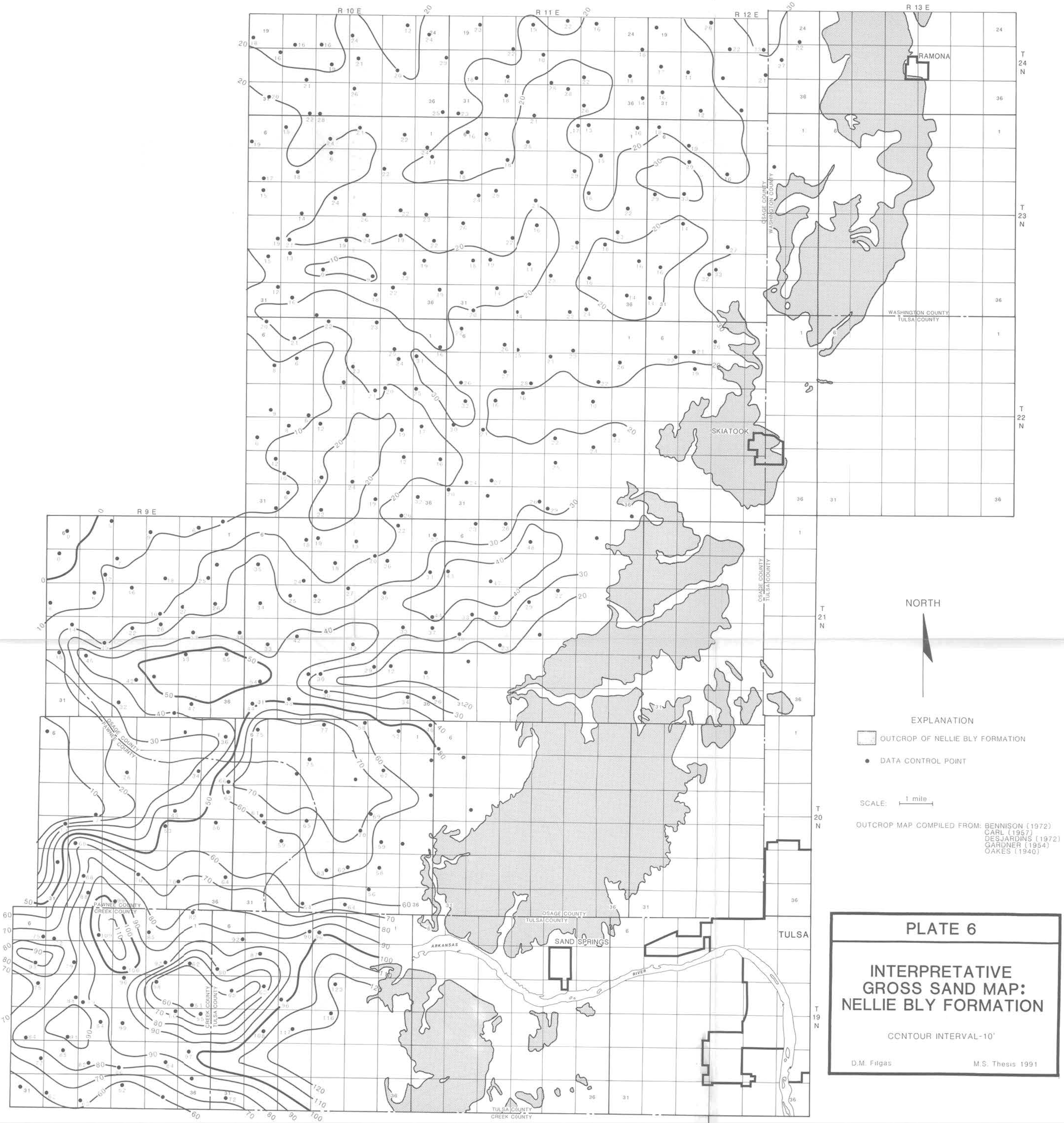


PLATE 6

INTERPRETATIVE GROSS SAND MAP: NELLIE BLY FORMATION

CONTOUR INTERVAL-10'

D.M. Filgas

M.S. Thesis 1991