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Charles J. Mankin, *Director*

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# GEOLOGY AND MINERAL RESOURCES OF PAYNE COUNTY, OKLAHOMA

JOHN W. SHELTON, JOHN S. ROSS, ARTHUR J. GARDEN,
and JAMES L. FRANKS

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# OKLAHOMA GEOLOGICAL SURVEY

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**Title Page Illustration**

Basal limestone bed of the Neva Limestone (Pennsylvanian, Gearyan) in south-central Payne County. This limestone bed is 1–2 feet thick at this locality and contains gastropods, pelecypods, bryozoans, crinoid fragments, and burrows. (See fig. 8.)


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# GEOLOGY AND MINERAL RESOURCES OF PAYNE COUNTY, OKLAHOMA

JOHN W. SHELTON,[1] JOHN S. ROSS,[2] ARTHUR J. GARDEN,[3] and JAMES L. FRANKS[4]

**Abstract**—Payne County is part of the transitional zone between the Central Redbed Plains and the Northern Limestone Cuesta Plains. The area lies in the Cimarron River drainage basin, except for the northernmost part, which is in the Arkansas River drainage basin. The range in elevation is from approximately 740 to 1,175 feet; local relief is commonly 100 feet.

Surface rocks, Pennsylvanian to Permian in age, become progressively younger westward. The section is characterized by red beds, particularly in the central and western parts of the County, and a cyclic or repetitious sequence of mudrock, lenticular sandstones, and thin carbonates. Continuous carbonate beds, which represent transgressive units of conventional cycles, are present in the lower 800 feet, or one-third, of the surface section. However, in the upper two-thirds of the section they are discontinuous, nonfossiliferous, nodular dolomites which formed during desiccation cycles. Although mudrock is the most common lithology, formally named mudrock units are commonly characterized by lenticular sandstones. The sandstones are fine to very fine grained and range in composition from quartzarenites to subarkoses. They are present as single genetic units (as much as 25 feet thick), multistoried complexes (as much as 80 feet thick), and rather widespread multilateral units. The sandstones characteristically have sharp erosional bases; some, however, have gradational bases. The amount of sandstone generally increases southward at the expense of mudrock.

Marine environments, together with deltaic conditions during influx of sand, are represented by the lower one-third of the surface section. Well-developed uppermost Pennsylvanian and Permian sandstones were deposited as parts of sand-rich, tide-dominated deltas during arid conditions. Where equivalent sections contain little sandstone, tidal-flat conditions were predominant. Supratidal carbonate was deposited during transgressions of the tidal flats. Mudrock and thin, well-defined carbonate beds were deposited during the Permian, when the area lay southeast and south of prominent tidal flats.

The area at the surface is characterized by westerly homoclinal dip, generally 40 to 50 feet per mile. The homocline may be described as an undulatory surface reflecting small structural noses. Nine local structures exhibit easterly dip; each is less than 1 square mile in area. The greatest structural complexity is in the eastern part of the County. Differential vertical movement, associated with faulting at depth, is suggested by an increase in folding intensity with depth in Pennsylvanian beds and is indicated by significant folding and faulting of Ordovician beds. The most prominent sets of vertical joints average N. 60° E. and N. 50° W. in orientation.

Petroleum is the major source of mineral reserves. Production has been primarily from Pennsylvanian and Ordovician sandstones. Other mineral resources include limestone for road metal, aggregate, and rip-rap; sand for fill, asphalt, masonry purposes, and concrete; and clay for brick. Deposits of copper, silver, gold, and radioactive minerals are present, but their potential is uncertain. Potable water is best developed in terrace and flood-plain deposits and sandstones of the Eskridge, Garrison, Matfield–Oketo, Doyle, and Wellington formations. The distribution of fresh ground water reflects local sandstone development, topography, and saline influent from the Cimarron River.

## INTRODUCTION

Payne County, located in north-central Oklahoma, west of Tulsa and north-northeast of Oklahoma City, encompasses an area of approximately 700 square miles (fig. 1). The county seat and largest city is Stillwater. Other towns include Perkins, Glencoe, Ripley, Cushing, and Yale. Small communities are Ingalls, Mehan, Vinco, and Quay. The area has an economy based on education (Oklahoma State University), oil and gas, agriculture, and an increasing number of industrial facilities. Good highways make the area accessible. Interstate Highway 35, U.S. Highway 177, and State Highways 108, 18, and 86 are north–south routes; State Highways 51 and 33 extend east–west; and the Cimarron Turnpike, by means of a spur, connects Stillwater with Tulsa. In

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[4]Independent, Oklahoma City, Oklahoma.

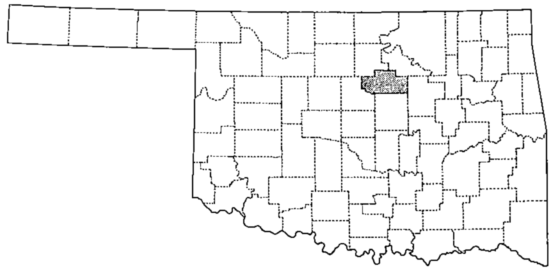


Figure 1. Index map of Oklahoma showing location of Payne County.

addition, most county roads are generally well kept by periodic grading and surfacing with crushed rock. Freight rail service is furnished by the Santa Fe Railway to Stillwater, Glencoe, Cushing, and Yale. The Missouri, Kansas, and Texas Railroad offers limited service to Cushing and Yale.

## Previous Investigations

Detailed geologic study of Payne County began in the early part of the century, when oil geologists conducted surface mapping as part of exploratory programs for structural traps. This type of investigation, supplemented by core-hole programs, was continued for a number of years—even after seismic methods were first used in the County. The many maps prepared during those studies, for the most part, were not available to the authors. However, some local maps were made available by various companies. They include those prepared by C. W. Ellison (courtesy of William A. Jenkins), H. K. Hudson (Cities Service Oil Co.), Rixleben (Skelly Oil Co.), H. W. Peabody, F. C. Greene, Castitle, and C. Schmurr (Sun Oil Co.). Other unpublished geologic studies were made by Fenoglio (1957), Nakayama (1955), and Philip P. Chandler. Fenoglio and Nakayama mapped eastern Payne County as University of Oklahoma M.S. theses, and Chandler prepared a map of the entire County. Koschmann (1930) wrote a brief report on the surface, subsurface, and petroleum geology of Payne County. A general map of Payne County which shows the geologic units with engineering significance has been compiled by Hayes and others (1967, opposite p. 88). Tarr (1910), Rogers (1916, p. 375), and Merritt (1940, p. 6–7) discussed the red-bed copper deposits of central Payne County. Snider (1911, p. 254) and Gould (1911, p. 172) noted briefly some of the geologic materials of Payne County utilized in construction. A county soil report and map were prepared by Cobb and Hawker (1918).

Ground-water features of the County were first summarized by Gould (1905, p. 113–114). Shannon (1917, p. 413–423) described in a cursory manner the structure of the Ingalls and Ripley Oil Fields. Other studies of subsurface strata include the work of Powers (1931), Frost (1940), Lukert (1949), Akmal (1950), Graves (1955), Ireland (1956), Stringer (1956), Heinzelmann (1957), Dalton (1960), McElroy (1961), Jordan (1962), Fambrough (1963), Tarr and others (1965), Berg (1968), and Cole (1968).

## Objectives and Methods

The primary objective of this study was to prepare a geologic map of Payne County and to describe the general geologic features. Determination of paleocurrent directions and general depositional environments of Pennsylvanian and Permian rocks in the area, presentation of structural framework by means of two structural-contour maps, and general description of stratigraphic units exclusively in the subsurface were corollary objectives.

The following data were used to prepare the geologic map: (1) local unpublished, detailed maps of petroleum geologists; (2) an unpublished geologic map of Payne County by P. P. Chandler; (3) unpublished geologic maps of eastern Payne County by Nakayama (1955) and Fenoglio (1957); (4) a county soil map by Cobb and Hawker (1918); (5) aerial photographs; and (6) electric logs of wells drilled for oil and gas.

In the central and western parts of the County, the stratigraphic section at the surface is primarily a sequence of lenticular sandstones, mudrock, and thin lenses of nodular dolomites. Because the rock sequence generally lacks unique rock parameters, lateral persistence, and thick units, standard methods of geologic mapping were difficult to apply. However, some of the carbonate units, which are the basis for subdividing the standard surface section of the Midcontinent, are recognized in the subsurface on electric logs. A shallow subsurface structure map and well-log correlation sections of formations present on outcrop to the east were prepared to assist in tracing thin stratigraphic units at the surface with aerial photographs. In this technique, the location of each formal unit on the surface was estimated by comparing the thickness of each formation to the depth of a key bed or member in each well—that is, extrapolation of a stratigraphic unit in the subsurface to the surface. Additional control was provided by the local unpublished maps noted above, but in virtually all cases each investigator has interpreted outcrop patterns differently. Consequently, those maps were used primarily to supplement field work in checking the existence of contacts mapped on aerial photographs.

Outcrop data were recorded graphically on forms designed specifically for stratigraphic–sedimentologic study, and paleocurrents for various stratigraphic units were estimated from rose diagrams of directional indicators.

## Acknowledgments

The Oklahoma Geological Survey, through Charles J. Mankin, director, provided financial support for field investigations, aerial photographs, and base maps. At Oklahoma State University, John E. Stone made the facilities of the Department of Geology available for study. The advice and aid of William D. Rose, as editor, and drafting support of the Oklahoma Geological Survey, are gratefully acknowledged.

Unpublished geologic maps were provided by G. E. McKinley and A. D. Buzzalini, Skelly Oil Co.; Fred Oglesby and R. Strom, Cities Service Co.; J. G. Ruby and M. H. Udden, Sun Oil Co.; and W. A. Jenkins.

Subsurface data were furnished by T. N. Berry and Co. and the Oklahoma City Geological Society Log Library. Sun Oil Co. and Don D. Hendrie provided the authors with subsurface base maps.

Oil- and gas-field outlines and field nomenclature for the Viola structure map (pl. 3) were compiled by Robert A. Northcutt, Oklahoma City, and Margaret R. Burchfield and Michelle J. Summers, Oklahoma Geological Survey.

Rick Connor, Oklahoma Corporation Commission, furnished Payne County oil- and gas-production figures for the period 1974–84. Robert A. Northcutt compiled cumulative oil-production figures for many of the largest fields in the County.

Fenton Gray, Department of Agronomy, Oklahoma State University, assisted with soils of the area. Jerry Irwin, Irwin Sand Co., furnished sand-production statistics.

Richard R. Heine and Robert O. Fay provided the authors with data on copper-bearing minerals.

Texas Oil and Gas Corp. provided drafting support in preparation of unpublished maps by Franks (1974).

Don R. White and F. Wayne Campbell aided in the preparation and compilation of maps. White served as a research assistant in preparation of maps, statistical data, and references.

JoAnn Jordan and Sherry Hempel typed the manuscript.

The comments and suggestions of critical reviewers, especially Allan P. Bennison and Robert O. Fay, were most valuable in putting together the final version of the manuscript.

## PHYSIOGRAPHY

Payne County lies in a transitional zone between the Central Redbed Plains and the Northern Limestone Cuesta Plains (Curtis and Ham, 1957). Much of the area has Redbed Plains characteristics, such as rolling plains with broad hills and valleys formed by nonresistant red shales and lenticular sandstones; however, the eastern part of the County has topography typical of the Limestone Cuesta Plains, where resistant limestones form steep escarpments.

Lithology is not the only control of topography in Payne County. Local structural nosing, in the predominantly west-dipping Prairie Plains Homocline, is also an important factor. Twin Mounds, the most prominent feature in Payne County, is an example of structural influence (fig. 2). It is near the junction of State Highways 51 and 18. The divide between the Cimarron and the Arkansas River drainage basins, along the northern border of the study area, is also an example of structural influence. Slight drainage anomalies at the Ramsey Oil Field, Stillwater Airport Oil Field, and Lost Creek Oil Field also reflect the effects of local structure on topography.

The predominant slope is to the southeast; local relief is commonly about 100 feet. Highest elevations are present in the western part of the Coun-

Figure 2. Twin Mounds, capped by Red Eagle Limestone, represents the most prominent physiographic feature of Payne County. View from east.

ty, where local areas are as high as 1,175 feet. The lowest elevation, approximately 740 feet, is along the Cimarron River at the eastern edge of the County.

Most of Payne County lies in the Cimarron River drainage basin; only the extreme northern part is in the drainage basin of the Arkansas River. The Cimarron River, which has characteristics of both braided and meandering streams, flows east-northeast across the area. Central Payne County is well drained with a dendritic drainage pattern that shows an overall southeasterly trend north of the Cimarron River and a northerly to northeasterly trend south of the river. Major tributaries to the Cimarron are Deer Creek, Euchee Creek, Skull Creek, and Salt Creek in the east; Big Creek, Little Stillwater Creek, Lost Creek, and Stillwater Creek in the central part; and Stillwater Creek, Wildhorse Creek, and Clear Creek in the west. Long Branch Creek and Camp Creek in the northern part of the County are in the Arkansas River drainage basin.

The mean annual temperature is 59°F, and the average annual rainfall is approximately 35 inches.

The geologic framework of the area exerts a strong influence on soil development. Residual soils reflect the underlying bedrock. Some upland soils are apparently related to a veneer of loess, which is commonly expressed as upland scarplets, generally 1 to 3 feet high, and soils in the stream valleys reflect the alluvial deposits on terraces and flood plains. The flood-plain soils of the Cimarron River and major creeks in the area, represented by the Yahola, Osage, and Miller Series, are the most productive cropland soils in the area. Soils of terrace deposits are cultivated where the surface is flat lying and not subject to rapid erosion. Terrace soils are represented by the Dougherty, Teller, Reinach, and Eufaula Series. Soils overlying sandstone, shale, and limestone are suited for pasture. The Kirkland Series is a well-developed soil on shale bedrock. Sandstone is the parent material for shallow soils of the Bates and Vernon Series. Soils overlying limestone or calcareous shales include the Summit and Vernon Series.

## STRATIGRAPHY

The surface formations of Payne County include approximately 2,200 feet of Upper Pennsylvanian and Lower Permian rocks overlain locally by thin Quaternary sediments (pl. 1). Because the surface rocks dip gently westward, progressively younger beds are exposed in that direction. Sedimentary rocks that occur exclusively in the subsurface range in age from Late Pennsylvanian to Cambrian. The entire sedimentary section, which has been penetrated in three wells in the eastern part of the County, ranges in thickness from approximately 3,500 feet in local eastern areas to probably 7,500 feet in the west.

Deposition during the Paleozoic was on the stable Northern Oklahoma Platform, on which unconformities are common. The depositional environment ranged from shallow marine to alluvial, and conditions changed repetitiously or periodically.

For the history of stratigraphic usage and nomenclature of surface rocks, the reader is referred to Greig (1959), Oakes (1959), Nakayama (1955), and Fenoglio (1957).

## Surface Stratigraphy

### Pennsylvanian System

Pennsylvanian rocks at the surface in Payne County are included in the Vamoosa and Ada Groups of the Virgilian Series and the Vanoss and Oscar Groups of the Gearyan Series (pl. 1).[1] The Vamoosa Group is represented by the uppermost part of the Vamoosa Formation. The overlying Pawhuska Formation is the basal unit of the Ada Group, which is approximately 300 feet thick. The group contains thin limestone units in a section dominated by shale and lenticular sandstone.

The Vanoss Group in Payne County is represented also by thin limestones, variegated shale, red claystone, and lenticular sandstones. The basal unit is the Reading Limestone Member of the Emporia Limestone, and the Roca–Salem Point Shale is the uppermost unit; the thickness is approximately 500 feet. The Oscar Group is approximately 600 feet thick and is characterized by the relatively thin but continuous Neva Limestone at the base, red claystone, and lenticular sandstone bodies. Sandstone is prominent in the Eskridge and Garrison Shales, and carbonate units are represented by thin, nodular dolomites. The uppermost unit of the Oscar Group is considered by the Oklahoma Geological Survey to be the thin, nodular, irregularly developed dolomite at the position of the Herington Limestone.

#### *Vamoosa Formation*

Only the uppermost 30 feet of the sandstone-rich Vamoosa Formation is present at the surface in Payne County. This is represented by shale and lenticular sandstone, which crop out below the Lecompton Limestone Member of the Pawhuska Formation in the eastern part of the County just north of the Cimarron River and along Deer Creek. The underlying Elgin Sandstone Member

[1]The Oklahoma Geological Survey classifies beds of the Admire, Council Grove, and Chase Groups, Wolfcampian Series, Permian System, as the uppermost part of the Pennsylvanian System, based on palynology. "Shawnee" and "Wabaunsee" have not been used as names for groups of the Pennsylvanian Virgilian Series because of facies changes.

of the Vamoosa Formation is present only in the subsurface. The shale of the Vamoosa subjacent to the Lecompton is bluish gray, but it grades downward to red claystone.

*Pawhuska Formation*

In Payne County the Pawhuska Formation consists of two limestone members separated by a thick interval of sandstone with shale. The formation ranges in thickness from about 50 feet (Nakayama, 1955, p. 13) to 130 feet in the shallow subsurface (pl. 2). In Pawnee County to the north, the thickness ranges from 56 to 96 feet (Greig, 1959, p. 38). The Pawhuska, which is 60 to 75 feet thick in northwestern Creek County, thins to only 20 feet some 25 miles to the south (Oakes, 1959, p. 50). The widespread, prominent sandstone between the two limestone members is generally fine grained and is more than 30 feet thick.

*Lecompton Limestone Member.*—This basal member of the Pawhuska is 1 to 2 feet thick (Nakayama, 1955, p. 13; Fenoglio, 1957, p. 8) and is dolomitic. The most prominent outcrop area in Payne County is along the Cimarron River, where the Lecompton is a bench former. It is quite fossiliferous with fusulinids, crinoid stems, and brachiopod fragments. The lower surface is commonly characterized by burrows. The outcrop area in Payne County is south and west of good carbonate development and is within the area where limestone changes southward into dolomite. The Lecompton is a dolomite where it is quarried in western Creek County 12 miles east of Cushing. In northwestern Creek County, immediately north of the Cimarron River and Oilton, the Lecompton is approximately 12 feet thick and is composed of lower and upper units of limestone and a middle dolomite unit (Shelton and Rowland, 1974, p. 18).

*Turkey Run Limestone Member.*—An interbedded section of sandstone and limestone, 7 feet thick, is present north of the Cimarron River. The lower limestone, which is 0.5 foot thick and maroon in color, contains fusulinids, crinoid stems, brachiopod fragments, and gastropods (Fenoglio, 1957, p. 10). The middle section consists of thin beds of limestone and fine-grained sandstone. The upper bed, 2.5 feet thick, is similar lithologically to the lower unit. The Turkey Run is a fossiliferous limestone with crinoid stems in the southeasternmost part of the County, where it is less than 2 feet thick.

In Pawnee County the Turkey Run ranges in thickness from 1.5 to 3 feet. It is a relatively pure carbonate mudstone (Greig, 1959, p. 41–42), but insoluble components increase in percentage and in grain size southward across Payne County (Nakayama, 1955, p. 16). The Turkey Run limestone apparently was not deposited south of the middle of T. 15 N. in Creek County, whereas the Lecompton Limestone was deposited as far south as the North Canadian River in T. 11 N. (Oakes, 1959, p. 50).

*Severy–Aarde Shale*

The lowermost formation of what formerly was referred to as the "Wabaunsee Group" is the Severy–Aarde Shale. It crops out locally along the Cimarron River, Deer Creek, and several minor creeks in northeastern Payne County but is exposed primarily along a north–south belt in the southeastern part of the County. The unit is 80 to 100 feet thick in the former area (pl. 2), but it thins southward to less than 50 feet in the latter area (Nakayama, 1955, p. 19).

The Severy–Aarde consists of a lower gray, fossiliferous shale, a middle sandstone-bearing section, and an upper part characterized by gray and red shale. The lower shale is commonly 10 to 20 feet thick and contains crinoid stems and fusulinids. Sandstone units, which may number as many as three, are generally fine grained and less than 25 feet in total thickness. The upper variegated shale is gray or bluish gray in its uppermost part below the overlying Bird Creek Limestone.

*Bird Creek Limestone*

In Payne County the Bird Creek Limestone is generally exposed in the same area as the underlying Severy–Aarde Shale. It forms the upper bench of an east-facing escarpment in the southeastern part of the County. The Bird Creek is generally a single unit of dense, gray to dark-gray limestone, 1 to 9 feet thick. It is thickest in sec. 15, T. 19 N., R. 6 E. (Fenoglio, 1957, p. 16) and in sec. 10, T. 18 N., R. 6 E. (Nakayama, 1955, p. 20). In the SW¼ sec. 29, T. 19 N., R. 6 E., the limestone is approximately 4 feet thick and contains an interbed of shale. Southward and northward from the area of best development the limestone is uniformly thin (Nakayama, 1955, p. 20; Greig, 1959, p. 49).

The percentages of sand and clay increase southward, and local variegated colors are present in the southern part of the outcrop area. The Bird Creek is commonly fossiliferous, with fusulinids and crinoid, brachiopod, and bryozoan fragments.

*Winzeler–Soldier Creek Formation*

The Winzeler–Soldier Creek Formation is a sequence of shale and sandstone which is recognizable only by its stratigraphic position between the Bird Creek and Wakarusa Limestones. The formation characteristically contains more shale than sandstone. It is generally 60 to 80 feet thick, although Nakayama (1955, p. 21) reports a thickness of 95 feet for southeastern Payne County, and Fenoglio (1957, p. 18) notes a range in thickness from 30 to 100 feet. The shale units are red to gray; the prominent sandstones are lenticular bodies as thick as 50 feet. The uppermost unit is generally a gray shale, but interbedded coal, gray shale, and fissile black shale are present below the overlying Wakarusa in the bluff east of the Cimarron River in sec. 2, T. 18 N., R. 6 E., and sec. 32, T. 19 N., R. 6 E. (Nakayama, 1955, p. 22; Fenoglio, 1957, p. 22). Also present locally in sec. 2, T. 19 N., R. 6 E., is a very thin limestone bed, a feature of the Winzeler–Soldier Creek in Pawnee County (Greig, 1959, p. 51). There, the limestones contain a sparse fauna.

In northeasternmost Payne County one gastropod is reported from a sandstone (Fenoglio, 1957, p. 20). The name Hallett formation has been used informally for the subsurface equivalent of the Winzeler–Soldier Creek in this area.

*Wakarusa Limestone*

Escarpments or benches are commonly formed by the Wakarusa Limestone in eastern Payne County, where it averages 6 feet in thickness. The range in thickness is approximately 3 to 8 feet. The limestone is thin bedded and includes some interbedded shale. Fusulinids, crinoids, bryozoans, brachiopods, a coral, and a trilobite constitute the fauna (Nakayama, 1955, p. 22; Fenoglio, 1957, p. 23). The Wakarusa is commonly gray, but mottled maroon and gray are present as superficial colors in parts of T. 19 N.

*Auburn Shale*

In Payne County the Auburn Shale, between the Wakarusa Limestone and the Reading Limestone Member of the Emporia Limestone, ranges from 20 to 80 feet in thickness. The shale is thinner in the northeastern part of the County than in the area to the south (Nakayama, 1955, p. 22), west (*B–B'* and *E–E'*, pl. 2), and north (Greig, 1959, p. 55). The Auburn consists of red to gray shale units and lenticular sandstones. Sandstone is commonly well developed in the lower part of the shale. An upper sandstone developed in the Yale area trends westerly. A clayey limestone in the middle part of the Auburn in sec. 16, T. 19 N., R. 6 E., is less than a foot thick and contains abundant fossil fragments (Fenoglio, 1957, p. 24). The uppermost shale unit commonly is gray to dark gray.

*Emporia Limestone*

The Emporia Limestone consists of the Reading Limestone Member at the base, the Harveyville Shale Member, and the Elmont Limestone Member at the top. Its thickness ranges from approximately 25 feet in the northeastern part of Payne County to as much as 65 feet in the southeastern part (Nakayama, 1955, p. 24–25). In Pawnee County, Greig (1959, p. 56) reports that the average thickness of the Emporia is 90 feet.

*Reading Limestone Member.*—In Payne County, the Reading is a thin, poorly developed limestone less than 2 feet thick. It may be gray or mottled gray and maroon in color, and locally is nodular or conglomeratic. The Reading is abundantly fossiliferous; fusulinids, crinoid fragments, bryozoans, brachiopods, pelecypods, gastropods, and wood fragments were noted by Nakayama (1955, p. 24) and Fenoglio (1957, p. 26). Greig (1959, p. 56–57) reported that the Reading is 15 to 26 feet thick in Pawnee County, where it consists of a lower mottled red and gray-green limestone bed, a middle unit of red and gray shale with thin limestones and (or) sandstones, and an upper gray fusulinid limestone. The Reading, as mapped in Payne County, may not represent just one bed, but rather several very thin lenses which formed at approximately the same stratigraphic position.

*Harveyville Shale Member.*—The Harveyville is a sequence of shale and sandstone, with locally developed thin limestones. It is approximately 20 feet thick in northeastern Payne County and as much as 60 feet thick in the southeast, where a thin nodular limestone with crinoid debris and bryozoans is rather persistent (Nakayama, 1955, p. 24–25). Generally, gray shale is present north of units of gray and red shale. Lenticular sandstones, most commonly less than 10 feet thick, are developed at various positions within the Harveyville. The section is sparsely fossiliferous, except for the thin limestone in the south and the lower part of the member in sec. 14, T. 19 N., R. 5 E., where fusulinids, crinoid fragments, bryozoans, brachiopods, and pelecypods were noted by Fenoglio (1957, p. 29).

*Elmont Limestone Member.*—In northeastern Payne County the Elmont consists of two limestone units, each less than 2 feet thick, and an intervening shale; the total thickness here is about 10 feet. In the southeast, the Elmont is represented by a single limestone unit about 2 feet thick, which generally is composed of two beds. According to Nakayama (1955, p. 25), the Elmont is an 8-foot unit of arenaceous limestone in sec. 12, T. 18 N., R. 5 E.

The lower limestone unit in the northeast is generally lighter colored than the upper unit, and it may be mottled red and gray. Limestones of the Elmont are fossiliferous; fusulinids, crinoid fragments, bryozoans, and pelecypods were noted by Nakayama (1955, p. 26) and Fenoglio (1957, p. 30–31). In Pawnee County, the lower limestone unit and associated shale of the 25-foot-thick Elmont contain abundant fusulinids.

*Gano Shale*

The Gano Shale is a shale–sandstone sequence which ranges in thickness from 50 to 60 feet on outcrop to approximately 125 feet in the shallow subsurface (pl. 2). Shale beds are generally red and (or) gray. The prominent units of the Gano are an argillaceous, nodular limestone (IPga-40), which contains abundant myalinid-type pelecypods, and a sandstone, which occurs in the lower part of the shale in the Yale–Norfolk area (fig. 3). The limestone, generally less than 3 feet thick, is 15 to 25 feet below the Grayhorse Limestone (Nakayama, 1955, p. 27; Fenoglio, 1957, p. 33). In northeastern Payne County, the limestone is underlain by a thin coal, which Fenoglio (1957, p. 32–33) correlates with the Larton coal in the French Creek Shale of Kansas. The abundant myalinid-type pelecypods are present above the coal. Other fossils in the limestone include crinoid fragments, bryozoans, brachiopods, pelecypods, gastropods, and cephalopods (Nakayama, 1955, p. 27; Fenoglio, 1957, p. 34).

Figure 3. Sandstone in lower part of Gano Shale in eastern part of Yale, showing prominent medium-scale crossbedding.

The sandstone overlying the Elmont is fine grained and crossbedded; it ranges from 10 to 15 feet in thickness. Medium-scale crossbedding indicates a paleocurrent direction of N. 10° E. Both limestone and sandstone units are developed locally at other stratigraphic positions within the Gano. Because of the presence of coal, the Gano exhibits more of a cyclic sequence than other Pennsylvanian formations in Payne County.

*Grayhorse Limestone*

The Grayhorse Limestone, the Pony Creek Shale, and the Brownville Limestone had previously been considered members of the Wood Siding Formation in northeastern Payne County, where the unit is rather prominent. The thickness ranges from 30 to 10 feet, and the thickest section is in the SE¼ sec. 15, T. 19 N., R. 5 E. South of the Cimarron River the thickness is generally 1 foot, a characteristic value also for northeastern Lincoln County (West, 1955, p. 21).

The Grayhorse is a light-gray, fossiliferous limestone. North of the Cimarron River, fusulinids are abundant; south of the river the unit is sandy and contains numerous crinoid stems (fig. 4). The Grayhorse also contains corals, bryozoans, brachiopods, pelecypods, and gastropods.

Figure 4. Grayhorse Limestone in northeasternmost part of sec. 16, T. 19 N., R. 5 E., overlying thin shale and sandstone. The limestone contains abundant fusulinids.

Apparently the Grayhorse and Brownville were inaccurately defined in Pawnee County by Greig (1959, p. 62–71), who designated the myalinid-bearing limestone in the Gano Shale as the Grayhorse and the fusulinid-bearing Grayhorse Limestone Member as the Brownville.

*Pony Creek Shale*

This formation generally is composed of shale and lenticular sandstone units, along with a thin limestone lens locally. The thickness is approximately 45 feet in northeastern Payne County (Fenoglio, 1957, p. 37) and 70 feet in the southeastern part of the County (Nakayama, 1955, p. 30). The shale is gray and red, with red being more common southward. A 4-foot conglomerate with clay and carbonate pebbles is present in the upper part of the Pony Creek in the NE¼ sec. 2, T. 19 N., R. 5 E. Fossils in the limestone lenses include fusulinids, crinoid fragments, bryozoans, and brachiopods.

*Brownville Limestone*

The thin Brownville Limestone is poorly expressed topographically. The best exposure is an outlier in sec. 1, T. 19 N., R. 5 E., where the unit is a gray, coarsely crystalline limestone (Fenoglio, 1957, p. 42). Elsewhere, it is mottled gray and red, with some limonite stain and nodules. The Brownville is commonly 1 foot thick, but in the NW¼ sec. 22, T. 19 N., R. 5 E., it is 11 feet thick and has an intraformational conglomerate at the top. In sec. 21, T. 18 N., R. 5 E., three thin limestones are interbedded with gray shale in a section 3 feet thick. The limestone contains various fossils: fusulinids, crinoid fragments, bryozoans, brachiopods, pelecypods, and gastropods were noted by Nakayama (1955, p. 31) and Fenoglio (1957, p. 43).

*Admire Shale*

In Payne County the Admire Shale is a sequence of red and gray shale, lenticular sandstone units, and thin limestone lenses. Nakayama (1955, p. 32) and Fenoglio (1957, p. 45) indicate that the Admire is less than 100 feet thick on outcrop, but it is approximately 150 feet thick in the shallow subsurface (pl. 2). Generally, it is poorly exposed on the slopes east of the prominent escarpments or benches formed by the overlying limestones. Stratigraphically, the Admire lies between the Brownville Limestone and the overlying Americus Limestone. Fenoglio (1957, p. 44–45) mistakenly considered the Americus Limestone as the Five Point Limestone Member of the Admire Shale, which is not recognized in Payne County. That error in correlation resulted in many errors in designations of units in the upper part of the Vanoss Group.

Sandstone is prominent in the lower part of the Admire. A crossbedded conglomerate is developed in the lowermost part of the formation in sec. 7, T. 18 N., R. 5 E. (Nakayama, 1955, p. 32). The fauna of limestone lenses includes brachiopods and pelecypods.

*Foraker Limestone*

The Foraker Limestone is composed of the Americus Limestone Member, the Hughes Creek Shale Member, and the Long Creek Limestone Member, in ascending order. It is approximately 55 to 70 feet thick in Payne County. The Foraker is 60 to 70 feet thick in Pawnee County (Greig, 1959, p. 79).

*Americus Limestone Member.*—This member is about 6 feet thick in the northern part of Payne County, where it is represented by bluish-gray fossiliferous limestone commonly interbedded with shale; in the south, it is only 1 foot thick. The Americus is tentatively considered as one arenaceous limestone bed in the southernmost part of Payne County and the adjoining part of Lincoln County (West, 1955, p. 26). In southern Pawnee County, the Americus is 8 feet thick and is composed of two limestones and interbedded shale (Greig, 1959, p. 80–81). The Americus fauna in Payne County consists of crinoid fragments, bryozoans, brachiopods, pelecypods, gastropods, and a shark tooth (Nakayama, 1955, p. 36; Fenoglio, 1957, p. 47).

*Hughes Creek Shale Member.*—Gray and red shale units and sandstone bodies compose the Hughes Creek Shale Member, which is generally 40 to 50 feet thick. The shale overlying the Americus locally contains pelecypods and a shark tooth in southeastern Payne County (Nakayama, 1955, p. 36); a fissile black shale with carbonaceous material is present at the top of a prominent sandstone in sec. 16, T. 19 N., R. 5 E. (Fenoglio, 1957, p. 45). Gray shale is common directly below the overlying Long Creek Limestone Member. In the Twin Mounds area, the Hughes Creek contains a prominently exposed fine-grained sandstone, which exhibits upward fining, parting lineation, crossbedding, and convolute bedding. Directional features in the sandstone indicate an average paleocurrent direction of N. 10° W.

*Long Creek Limestone Member.*—Across Payne County the Long Creek Limestone Member consists of lower and upper limestones and an intervening shale. The limestones are similar in lithology and thickness. The member is 10 to 15 feet thick, and each limestone is generally 2 feet or less in thickness. Both limestones are dense, fossiliferous, and light to dark gray. The lower part of the lower unit is arenaceous, and the upper part is conglomeratic. In parts of sec. 16, T. 19 N., R. 5 E., the lowest bed of the unit is a calcareous sandstone. Fusulinids are present in the upper limestone, which also contains a 2-inch coal bed in parts of southeastern Payne County (Nakayama, 1955, p. 37). Shale between the two limestones is generally light gray and fossiliferous. A thin sandstone is present in the upper part of the shale in sec. 17, T. 19 N., R. 5 E. In addition to fusulinids, fauna of the Long Creek consists of crinoid fragments, bryozoans, brachiopods, pelecypods, gastropods, and a trilobite (Nakayama, 1955, p. 37–38; Fenoglio, 1957, p. 48, 50, 52–53).

*Johnson Shale*

The Johnson Shale is 40 to 60 feet thick and is composed of red and gray shales with lenticular sandstones. Exposures of the shale both in Payne County and in Pawnee County (Greig, 1959, p. 86) commonly are characterized by slumping. Shale beds directly above the Long Creek and directly below the overlying Red Eagle Limestone are gray, whereas most of the other shale units are red. Sandstone units increase in prominence southward and are generally thin, but a sandstone exposed along the Cimarron River is as thick as 20 feet (Nakayama, 1955, p. 38). Fusulinids in a nodular limestone lens are the only fossils noted in the Johnson Shale.

*Red Eagle Limestone*

The Red Eagle Limestone forms prominent escarpments across Payne County as it increases in thickness southward from 6 to 11 feet. On the outcrop, it appears as dark-gray, medium-crystalline, fossiliferous limestone beds with interbedded zones of very finely crystalline limestone (fig. 5). The limestone is locally dolomitic, and south of the Cimarron River it is red in color. The very finely crystalline zones contain abundant fusulinids. Other fossils that characterize the unit are crinoid fragments and brachiopods.

Figure 5. Red Eagle Limestone on outcrop in sec. 24, T. 19 N., R. 4 E. The 6-foot unit is composed of beds with crystalline carbonate. Less resistant, finely crystalline layers contain abundant fusulinids.

*Roca–Salem Point Shale*

The Roca–Salem Point Shale, between the Red Eagle Limestone and the Neva Limestone, is mostly red to gray shale or claystone with some thin limestones and lenticular sandstones that grade upward into siltstone. The Roca–Salem Point is consistent in thickness, thinning only from 115 feet in the north to 100 feet in the south. Paleocurrent measurements in the sandstones indicate a primary current direction of approximately N. 15° E. and secondary directions of N. 80° E. and N. 40° W. (fig. 6).

Two limestones present in the Roca–Salem Point Shale in Pawnee County (Greig, 1959, p. 92) do not crop out in Payne County. However, two persistent sandstone units are present 35 and 115 feet above the Red Eagle Limestone. In sec. 24, T. 19 N., R. 4 E., the lower sandstone consists of 5 feet of fine- to very fine-grained, laminated, light-gray sandstone, which is overlain by 6 feet of red shale and sandy limestone. One mile west of the exposure, the unit is a red sandstone, 6 feet thick, characterized by a sharp base, an overall upward decrease in grain size from fine to very fine, initial dip, and small-scale crossbedding. At most sections, the upper sandstone is tan in color and is at least 16 feet thick. It is characterized by a sharp base, an overall upward decrease in grain size from fine to very fine, and initial dip. However, in sec. 13, T. 19 N., R. 4 E., the upper sandstone is only 2 feet thick and has a gradational base, horizontal lamination, shale interbeds, and fossil casts and molds near the top. One mile west of this location, in sec. 14, the sandstone is 9 feet thick, highly calcareous, and contains tracks and trails, burrows, and fossils (fig. 7). At that locality, it has an irregular base, interbeds, parting lineation, and an overall upward decrease in grain size.

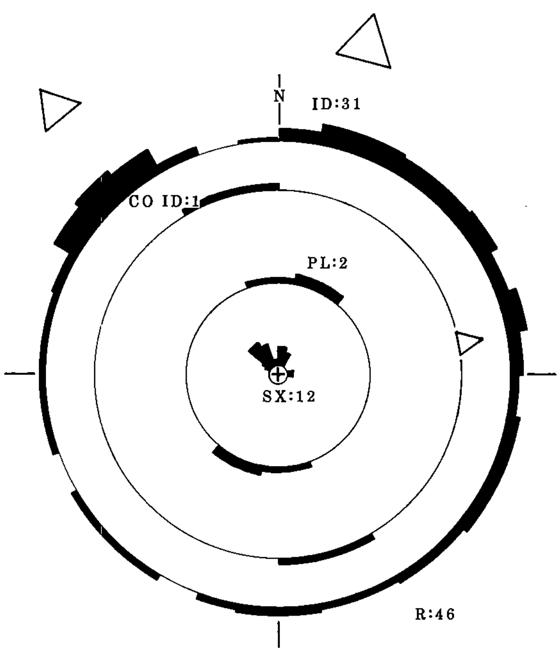



Figure 6. Paleocurrent diagram of sandstones in Roca–Salem Point Shale, showing a primary direction of N. 15° E. and secondary trends of N. 80° E. and N. 40° W. Size of arrow indicates prominence of direction. Key to symbols: *ID*, initial dip; *CO ID*, cutout initial dip; *CO*, cutout trend; *LX*, large-scale crossbedding; *MX*, medium-scale crossbedding; *SX*, small-scale crossbedding; *PL*, parting lineation; *R*, total number of readings. A 30° sliding average was used in preparing diagram.

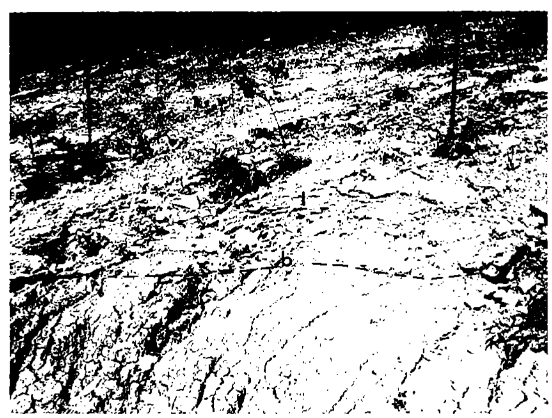


Figure 7. Sandstone below Neva Limestone in sec. 14, T. 19 N., R. 4 E., showing undulatory base (*b*) and interbeds (*I*). Sandstone contains fossil molds or casts.

*Neva Limestone*

In Pawnee County, the Neva Limestone thins from 40 feet of limestone and shale, characterized by chert nodules and fusulinids, to 20 feet of sparsely fossiliferous shale and relatively thin limestone ledges (Greig, 1959, p. 95–97). The limestone beds of the Neva extend as thin units across Payne County into Lincoln County to the south. In Pawnee County the Neva is the uppermost limestone characterized by a brachiopod–fusulinid assemblage, and in Payne County it is the uppermost continuous and fossiliferous limestone. However, in Payne County the Neva Limestone is difficult to map because in most places it is composed of thin, nonresistant limestone beds separated by shale and bounded on the top and bottom by thick sandstones. The thickness and composition of the limestone change locally and regionally. The Neva Limestone is thicker in the northern part of the County than in the south.

In sec. 14, T. 19 N., R. 4 E., the Neva is 23 feet thick; it consists of three limestone units. The basal and middle limestones are separated by sandstone, and the middle and upper limestones are separated by shale (Fenoglio, 1959, p. 58). The basal limestone, 1 foot thick, is tan and medium crystalline. The overlying sandstone is 8 feet thick and is light gray, very fine grained, calcareous, and burrowed. The middle unit, which is 9 feet thick, consists of limestone and thin beds of shale. The carbonate is generally medium-crystalline, red to gray sandy dolomite, with many tracks and trails but few fossils. The shale that separates the upper and middle limestones is 5 feet thick. The upper limestone, which is badly weathered on outcrop, consists of brown, fossiliferous, fine-grained sandy limestone, 1 foot thick.

One mile to the east, in sec. 13, the Neva is a 12-foot section of two limestone units and red shale. The upper bed is a sandy limestone, 1.5 feet thick, which contains many crinoid fragments. The lower unit is 5 feet of nonfossiliferous sandy limestone with thin shale partings.

To the south, in sec. 19, T. 18 N., R. 4 E., the Neva consists of three thin, sandy limestones and intervening shale, with a total thickness of 15 feet. The basal unit is a red, very fossiliferous sandy limestone, 1 to 2 feet thick (fig. 8). The upper carbonate beds, consisting of red sandy dolomite, are individually less than 1 foot thick. Both the upper and lower units contain tracks, trails, and burrows, but the lower limestone is more fossiliferous and less sandy. It contains crinoid fragments, bryozoans, pelecypods, and gastropods.

Figure 8. Basal limestone bed, 1 to 2 feet thick, of the Neva Limestone in sec. 19, T. 18 N., R. 4 E. The limestone contains gastropods, pelecypods, bryozoans, crinoid fragments, and abundant burrows. Vertical joints trend N. 80° E. Upper units of Neva, which is 15 feet thick at this locality, are shown in figure 10.

### *Eskridge Shale*

The Eskridge Shale includes the beds between the top of the Neva Limestone and the base of the Cottonwood Limestone. In Payne County, the formation is similar to the section described by Greig (1959, p. 100) in Pawnee County, but red is the dominant color in Payne County. The unit consists of 80 feet of red claystone, or shale, and siltstone, with thick, lenticular sandstones and thin stringers of nodular dolomite. The claystone is poorly exposed at the surface; the best outcrops are immediately below sandstone beds, which generally are characterized by sharp, erosional bases. Sandstone predominates over claystone, and the pëercentage of sandstone increases to the south. Paleocurrent indicators in the sandstones of the Eskridge Shale suggest a major current direction of N. 45° W. and secondary trends of N. 55° E. and S. 35° W. (fig. 9).

Two of the more prominent sandstones are designated IPes-20 (20 feet above the Neva) and IPes-40 (40 feet above the Neva). Because of the difficulty of showing both the Neva and IPes-20 on the map, the latter is mapped only where the Neva

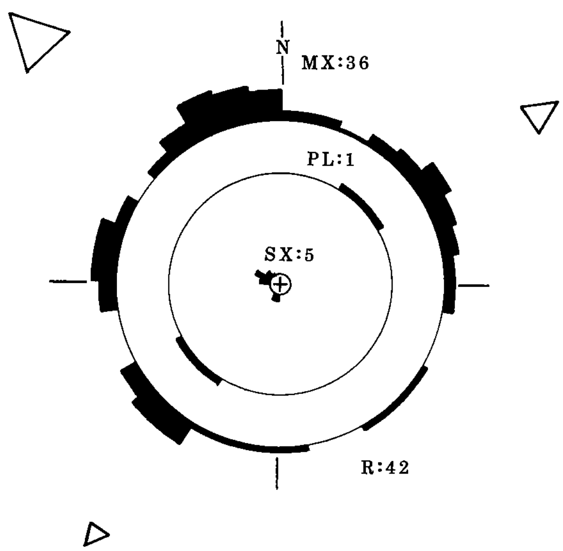



Figure 9. Paleocurrent diagram of sandstones in Eskridge Shale. Primary direction is N. 45° W. Secondary directions are N. 55° E. and S. 35° W. See figure 6 for explanation of diagrams.

does not crop out. In sec. 19, T. 18 N., R. 4 E., IPes-20 consists of at least two genetic units (fig. 10). The lower unit is 0 to 5 feet thick. It has a gradational base, an overall upward increase in grain size from silt to very fine-grained sand, horizontal interbeds, small-scale crossbeds near the top, and burrows near the base. The upper unit is 13 to 20 feet thick. Along the line of outcrop, it completely cuts out the lower sandstone. The erosional base, an overall upward decrease in grain size from fine to very fine, medium- and small-scale crossbedding, and some convolute bedding are characteristic features of the unit. In some places, clay-pebble conglomerate is present at the base. North of this location, in sec. 16, T. 19 N., R. 4 E., the two sandstone units are separated by approximately 10 feet of red claystone. In sec. 10, T. 19 N., R. 4 E., where IPes-20 is 30 feet thick, it is characterized by cut-and-fill, fine-grained sand with an overall upward fining, and medium- and small-scale crossbedding. Measurements of paleocurrent indicators in the sandstone within sec. 10 suggest a current direction of N. 75° W.

Sandstone IPe-40 is mappable only in the southern half of the County. In sec. 8, T. 18 N., R. 4 E., it consists of 32 feet of sandstone in three genetic units. Although the basal unit is approximately correlative with IPes-20, it is included in the multistoried IPes-40 for mapping purposes. This bed is 10 feet thick, and it has a gradational base, an overall upward coarsening from silt to very fine-grained sand, horizontal lamination, and some interbeds. The lower unit is cut out by a middle sandstone, which in turn is cut out by an upper sandstone. Both the middle and upper sandstones are characterized by an upward decrease in grain size from fine to very fine, dolomitic cement near the base, deformed bedding, initial dip, and medium-scale crossbedding. The middle sandstone is horizontally bedded in places. Paleocurrent indicators suggest a current direction of S. 20° W. for the middle unit and north for the upper sandstone.

Figure 10. Eskridge sandstone IPes-20 in sec. 19, T. 18 N., R. 4 E., a multistoried complex of a distributary sandstone (*d*) above a delta-fringe unit (*f*). The latter, with a gradational base (*b*) overlying the Neva Limestone (*n*), has burrows and horizontal bedding in lower part and interbeds and small-scale crossbedding in upper part (*i*). The distributary sandstone has a sharp, erosional base (*c*).

### *Cottonwood Limestone*

According to Greig (1959, p. 102–103), the Cottonwood is an algal limestone which thins to an unrecognizable unit in southern Pawnee County. The outcrop of the Cottonwood, which consists of thin, discontinuous lenses of dolomite nodules, is shown on the geologic map (pl. 1) to extend to Lincoln County. Although this unit is extremely hard to map on the surface because the lenses produce no topographic expression, it is relatively easy to correlate in the subsurface. In order to overcome the difficulty in mapping the Cottonwood, a sandstone directly above the limestone and electric-log projection were used to delineate its position. The thickness of the bed of nodules is difficult to determine because the nodules generally are present only as float; however, the interval is thought to range in thickness from less than 1 foot to more than 10 feet.

In sec. 35, T. 20 N., R. 4 E., the Cottonwood is more than 10 feet thick. In part of this area it consists of nodules, generally 1 inch in diameter, and in other parts of the area it is a thin, continuous bed that is partially cut out by an overlying sandstone. The nodules are red and are composed of fine carbonate mudstone (dismicrite) with some very fine-grained quartz sand and clay. Many are interlaced with calcite veinlets. The continuous bed is red to green, sandy and clayey dolomitic sandstone.

### *Garrison Shale*

The Garrison Shale includes the beds between the Cottonwood and the Wreford Limestones. According to Greig (1959, p. 103–104), the gray and olive shale with algal limestone that characterizes the Garrison in northern Oklahoma is not present in Pawnee County. There, the Garrison Shale is 140 feet thick and consists of red shale and red to tan lenticular sandstone which increases in abundance southward. In Payne County, the Garrison Shale includes 140 to 180 feet of red shale or claystone and red to tan lenticular sandstone. Zones of nodular dolomite lenses, present at several positions in the shale, range in thickness from less than 1 foot to more than 10 feet. These lenses are poorly exposed and have no topographic expression. However, dolomitic beds are exposed in road cuts along Highway 108 just south of Highway 51. In that area, sandstone is virtually absent, and the beds are locally more than 10 feet thick. Zones of dolomite also occur below sandstone beds in exposures of mudstone. The lenticularity and lithologic similarity of these dolomite lenses make surface correlation very difficult.

Sandstone probably composes a greater percentage of the Garrison than shale or claystone. The sandstone bodies occur as single genetic units, averaging 12 feet in thickness, to multistoried complexes as much as 50 feet thick. The sandstones are lenticular and are characterized by erosional bases, fine to very fine grain size, and a red to tan color. Initial dip and medium- and small-scale crossbedding are the most common sedimentary structures. Cut-out channels filled with silt and clay and basal dolomitic and clay-pebble conglomerates are common features of some sandstone bodies.

Several sandstones have been mapped for various distances across the County and are designated according to their position above the base of the Garrison. The most persistent sandstones include IPg-10, IPg-40, IPg-60, IPg-125, and IPg-175. Paleocurrent indicators for these units suggest a major trend of approximately N. 50° W. and secondary trends of S. 40° W. and S. 50° E. (fig. 11).

Sandstone IPg-10, which locally cuts out the Cottonwood, is present as a single genetic unit 12 feet thick and as a member of a multistoried complex 50 feet thick. In sec. 35, T. 20 N., R. 4 E., the grain size of IPg-10 decreases upward from fine to very fine. In sec. 19, T. 18 N., R. 4 E., where the sandstone is thickest, the grain size ranges from medium to fine. At both localities, the sandstone is characterized by an erosional base, initial dip, and medium- and small-scale crossbedding. Convolute bedding is prevalent in the southern section. The paleocurrent trend for the sandstone at the southern locality is S. 30° W.

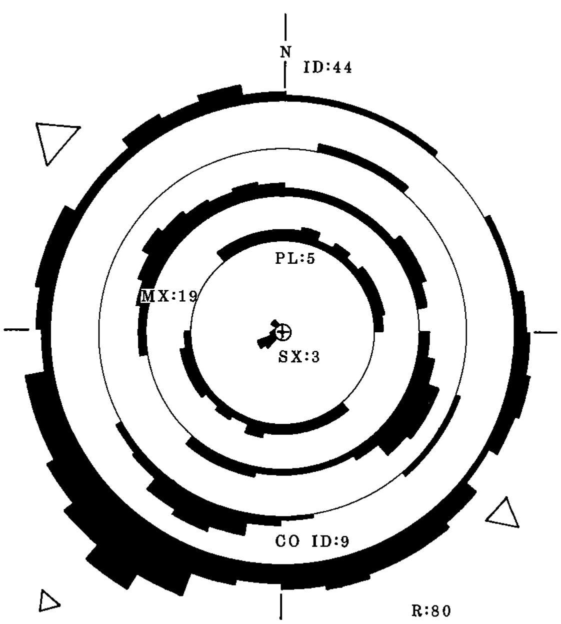



Figure 11. Paleocurrent diagram of sandstones in Garrison Shale, indicating primary direction of N. 50° W. and secondary directions of S. 50° E. and S. 40° W. See figure 6 for explanation of diagrams.

Sandstone IPg-40 is mappable north of Highway 51. In sec. 5, T. 19 N., R. 4 E., the unit is 10 feet thick and has an erosional base and an upward decrease in grain size. The characteristic sedimentary structure is initial dip, measurements of which suggest a current trend of N. 5° E.

In sec. 33, T. 20 N., R. 4 E., sandstone IPg-60, which is mappable across the County, is similar to IPg-40. In that area it is 10 feet thick and is characterized by an erosional base, an upward decrease in grain size, and initial dip. IPg-60, however, contains some medium-scale crossbedding, parting lineation, and a basal dolomite conglomerate. South of Stillwater Creek, IPg-60 is as much as 15 feet thick. Dolomite nodules are present in the red mudstone below the unit. Paleocurrent trend, based on initial dip, is westerly.

IPg-125 is also a persistent sandstone across Payne County. In sec. 4, T. 20 N., R. 4 E., where it is 18 feet thick, the prominent features are an erosional base, upward fining from fine-grained sand to silt, and cut-out channels near the top. Dolomite nodules are present in the red claystone below the base of the sandstone. Initial dip and medium- and small-scale crossbedding are characteristic structures, which indicate a channel trend of N. 80° W. South of Highway 51 near Stillwater Creek, IPg-125 is only 8 feet thick.

Sandstone IPg-175 was used in delineating the position of the overlying Wreford Limestone. In T. 20 N., R. 4 E., it is 15 to 20 feet thick. IPg-175 is fine to very fine grained, is composed of medium-scale crossbedding, and is bounded by an erosional base. In sec. 2, T. 17 N., R. 3 E., the sandstone is 20 feet thick, and the features are similar to those at the northern location. Paleocurrent indicators suggest a channel trend of S. 60° E. for the southern exposure and N. 40° W. for the northern exposure.

### *Wreford Limestone*

In Pawnee and Noble Counties the Wreford Limestone grades southward from a 6-foot interval containing two thin beds of gray fossiliferous limestone and shale to a red sandy, dolomitic limestone, only a few inches thick (Greig, 1959, p. 106–109; Shelton and others, 1979, p. 7). In Payne County, the Wreford is represented by nodular dolomite lenses that range in thickness from less than 1 foot to more than 10 feet. The nodules are composed of fine carbonate mud, and many have a septarian structure. Others consist of an interwoven network of calcite or dolomite veinlets. The nodules are red to green and range in size from less than 1 inch to 1 foot in diameter.

The Wreford of Payne County is extremely difficult to map on the surface. Because the dolomite lenses form no topographic feature, the escarpment of an underlying sandstone, IPg-175, and electric-log projection were used as control.

*Matfield–Oketo Shale*

The Matfield–Oketo Shale includes the beds between the Wreford and Fort Riley Limestones. The Matfield–Oketo undergoes a facies change southward from Kay County, where it is a 60- to 95-foot sequence of red and tan shale and claystone with a sandy algal limestone (Greig, 1959, p. 110). In Pawnee and Payne Counties, the Matfield–Oketo is composed of 100 feet of red shale and lenticular sandstone, and thin nodular to conglomeratic limestone. Sandstone composes a greater percentage of the section than shale in the study area.

Sandstones of the Matfield–Oketo Shale range in thickness from 10 feet for a single genetic unit to 40 feet for a multistoried complex. Each unit is characterized by an erosional base, fine to very fine grain size, upward fining, initial dip, and medium- and small-scale crossbedding. Local features of sandstones are cut-out channels filled with clay and silt, and basal clay-pebble and dolomite conglomerates. Thin green bands generally are present in shale directly above or below a sandstone body, and they are commonly associated with dolomite nodules (fig. 12). Compilation of paleocurrent measurements in the sandstones of the Matfield–Oketo Shale indicates a depositional current of approximately N. 85° W. (fig. 13).

Two prominent sandstones mapped over most of the County are designated IPmo-35 and IPmo-80. Sandstone IPmo-35 is mapped from a point near the northern edge of Payne County to Highway 51. In sec. 14, T. 19 N., R. 3 E., it is 10 feet thick and fine to very fine grained (fig. 14). Important characteristics include an erosional base, upward fining, some medium-scale crossbedding, and much deformed bedding. At other localities, initial dip is a major sedimentary structure. Measurements of initial dip and parting lineation suggest a westerly channel trend.

Unit IPmo-80 is a highly persistent sandstone across Payne County. In sec. 22, T. 19 N., R. 3 E., where the sandstone is more than 20 feet thick, it is a multilateral and multistoried body consisting of several lenticular units at approximately the same stratigraphic position (figs. 15, 16). It is very

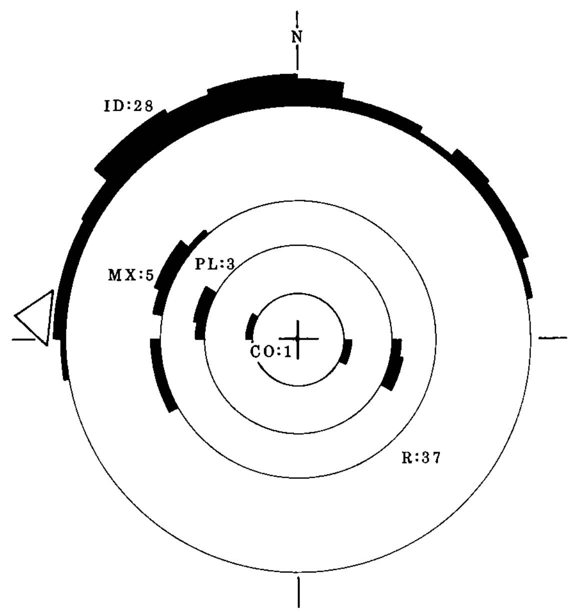



Figure 13. Paleocurrent diagram of sandstones in Matfield–Oketo Shale, showing trend of N. 85° W. See figure 6 for explanation of diagrams.

Figure 12. Typical outcrop of nodular dolomite in Matfield–Oketo Shale. The carbonate lies directly above sandstone IPmo-80 and is located in sec. 32, T. 19 N., R. 3 E.


Figure 14. Matfield–Oketo sandstone IPmo-35 with erosional base in sec. 14, T. 19 N., R. 3 E. The single genetic unit (*s*) is a sandstone-filled channel, which cuts down into underlying mudstone (*m*).


Figure 15. Matfield–Oketo sandstone Pmo-80, a multistoried and multilateral complex, in sec. 22, T. 19 N., R. 3 E., showing sandstone-filled channel (*a*), which cuts out part of adjacent channel (*b*). The sandstone displays initial dip (*i*) and medium-scale crossbedding (*m*).

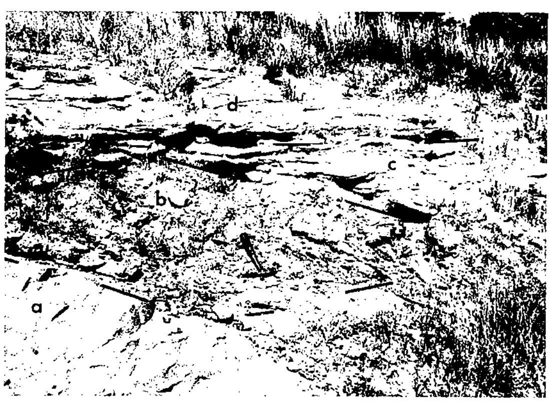



Figure 16. Mudstone-filled channel (*b*) in Matfield–Oketo sandstone Pmo-80 at same locality as figure 15. The channel, which cuts into underlying sandstone (*a*), is cut out by sandstones (*c* and *d*).

fine to medium grained and shows an overall upward fining. Cut-and-fill, some with clay fills, and medium-scale crossbedding are the major sedimentary structures. Paleocurrent indicators suggest a channel trend of N. 85° W.

### *Fort Riley Limestone*

In Noble County the Fort Riley Limestone thins southward from 30 feet of fossiliferous (primarily algal) limestone, with interbedded shale and thin siltstone, to less than 1 foot of sandy, fossiliferous dolomite in the middle of a prominent sandstone section (Shelton and others, 1979, p. 10). On the Noble–Payne County line, immediately north of Glencoe, the Fort Riley is represented by 1 foot of fossiliferous limestone in a section of gray shale below a thick sandstone. One mile south of this exposure, lenticular beds of red to green, sandy, nonfossiliferous, nodular dolomite are present below this sandstone. This dolomite, regarded as the Fort Riley Limestone, is recognized at various localities across Payne County.

Although the Fort Riley is poorly exposed on the surface and is difficult to map, it generally can be correlated in the shallow subsurface by means of electric logs. The position of the limestone was extended to the southern edge of Payne County by mapping the overlying resistant sandstone and using stratigraphic thicknesses and well depths of older beds (i.e., projecting subsurface data up to the surface).

The Fort Riley is most prominent in secs. 16 and 20, T. 19 N., R. 3 E. At those places, the unit is 1 foot or less in thickness and is locally truncated by the overlying sandstone. It consists of dolomite nodules that range from less than 1 inch to about 6 inches in diameter. The nodules are generally composed of fine-crystalline mud with interwoven calcite or dolomite veinlets, and many have septarian structures.

### *Doyle Shale*

The Doyle Shale includes the beds between the top of the Fort Riley and the base of the Winfield Limestone. The Doyle thickens and undergoes a facies change southward. In Kay County, it consists primarily of a section of red shale with thin limestones, 125 to 135 feet thick. In Pawnee and Noble Counties the limestones are absent, and the Doyle section is represented by 120 to 170 feet of red shale, or claystone, and lenticular sandstones (Greig, 1959, p. 115; Shelton and others, 1979, p. 10–11). The amount of sandstone increases to the south. In Payne County, the Doyle is approximately 170 feet of red shale, or claystone, with lenticular sandstones and nodular dolomite lenses. Sandstone composes a greater percentage than mudstone.

Sandstones of the Doyle Shale range from single genetic units 10 feet thick to multistoried complexes 30 to 40 feet thick. Each sandstone is characterized by an erosional base, silt to fine-grained sand, an overall upward decrease in grain size, initial dip, and medium- and small-scale crossbedding. Dolomite conglomerates, clay-pebble conglomerates, and zones of calcareous and dolomitic cement are present locally at the base of the sandstones. A feature of the mudstone, also noted by Greig (1959, p. 116) in Pawnee County and Shelton and others (1979, p. 11) in Noble County, is a green band or zone at the top and (or) base of individual sandstone units. The band is generally associated with dolomite nodules in Payne County. The major current directions suggested by the summation of paleocurrent indicators for the Doyle sandstones are approximately N. 40° W. A secondary trend is approximately S. 45° W. (fig. 17).

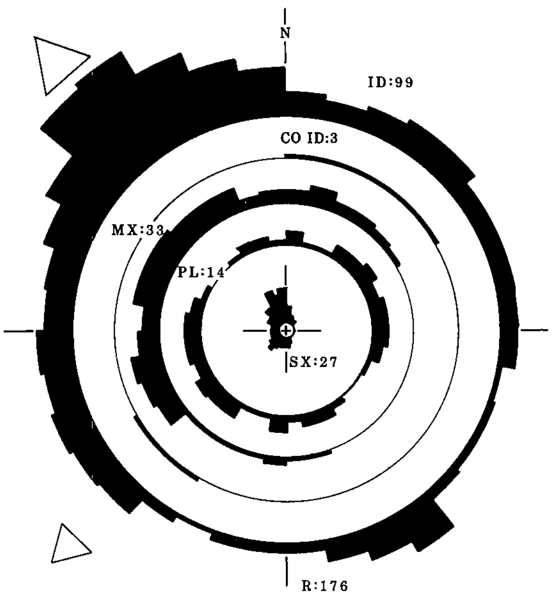



Figure 17. Paleocurrent diagram of sandstones in Doyle Shale, indicating primary direction of N. 40° W. and secondary trend of S. 45° W. See figure 6 for explanation of diagrams.

Five sandstones were mapped along various parts of the outcrop belt of the Doyle Shale. They are designated, on the basis of stratigraphic position, as IPd-10, IPd-60, IPd-90, IPd-105, and IPd-165.

Unit IPd-10 is the prominent sandstone used in delineating dolomite nodules at the position of the Fort Riley Limestone. At the six localities where it is described, the sandstone has an erosional base, initial dip, and medium- and small-scale crossbedding. It is generally characterized by an overall upward decrease in grain size. However, in sec. 24, T. 20 N., R. 3 E., the sandstone exhibits both upward and downward fining, and in sec. 29, T. 18 N., R. 3 E., a shale zone 1 foot thick is present in the middle of the sandstone. The IPd-10 unit ranges in thickness from 11 to 20 feet. Paleocurrent measurements suggest a major current trend of N. 80° W. and a secondary trend of approximately N. 10° W.

Sandstone IPd-60 forms a prominent ridge across most of Payne County. In sec. 22, T. 20 N., R. 3 E., it occurs as a single genetic unit 9 feet thick. South of Stillwater Creek, the unit is commonly the upper part of a multistoried complex 30 to 40 feet thick. At every locality where sandstone IPd-60 was observed, it is characterized by an erosional base, fine to very fine grain size, overall upward fining, initial dip, and medium-scale crossbedding. At most places dolomite nodules are present in red claystone below the base of the sandstone. In sec. 22, T. 20 N., R. 3 E., spherical carbonate concretions are found in the sandstone directly above the base of IPd-60, and in sec. 28, T. 18 N., R. 3 E., the basal foot is cemented with calcite. The dominant paleocurrent direction, as suggested by medium-scale crossbedding, is approximately north.

Sandstone IPd-90 was mapped for only a limited extent in the north-central part of the County, where it caps prominent hills. The unit is 11 feet thick and is fine to very fine grained. It is characterized by a sharp base, an overall upward decrease in grain size, and medium-scale crossbedding.

Sandstone IPd-105 is best developed south of Stillwater Creek, where it is part of a multistoried complex with a minimum thickness of 33 feet. It was mapped in the area north of Stillwater Creek, although exposures there are generally poor. In sec. 17, T. 18 N., R. 3 E., the complex is fine to very fine grained and shows an overall upward decrease in grain size. It is characterized by cut-and-fill, which represents a number of channels at about the same stratigraphic position. Initial dip and medium-scale crossbedding are the major sedimentary structures. A silt- or clay-filled cutout is present near the top of the sandstone body. Zones of abundant ferruginous cement, approximately 1 foot thick, are found at the top and 9 feet below the top of the complex. Paleocurrent indicators suggest a current direction of N. 45° W.

Sandstone IPd-165 was mapped across the County, even though exposures of the unit are rather poor in areas north of Stillwater. The maximum elevations of central Payne County are present in those areas; soil formation is advanced (Cobb and Hawker, 1918, p. 14–15). The poor quality of outcrop is believed to be due to weathering rather than sandstone pinch-out. Unit IPd-165 ranges from a genetic unit 9 feet thick to a multistoried complex 30 feet thick. It has an erosional base and overall upward fining from fine to very fine grained. Initial dip and medium- and small-scale crossbedding are the major sedimentary structures. Locally, dolomite nodules occur in the red claystone at the base of the sandstone. In secs. 12 and 13, T. 19 N., R. 2 E., a maroon dolomite-limestone conglomerate is present at the base of the sandstone. Vertical tubular structures about ¼ inch in diameter, which resemble burrows, are present in sec. 26, T. 19 N., R. 2 E. These burrow-like structures are also present along with a mold of wood in sec. 12, T. 19 N., R. 2 E. Paleocurrent measurements of small-scale crossbedding and parting lineation at the latter locality suggest a channel trend of S. 35° W.

### *Winfield Limestone*

The Winfield sequence demonstrates a facies change in Noble County (Shelton and others, 1979, p. 11). It grades from 2 feet of fossiliferous limestone (grainstone) to less than 1 foot of red, nonfossiliferous, nodular limestone. The nodular limestone of southern Noble County was traced southward to the Lincoln–Payne County line. The escarpment of an underlying sandstone and intervals from well control are used in determining the position of the Winfield. Scattered exposures indicate that the unit is less than 1 foot thick and consists of red dolomite or limestone nodules which are similar lithologically to the other limestone units of central Payne County.

### *Enterprise Shale*

The Enterprise Shale represents the interval between the Winfield and Herington Limestones. In Noble County, the Enterprise Shale is 70 feet thick and is characterized by red shale or claystone and lenticular sandstone (Shelton and others, 1979, p. 12). The Enterprise of Payne County is 60 feet thick and is distinguished from the other shale units of the Oscar Group in that it is relatively free of sandstone and nodular dolomite. Thin, lenticular sandstone units are locally present 5 to 20 feet above the Winfield position and also are associated with the Herington Limestone. Exposures of the Enterprise Shale are sparse, but where it is observed it consists of red shale or claystone. South of Stillwater Creek, in secs. 26 and 35, T. 19 N., R. 2 E., the Enterprise Shale apparently thins locally to 40 feet.

### *Herington Limestone*

The Herington Limestone is the youngest unit of the Oscar Group. In Noble County, the Herington grades southward from a fossiliferous grainstone-packstone less than 8 feet thick to a thin sequence of red, nodular, dolomitic limestone and interbedded sandstone (Shelton and others, 1979, p. 3). In Payne County, the Herington Limestone is essentially identical to the red, nodular, dolomitic limestone of southern Noble County. It occurs in lenses less than 1 foot thick and was traced to the Lincoln–Payne County line by using intervals projected from well control and by mapping an overlying sandstone. In the northern part of the County, the nodules are pink and finely crystalline and are commonly associated with a thin, lenticular sandstone. This sandstone, which is less than 5 feet thick and very fine grained, exhibits initial dip as its major structure. South of Stillwater Creek, the nodules are red, sandy, and interlaced with calcite or dolomite veinlets.

## Permian System

Permian rocks include approximately 800 feet of the Wellington Formation, the lowest unit of the Cimarronian Series, as defined by the Oklahoma Geological Survey.

### *Wellington Formation*

In Noble County, the Wellington is a sequence of red shale or claystone, lenticular sandstone, gray-green shale, and thin dolomite beds. Aside from the red color, the most dominant characteristic of the Wellington in Noble County is a facies change wherein lenticular sandstones are developed southward at the expense of red mudrock and thin dolomite units (Shelton and others, 1979, p. 13). The formation in western Payne County not only is lithologically similar to the Wellington of Noble County but also, as in Noble County, is characterized by better sandstone development southward.

Patterson (1933, p. 248–251) subdivided the Wellington into a lower member, the Fallis, dominated by sandstone, and an upper member, the Iconium, dominated by shale. This subdivision is difficult to follow in the study area because of sandstone bodies developed in both the upper and lower parts of the Wellington. In Noble County, Shelton and others (1979, p. 14) subdivided the Wellington into four unnamed units using three key beds. In Payne County, the Wellington is subdivided into three unnamed units using two relatively prominent sandstone sequences as key beds. The lower and upper key beds, sandstones 200 and 600 feet above the base of the Wellington and designated Pw-200 and Pw-600, respectively, separate the formation into lower, middle, and upper units.

*Lower unit and lower key bed.*—The lower unit of the Wellington Formation, some 200 feet thick, is characterized by red mudrock, discontinuous lenticular sandstones, and thin, discontinuous carbonate beds. The interval between the Herington Limestone and the lower key bed (Pw-200) has no sandstone which is continuous throughout the area, but several units are locally developed.

Unit Pw-20, the lowest sandstone of the Wellington Formation, is 10 to 12 feet thick. This very fine-grained sandstone is best developed in and south of Stillwater. North of Stillwater, it is difficult to trace because of the topography and character of the sandstone. In sec. 2, T. 20 N., R. 2 E., Pw-20 is a 10-foot section, with a slight overall upward decrease in grain size and an erosional base. Brown calcareous streaks are present in the sandstone, and a brown limestone conglomerate forms its base. The sedimentary structures include initial dip, small-scale crossbedding, and parting lineation. Within and south of Stillwater the sandstone is 10 to 15 feet thick, and at some localities it is gray in color. The major paleocurrent direction for Pw-20 is approximately N. 20° W.; a secondary trend is S. 65° W.

Sandstone Pw-40 is relatively continuous in the north but discontinuous in the south; and Pw-80, Pw-100, and Pw-160 are highly restricted and (or) discontinuous. Units Pw-120 and Pw-180 are sandstone sequences mappable only in the north, whereas Pw-20 and Pw-60 are developed only in the south. Several of these sandstone sequences are multistoried and multilateral complexes which range up to 50 feet in thickness and a mile or more in outcrop length. In the north, Pw-140 is associated with a carbonate which is a clay-pebble conglomerate, less than 1 foot thick; in the south, it is associated with a nodular dolomite or dolomite-cemented, cellular sandstone, 1 to 2 feet thick, containing animal trails.

The lower key bed, Pw-200, is a series of lenticular sandstones developed at approximately the same stratigraphic position. Its thickness ranges from less than 5 feet for a genetic unit in sec. 21, T. 20 N., R. 2 E., to more than 50 feet for a multistoried complex. It is generally characterized by a sharp undulatory base, although the base is gradational locally. Unit Pw-200 is fine to very fine grained, exhibits moderate to good sorting, and contains a few intraformational rock fragments.

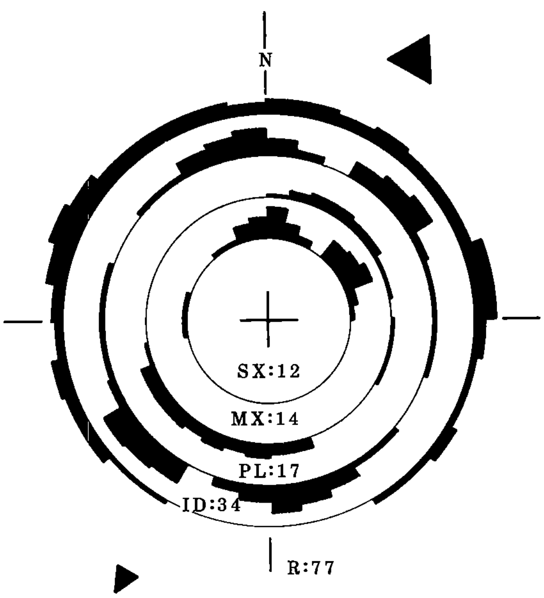



Figure 18. Paleocurrent diagram of sandstones in lower unit of Wellington Formation, showing primary direction of N. 30° E. and secondary direction of S. 30° W. See figure 6 for explanation of diagrams.

Sandstones in the lower unit, including the lower key bed, show an average paleocurrent direction of N. 30° E. A minor, or secondary, direction is S. 30° W. (fig. 18).

*Middle unit.*—Red mudrock, multilateral lenticular sandstones, nodular dolomite, and algal-mat carbonate beds characterize the middle 400 feet of the Wellington Formation. The mapped sandstones are fine to very fine grained, and many have sharp undulatory bases and sharp lateral contacts.

The 400-foot interval between Pw-200 and Pw-600 has several relatively continuous sandstone sequences. Units Pw-320, Pw-380, Pw-420, Pw-460, and Pw-500 extend across the County. Pw-380 is a multilateral sandstone sequence from less than 5 feet to almost 40 feet thick, with some carbonaceous material. Pw-460 is also a good example of a multilateral sequence (fig. 19). Pw-240 and Pw-260 are developed in the north, whereas Pw-280 is a multilateral, multistoried, carbonate-cemented sandstone in the south. Pw-400 is developed only in the area south of Lake Carl Blackwell. Pw-480, Pw-560, and Pw-580 are discontinuous sandstones found only in the south; Pw-480 and Pw-580 have intraformational fragments. The thickness of Pw-480 increases southward to more than 20 feet in sec. 32, T. 18 N., R. 1 E. This southward increase in sandstone thickness characterizes several other units, especially those from 240 to 300 feet above the base. That interval contains several thin sandstones in T. 18 N., R. 1 E., and R. 2 E., but becomes largely sandstone at Horsethief Canyon in Logan County, just south of the Cimarron River (fig. 20). Sandstone Pw-500 in sec. 10, T. 19 N., R. 1 W., is a 5-foot genetic unit associated with nodular dolomite, whereas it is more than 20 feet thick in sec. 17, T. 18 N., R. 1 E. At the latter locality the multistoried sandstone contains carbonate cement, intraformational fragments, iron minerals replacing wood

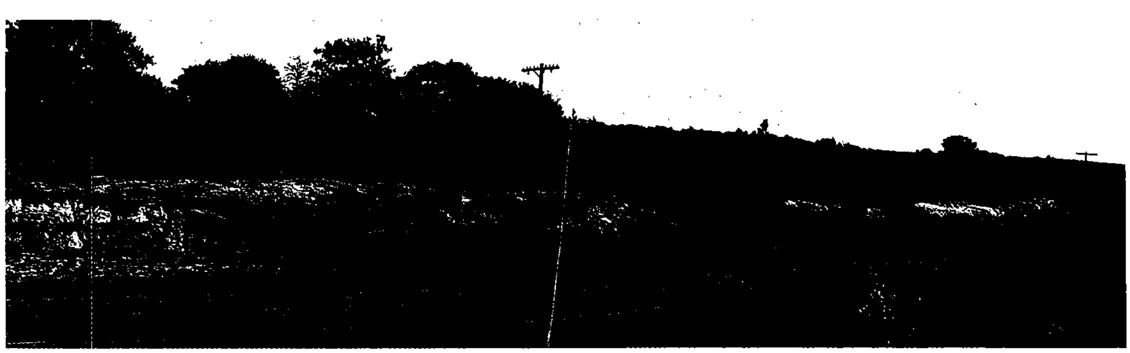


Figure 19. Wellington sandstone Pw-460, showing multilateral development in sec. 21, T. 19 N., R. 1 E.

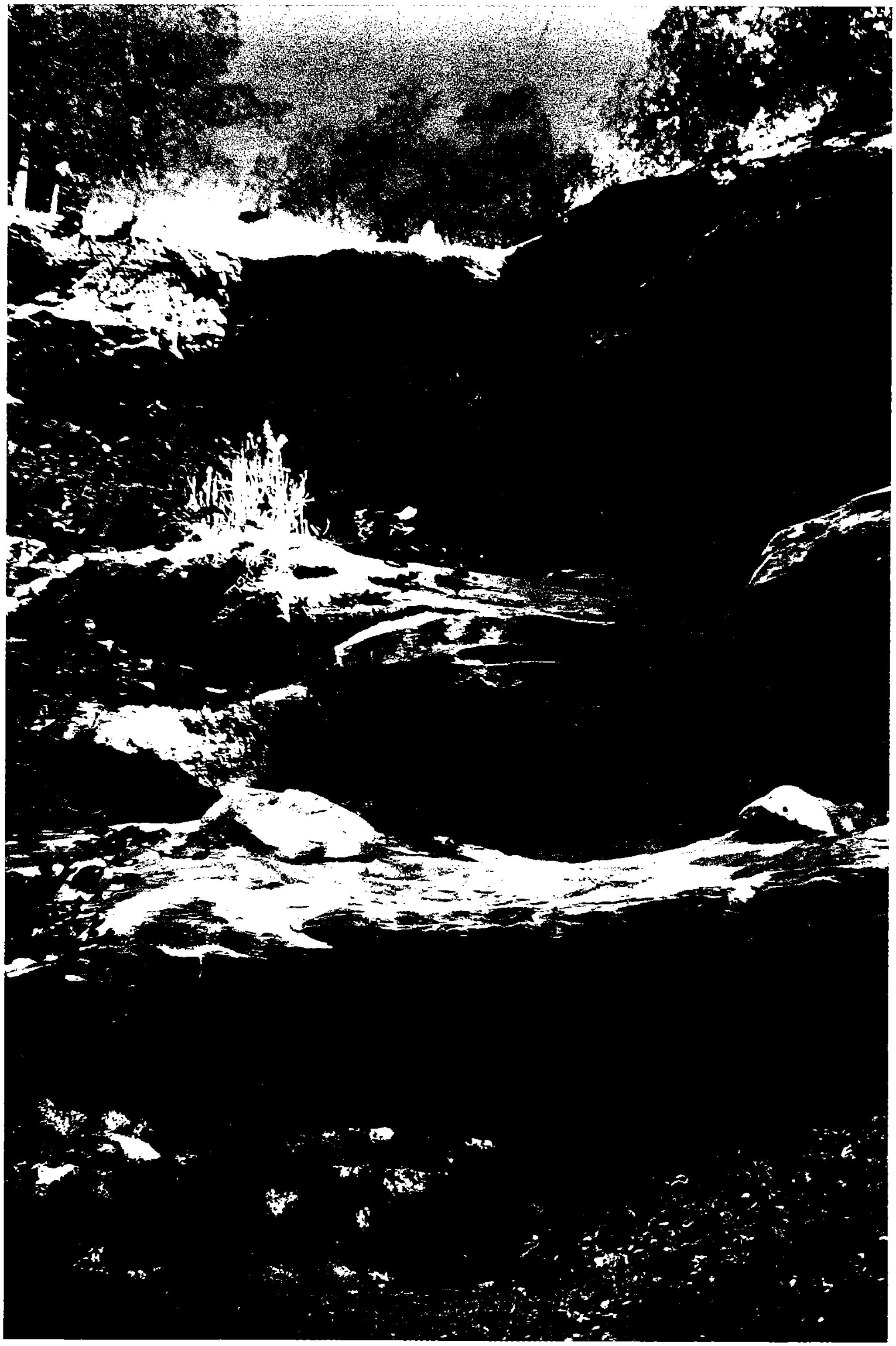


Figure 20. Wellington sandstones Pw-240 through Pw-300 as a continuous exposure, approximately 60 feet high, in sec. 14, T. 17 N., R. 1 E., Logan County, just south of Cimarron River.

fragments, and crinoid fragments. Farther south, in sec. 31, T. 18 N., R. 1 E., Pw-500 is a multilateral, multistoried complex almost 50 feet thick, with three dolomite, clay-pebble conglomerates.

Sandstones of the middle unit show a major paleocurrent direction of N. 55° W.; a minor trend extends N. 55° E. (fig. 21).

Dolomite lenses are locally developed at various stratigraphic positions in the middle unit of the Wellington Formation. The most impressive outcrop of dolomite in the study area is a sequence of algal-mat carbonate beds in sec. 15, T. 19 N., R. 1 W., which contain stromatolites similar to those found in supratidal to intertidal areas.

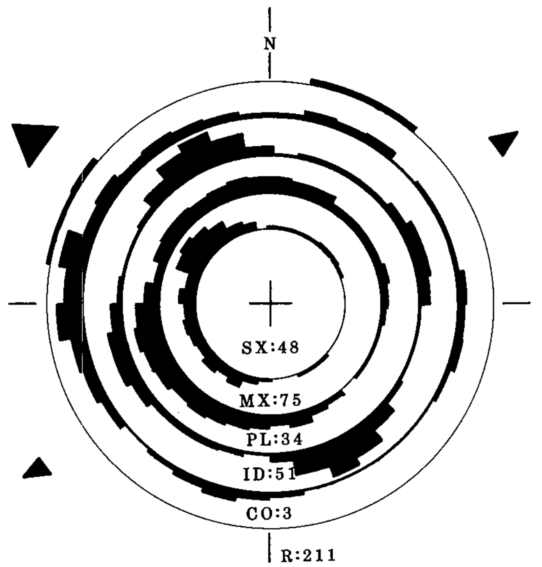



Figure 21. Paleocurrent diagram of sandstones in middle unit of Wellington Formation. Primary direction is N. 55° W. Secondary trend is N. 55° E. See figure 6 for explanation of diagrams.

*Upper unit and upper key bed.*—The upper part of the Wellington Formation exposed in Payne County includes 180 feet of rather persistent sandstone sequences, composed of individually lenticular units, thin nodular dolomite, and thin carbonate beds.

The upper key bed (Pw-600) is fairly continuous sandstone throughout the area, with lenticular bodies developed at approximately the same stratigraphic position. It is 5 to 15 feet thick, is characterized by a sharp undulatory base, and is fine to very fine grained and well sorted. Locally, nodular dolomite is associated with Pw-600.

Units Pw-620, Pw-640, Pw-660, Pw-680, Pw-700, and Pw-740 are similar in range of thickness, lateral continuity, and grain size. Pw-640 and Pw-660, with some medium-grained sandstone beds, are coarser than other beds. Pw-640 contains fossil fragments in sec. 8, T. 19 N., R. 1 W. Pw-640 and Pw-740 are not as continuous as the other beds. Thin limestone and nodular dolomite beds are commonly associated with Pw-620. In secs. 1 and 13, T. 18 N., R. 1 W., two nodular dolomite beds are present (fig. 22), whereas three limestone beds are present locally to the south. Pw-660 in sec. 5, T. 19 N., R. 1 W., contains large-scale crossbedding (fig. 23). Pw-680 was quarried in sec. 17, T. 19 N., R. 1 W., for subbase material for Interstate Highway 35. Intraformational clay and carbonate fragments are locally present in many of the sandstones in the upper unit.

The major paleocurrent direction for sandstone of the upper unit, including the upper key bed, is N. 45° W. An apparent secondary direction is N. 50° E. (fig. 24).

## Quaternary System

The Quaternary deposits of Payne County are alluvial sand, silt, and clay, and eolian sand and silt. These sediments, except for eolian silt, occur as mappable units in the flood plain and terraces of the Cimarron River and along major creeks.

### *Terrace Deposits*

Terraces were mapped along the Cimarron River and some of the major creeks. They are best developed along the Cimarron River and Stillwater Creek; only isolated terrace remnants occur along West Brush Creek and the lower reaches of Little Stillwater Creek. Cimarron River terraces are composed primarily of sand with accessory amounts of gravel, silt, and clay. Silt also occurs as loess, which blankets some terrace surfaces and other upland surfaces. The best exposure is in the southwest corner of sec. 25, T. 18 N., R. 2 E., where the contact between tan loess and red bedrock is striking. Sand dunes are found on tree-covered hills on the relatively even Cimarron River terrace surfaces. The best preserved dunes are on the lower terraces. Deposits on terraces are best exposed in road cuts and in sand pits near Perkins and in sec. 24, T. 18 N., R. 1 W. (fig. 25). The last locality, which is 4 miles north of the river and 120 feet above it, contains more than 20 feet of sand. In sec. 2, T. 17 N., R. 3 E., approximately 30 feet of red to tan, fine-grained sand is present.

Scattered large, round quartzite pebbles are present locally on upland areas as far north as Highway 51. These pebbles are thought to be remnants of widespread deposits of one or more extensive high terraces of the Cimarron River, or a predecessor.

### *Alluvial Deposits*

Alluvial deposits compose the flood plain and channel of the Cimarron River and of major creeks. The deposits consist primarily of sand,

Figure 22. One of two beds of nodular dolomite in upper unit of Wellington Formation in secs. 1 and 13, T. 18 N., R. 1 W. Hammer and notebook for scale.

Figure 23. Large-scale crossbedding (*LX*) in Wellington sandstone Pw-660 in sec. 5, T. 19 N., R. 1 W. Fence post is about 5 feet high.

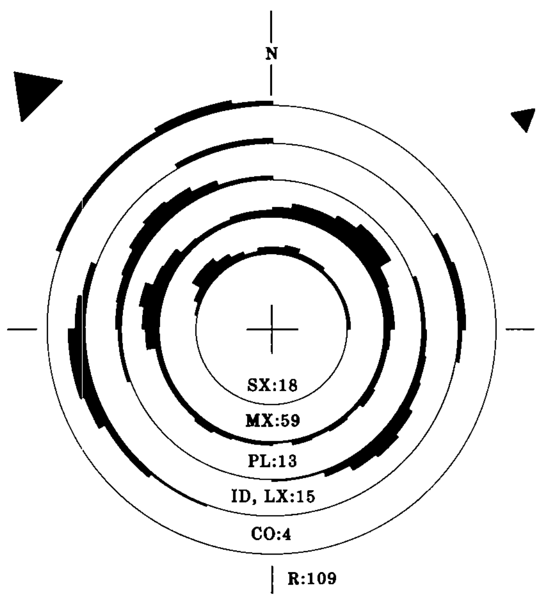



Figure 24. Paleocurrent diagram of sandstones in upper unit of Wellington Formation. Primary direction is N. 45° W. Secondary direction is N. 50° E. See figure 6 for explanation of diagrams.

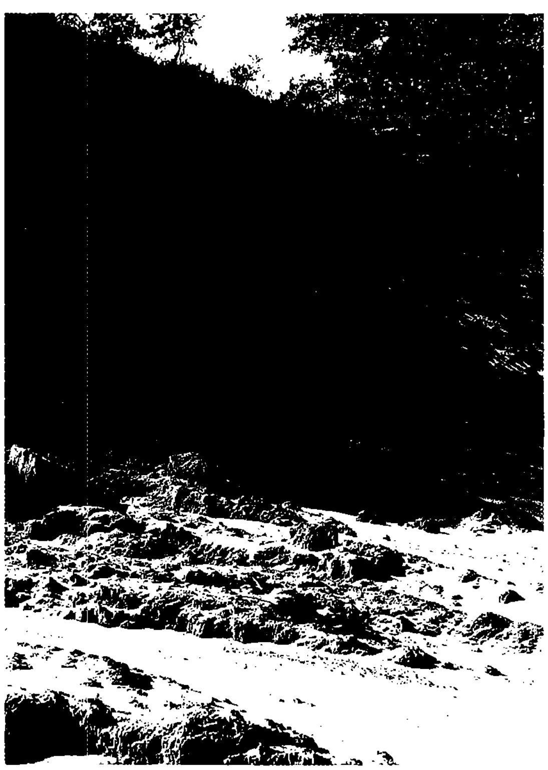


Figure 25. Exposure of terrace sand, with some 20 feet shown; total thickness is 40 feet. Location is in sec. 24, T. 18 N., R. 1 W., 4 miles north of and 120 feet above Cimarron River.

with some gravel, silt, and clay. Some sand dunes with large-scale crossbedding are also present on the flood plain along the Cimarron River. The best exposures of alluvial material are on the banks of the Cimarron River south of Perkins and in Stillwater Creek south of Stillwater. In the exposure along the Cimarron River the section consists of sand, with some gravel at or below low-water level, and thin interbeds of clay in a sequence which exhibits an overall upward fining. The sand is tan in color and is characterized by horizontal bedding and medium- and small-scale crossbedding (Noble, 1973, p. 25; Shelton and Noble, 1974, p. 743–744). In the Stillwater Creek exposure, alluvium is approximately 20 feet thick and is composed primarily of red coarse silt, very fine-grained quartz sand, and some clay.

## Subsurface Stratigraphy

The subsurface of Payne County has been studied extensively by petroleum geologists investigating the Oklahoma Platform. However, most of the results are not generally available because of proprietary reasons. Because the primary purpose of this study was to investigate surface geology, and because the geologic framework of subsurface rocks is well known by petroleum geologists, the following section primarily represents a summary of the investigations of Frost (1940), Lukert (1949), Hollrah (1977), Akmal (1950), Graves (1955), Stringer (1956), Dalton (1960), Clayton (1965), Kochick (1978), Cole (1968), Berg (1969), Astarita (1975), Candler (1975), and Shipley (1975).

A representative subsurface section, shown in figure 26, illustrates the stratigraphic positions, thicknesses, and electric-log features of the various stratigraphic units.

### Precambrian Rocks

Precambrian rocks identified as the Spavinaw Granite are present in three wells in eastern Payne County (Muehlberger and others, 1967, p. 2364). The Spavinaw Granite subcrops along a southwest-trending Precambrian arch from southwestern Missouri to Payne and Lincoln Counties. It typically is a micrographic granite porphyry which is richer in femic minerals than other basement rocks of northeastern Oklahoma (Muehlberger and others, 1967, p. 2365). Quartz and perthite with some plagioclase compose more than 90 percent of the rock. The Central Oklahoma Granite Group, which is characterized by both microcline and oligoclase, extends southward through western Payne County (Muehlberger and others, 1967, p. 2364–2366). Both units are approximately 1,200 m.y. old (Muehlberger and others, 1967, p. 2364).

Significant relief was apparently developed on the Precambrian surface prior to deposition of low-

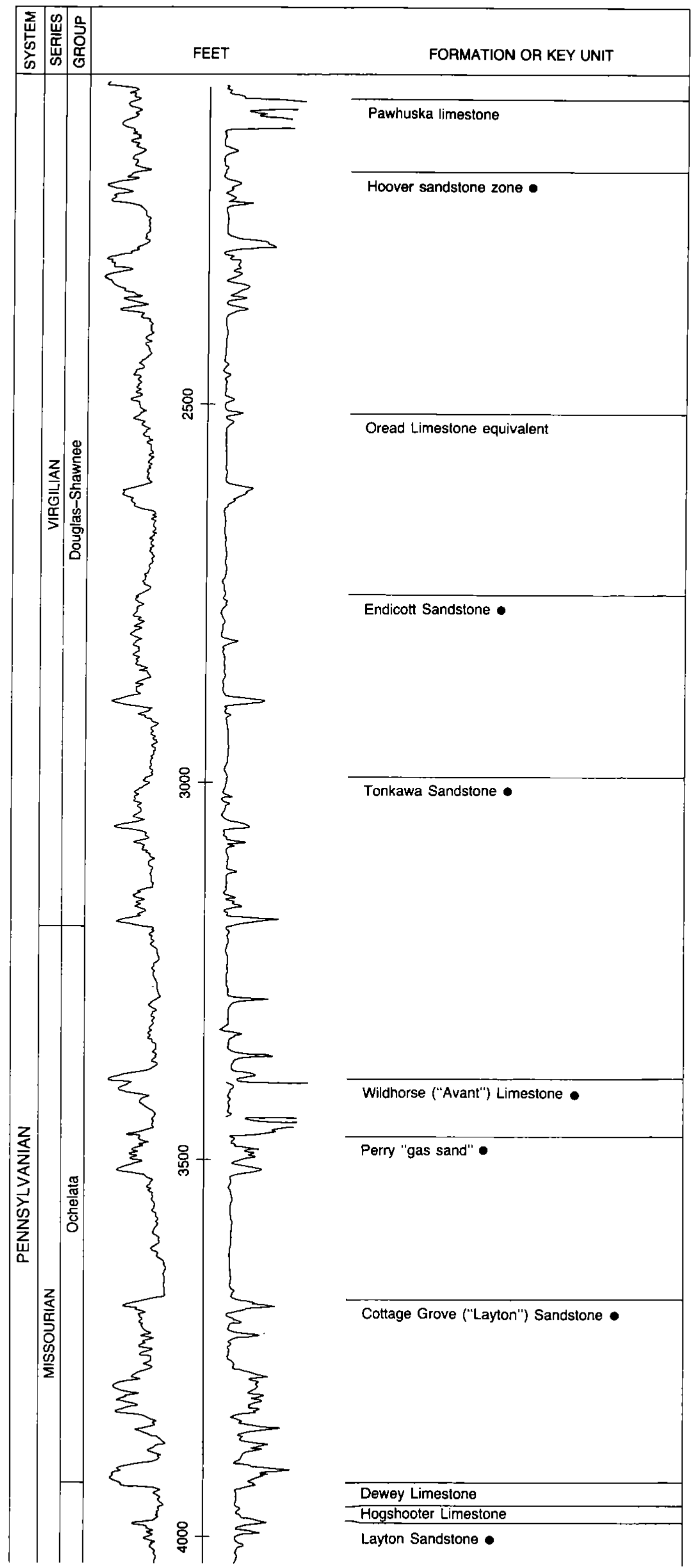
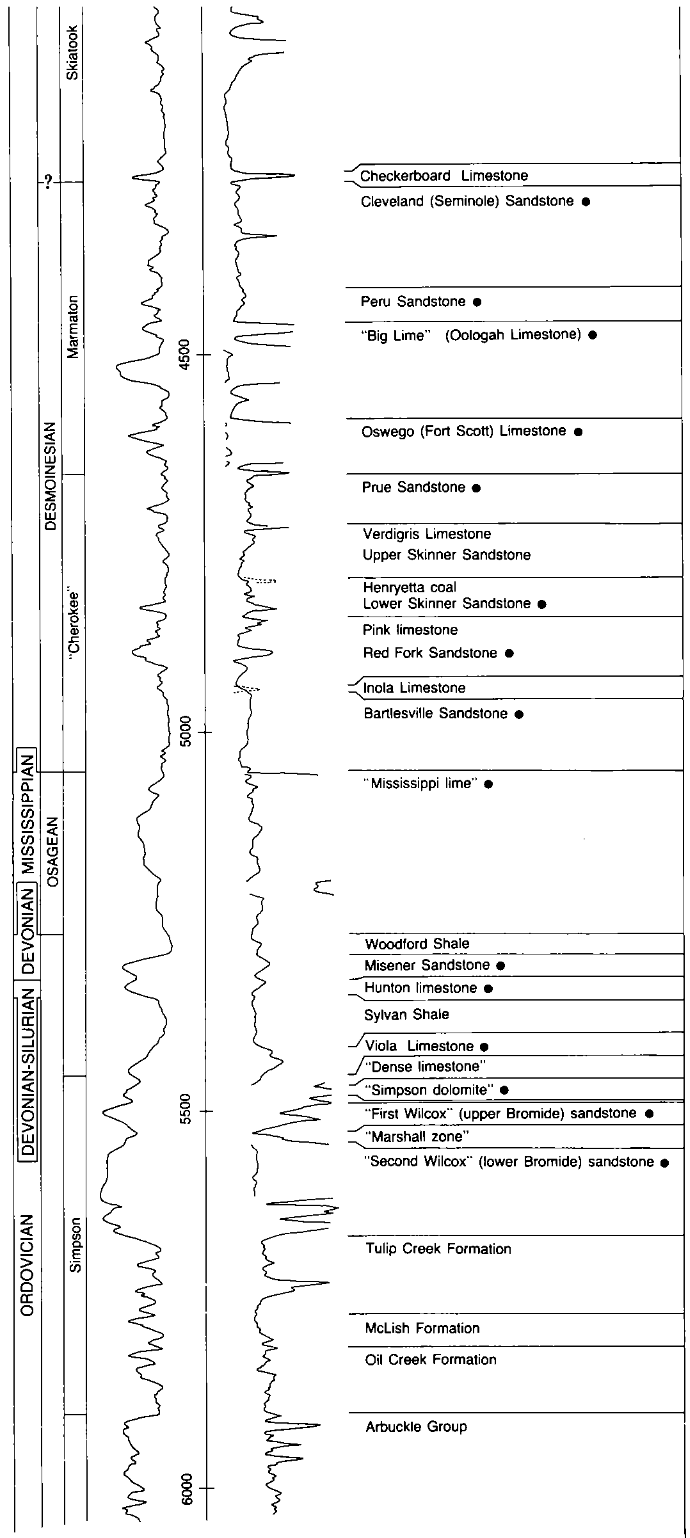



Figure 26. Composite section of subsurface rocks showing position, thickness, and electric-log characteristics of stratigraphic units. Section is shown in two segments, with top at upper left and bottom at lower right. Petroleum-producing reservoirs are indicated by solid circles. Correlations adapted from Lukert (1949, pl. 2) and Stringer (1956, fig. 2).


ORDOVICIAN
DEVONIAN-SILURIAN
DEVONIAN
MISSISSIPPIAN
OSAGEAN
DESMOINESIAN
?
Skiatook
Marmaton
"Cherokee"
Simpson
4500
5000
5500
6000
Checkerboard Limestone
Cleveland (Seminole) Sandstone ●
Peru Sandstone ●
"Big Lime" (Oologah Limestone) ●
Oswego (Fort Scott) Limestone ●
Prue Sandstone ●
Verdigris Limestone
Upper Skinner Sandstone
Henryetta coal
Lower Skinner Sandstone ●
Pink limestone
Red Fork Sandstone ●
Inola Limestone
Bartlesville Sandstone ●
"Mississippi lime" ●
Woodford Shale
Misener Sandstone ●
Hunton limestone ●
Sylvan Shale
Viola Limestone ●
"Dense limestone"
"Simpson dolomite" ●
"First Wilcox" (upper Bromide) sandstone ●
"Marshall zone"
"Second Wilcox" (lower Bromide) sandstone ●
Tulip Creek Formation
McLish Formation
Oil Creek Formation
Arbuckle Group

er Paleozoic units. For example, in one basement test only 200 feet of sandstone separates the Devonian Woodford Shale from granite; also, the Precambrian is overlain by a very thin Cambrian–Ordovician Arbuckle section in a second Precambrian well.

### Cambrian System

The Upper Cambrian Reagan Sandstone is 100 feet thick in southern Noble County, northwest of Payne County. Its distribution in Payne County is thought to be irregular because of paleotopographic relief on the surface of the basement. In southern Noble County the Reagan is fine- to coarse-grained glauconitic sandstone with dolomite, which overlies 20 feet of sandy dolomite and gray-brown shale containing feldspar fragments (Page, 1955, p. 11).

### Cambrian and Ordovician Systems

The Arbuckle Group, Croixan and Canadian in age, is poorly known from wells in Payne County. In one of the three basement wells the Arbuckle is represented by only 45 feet of crystalline dolomite, with some chert. The well with greatest stratigraphic penetration in the western part of Payne County drilled only 140 feet of Arbuckle above total depth (Stringer, 1956, p. 31). In the basement test in southern Noble County, the Arbuckle consists of 1,455 feet of gray and brown dolomite in various crystal (grain) sizes, with thin beds of sandstone. The beds commonly contain some chert, which is generally less abundant in the basal and uppermost parts.

### Ordovician System

Post-Arbuckle Ordovician rocks are locally variable in thickness because of erosion associated with growth of structures; this thickness variation is more uniform across Payne County because of the more regional influence of the Ozark Uplift. Subcrop patterns trend northwest to west-northwest (Tarr and others, 1965). The regional subcrop of the Simpson Group below the Devonian Woodford Shale lies east and northeast of Payne County. Local subcrop areas are present in eastern Payne County as a northwesterly trend. The subcrop belt of the Viola Limestone (below the Woodford) is about 10 miles wide, and the downdip edge extends from the southeast edge of the County to the northwest corner of T. 20 N., R. 2 E. Two local subcrop areas, corresponding to domal or anticlinal features, are present in T. 19 N., R. 4 E. The Sylvan Shale is present in the area southwestward from its subcrop edge.

#### *Simpson Group*

The Simpson Group thickens gradually from less than 100 feet in the northeastern and eastern parts of the County to approximately 500 feet in the west. The lower part, which is thought to be approximately equivalent to the Oil Creek, McLish, and Tulip Creek formations, is regarded by some workers as the "Tyner zone." This sequence contains interbedded green shale, local zones of red shale, limestone, dolomite, and dolomitic sandstone. In the western part of the area, where a complete Simpson section is present, a representative thickness for this part of the group is 250 feet. The "Second Wilcox" sandstone, the "Marshall zone," the "First Wilcox" sandstone, the "Simpson dolomite," and the "Dense limestone" are informal units which are thought to be the approximate equivalent of the Bromide Formation. The "Wilcox" sandstones are quartz-rich, porous quartzarenites, which were deposited in shallow-marine waters, along with green shale which contains muscovite, biotite, chlorite, and scattered dolomite rhombs (R. E. Denison, oral communication, 1973).

The "Second Wilcox" is commonly 100 feet thick; the "First Wilcox" is thinner, generally 20 to 40 feet. The reservoir quality of the "First Wilcox" may be impaired locally by clay and carbonate cement. The "Marshall zone," which thickens westward and southward, ranges in thickness from 15 to 100 feet. It is an interbedded sequence of dolomite and shale, with thin beds of sandstone. The "Simpson dolomite," 20 feet or less in thickness, is finely crystalline. Locally, the lowermost part is a thin sandstone and (or) chert. The "Dense limestone" is a light-colored, fine-grained unit which is 5 to 50 feet thick.

#### *Viola Limestone*

The Viola Limestone is one of the most widely used lower Paleozoic stratigraphic markers in north-central Oklahoma. The top of the Viola is the reference surface of a structural-contour map which portrays the deeper subsurface structure in Payne County (pl. 3). The limestone shows a variation in lithology from mud-supported to grain-supported rock types; it also contains crystalline carbonate and chert. The maximum recorded thickness of the Viola is 55 feet; it generally thickens westward and southwestward across the County.

In 1983 Amsden redefined the Viola Limestone, as used in this report, as the Viola Group, which consists of the Viola Springs Formation and the overlying Welling Formation ("Fernvale" equivalent). We retain the term Viola Limestone here, principally because it follows standard subsurface usage.

#### *Sylvan Shale*

The Sylvan Shale is a green-gray shale, which increases in thickness in a southwesterly direction from 0 to approximately 80 feet. The shale is dolomitic and blocky rather than fissile.

### Silurian and Devonian Systems

The Hunton Group, which is present in the western part of the County, was deposited in an embayment. It is characterized by overall northward thinning owing to erosion before deposition of the overlying Woodford Shale. The Hunton extends as far north as secs. 32 and 33, T. 20 N., R. 2 E. (Hollrah, 1977, pl. 1). Its maximum thickness is about 125 feet, in the northeastern part of T. 17 N., R. 1 E. The axis of the embayment, along which the Hunton is somewhat thicker than in adjacent areas to the east and west, is essentially coincident with the north-northeast-trending fault system that extends through the Ramsey Field in sec. 18, T. 18 N., R. 2 E. (Hollrah, 1977, pl. 1).

The Hunton, which is composed almost entirely of limestone and dolomite, is represented by the Silurian "Basal dolomite" and the Chimneyhill Formation (or Subgroup) (Hollrah, 1977, fig. 8).

### Devonian System

Upper Devonian beds are represented by the widespread Woodford Shale and the underlying, locally developed Misener Sandstone. Prominent unconformities separate the Woodford from underlying and overlying sequences.

#### *Misener Sandstone*

The irregularly developed Misener Sandstone is a dolomitic, quartzose sandstone, characterized by sharp changes in thickness. Locally, the sandstone is as much as 50 to 60 feet thick (Kochick, 1978, pl. 1). In eastern Payne County, the Misener is present as two northwest-trending belts (Kochick, 1978, pl. 1). The areal distribution of the sandstone was apparently influenced by pre-Woodford topography, which in turn was influenced by pre-Woodford subcrop patterns. Generally, the Misener is best preserved in paleotopographic depressions, and trends of relatively thick sandstone are thought to represent narrow channel deposits that were preserved during the Woodford transgression.

#### *Woodford Shale*

The Woodford is rather uniform in thickness and character throughout the area. The range in thickness is 25 to 70 feet. The Woodford is readily recognizable as hard, partly siliceous and phosphatic, *Tasmanites*-bearing ("spore"-bearing), organic, dark-brown to black shale. To the petroleum geologist, the widespread marine transgression associated with the Woodford and the euxinic conditions represented by it together constitute one of the most important geologic events prior to the Pennsylvanian.

### Mississippian System

Mississippian units, like the Woodford and Hunton, are preserved above and below unconformities. Mississippian beds are generally assigned to the Osagean Series, but Meramecian units have been recognized in the southeastern part of the County (Jordan, 1962). The Mississippian consists of various limestone rock types, with crystalline carbonates and chert being common. The thickness is as much as 250 feet. Mississippian beds are locally absent over several prominent oil-field structures such as Cushing, the west flank of which is in easternmost Payne County; Ramsey, in T. 18 N., Rs. 1 and 2 E.; and Orlando, in T. 19 N., R. 1 W. Although informal units are mappable, it is common for the "Mississippi lime" to be regarded as an entity. A porous, chert-bearing zone (or zones) locally developed at the top of the limestone is known as the "Chat."

### Pennsylvanian System

At the base of the Pennsylvanian is a prominent unconformity (Jordan, 1962); the lowermost rocks of the system are assigned to the Desmoinesian Series. Rocks of the Missourian Series are the youngest beds, which are present exclusively in the subsurface of Payne County. The total thickness of Desmoinesian and Missourian units is 1,600 to 2,600 feet. Unlike older units, Pennsylvanian beds show a general thickening to the east and southeast. Numerous cyclothemic patterns are associated with abundant unconformities; some unconformable surfaces are of considerable lateral extent, whereas others are local features. Both are thought to have formed during changes of sea level on the rather featureless Oklahoma Platform. The rocks, in gross lithologic terms, are interbedded shales, limestone, sandstones, and several coals.

#### *Desmoinesian Series*

This series includes a lower group, informally known as the "Cherokee," which has been formally divided into the Krebs Group and the overlying Cabaniss Group, and an upper group, the Marmaton.

The "Cherokee" consists of lenticular sandstones, dark shales, several thin but persistent limestones, and a few coal beds. The thickness of the "Cherokee" ranges from less than 250 feet to more than 500 feet. Local variations reflect relief developed on the top of the Mississippian and growth of structures, whereas the overall westward thinning reflects the Nemaha Uplift on the west. Formal and informal stratigraphic units of the Group, which are widely recognized are, in ascending order, Burgess Sandstone (locally developed in the eastern part of the County), Brown

Limestone, Bartlesville Sandstone, Inola Limestone, Red Fork Sandstone, Pink limestone, Skinner Sandstone, Verdigris Limestone, and Prue Sandstone. The generalized distribution of each sandstone in Payne County reflects a characteristic deltaic pattern (figs. 27–30). To some extent, distribution of the Bartlesville may reflect Mississippian paleotopography.

The Marmaton Group, which is approximately 350 to 450 feet thick, is composed of two prominent limestone formations, separated by shale and locally by sandstone, below a prominent shale with locally developed sandstone near its base, and the Cleveland Sandstone (Seminole on outcrop) at the top (Berg, 1968, p. 60). Major trends of the Cleveland are shown in figure 31. In some places the Cleveland is divided into lower and upper parts, and recent palynological studies of the equivalent Seminole on outcrop by L. R. Wilson of the Oklahoma Geological Survey indicate that the uppermost part is Missourian in age.

The limestones are the Oswego, or Fort Scott, Limestone and the overlying "Big Lime" or Oologah Limestone. The total limestone thickness is commonly 80 to 100 feet. Local limestone banks that apparently were formed by phylloid algae are responsible for most of the variation in thickness. Shale separating the two limestones is considered to be equivalent to the Labette Shale and is 20 to 40 feet thick. The lenticular sandstone overlying the "Big Lime" is the Wayside "Peru" Sandstone (Wewoka Sandstone on outcrop).

*Missourian Series*

Missourian strata, approximately 1,100 feet thick in the west, thicken to 1,650 feet in the east. The series is composed of shale, sandstone, and several limestones arranged into two groups, the Skiatook and the overlying Ochelata.

The Skiatook Group is about 400 feet thick in the west and as much as 700 feet thick in the east. It includes the Checkerboard Limestone (an excellent marker) near the base, the Layton Sandstone, the Hogshooter Limestone, and the Dewey Limestone, in ascending stratigraphic order.

The Ochelata Group includes the "Osage Layton," or Cottage Grove, Sandstone, Perry "gas sand," and "Avant" or Wildhorse Limestone.

*Virgilian Series*

The basal Virgilian unit is the Tonkawa Sandstone, which, together with the Endicott and Hoover/Elgin Sandstones, is the approximate subsurface equivalent of the Vamoosa Formation. The uppermost part of the Vamoosa is the oldest stratigraphic unit exposed in Payne County.

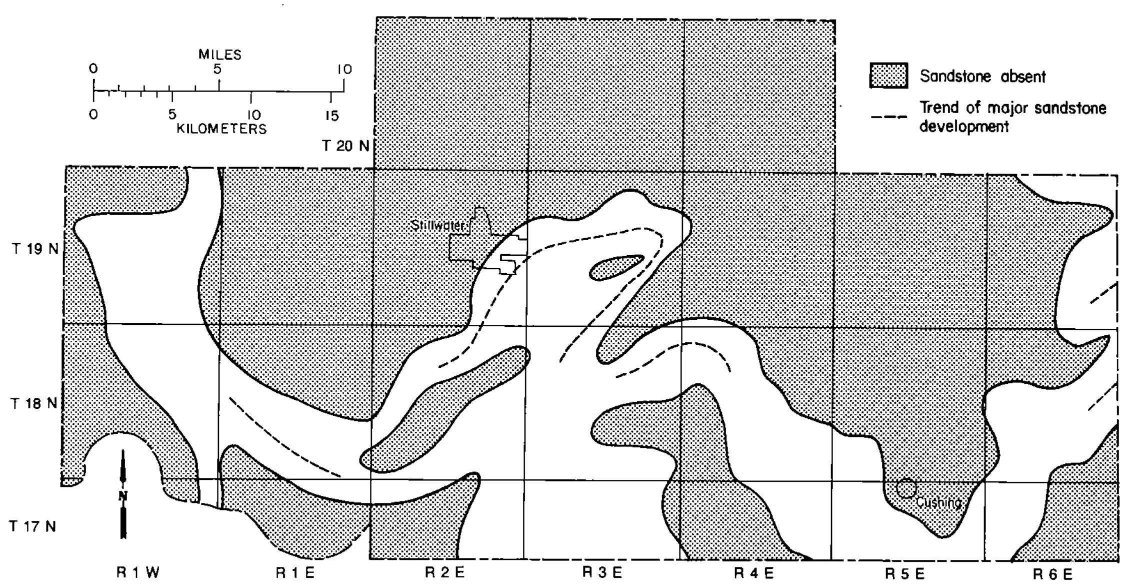



Figure 27. Map of Payne County showing distribution of Bartlesville Sandstone. Trends of major sandstone development represent deltaic distributaries. The Bartlesville is a multistoried as well as a multilateral sequence.

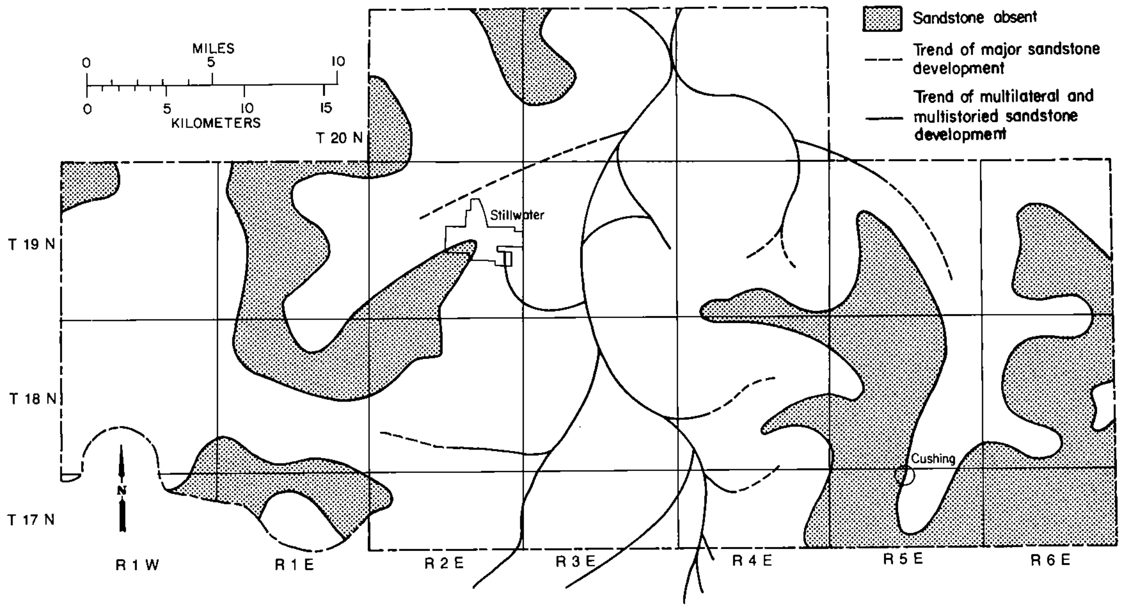



Figure 28. Map of Payne County showing distribution of Red Fork Sandstone. Major trends of sandstone development represent deltaic distributaries; some trends are multistoried and multilateral distributary deposits.

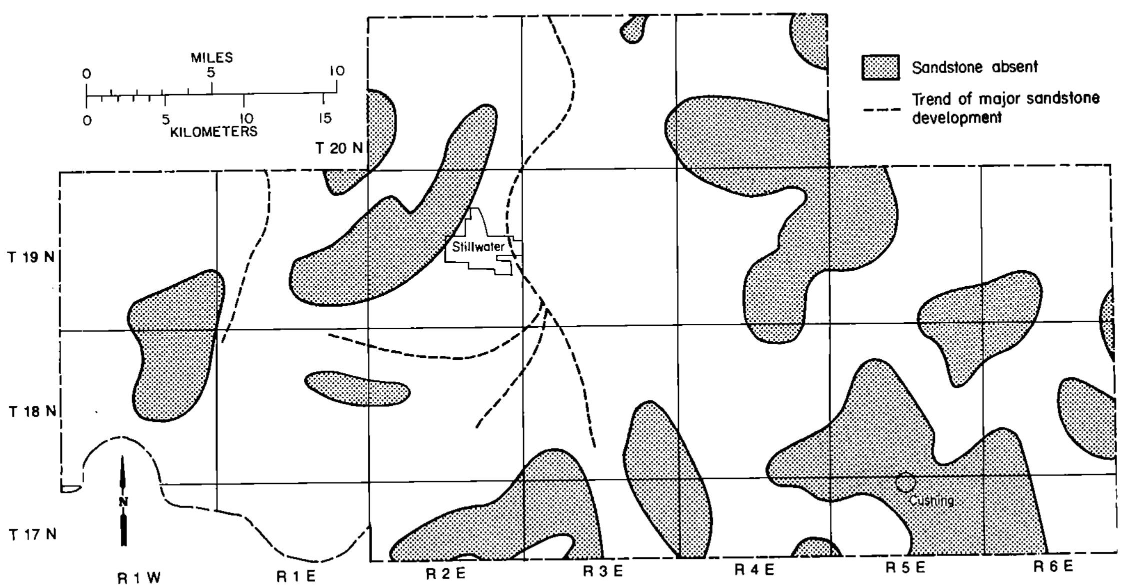



Figure 29. Map of Payne County showing distribution of Skinner Sandstone, with trends of major distributary deposits in both upper and lower parts. The Skinner represents more than one regressive sequence.

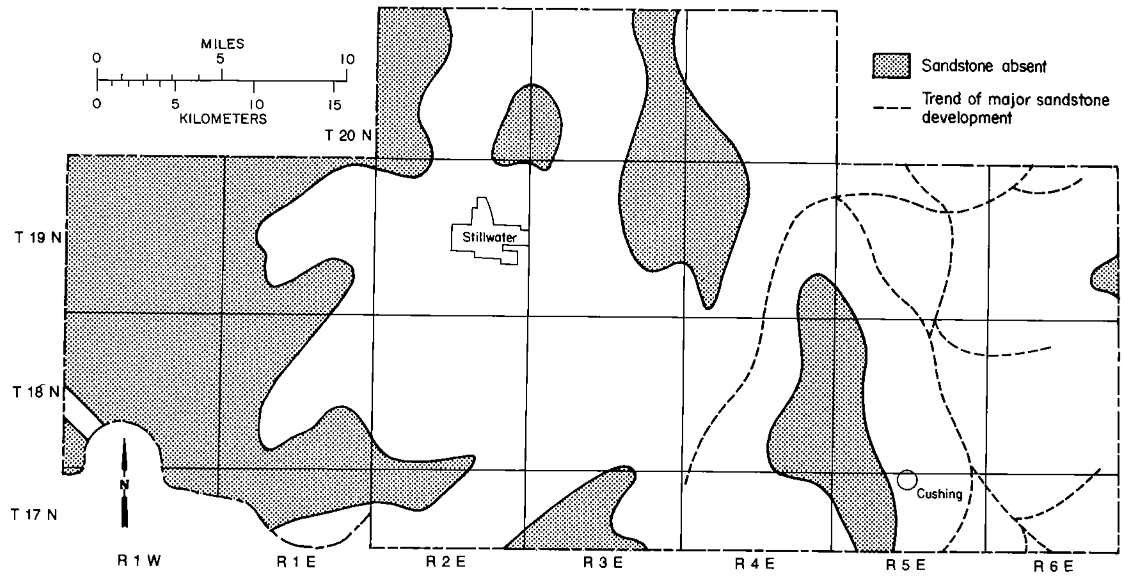



Figure 30. Map of Payne County showing distribution of Prue Sandstone. Major trends represent multilateral and multistoried distributary deposits.

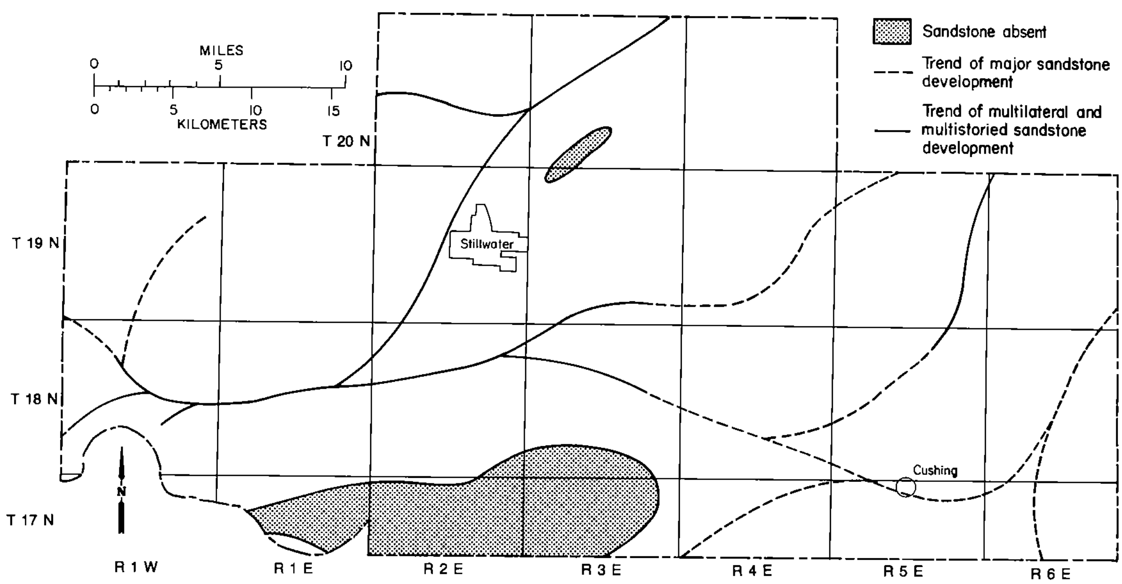



Figure 31. Map of Payne County showing distribution of Cleveland Sandstone, including both upper and lower parts. Major trends represent distributary deposits, some of which are multistoried and multilateral.

## FOSSILS

Paleontological material is common in the limestones and some of the shale units in eastern Payne County, but it is sparse in most units of central and western Payne County. Most of the red beds are barren; some red dolomites contain algal mats.

The most common fossils in the units up to and including the Neva are brachiopods, gastropods, pelecypods, bryozoans, crinoid fragments, and fusulinids. A few coral, trilobite, and shark fragments are also present.

Fossils identified by several workers are listed in table 1, which is arranged primarily for the nonpaleontologist. Occurrences of palynomorphs are not listed. Readers interested in locations of fossil sites are referred to Nakayama (1955), Fenoglio (1957), Ross (1972), and Garden (1973).

Table 1.—Stratigraphic Occurrences of Fossils in Payne County

| Fossils | Wellington | | | | | | | | | | | | | | | | | Foraker | | | | | | | | Emporia | | | | | | | Pawhuska | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper | Middle | Lower | Herington | Enterprise | Winfield | Doyle | Fort Riley | Matfield-Oketo | Wreford | Garrison | Cottonwood | Eskridge | Neva | Roca-Salem Point | Red Eagle | Johnson | Long Creek | Hughes Creek | Americus | Admire | Brownville | Pony Creek | Grayhorse | Gano | Elmont | Harveyville | Reading | Auburn | Wakarusa | Winzeler-Soldier Cr | Bird Creek | Severy-Aarde | Turkey Run | Lecompton | Vamoosa |
| ALGAE | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | 5 | |
| FUSULINIDS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Triticites* sp. | | | | | | | | | | | | | | | | 1,3 | | 3 | | | | 1 | | 1 | | 1,3 | 1 | 1,3 | | 3 | | 1,3 | 3 | 1,3 | 1,3 | |
| *Schwagerina* sp. | | | | | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | |
| CORALS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Caninia* sp. | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| *Lophophyllidium* sp. | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | | | | | 3 | |
| BRYOZOANS | | | | | | | | | | | | | | 4 | | | | | | | | | | | | | 3 | | | | | | | | | |
| *Fenestrellina* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | |
| *Rhombopora lepididendroides* | | | | | | | | | | | | | | | | 3 | | | | | | | 3 | | 3 | | | 3 | | | | | | 3 | | |
| *Rhombopora* sp. | | | | | | | | | | | | | | | | | | | | 3 | | | | 3 | | 3 | | | | 3 | | | | | | |
| Fenestrate type | | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | 1 | 1,3 | | 1,3 | | 1 | | 1,3 | | 1,3 | 1,3 | |
| Ramose type | | | | | | | | | | | | | | | | 3 | | 1 | | | 1 | | 3 | 1,3 | 1,3 | 1 | | 3 | | 1 | | 3 | | | | |
| CRINOIDS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Delocrinus brownvillensis* | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | | | | | |
| *Delocrinus* sp. | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| Stems and fragments | | 2 | | | | | | | | | | | | 1, 3,4 | | 1 | | 1,3 | | 1,3 | | 1 | 3 | 1 | 1,3 | 3 | 1,3 | 1,3 | | 1,3 | | 1,3 | 3 | 1,3 | 1,3 | |

Sources for data: 1 - Fenoglio (1957); 2 - Garden (1973); 3 - Nakayama (1955); 4 - Ross (1972); 5 - present study.

TABLE 1.—STRATIGRAPHIC OCCURRENCES OF FOSSILS IN PAYNE COUNTY—*Continued*

| Fossils | Wellington | | | | | | | | | | | | | | | | | Foraker | | | | | | | | Emporia | | | | | | | | Pawhuska | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper | Middle | Lower | Herington | Enterprise | Winfield | Doyle | Fort Riley | Matfield-Oketo | Wreford | Garrison | Cottonwood | Eskridge | Neva | Roca-Salem Point | Red Eagle | Johnson | Long Creek | Hughes Creek | Americus | Admire | Brownville | Pony Creek | Grayhorse | Gano | Elmont | Harveyville | Reading | Auburn | Wakarusa | Winzeler-Soldier Cr | Bird Creek | Severy-Aarde | Turkey Run | Lecompton | Vamoosa |
| BRACHIOPODS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ambocoelia expansa* | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | 1 | | | | |
| *Aviculopinna americana* | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Chonetes granulifer* | | | | | | | | | | | | | | | | 3 | | 1 | | 1,3 | | 3 | 3 | | 1 | 1,3 | 1 | 1,3 | | 3 | 1 | | | | | |
| *Chonetes granulifer* var. *armatus* | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Chonetes* sp. | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| *Composita subtilita* | | | | | | | | | | | | | | | | 3 | | 1 | | 1,3 | | | | | 1,3 | | | 1 | | 1,3 | | | | | | |
| *Crurithyris planoconvexa* | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | 1 | | | | | | | | 3 | |
| *Crurithyris* sp. | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | 1 | | | | | | | | |
| *Derbyia crassa* | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | |
| *Derbyia* sp. | | | | | | | | | | | | | | | | 3 | | 1 | | | | | | | 1 | | 1 | | | 1,3 | | | | | | |
| *Dielasma bovidens* | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | | | | |
| *Dielasma* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | |
| *Dictyoclostus americanus* | | | | | | | | | | | | | | | | | | | | 3 | | | | | 1 | 1,3 | | 1 | | | | | | | | |
| *Dictyoclostus portlockianus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | |
| *Dictyoclostus* sp. | | | | | | | | | | | | | | | | 1 | | | | | | 3 | | | | | | 3 | | 1,3 | | | | | 1 | |
| *Echinoconchus moorei* | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | |
| *Echinoconchus* sp. | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | | | | |
| *Enteletes hemiplicatus* | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1,3 | | 1 | | | | | | | | |
| *Enteletes plattsmouthensis* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | |
| *Hustedia mormoni* | | | | | | | | | | | | | | | | | | 1 | | 3 | | | | | | | | | | | | | | 3 | | |
| *Juresania nebrascensis* | | | | | | | | | | | | | | | | | | | | 3 | | | 3 | | 1 | | | 2 | | | | | | | | |
| *Juresania symmetrica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | |
| *Juresania* sp. | | | | | | | | | | | | | | | | | | 1 | | 2 | | | | | | 1 | | 3 | | 1,3 | | | | | | |
| *Linoproductus prattenianus* | | | | | | | | | | | | | | | | 1 | | 3 | | 3 | | | 3 | | | | | | | | | | | | | |
| *Linoproductus* sp. | | | | | | | | | | | | | | | | 3 | | 3 | | | | 3 | 3 | 3 | | | | 3 | | | | | | | | |
| *Marginifera* sp. | | | | | | | | | | | | | | | | 3 | | | | | | | | | | 3 | | 1 | | | | | | | 3 | |
| *Meekella straiatocostata* | | | | | | | | | | | | | | | | 1,3 | | 1 | | | | | 3 | | | 3 | | 1 | | 3 | | | | | | |
| *Neospirifer cameratus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| *Neospirifer* cf. *N. condor* | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Neospirifer dunbari* | | | | | | | | | | | | | | | | 1 | | | | 3 | | 3 | 3 | 1 | 1,3 | 3 | | 1 | | 1,3 | | | | | | |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Neospirifer* sp. | | 1,3 | 1 | | 1,3 | 3 | 1 | | 3 | 1 | 1 | | | | | | |
| *Orbiculoidea* sp. | | | | | | | | | 3 | 3 | | | | | | | |
| *Productus* sp. | | | | | 1 | | | | | | | | | | | | |
| *Punctospirifer kentuckiensis* | | | | | | | | 3 | | 1,3 | 1 | | | 3 | | | |
| *Punctospirifer* sp. | | | | | | | | | | | | | | | | | 3 |
| *Roemerella patula* | | | | | | | 1 | | | | | | | | | | |
| *Wellerella delicatula* | | 1 | 1 | | | | | | | | | | | | | | |
| GASTROPODS | 4 | | 1 | | | | 1 | | 1 | | | | | | | | |
| *Amphiscapha catilloides* | | | | | | | | | | | | | | 3 | | | |
| Bellerophontidae | | | 1 | | | | | | | | | | | | | | |
| *Euphemites* sp. | | | | | | | | | 3 | | | | | | | | |
| *Murchisonia gouldii* | | | | | | | | | | | | | | | 1 | | |
| *Pharkidonotus tricarinatus* | | | | | | | | | | 3 | | | | | | 1 | |
| *Phymatopleura brazoensis* (Shumard) | | | | | | | | | | 3 | | | | | | | |
| *Trepospira discoidalis* | | | | | | | | | | 3 | | | | | | | |
| PELECYPODS | 4 | | 1 | | | | | | | | | | | | | | |
| *Acanthopecten* sp. | | | | | | | | | | | | | | 3 | | | |
| *Allorisma costatum* | | | | | | | | | | | | | 1 | | | | |
| *Allorisma granosum* | | | | | | | | | | 1 | | | | | | | |
| *Allorisma* sp. | | 3 | 3 | | 1 | | 1,3 | | | 3 | | | | 1 | | | |
| *Astartelia vera* | | | | | 3 | | | | | | | | | | | | |
| *Myalina (Orthomyalina) slocomi* | | | | | | | | | | 1,3 | | | | | | | |
| *Myalina (Orthomyalina) subquadrate* | | | | | | | | | | 1,3 | 1 | | | | | | |
| *Myalina* sp. | | | 3 | 3 | 3 | 1,3 | 3 | | 1,3 | | | 1 | 1 | 1,3 | | | |
| *Septimyalina* sp. | | | | | | | | | | 1 | | | | | | | |
| CEPHALOPOD | | | 3 | | | | | | | 1 | | | | | | | |
| *Pseudorthoceras* sp. | | | | | | | | | | 1 | | | | | | | |
| TRILOBITE | | | | | | | | | | | | | | | | | |
| *Ameura* sp. | | | 1 | | | | | | | | | | | 1 | | | |
| SHARKS | | | | | | | | | | | | | | | | | |
| *Deltodus* sp. | | | | | 3 | | | | 3 | | | | | | | | |
| *Metrochus tenuimarginatus* | | | | | | | | | | 3 | | | | | | | |
| *Petalodus destructor* | | 3 | | 3 | 3 | | | | 3 | | | | 3 | 1,3 | | | |

Sources for data: 1 - Fenoglio (1957); 2 - Garden (1973); 3 - Nakayama (1955); 4 - Ross (1972); 5 - present study.

# PETROLOGY

The most prominent rock type at the surface in Payne County is sandstone, but mudrock, including both mudstone and shale, is the most abundant type. The carbonate rocks of Payne County consist of both limestone and dolomite. Limestone is more common in the eastern part of the County, and dolomite is more common in the thin beds and irregularly distributed units of the remaining part of the County. The investigation of sandstones was concerned primarily with sedimentary structures and general textural features, and secondarily with composition. Only a cursory study was made of mudrock in the field. Certain carbonates were examined megascopically and in thin section.

## Sandstones

The study of sandstones emphasizes determination of depositional environment and paleocurrent trend in the field from examination of structures and textures. A general description of megascopic constituents is part of the outcrop investigations; study of thin sections is the basis for classifying selected sandstones.

### Structures

The most characteristic sedimentary structures of the sandstones of Payne County are initial dip, medium- and small-scale crossbedding, parting lineation, and cut-out. Initial dip is accretionary cross-stratification that is coincident with the depositional slope. The initial dip is variable in the sandstones of the study area, but generally it is more than 10°.

Medium-scale crossbedding represents the foreset beds of sand waves or dunes which migrate in the direction of flow. Both planar and festoon (or trough) types of crossbedding are present. Certain exposures of initial dip and medium-scale crossbedding are similar in appearance. Initial dip is commonly distinguished by a larger size, low angle of initial dip, parallelism to cut-outs, and the presence of shale interbeds. In the study area, however, where interbeds are not common and initial dip is rather steep, the two structures were difficult to classify. Paleocurrent diagrams illustrate that crossbedding parallels the initial dip, whereas foreset dips in channel sandstones are generally perpendicular to the direction of initial dip. Allen (1968, p. 31, 41, 51) suggests that the dip of medium-scale crossbedding may form an acute angle with initial dip.

In the study area, small-scale crossbedding and parting lineation are commonly found near the tops of sandstones, where grain size is finest. Parting lineation, however, is also present in the lower parts of sandstones. Both parting lineation and small-scale crossbedding generally show a narrower range of dip directions than medium-scale crossbedding.

Channel deposits, exhibiting various forms of cut-out, occur as three types. There are single genetic sandstone units, which are cut into carbonate, shale, or mudstone. Also present are multistoried and multilateral sandstone complexes with erosive contacts with mudrock and into adjacent and (or) lower sandstone bodies. Relatively small lenses or channel-fills of siltstone and mudstone, with thin dolomite nodules, truncate the upper parts of some sandstone units in central and western Payne County. The latter type of cut-out may represent crevasse deposits.

Other structures are convolute bedding, burrows, tracks, trails, molds of wood, and some invertebrate fossils. The organic structures are present in sandstones designated as marine, delta-fringe, or tidal-flat creek.

Some 886 measurements made of paleocurrent indicators include initial dip, medium- and small-scale crossbedding, parting lineation, and cut-outs. In the interpretation of average current direction, crossbedding and cut-outs are considered the most diagnostic indicators. In estimating paleocurrents of certain sandstone bodies, initial dip and parting lineation were deleted because of uncertainty in interpreting their relationship to crossbedding. Paleocurrent directions for sandstones in many of the formations were noted heretofore. Compilation of paleocurrent indicators in sandstones of eastern Payne County, in Pennsylvanian beds below the Admire Shale regarded as Virgilian–Gearyan in age, suggests an average direction of N. 45° W. and a secondary trend of N. 25° E. (fig. 32). The average direction for sandstones in central Payne County, in units regarded as Wolfcampian or Gearyan (Admire Shale–Herington Limestone), is N. 50° W. (fig. 33). Compilation of features in Wellington sandstones shows an average major direction of N. 35° W. and secondary directions of N. 40° E., S. 35° E., and S. 60° W. (fig. 34).

### Texture and Composition

The sandstones vary from conglomeratic beds with dolomite, limestone, and clay pebbles to silty units. Sandstones in the eastern part of the County, regarded as Virgilian–Gearyan in age, are generally fine to very fine grained. A bed of medium-grained sandstone is present in certain units. The sandstones, exclusive of the conglomerate units, are typically well sorted; the grains are most commonly subangular; and line contacts between grains are predominant. The sandstones are generally friable, quartz-rich units. A representative sandstone, compositionally, is thought to be a quartzarenite with less than 5 percent feldspar and less than 5 percent rock fragments, or a quartz-rich subarkose with 5

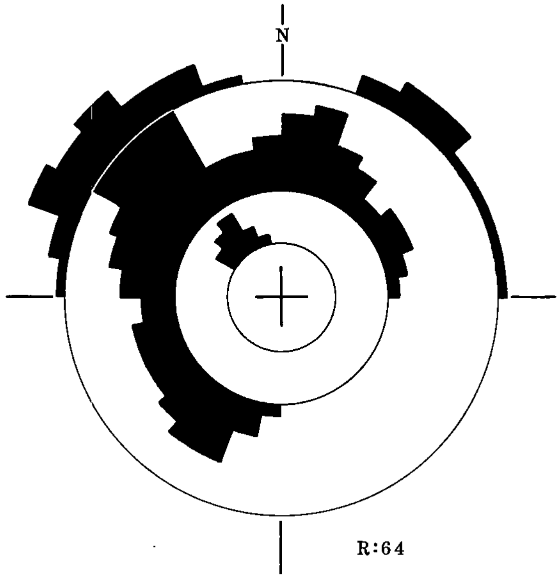



Figure 32. Paleocurrent diagram of Pennsylvanian sandstones below Admire Shale. Primary direction is N. 45° W., and secondary trend is N. 25° E. See figure 6 for explanation of diagrams.

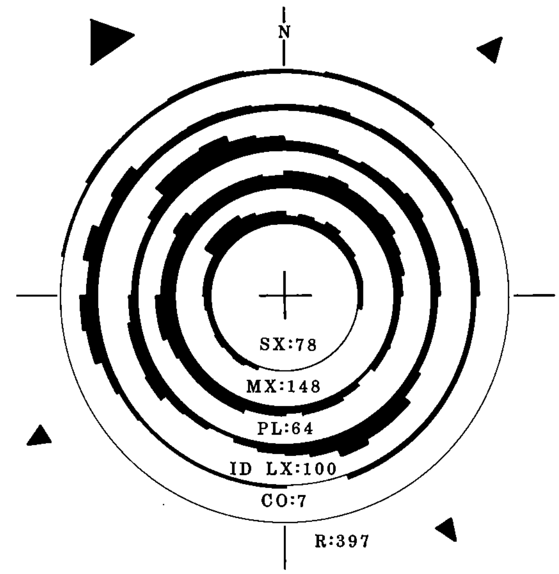



Figure 34. Composite paleocurrent diagram of Wellington sandstones of western Payne County. Average major direction is N. 35° W., and secondary directions are N. 40° E., S. 35° E., and S. 60° W. See figure 6 for explanation of diagrams.

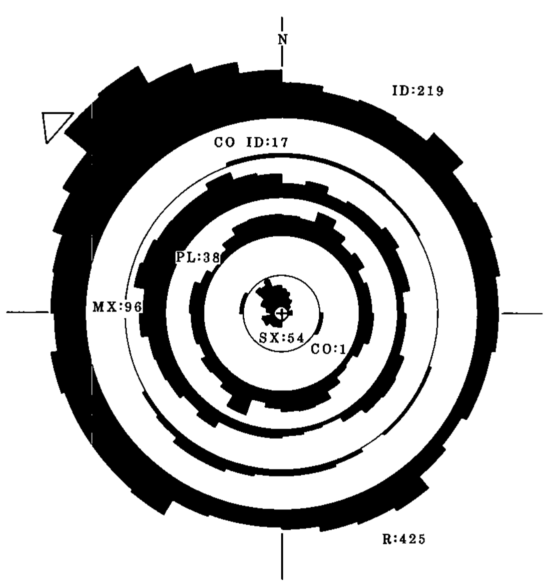



Figure 33. Paleocurrent diagram of sandstone in units regarded as Wolfcampian or Gearyan in central Payne County. Average direction is N. 50° W. See figure 6 for explanation of diagrams.

to 7 percent feldspar and 4 percent rock fragments. Carbonate is not an uncommon constituent as cement. Although clay pebbles are more common than carbonate pebbles, both are scattered in distribution. Carbonized wood is another rare constituent.

The sandstones in the central part of the County consist predominantly of well-sorted, fine- to very fine-grained quartzose sands. Also present are a few zones of poorly sorted, medium-grained quartz sand, or sand with as much as 15 percent potassium feldspar. Megascopically, sandstones in the study area are friable, quartz-rich units which decrease in average grain size from fine in the lower formations to an average size of very fine in the upper Doyle Shale. The predominant colors of the sandstone bodies are red and tan; however, maroon, green, and white units are also present. Maroon sandstone occurs in the uppermost part of some highly weathered units and in zones where the sandstone is tightly cemented. A thin green band, which is present at the top of many claystone units, is also developed in the lowermost parts of various sandstones. These green bands are most common in the Matfield and Doyle Shales, where they are generally associated with nodular dolomite.

Conglomerates with locally derived fragments are present at the base of some sandstones in all formations above the Neva Limestone. The granules and pebbles of dolomite and limestone in carbonate conglomerate have an average diameter of approximately 3 mm and a maximum size of 80 mm. The pebbles closely resemble the material of the nodular-dolomite lenses. The conglomerates, which are maroon to brown, contain fine- to very fine-grained quartz sand and clay fragments. The less common clay-pebble conglomerates generally contain larger pebbles than the carbonate conglomerates; at some places the average particle size (diameter) is as much as 15 mm, and the maximum size is 100 mm. The pebbles of dolomite and limestone are thought to have been derived from erosion of the tidal-flat carbonates and redeposited in the distributary or tidal channels. The clay-pebble material may have been derived from several areas, such as tidal flats, interdistributary bays, or banks of distributaries.

A petrographic study was made of the sandstone directly below the Neva Limestone, sandstone IPd-10, and sandstone IPd-165. The sandstone directly below the Neva Limestone is the coarsest, with an average grain size of approximately 0.20 mm. The grains are generally subangular, and contacts between them are line and wedge. Matrix material is primarily clay stained by iron oxide. Porosity is estimated to be 10 to 15 percent. The rock is classified as a quartz-rich subarkose consisting of 94 percent quartz, 5 percent potassium feldspar, 1 percent hematite, and traces of plagioclase and muscovite (fig. 35). The other sandstones are feldspar-bearing quartzarenite with approximately 96 percent quartz, 3 percent potassium feldspar, 1 percent hematite, and a trace of plagioclase and muscovite. The average grain size is 0.15 mm in unit IPd-10 and 0.10 mm in IPd-165, and the sandstones are well sorted. Grains are angular to subangular; contacts are primarily point and line, and secondarily wedge. The matrix is composed of clay with hematite stain. IPd-165 is distinguished from other samples by zones of calcite cement (fig. 36).

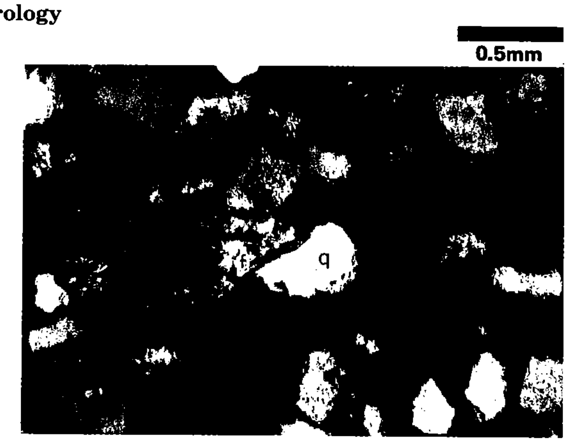



Figure 35. Photomicrograph of sandstone directly below Neva Limestone. The quartz-rich subarkose is primarily composed of subangular, well-sorted, fine-grained quartz (*q*) and feldspar (*f*). Crossed nicols.

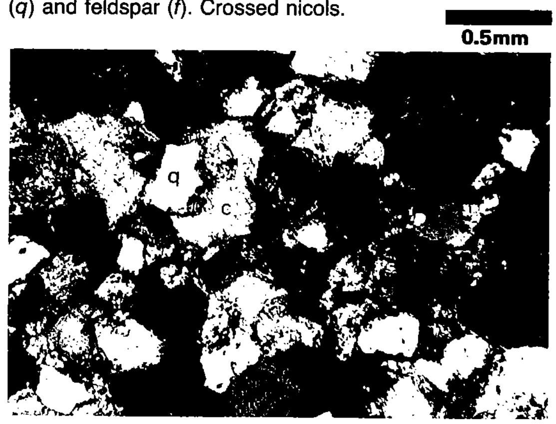



Figure 36. Photomicrograph of sandstone IPd-165 in Doyle Shale. The feldspar-bearing quartzarenite is composed primarily of subangular, well-sorted, very fine-grained quartz (*q*) with feldspar and calcite cement (*c*). Crossed nicols.

Sandstones of western Payne County are generally well sorted and medium to very fine grained. In the field, most of the sandstones are friable as a result of limited cementation. Most of the sandstones have various amounts of reddish stain, but some are white to tan. Green siltstone has been observed at the base of several sandstone units. The green color is probably the result of reduction of iron oxide and (or) the presence of chlorite as a clay mineral.

Units Pw-200 and Pw-600 megascopically are considered typical Wellington sandstones, and they represent positions of widespread sandstone bodies. Both sandstones are well sorted. The average grain size of Pw-200 is 0.15 mm; the grains are dominantly subangular, with angularity ranging from subround to angular. Concavo-convex, line, and point contacts are present. Many grains are coated by hydrous iron oxide. Compositionally, Pw-200 is unlike other sandstones of Payne County that have been studied petrographically. It is a feldspar-rich subarkose containing approximately 70 percent quartz, 25 percent feldspar, 3 percent muscovite and sericite, 1 percent hematite, and a trace of carbonate (fig. 37). The average grain size of Pw-600 is 0.09 mm; grains are generally subangular, and contacts are concavo-convex, line, and point. It is a quartz-rich subarkose composed of 93 percent quartz, 3 percent feldspar, 2 percent hematite, 1 percent carbonate, and less than 1 percent muscovite and sericite (fig. 38). The matrix is clay and iron oxide.

## Carbonates

Carbonates in the eastern part of Payne County, in Gearyan–upper Virgilian units, are dominantly limestone with some dolomite. The carbonates are present in laterally persistent, but petrographically variable, units. Within each carbonate-rich stratigraphic unit, the content of dolomite generally increases southward. Accompanying

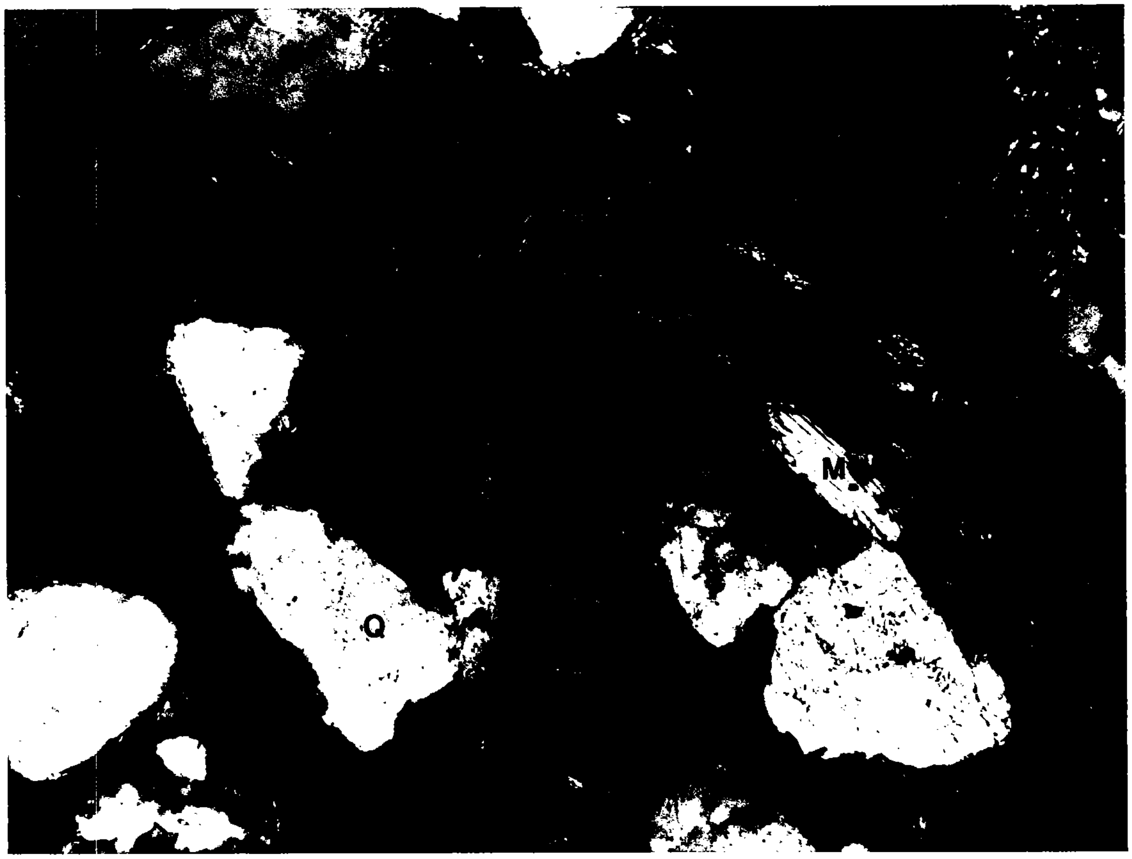



Figure 37. Photomicrograph of Wellington sandstone Pw-200, with quartz (*Q*), feldspar (*F*), muscovite (*M*), and hydrous iron oxide rimming many grains. Concavo-convex and line contacts indicate close packing of grains, which are dominantly subangular. Crossed nicols. Width of photograph represents 0.90 mm.

the increase in dolomite is an increase in the amount of red and (or) maroon shale in overlying and underlying units.

Eastward from Payne County, in the Oilton area of western Creek County, the Lecompton Limestone is composed of a lower dolomite 4 feet thick, a middle 4 feet of limestone with shale, and an upper dolomite 4 feet thick (Shelton and Rowland, 1974, p. 18). The lower dolomite is fine to medium grained, skeletal, and micritic and contains quartz sand in the lowermost part. The limestone is a skeletal, algal, dolomitic wackestone. The upper dolomite is skeletal and medium to coarse grained.

The Bird Creek, Wakarusa, and Elmont limestones in the Yale area are calcareous packstones. The gray Bird Creek contains phylloid algal plates, fusulinids, and quartz grains; the Wakarusa is maroon and contains grains of fusulinids, other foraminifers, and fragments of crinoids and mollusks. The Elmont is gray to dark gray and contains a large number of fusulinids. The Grayhorse Limestone in the Twin Mounds area is a gray skeletal packstone with fusulinids, sparry calcite, and a significant percentage of mud or micrite. At or near the Cimarron River, where it is associated with maroon mudrock, the Grayhorse is also a skeletal packstone, but it contains fragments of bryozoans, brachiopods, crinoids, and echinoids.

The lower unit of the Long Creek Limestone in the Twin Mounds area is a gray to dark-gray skeletal packstone containing crinoid fragments and fusulinids. The upper unit, on the other hand, is a gray, skeletal, intraclastic grainstone with some quartz grains.

Carbonate units of central Payne County show a range in characteristics, from continuous and uniform marine limestones to the more common discontinuous lenses of nodular dolomite. The marine carbonate units are sandy, crystalline limestone or dolomite and calcareous shale. The Red Eagle and Neva limestones in thin section are composed of crystal mosaics of calcite and dolomite with floating, angular quartz-sand grains. The Red Eagle at the sampling locality is almost entirely crystalline carbonate, with only a trace of quartz and plagioclase. The Neva in thin section

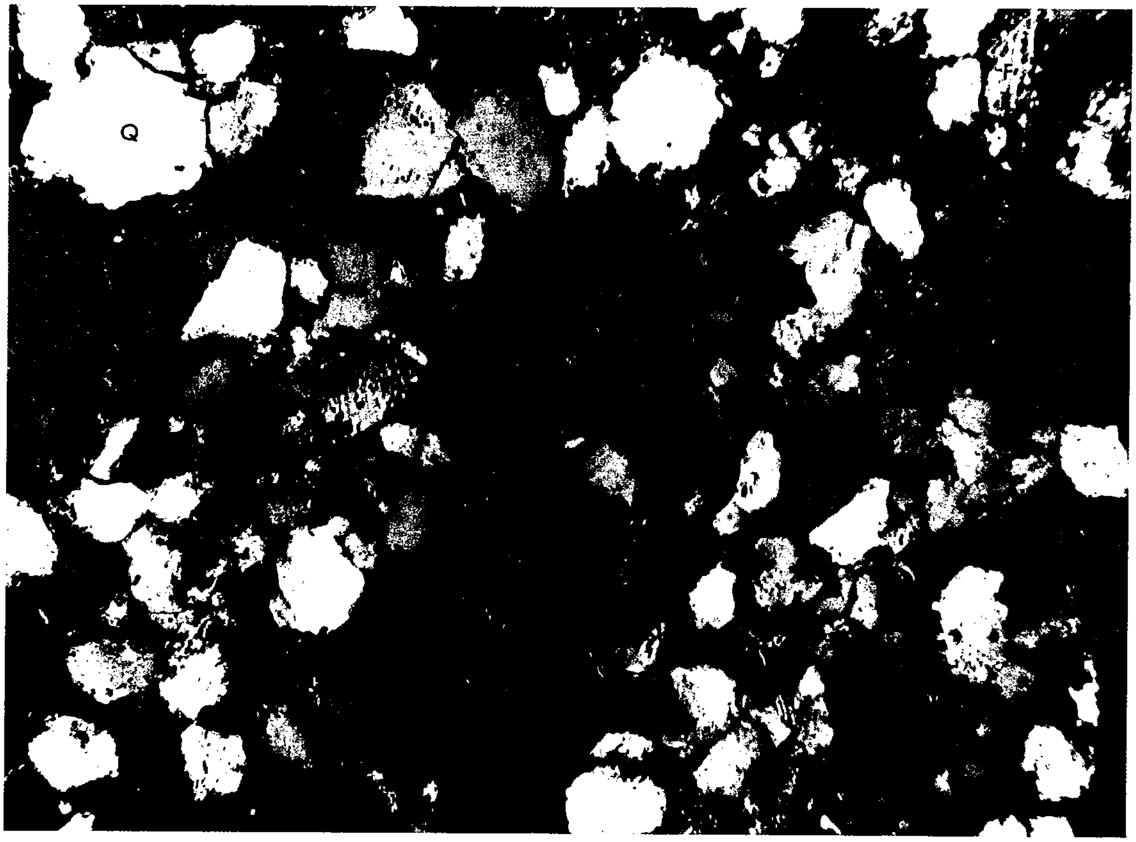



Figure 38. Photomicrograph of Wellington sandstone Pw-600, with quartz (*Q*), feldspar (*F*), and scattered muscovite and sericite. The average grain is subangular, and contacts range from point to concavo-convex. Crossed nicols. Width of photograph represents 0.90 mm.

consists of 50 percent sparry calcite and 45 percent quartz sand (average size, 0.10 mm) and 5 percent red calcitic mud (fig. 39). Some fossil relicts, filled with sparry calcite, are present in the Neva sample. The Neva is a brachiopod- and crinoid-bearing, arenaceous, crystalline limestone.

The nodular carbonates are composed of a mudstone cut by veinlets of crystalline calcite or dolomite radiating out from a crystalline center or by networks of calcite or dolomite veinlets. The Wreford Limestone in thin section is a dismicrite (fig. 40), with calcitic mud, sparry calcite, and 10 to 20 percent angular, very fine-grained quartz particles. The quartz grains are floating within both the microcrystalline and sparry calcite.

Lenses of nodular dolomite and dolomitic nodules within mudrock are the main types of occurrences of carbonate in western Payne County. Carbonate minerals are also present as pebbles in conglomerates, cement in sandstone, and fossil fragments. A petrographic study of nodular dolomite in unit Pw-620 indicates that it is a grain-supported, muddy carbonate (a packstone) (fig. 41). The supporting grains are pelletlike and average 0.15 mm in diameter. Many of the pellets have a thin accretionary rim. The mud includes iron-oxide-stained clay, or micrite, and silt-sized quartz grains. Secondary sparry calcite is also present as veinlets and vug linings. One vug containing secondary kaolinite was noted.

# STRUCTURE

## Surface Structure

### Folds and Faults

#### *Local Features*

Three reference surfaces—the base of the Lecompton Limestone in the east, the top of the Red Eagle Limestone in the central part, and the top of the Fort Riley Limestone in the west—were used to prepare a shallow-subsurface structure map (pl. 1). The map illustrates the gentle homoclinal westward dip in the study area. Payne County is part of the Prairie Plains Homocline, a regional feature dipping off the Ozark Uplift. The dip averages 40 to 50 feet per mile; locally, it is as much as 200 feet per mile and as little as 20 feet

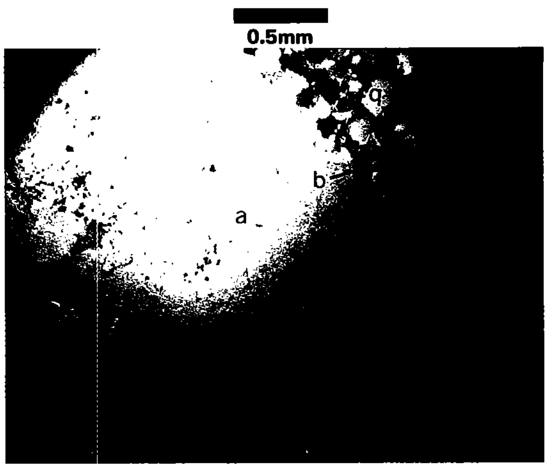



Figure 39. Photomicrograph of Neva Limestone. The brachiopod- and crinoid-bearing, arenaceous crystalline limestone consists of crinoid fragments (*a*), brachiopod fragments, quartz grains (*q*), and calcite cement (*b*). Crossed nicols.

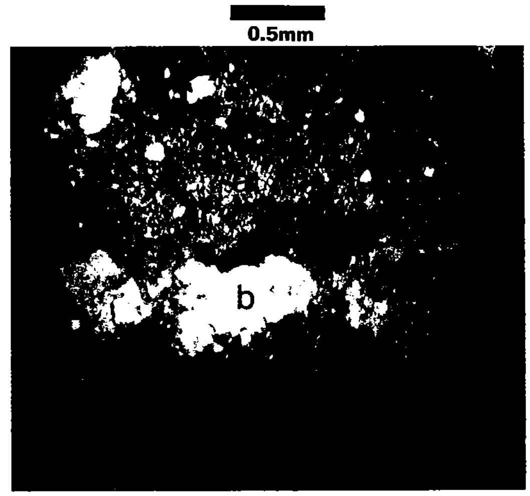



Figure 40. Photomicrograph of Wreford Limestone, showing microcrystalline calcite mud (*a*) and sparry calcite (*b*), characteristics of dismicrite. Crossed nicols.

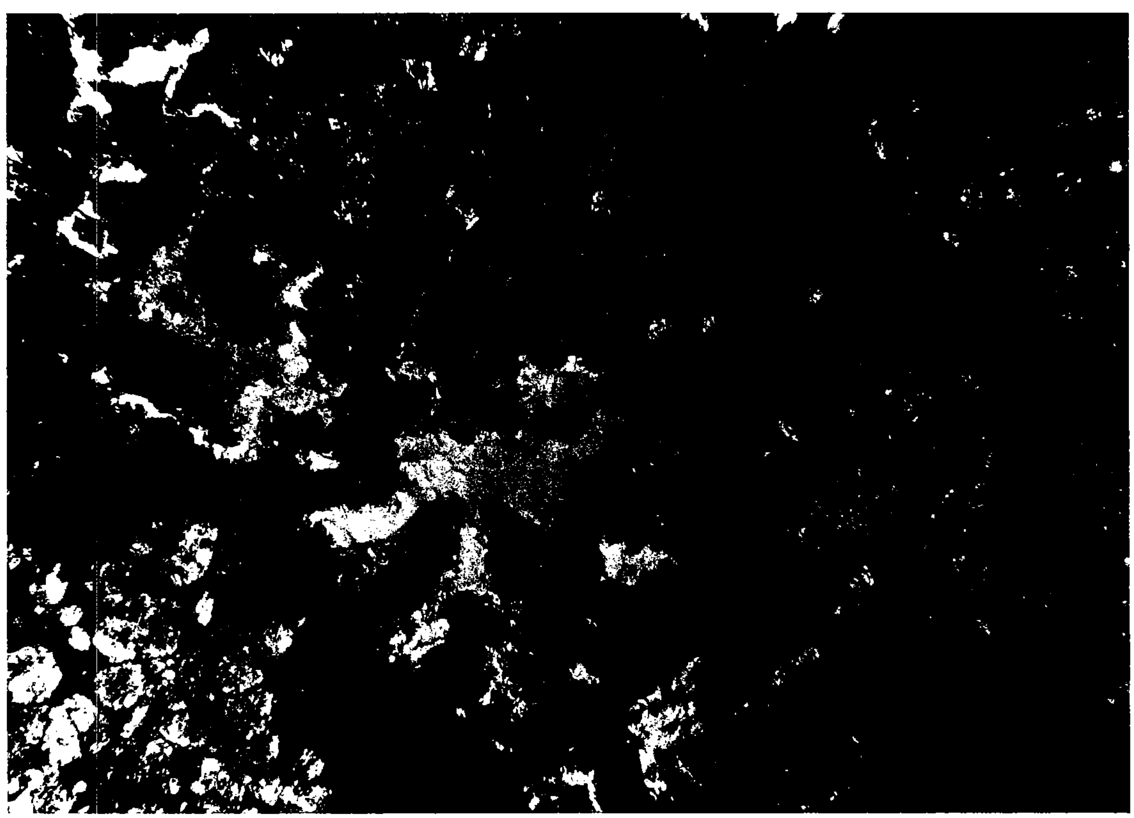


Figure 41. Photomicrograph of nodular dolomite in Wellington unit Pw-620, showing pelletlike grains, patches of mud (dark), and secondary calcite filling veinlets and vugs (clear). Crossed nicols. Width of photograph represents 0.90 mm.

per mile. The steepest dip is in the southeastern part of the County, which corresponds to the west flank of the Cushing Anticline. The gentlest dip over a rather extensive area is in the west, where the dip is generally to the west-southwest.

The homocline is best described as having an undulatory surface caused by local steepening and flattening of dip. Most of the folds are noses and saddles that formed by local changes in the magnitude of regional dip. Six local structures in the eastern part of the County, one in the central part, and two in the western part exhibit easterly dip. Each is less than 1 square mile in area.

The greatest amount of structural complexity is exhibited in the east, where three prominent noses and several minor normal faults are present. A nose with two closed structures at the position of the Lecompton Limestone extends northwestward for at least 5 miles from Cushing; the Cushing Townsite, March, and Broyles Fields lie along that structural trend. A west-trending nose, or a complex of several noses, extends along the northernmost tier of sections in T. 18 N., R. 5 E., and T. 18 N., R. 6 E. Oil has been produced along this structural feature at the Markhan Field to the east and the Norfolk Field to the west. The third prominent nose, some 5 miles long, extends northwestward through Yale, where it branches into two separate structures. The overall trend is at a high angle to the north-northeasterly elongation of the Yale–Quay Field.

In central Payne County, small folds form subtle complexes 10 to 35 square miles in area. Although the structures cannot be recognized at the surface by variation in stratal dip, they are expressed topographically by drainage anomalies. For example, anomalous radial patterns have formed on the Ingalls–Mount Hope structure (secs. 27 and 34, T. 19 N., R. 4 E.), the Mehan nose (secs. 10 and 15, T. 18 N., R. 3 E.), and the Ripley nose (secs. 31 and 32, T. 18 N., R. 4 E., and secs. 5 and 6, T. 17 N., R. 4 E.). An arcuate stream course is present over one of the Mehan structures in sec. 24, T. 18 N., R. 3 E. The Ingalls–Mount Hope structure is 5 miles long and 3 miles wide, and the crest is in the easternmost part of the fold, where closure on the Red Eagle horizon is approximately 30 feet. The steepest dip is to the west and southwest. The Mehan–Ripley fold complex, which contains several noses, is approximately 7 miles long and 5 miles wide. No structural closure is present on the complex, but the dip is locally rather variable. For example, on the west flank, in sec. 17, T. 18 N., R. 3 E., and sec. 27, T. 18 N., R. 3 E., the dip is as much as 100 feet per mile and as little as 20 feet per mile on the east in secs. 24 and 25, T. 18 N., R. 3 E., and secs. 18, 19, and 30, T. 18 N., R. 4 E. The Southeast Stillwater–Boomer Valley–Northwest Council Creek group of structures, in the southeastern part of T. 19 N., R. 3 E., is 4 miles long and 3 miles wide. Neither structural closure nor abnormally steep dip is present in shallow beds; the maximum dip of 60 feet per mile is observed on part of the west flank.

The only structures in western Payne County with eastward dip are in the Stillwater Airport Oil Field in sec. 32, T. 20 N., R. 2 E., and the East Willow Springs Oil Field in sec. 6, T. 18 N., R. 2 E., where closures of 20 feet have been noted. They combine with other, less prominent noses to form complexes that are several square miles in area. Koschmann (1930, p. 163) and Powers (1931, p. 121) indicate that folding in this region increases in intensity with depth. The larger structures at depth are thought to be the result of differential vertical uplift of basement blocks (Powers, 1931, p. 131; Lyons, 1950, p. 41).

A zone of normal faults in the eastern part of the mapped area extends in an *en-echelon* arrangement from Cushing to Yale. Individual faults strike northwest to north-northwest, and each is recognized for a distance of less than 2 miles. They are part of a zone which extends south-southwestward into east-central Lincoln County. No faults were observed on the surface or in the shallow subsurface of central and western Payne County. However, a fault may be present in the shallow subsurface at the Stillwater Airport Field.

*General Considerations*

Regionally, Payne County is part of the Central Oklahoma Platform, which corresponds to the southern portion of the Prairie Plains Homocline (Arbenz, 1956). The Nemaha Ridge, 15 to 20 miles west of Payne County, is an arcuate zone of basement fault blocks that strike south-southeast in the south and north-northwest in the north. Payne County is east of the change in strike. The ridge is thought to reflect a differential vertical component of displacement of individual basement blocks along strike-slip faults. The regional north-northeast-trending *en-echelon* fault system in eastern Payne County is also thought to be associated with strike-slip faulting in the basement. Sherrill (1929, p. 35–37), however, regarded the system to be associated with unequal vertical movements in the basement. The Cushing Anticline and the Cleveland Dome to the northeast parallel the zone of faulting and apparently reflect faulting at depth. The folds of Payne County are thought to be drape features associated with differential vertical uplift of blocks with various orientations. Some of the smaller structures, however, were probably caused by differential compaction associated with irregular unconformable surfaces and (or) lenticular sandstone bodies.

## Joints

Numerous open joints, generally characterized by vertical dip, are present at the surface in sandstone and limestone units. A plot of strike frequency for 45 joints in the eastern part of the County indicates that two sets are predominant (fig. 42), and they apparently form a conjugate system. One set averages approximately N. 80° E. in orientation, and the other set trends N. 50 ° W. The northwesterly set subparallels most of the faults. Two sets, averaging N. 60° E. and N. 50° W., can be seen on a plot of strike frequency for 50 joints in central Payne County (fig. 43). In western Payne County a plot for 51 joints also shows two sets, averaging N. 55° E. and N. 45° W. (fig. 44). The predominant sets for the entire County average N. 60° E. and N. 50° W. (fig. 45). The average strikes for these two sets are consistent with the joint patterns mapped by Melton (1929, fig. 3) in a large area north and northwest of the Ouachita Mountains, and they are similar in orientation to the strike of joints in Noble County (Shelton, 1979, p. 33–34).

The joints are thought to be extensional. It is not readily apparent whether the dominant joint sets (1) represent a regional orthogonal extensional system, as suggested by directions of N. 45° W. and N. 55° E. in western Payne County, or (2) represent a conjugate shear system, as suggested by directions of N. 80° E. and N. 50° W. in the east, N. 60° E. and N. 50° W. in the central part and for overall averages, and N. 65° E. and N. 45° W. for the general area (Melton, 1929, p. 734, fig. 3). Price (1966, p. 133–135) suggests that orthogonal extensional joints, or fracture patterns, are the result of regional uplift of an area which originally

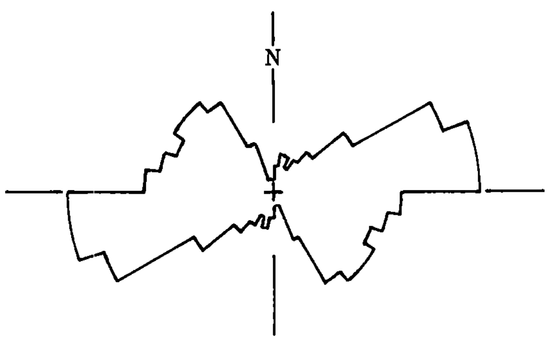



Figure 42. Strike-frequency diagram of 45 joints in eastern Payne County. The two predominant sets strike N. 80° E. and N. 50° W. A 30° sliding average was used in preparing diagram.

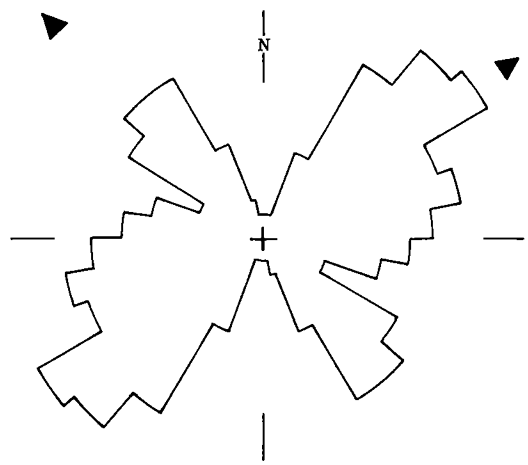



Figure 44. Strike-frequency diagram of 51 joints in western Payne County. The two predominant sets strike N. 55° E. and N. 45° W. A 30° sliding average was used in preparing diagram.

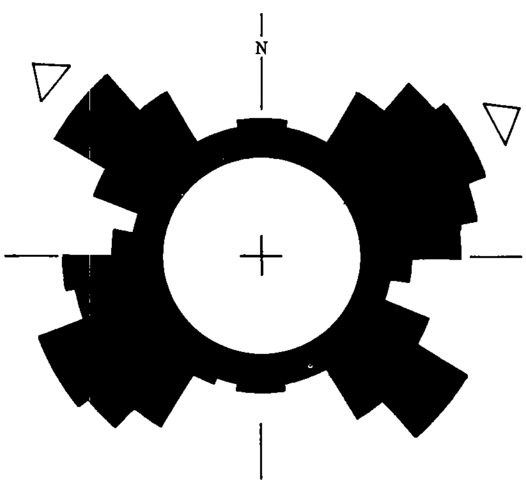



Figure 43. Strike-frequency diagram of 50 joints in central Payne County. The two predominant sets strike N. 60° E. and N. 50° W. A 30° sliding average was used in preparing diagram.

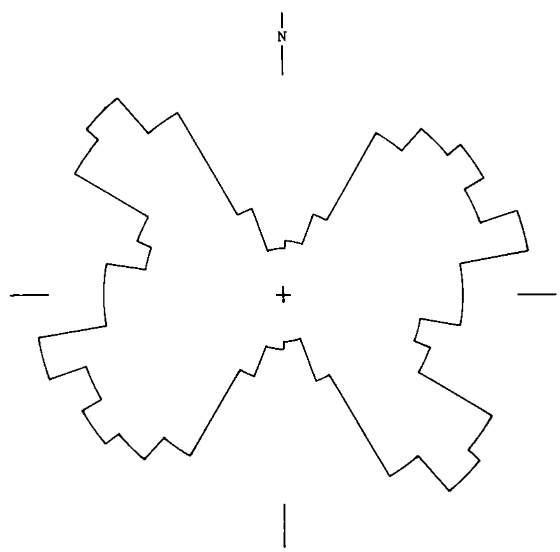



Figure 45. Composite strike-frequency diagram of joints in Payne County, showing two trends, N. 60° E. and N. 50° W.

was characterized by approximately "hydrostatic" stress conditions. He also suggests (p. 135–137) that conjugate vertical shear fractures may form as a result of uplift of an area with residual tectonic stresses which remained after a compressive phase. The northwesterly set, or sets, is subparallel to the Ouachita compressional stress direction. They are also subparallel to the northwesterly trend of normal faults, but the faults necessarily require a local stress field in which the maximum stress is vertical. If the joints represent a conjugate shear system, the compressive stress would have been oriented N. 80° W.–S. 80° E. rather than the direction compatible with development of the Ouachita system.

## Subsurface Structure

### General Comments

The general structural configuration expressed in Pennsylvanian beds in the subsurface is reflected to a large degree by the structural-contour map of three shallow limestones (pl. 1). Intensity of structural deformation increases to some extent with depth. Noses in the shallow subsurface are commonly closed structures at the position of the "Cherokee" Group. Faults in eastern Payne County are more prominent with depth; throw at the base of the Oswego Limestone is as much as 100 feet.

Angular unconformities at the base of the Pennsylvanian are locally marked as a result of growth of the Cushing, Ramsey, and Orlando structures after deposition of the Mississippian. Elsewhere, a regional subtle, angular unconformity at the base of the Pennsylvanian reflects the influence of the Ozark Uplift. The angular unconformity at the base of the Woodford Shale, or Misener Sandstone, is similar to the one at the base of the Pennsylvanian in reflecting local structural growth and regional influence of the Ozark Uplift. More structures experienced growth prior to deposition of the Woodford than after deposition of the Mississippian.

### Local Features

Although the structure below the Woodford, such as at the position of the Viola Limestone (pl. 3), is distinctly more complex than that at the position of the "Cherokee" Group, subtle Pennsylvanian structures commonly reflect deeper structural features. Examples include the west-northwest trend of the Cushing Townsite, March, and Broyles Fields; the Ingalls–Mount Hope structure; the Mehan Fields; the Ripley Field; and the Stillwater Airport Field. Prominent faults and closed structures are imposed on an overall easterly dip, which in the easternmost part of the County also reflects the west flank of the Cushing structure.

Most of the prominent structural features are in the eastern half of the County, which corresponds approximately to the subcrop area of the Spavinaw Granite of Precambrian age. One of the prominent trends there is north-northeast in the direction from Cushing to Quay (pl. 3). Preferred orientation of structures is not particularly marked, with local structures showing a wide range in trends. The west-northwest trend of the Cushing Townsite, March, and Broyles Fields is rather prominently expressed. Two north-trending structures in the southwestern part of T. 19 N., R. 5 E., and the northwestern part of T. 18 N., R. 5 E., are normal to the trend of a nose expressed by shallow beds. A northeasterly trend extends, perhaps in *en-echelon* fashion, from the Mehan Field to the Ingalls–Mount Hope structure.

Prominent faults in the eastern part of the County are illustrated by the fault in sec. 10, T. 19 N., R. 5 E., which has a maximum displacement of approximately 400 feet, and the fault in secs. 7 and 8, T. 18 N., R. 4 E., which has a maximum displacement of 300 feet. In the western part of the County, the Ramsey Field is a prominent faulted domal fold; the structure is thought to be part of a north-northeast trend extending through the Stillwater Airport Field. An extensive alignment of structures extends east-southeast from the northern part of the Orlando Field to the Stillwater Airport Field. Immediately south of that trend, the strata dip west-southwest. The folds and trend are associated with a fault, displacement for which is as much as 300 feet. An east-trending fault with as much as 200 feet of displacement is present in the northern part of T. 17 N. It extends eastward as far as the eastern part of T. 17 N., R. 1 E., where it bifurcates into two faults, the southern of which extends to the eastern part of T. 17 N., R. 2 E. A structure in the central part of T. 18 N., R. 1 W., is a faulted dome with more than 150 feet of relief.

# DEPOSITIONAL FRAMEWORK OF SURFACE ROCKS

The rocks of Payne County represent a variety of recurring depositional environments, which resulted from cyclic sedimentation. With time, the nature of the cycles changed from regressive–transgressive sequences reflecting eustatic changes in sea level to desiccation cycles caused by increases in aridity.

The earliest major transgression is represented by the Lecompton Limestone. During that transgression and subsequent transgressions, represented by limestones up to and including the Neva, essentially normal-marine conditions prevailed. Some lateral changes in environment are suggested by southward increases in dolomite, but it is thought that supratidal conditions generally were not present. Algal-mat carbonates are not present; rather, the dolomite commonly is skeletal.

The shale and sandstones in eastern Payne County were deposited principally during regressions, each of which was probably terminated rather abruptly by a subsequent transgression. Most of the shale units are thought to represent prodelta-type depositional conditions. The lenticular sandstones are considered to be representative of deltaic environments. The most prominent sandstones in the area are in the Vamoosa Formation below the Lecompton, a Gano sandstone in the Yale–Norfolk area, a Hughes Creek sandstone in the Twin Mounds area, and the rather widespread sandstone in the upper part of the Roca–Salem Point Shale. Each is thought to represent channel deposits of deltas, specifically distributary deposits. Thin sandstones which show some lateral persistence are considered to be delta-fringe units, which formed in front of, or marginal to, distributaries.

Tidal-flat conditions are suggested for some units deposited during the Roca–Salem Point regression, which followed the Red Eagle transgression. A strand-plain–shallow-marine platform, which is thought to have developed during Neva deposition, received both clastic and carbonate sediments. The Eskridge regression, which followed strand-plain deposition, resulted in the termination of marine conditions in Payne County during the Permian. Marine deposition continued to the north and west of the study area, and during later transgressions formed the upper part of an expansive tidal flat. In that area, deposits of carbonates were restricted to supratidal, nodular limestones and dolomites. The climate during formation of the carbonate and associated red beds is thought to have been arid to semiarid. The color of the red beds most likely formed soon after deposition (Walker, 1967, p. 363; McBride, 1974, p. 764). Walker (p. 364) favors arid conditions, whereas McBride (p. 772) is of the opinion that the red color formed by the alternation of dry and wet seasons.

Delta progradation occurred during the Eskridge, Garrison, Matfield–Oketo, and Doyle regressions. The Eskridge is represented by a well-developed sequence of delta-fringe and distributary channel sands. Sandstones with gradational bases and horizontal interbeds are regarded as delta-fringe, whereas those with erosive bases are considered to be distributary deposits. In the younger delta systems, only distributary channel deposits are present on outcrop. Delta-fringe units and components of deltaic destruction are absent, probably because the study area lay above, or landward of, normal-marine waters during intervening transgressions. The deltas, described as tide-dominated, have a high sand load. Because the northwesterly (N. 50° W.) trend of paleocurrents suggests a northeasterly depositional strike, equivalent units in Noble County to the northwest represent a lower deltaic plain and (or) expansive tidal flats (Shelton and others, 1979, p. 35–37). Evidence in the study area for strong tidal input includes a relatively high sandstone percentage, an absence of delta-plain mudstones, and widespread sandstones of poorly stabilized distributaries. Tidal-flat conditions during deposition of the upper Doyle, Enterprise, and lowermost Wellington are suggested by very fine-grained, highly lenticular sandstones, with burrows and calcareous zones, and abundant mudstone.

The average environmental conditions of the Wellington Formation in western Payne County, however, were those of a delta. The lenticular sandstones are thought to represent regressive deposits in distributary and tidal channels. Sandstones with gradational bases and horizontal interbeds of mudrock are believed to represent delta-fringe deposits. Mudrock is thought also to have been deposited in interdistributary bays and on tidal flats. During maximum regression, mud may have been deposited in flood basins. Tidal-flat conditions are suggested by the thin, nodular dolomites, each of which is thought to represent an authigenic/diagenetic unit which formed under supratidal conditions during a minor transgression. Seasonal and storm tides supplied water for deposition, and evaporation was responsible for conditions conducive to the formation of dolomite. The specific conditions may have been similar to those described by Lucia (1972, p. 162–163), Cook (1973, p. 1000–1001), and (or) Walter and others (1973, p. 1025–1026). The northwesterly trend of paleocurrents suggests a northeasterly depositional strike. The general climate during formation of the Wellington red beds containing nodular dolomite was probably arid to semiarid (Walker, 1967, p. 364; McBride, 1974, p. 772). The repetitious nature of red beds, dolomites, and anhydrite (in the shallow subsurface) is indicative of desiccation cycles or periods (Tasch, 1964, p. 485).

Paleocurrent data support the interpretation that the Ouachita Mountains were a prominent source area. The one sample of arkose suggests that the Wichita and Arbuckle Uplifts also may have contributed some sediments to the area.

## ECONOMIC GEOLOGY

Mineral resources of economic importance in Payne County are petroleum, ground water, and sand and gravel. Locally, limestone and sandstone have been used for construction materials. Deposits of copper, and possibly silver, gold, and uranium, may be of economic significance in the future.

### Petroleum

Oil was discovered in Payne County more than 70 years ago. Although no cumulative-production figures are available for the County, about one-third of this production is estimated to have come from the Yale–Quay Field. Gas production has been minor relative to that of oil.

The only reliable production totals for Payne County as a whole cover the period 1974–84 and were provided by Rick Connor, Oklahoma Corporation Commission. During this 11-year period, approximately 22.9 million barrels of crude oil and 13.1 billion cubic feet of natural gas were produced.

Most of the oil and gas has come from structural traps (fig. 46). Most structures were formed by deep-seated faults, which change upward into gentle folds. Recurrent movement is probably the most significant feature of the faulting. Early and continued structural growth formed traps for fluids that migrated from the source rocks, and late movement permitted pioneer geologists to detect various structures by surface mapping. Prior to deposition of the Woodford Shale, movement had formed significant structures (Tarr and others, 1965). Although significant structural activity is thought to have terminated in early Virgilian time (Arbenz, 1956), some later movement is reflected in Gearyan and Cimarronian beds of Payne County.

Through 1980, less than 5 percent of the oil produced in the County is estimated to have come from fields discovered since 1960, and less than 10 percent from fields discovered since 1950. Robert A. Northcutt (Oklahoma City, written communication, 1985) kindly furnished estimated cumulative oil-production figures through 1983 for many of the largest fields (compiled from production reports published by Petroleum Information Corp.). This information, along with the most important producing units, is tabulated as follows:

| *Field* | *Estimated cumulative oil production (barrels)* | *Major producing units* |
|---|---|---|
| Yale–Quay | 51,452,000 | Red Fork, "Wilcox" |
| Ramsey | 20,626,000 | Hunton, Misener, "Wilcox" |
| Coyle | 12,643,000 | Hunton, "Wilcox" |
| Ingalls | 10,017,000 | Red Fork, Bartlesville, Misener |
| Garr and [1]North Garr | 5,417,000 | Red Fork, Misener, "Wilcox" |
| Mehan | 6,268,000 | Bartlesville, "Wilcox" |
| [2]Orlando | 6,876,000 | Misener, "Wilcox" |

The shallowest production is at approximately 1,400 feet, from the Layton Sandstone at the West Drumright Field; the deepest is at approximately 5,300 feet, from the "First Wilcox" sandstone at Southeast Prairie View.

Detailed accounts of oil developments in Payne County have been given by a number of workers, including Shannon (1917, p. 413–423), Koschmann (1930, p. 164–167), Frost (1940, p. 1995–1996), Umpleby (1956, p. 124), Akmal (1950, p. 11), Graves (1955, p. 27–36), Stringer (1956, p. 46–50), Dalton (1960, p. 54–60), and Clayton (1965, p. 59).

The large quantity of hydrocarbons produced indicates that the three principal requirements

[1]Also in Pawnee County.
[2]Also in Noble County.

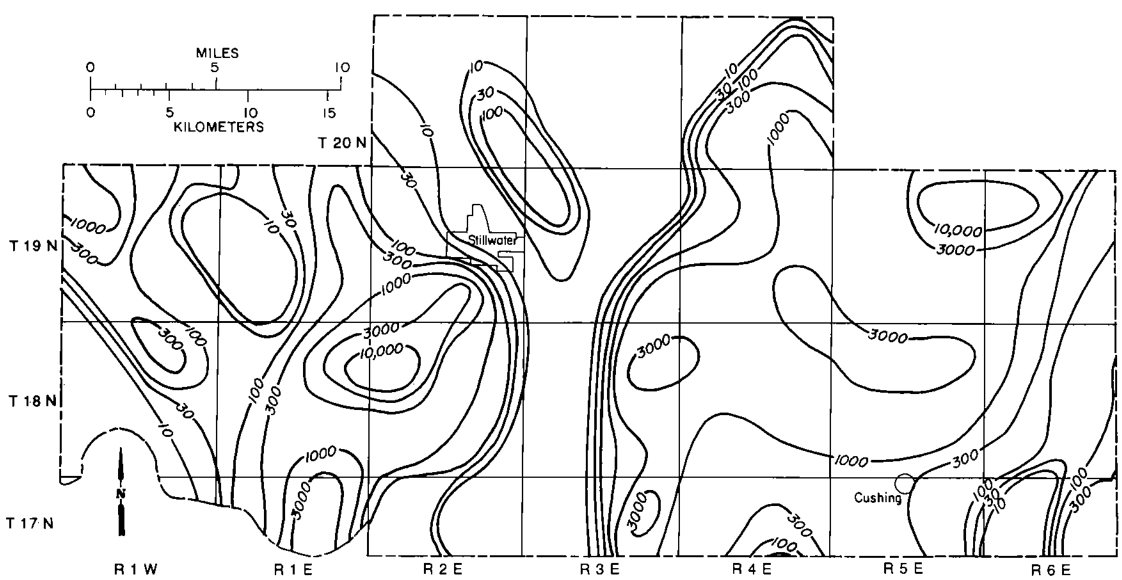



Figure 46. Petroleum-production map of Payne County. Contours are in thousands of barrels per square mile, on ¼ township grid. A smoothing routine was used in contouring. Data from International Oil Scouts Association (1971).

for commercial accumulation—source rock, reservoir, and trap—have been abundantly satisfied in parts of Payne County. Furthermore, the various shapes and trends of fields and the range in age in producing reservoirs from Ordovician to Pennsylvanian suggest that the conditions were met in a variety of ways.

### Source Rock

Although geochemical data are not available to the authors concerning source-rock quality in Payne County, empirical relationships suggest that a number of source beds are present. The Woodford Shale has been considered a prime source rock over the entire region. In parts of the Yale–Quay and Norfolk Fields, producing "Wilcox" reservoirs lie unconformably below the Woodford. Source-rock units may be present also in Simpson Group (Middle Ordovician) shales. A number of source beds in the Pennsylvanian are suggested by the large number of productive stratigraphic units.

### Reservoirs

More than 20 stratigraphic units are oil-producing reservoirs (fig. 26). The Pennsylvanian (Virgilian) Vertz sandstone (above the Wakarusa Limestone) is the youngest reservoir, and the "Second Wilcox" sandstone of the Ordovician Simpson Group is the oldest productive unit. Pennsylvanian reservoirs include a large number of sandstones and, locally, the Avant, "Big Lime," and Oswego limestones. Mississippian reservoirs are represented by several units of the "Mississippi" limestone. Local production is from the Devonian Misener Sandstone and Silurian–Devonian Hunton Dolomite. Ordovician reservoirs include the Viola Limestone and "Wilcox" sandstones, and the carbonates of the Simpson Group. The most prolific reservoirs are the "Wilcox" sandstones and the "Cherokee" sandstones.

### Traps

Known traps include faulted and folded structures, illustrated by the Yale–Quay, Coyle, and Ingalls Fields (pl. 3), and stratigraphic traps such as the Stillwater Field. The most common traps for Pennsylvanian oil are gentle noses or folds draped over faulted lower Paleozoic beds, across which some variation in reservoir quality is developed. Production from "Wilcox" sandstones is almost entirely from structural traps, where closure is present at the position of the sandstones.

### Present and Future Activity

The renewed activity that began in 1974 as a result of more favorable prices because of an uncertain national and world supply of oil has resulted in discoveries in which prospects are drilled to seek structural, stratigraphic, and stratigraphic–structural traps. The structures generally are small, subsidiary features to larger features. Traps with significant stratigraphic elements are due in large measure to the trend and distribution of rather narrow and (or) thin Pennsylvanian sandstones, porosity development in the "Mississippi lime," and local distribution of the Misener Sandstone. New production has been obtained from established fields, even those in which secondary-recovery methods had been utilized.

This renewed activity reflects a "quantum jump" in economic incentives rather than in technology. Probably the most significant technological advance is recognition of the production capabilities of low-resistive sandstones with microporosity, as reflected on geophysical logs. The future probably will be characterized by about the same level of activity, followed by a general decline. Any resurgence is expected to reflect either a new price structure, encouraging completion of presently uneconomical reservoirs and very closely spaced drilling, or a technological advance in enhanced-recovery methods.

## Water Resources

### Introduction

Published information on the water resources of Payne County includes the results of reconnaissance investigations undertaken by the U.S. Geological Survey in cooperation with the Oklahoma Geological Survey. These studies have been published by the Oklahoma Geological Survey, at a scale of 1:250,000, as a series of hydrologic atlases covering the State of Oklahoma except for the Panhandle. Each atlas consists of four sheets, including a geologic map and maps showing the availability of ground water, quality of ground water, and surface-water quality and resources. The Enid Quadrangle (HA-7; Bingham and Bergman, 1980) embraces an area that includes most of Payne County, and the adjoining Oklahoma City Quadrangle (HA-4; Bingham and Moore, 1975) covers the southernmost part of the County.

The following discussion of the ground- and surface-water resources of Payne County tends to be more specific than the texts that accompany the hydrologic atlases.

### Ground Water

Wells provide water for many rural homes, for municipal use in small communities, and for small industries. The area most favorable for ground-water development is along the flood plain and terraces of the Cimarron River.

Flood-plain alluvium and terrace alluvium along the Cimarron River ranges from 50 to 120 feet in thickness, and yields of wells range from 50 to 100 gpm (gallons per minute). Where alluvium is thinner and finer grained, yields are about 25 to 50 gpm. The overall water quality is fair to good, with dissolved-solids content typically less than 500 mg/L (milligrams per liter). However, wells very close to the river on the flood plain may experience a decline in water quality if they are pumped heavily for an extended period of time. This heavy pumping lowers the water table, and the flow of water into the alluvium from the river causes deterioration of ground-water quality.

Flood-plain alluvium along Stillwater Creek is about 30 to 40 feet thick. The average yield is about 20 to 50 gpm, although yields of 100 gpm are possible where wells penetrate local lenses of gravel at the base. The quality of the ground water is generally good. Elsewhere, with local exceptions, flood-plain and terrace deposits are too thin to yield significant amounts of water.

Because the depth to the base of fresh water represents the lower depth of ground-water development in bedrock, plate 4 represents the approximate depth to the fresh-water–salt-water contact. A contour interval of 100 feet was used throughout the County, except in the southeastern part, where greater depths are portrayed by a geometrically progressive contour interval. The depth to salt water is controlled by sandstone development, topography, and saline influent from the Cimarron River. Areas of bedrock deposits (sandstone, limestone, and shale) are generally considered to be least favorable for ground-water development, but some sandstones do yield amounts of 25 to 50 gpm. Thicker, coarser grained beds of the Vamoosa Formation may yield as much as 200 gpm in the southeastern part of the County. Other areas favorable for possible ground-water development in sandstone are shown on the map east, southeast, and west of Stillwater (pl. 4). Although the quality of water is variable in these irregular lenses of sandstone, it generally is of fair to good quality. In other areas, where sandstones may be thin or tightly cemented, the quality of water is poor to fair, and (or) the depth to salt water is shallow.

### Surface Water

Water from the Cimarron River and the lower part of Stillwater Creek in Payne County does not meet the accepted water-quality standards for municipal and domestic use. It is characterized as very hard to brackish water, with dissolved solids greater than 1,000 mg/L. The Cimarron River has high hardness (calcium carbonate) and high chloride content, and the dissolved solids content locally exceeds that of sea water. The high mineral content is primarily due to solution of salt or gypsum from bedrock upstream. Local stream pollution may occur in proximity to oil production, livestock operations, and waste-disposal facilities.

The larger lakes in the County which provide water of good quality are Lake Carl Blackwell, Boomer Lake, and Cushing Lake. In addition, Lake McMurtry, just to the north of Payne County in Noble County, provides a source of good water to supplement the water supply from Lake Carl Blackwell for Stillwater. Abundant surface water is present just to the east at Keystone Reservoir in Pawnee and Creek Counties, but the quality of water there is fair to poor. A pipeline some 40 miles in length was completed in 1982 to the Kaw Reservoir on the Arkansas River east of Ponca City for utilization by the City of Stillwater. The proposed Lower Black Bear Creek Watershed Project Site 19, just north of the Payne–Pawnee County line, is another possible source of surface water for part of northeastern Payne County.

The quality of water in some of the smaller streams, lakes, and ponds in the area may be good, though some of these waters are locally polluted.

## Sand and Gravel

Sand is plentiful on the flood plain of the Cimarron River. Together with limited amounts of gravel, the sand is available for use in fills, asphalt, concrete, and masonry work. Processed sand from the flood plain is class A and masonry grade. A slurry operation in the Perkins area, which produces as much as 50,000 tons of sand annually, has supplied local concrete plants and masonry contractors. Sand from the flood plain has also been used by highway contractors.

The material of the Cimarron River terraces, which commonly has a rather high iron oxide content, is generally used only in fills and asphalt. The sand pits in the terrace deposits near Perkins usually operate intermittently.

## Limestone

The Red Eagle Limestone has been quarried at several localities in the study area. Locally, it is a good source of road metal for county roads, concrete aggregate, and riprap, but it is generally thin or shaly. Other limestones that may be suitable as a local resource include the Lecompton and Wakarusa. Most other limestones in the area are considered too thin for development as resource material. Thin, nodular dolomites have been used as road metal for some county roads.

## Sandstone

Sandstones of Payne County were used locally for building stone, and one sandstone was quarried for subbase material for Interstate Highway 35. However, the sandstones in Payne County are generally considered too friable for modern construction purposes.

## Metals

Known deposits of copper, with some silver, and gold are located southwest, south, and southeast of Glencoe.

Copper-bearing minerals were observed by Ross (1972) and Heine (1975) on the surface in the SW¼ sec. 2, T. 19 N., R. 3 E.; SE¼ sec. 3, T. 19 N., R. 3 E.; NE¼ sec. 5, T. 19 N., R. 3 E.; SE¼ sec. 22, T. 20 N., R. 3 E.; SE¼ sec. 23, T. 20 N., R. 3 E.; SW¼ sec. 24, T. 20 N., R. 3 E.; NW¼ sec. 25, T. 20 N., R. 3 E.; NE¼ sec. 26, T. 20 N., R. 3 E.; NE¼ sec. 13, T. 20 N., R. 4 E.; NE¼ and NW¼ sec. 24, T. 20 N., R. 4 E.; NE¼ sec. 31, T. 20 N., R. 4 E.; and NW¼ sec. 32, T. 20 N., R. 4 E. Minerals containing copper have also been observed in samples from water-well drilling in an area of approximately 15 square miles which includes the surface exposures in T. 20 N., R. 3 E. (Tarr, 1910). The mineralization is typical of red-bed copper deposits in occurring as layers only a few inches thick, replacing fossil wood in sandstone. Chalcocite is the chief copper mineral; it is associated with pyrite, malachite, azurite, and some chalcanthite and covellite (Tarr, 1910; Rogers, 1916, p. 372, 375, pl. 18). The occurrence in the SE¼ sec. 22, T. 20 N., R. 3 E., differs from typical red-bed copper deposits in containing an abnormally high content of silver and gold (Tarr, 1910). The chalcocite at this locality consists of 31.25 oz./ton of silver and 0.1 oz./ton of gold. The most likely origin of the copper deposits is precipitation from ground water in a reducing environment formed by organic matter (Tarr, 1910; Rogers, 1916; Merritt, 1940, p. 6–7). Attempts at mining the copper deposits in secs. 22 and 23, T. 20 N., R. 3 E., were made in the early part of this century, and interest has been expressed recently by several companies.

Cuprified fossil-wood deposits in Pawnee County yield from 0.002 to 0.068 percent uranium, and selected samples contain as much as 16.3 percent (Branson and others, 1955, p. 11). Although no radioactive-mineral analyses were made of Payne County copper deposits, it is thought that they may also contain some radioactive minerals. Traces of radioactive cuprified wood fragments are associated with the Red Eagle Limestone in sec. 26, T. 18 N., R. 4 E. (Nakayama, 1955, p. 56).

## SUMMARY

1. Pennsylvanian–Permian beds are arranged into units (formations and members) of the standard stratigraphic section of the Midcontinent; surface rocks include approximately 2,200 feet of sediments.
2. The stratigraphic section is represented by mudrock, lenticular sandstone, limestone–dolomite, and nodular dolomite. The lower 800 feet is characterized by laterally continuous carbonate units, whereas discontinuous, thin, nonfossiliferous dolomite units are present in the remaining part of the section. Red beds are particularly prominent in the upper two-thirds of the section.
3. Sandstone is prominent in the Eskridge, Garrison, Matfield–Oketo, Doyle, and Wellington formations. Sandstone units are characterized by erosive bases, initial dip, small- and medium-scale crossbedding, parting lineation, and cutout. Sandstones with gradational bases are present in the lower Eskridge Shale and parts of the Wellington Formation. The sandstones are fine to very fine grained and range in composition from quartzarenite to subarkose.
4. Burrows and fossil fragments are locally present in the upper two-thirds of the section.
5. Carbonate units are crystalline dolomitic limestones to packstones in the lower part; and nodular carbonates are dismicrites.
6. Pennsylvanian sandstones below the Admire Shale show an average paleocurrent direction of N. 45° W. and a secondary trend of N. 25° E. The average direction for sandstones between the Admire Shale and the Herington Limestone is N. 50° W. Features in Wellington sandstones show an average paleocurrent direction of N. 35° W., with several secondary directions.
7. During deposition of carbonates in the lower one-third of the section, marine conditions predominated. These conditions were repeatedly interrupted by deltaic regressions, during which various amounts of sand and mudrock were deposited.
8. The red beds with prominent sandstones are thought to have been part of an upper deltaic plain of tide-dominated deltas.
9. Nodular carbonate units are thought to represent deposition during transgressions in the supratidal zone of carbonate tidal flats.
10. Tidal-flat deposition characterized much of the uppermost part of the Pennsylvanian.
11. Tide-dominated deltas characterized conditions during deposition of much of the Wellington.
12. The area is characterized by homoclinal westerly dip; the undulatory surface of the homocline reflects local structural noses. Each of nine closed structures averages less than 1 square mile in area. The noses and anticlines increase in area and intensity with depth.
13. The prominent directions for vertical joints are N. 60° E. and N. 50° W. These directions are consistent with the joint patterns mapped by Melton (1929, fig. 3).
14. The dominant structural style is thought to reflect local differential vertical uplift. However, vertical movement probably reflects strike-slip faulting.

15. Petroleum is the major mineral resource. Also present are limestone for road metal, concrete aggregate, and riprap; sand for fill, asphalt, masonry purposes, and concrete; and clay for bricks. The potential yield is uncertain for copper, silver, gold, and radioactive minerals. Potable water is best developed in terrace and flood-plain deposits and in sandstones in the Eskridge, Garrison, Matfield–Oketo, Doyle, and Wellington formations. Distribution of fresh water reflects local sandstone development, topography, and saline influent from the Cimarron River.

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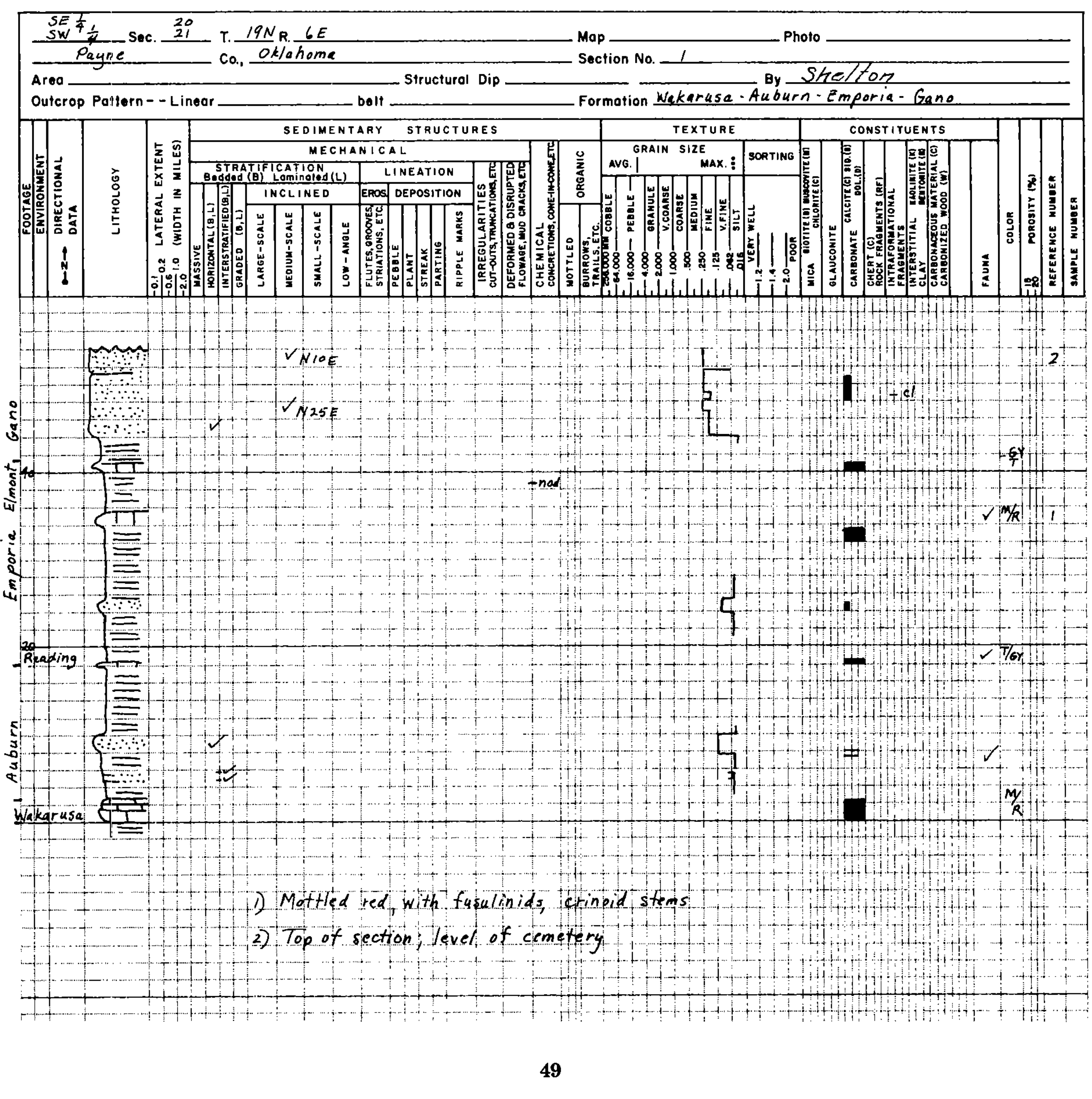
# APPENDIX

## Measured Stratigraphic Sections

Representative sections of the key stratigraphic units are given in graphic form. Although the form utilized has been described (Shelton, 1963), several explanatory notes are given herein. The form allows the lithology, thickness, and resistance to weathering to be shown graphically. A list for sedimentary structures serves as a checklist that can be keyed to the appropriate bed. Grain size and sorting are shown as graphic vertical sections. The list of constituents is given in such a manner that, by shading in the appropriate areas, qualitative values of rare, common, and abundant can be noted for the frequency of each material. Photographs, paleocurrent measurements, notes, and samples can be plotted opposite the appropriate bed.

The form is thought to allow for more meaningful correlation and comparison of different sections, including the subsurface. It is thought further that the form can aid in reducing operator error and aid in obtaining a greater degree of reproducibility by subsequent workers. The desired end result is greater utilization of the measured sections not only in the original work but also in later studies of an area.

### 1. Wakarusa–Auburn–Emporia–Gano Formations



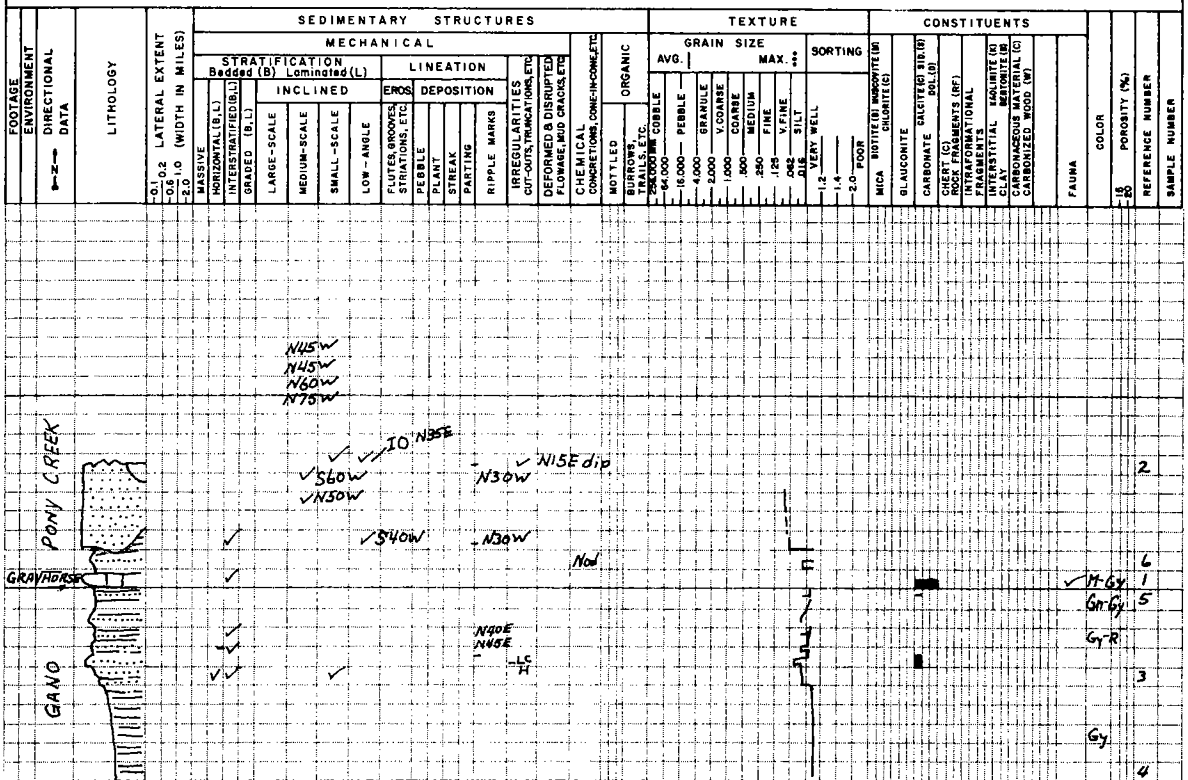
## 2. Gano–Grayhorse–Pony Creek Formations

SW SE Sec. 10 9 T. 18N R. 5E Map ______ Photo ______

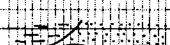
PAYNE Co., OK Section No. 2

Area ______ Structural Dip ______ By SHELTON

Outcrop Pattern -- Linear ______ belt ______ Formation GANO - GRAYHORSE - PONY CREEK




1) Foss, frag, bryozoans, brach, crinoid stems, echinoid & crinoid plates
Packstone
gy (fresh), maroon on surface
2) cut-out filled with red clay & IB vf ss w/ burrows
3) brackish water fauna - Lingula, Orbiculoidea
4) marine fauna - Neospirifer, Punctospirifer
5) Shark tooth
6) Channel trend - N60W



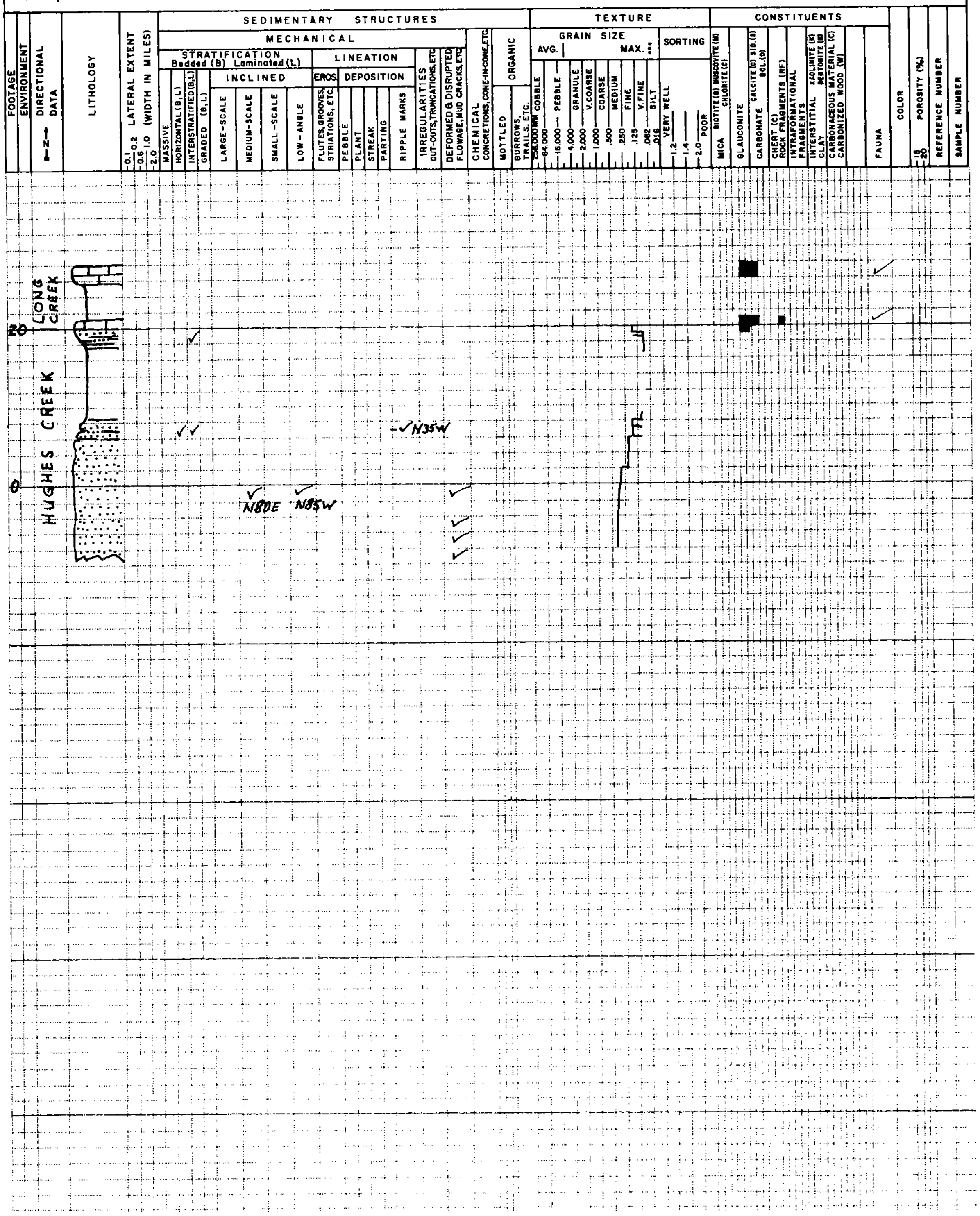
## 3. Hughes Creek–Long Creek Members of Foraker Limestone

NW ¼ (ALONG W LINE) Sec. 16 T. 19 N R. 5 E Map ______ Photo ______

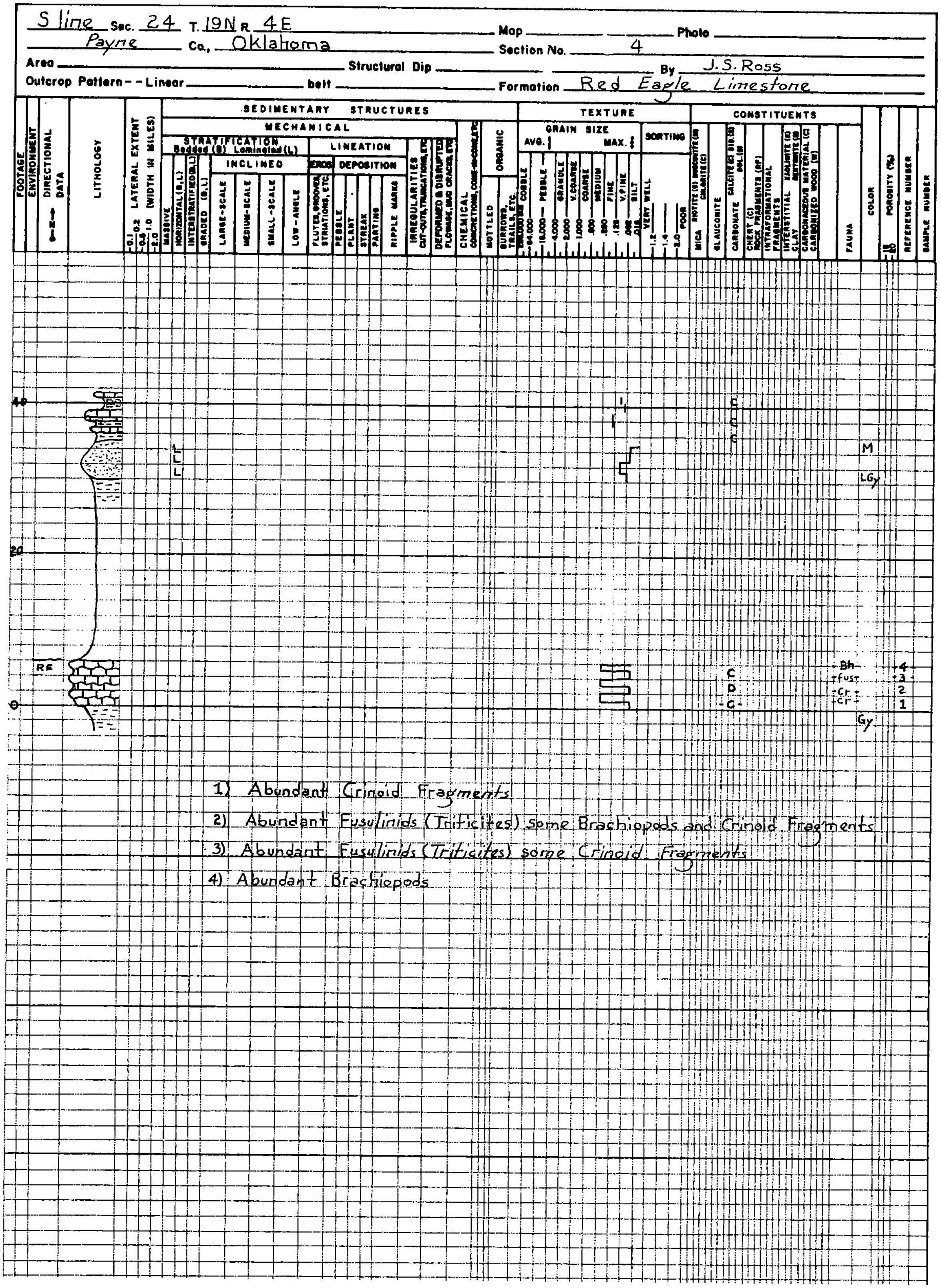
PAYNE Co., OK Section No. 3

Area ______ Structural Dip ______ By SHELTON

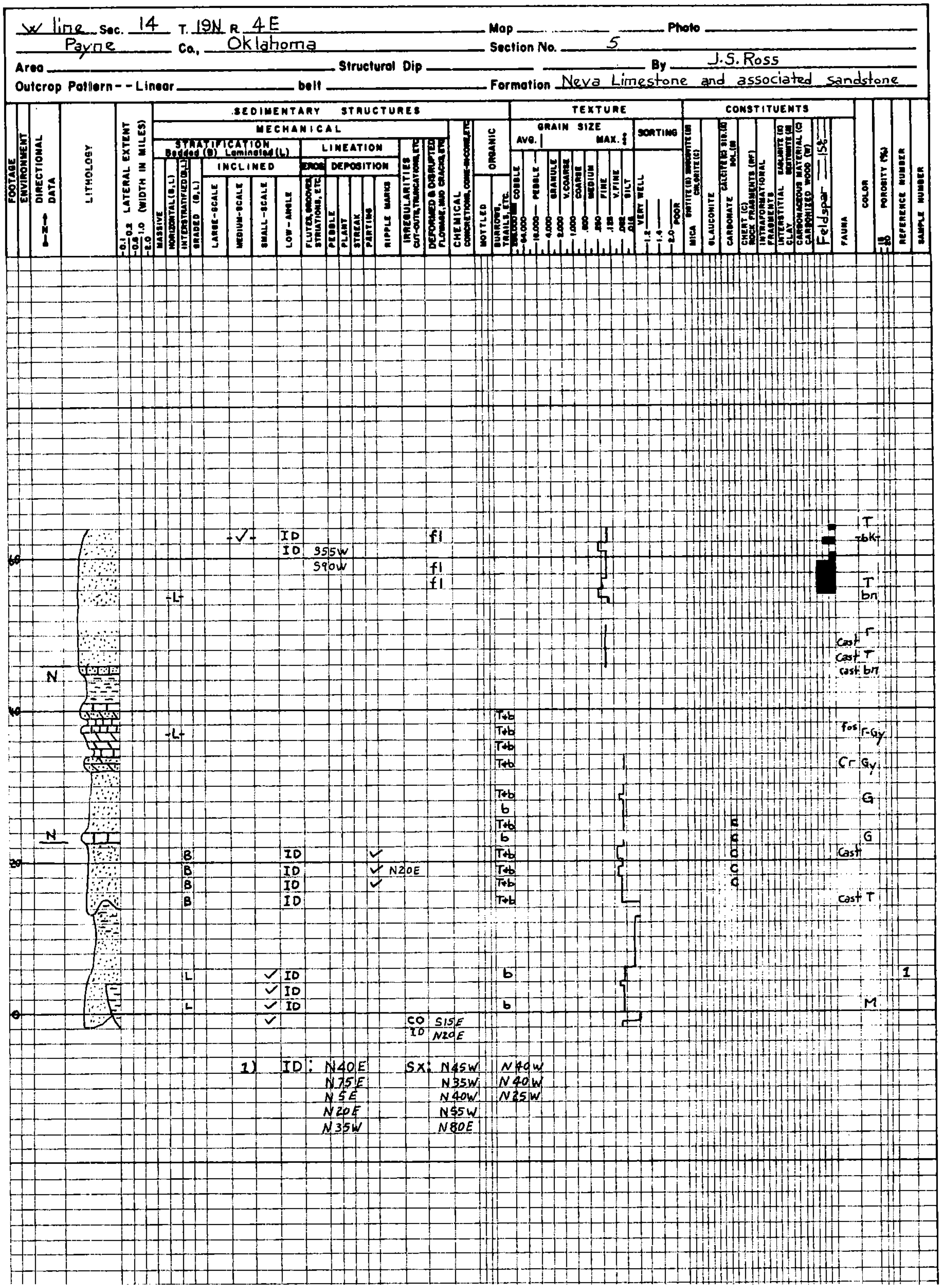
Outcrop Pattern -- Linear ______ belt ______ Formation HUGHES CREEK – LONG CREEK



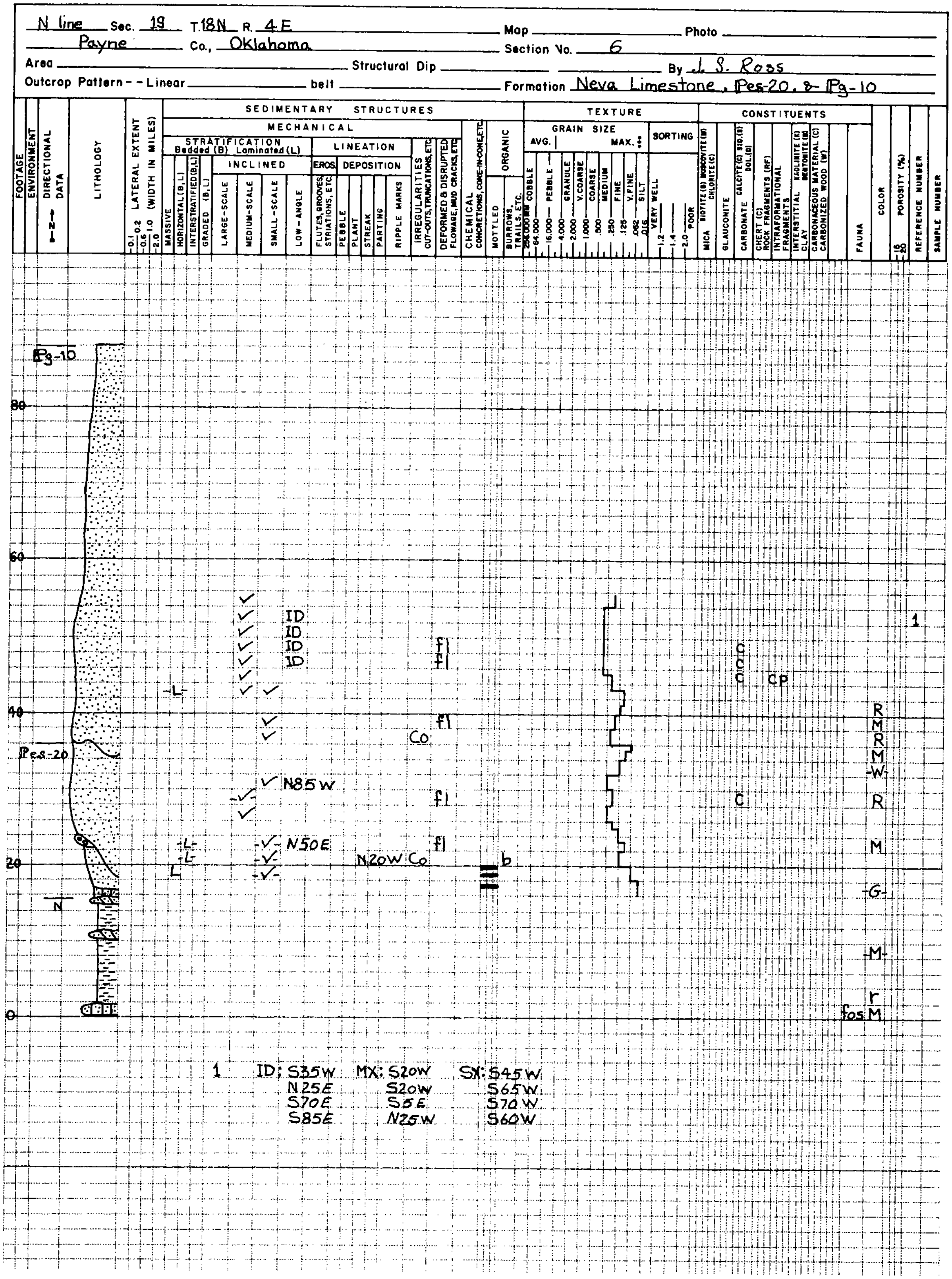
## 4. Red Eagle Limestone



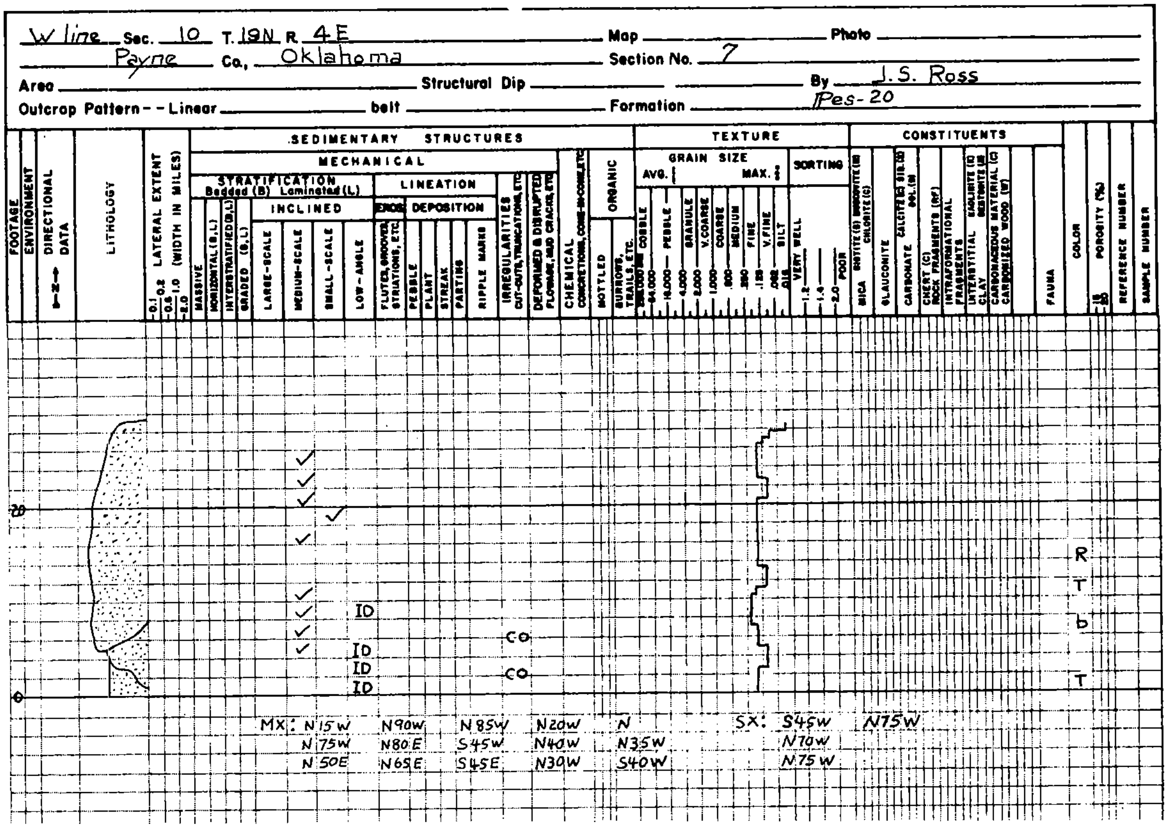
## 5. Neva Limestone and Associated Sandstone



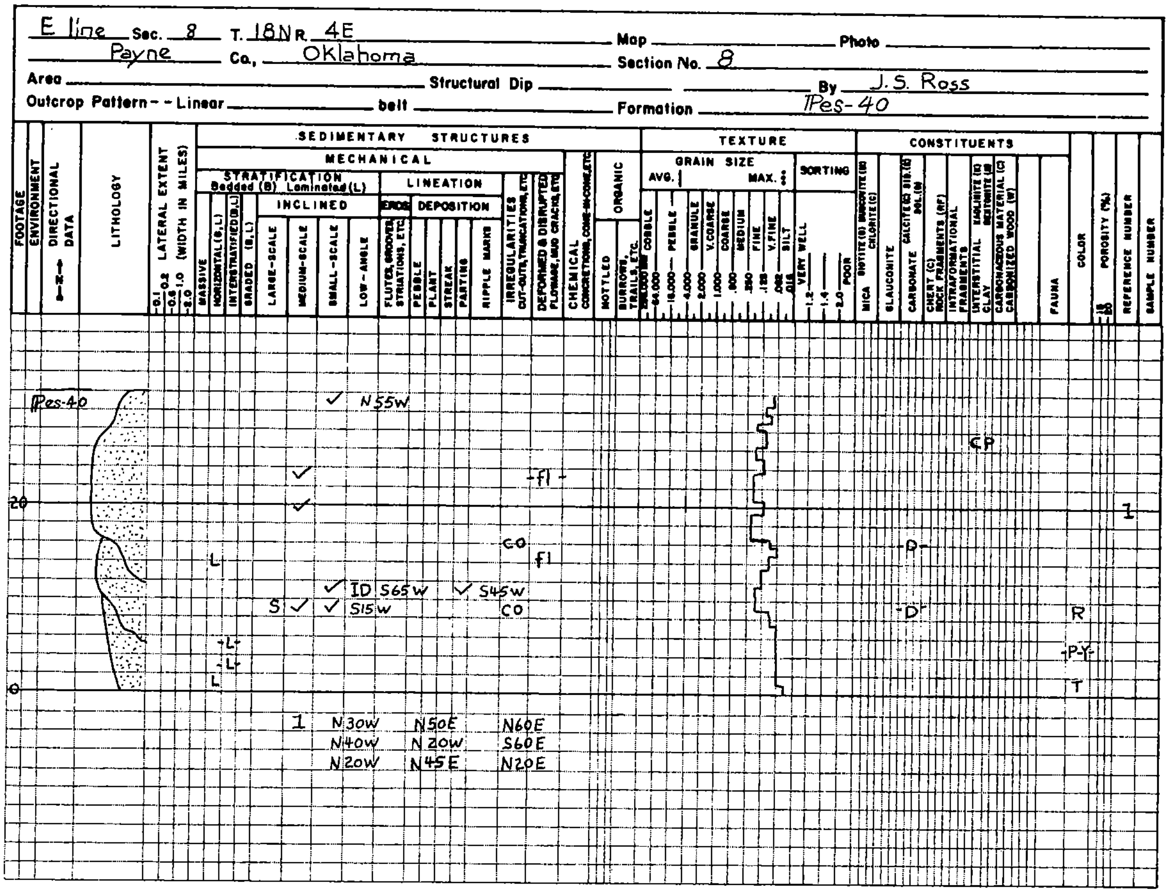
## 6. Neva Limestone and Associated Sandstone



## 7. Sandstone in Eskridge Shale

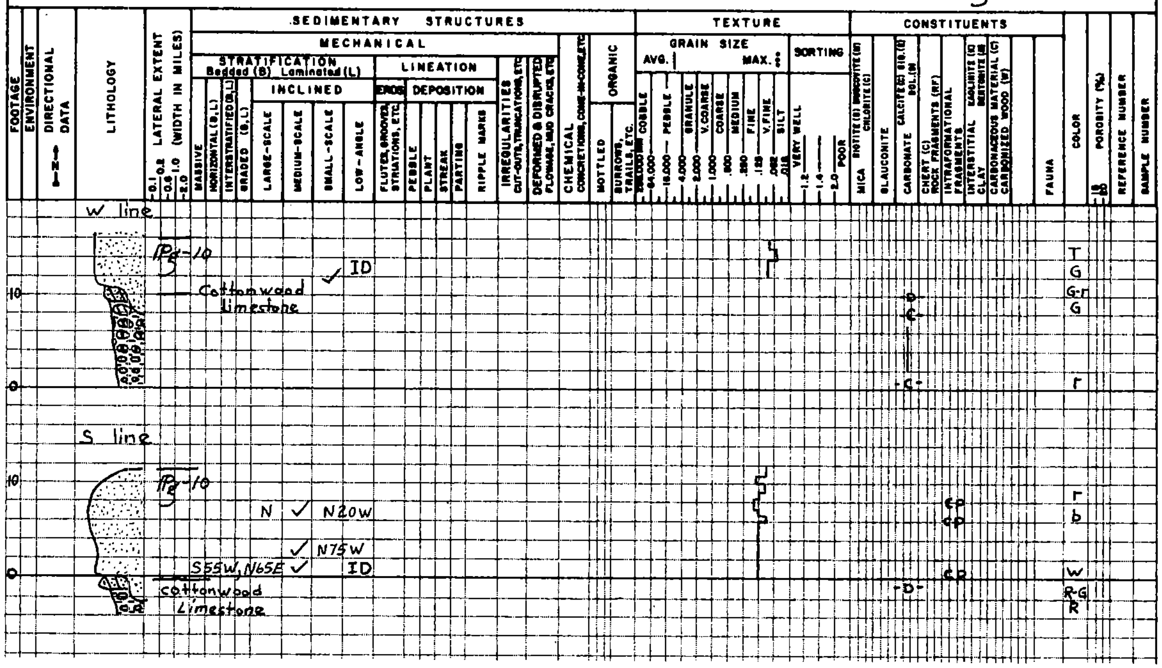


## 8. Sandstone in Eskridge Shale



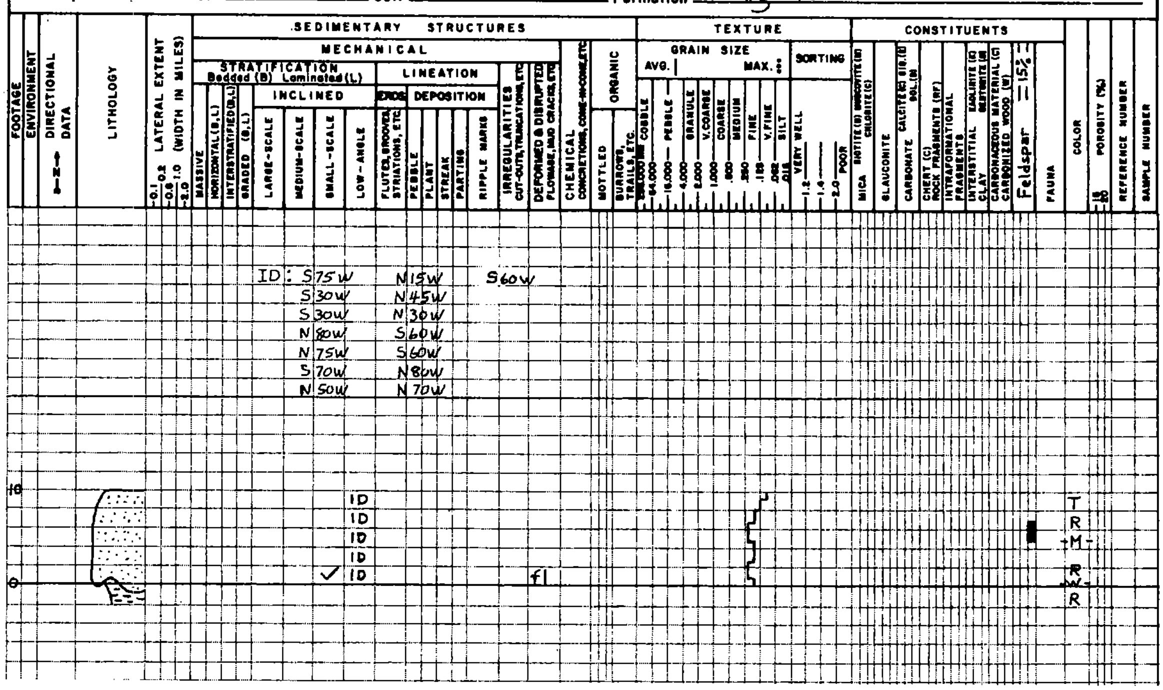
## 9. Cottonwood Limestone and Sandstone in Garrison Shale

W+S lines Sec. 35 T. 20N R. 4E Map ____ Photo ____
Payne Co., Oklahoma Section No. 9
Area ____ Structural Dip ____ By J.S. Ross
Outcrop Pattern--Linear ____ belt ____ Formation Cottonwood Limestone and Pg-10

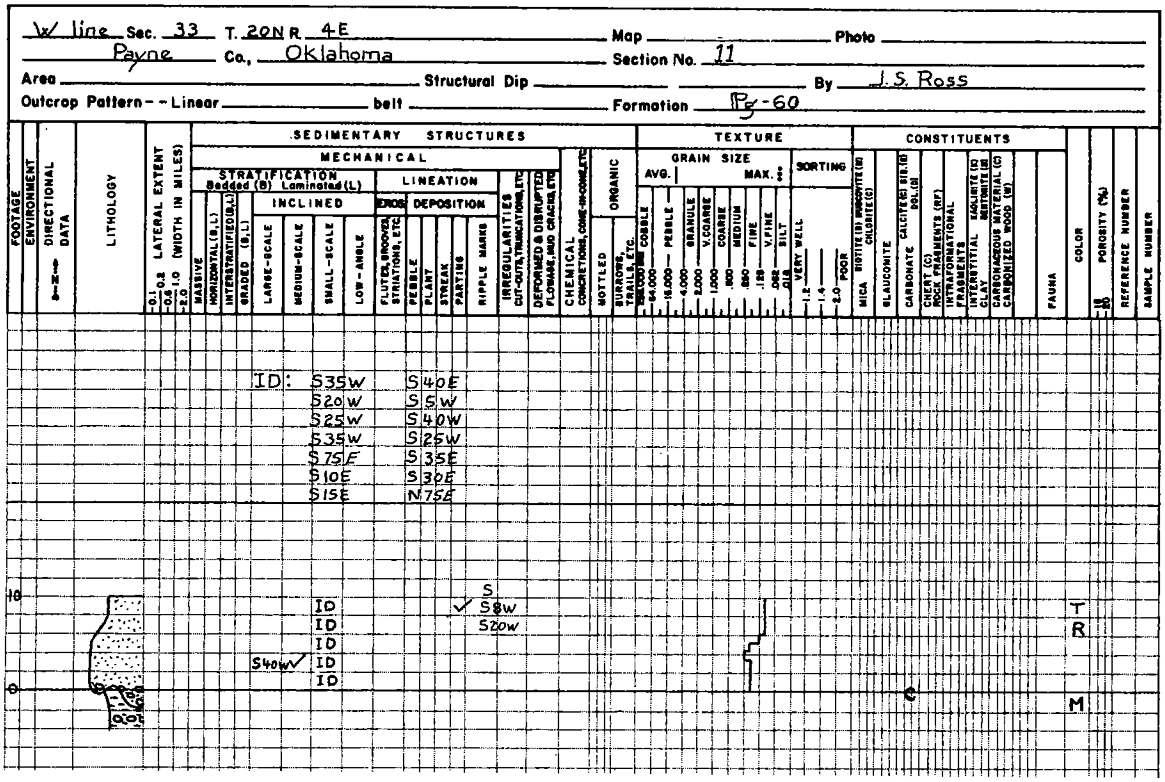



## 10. Sandstone in Garrison Shale

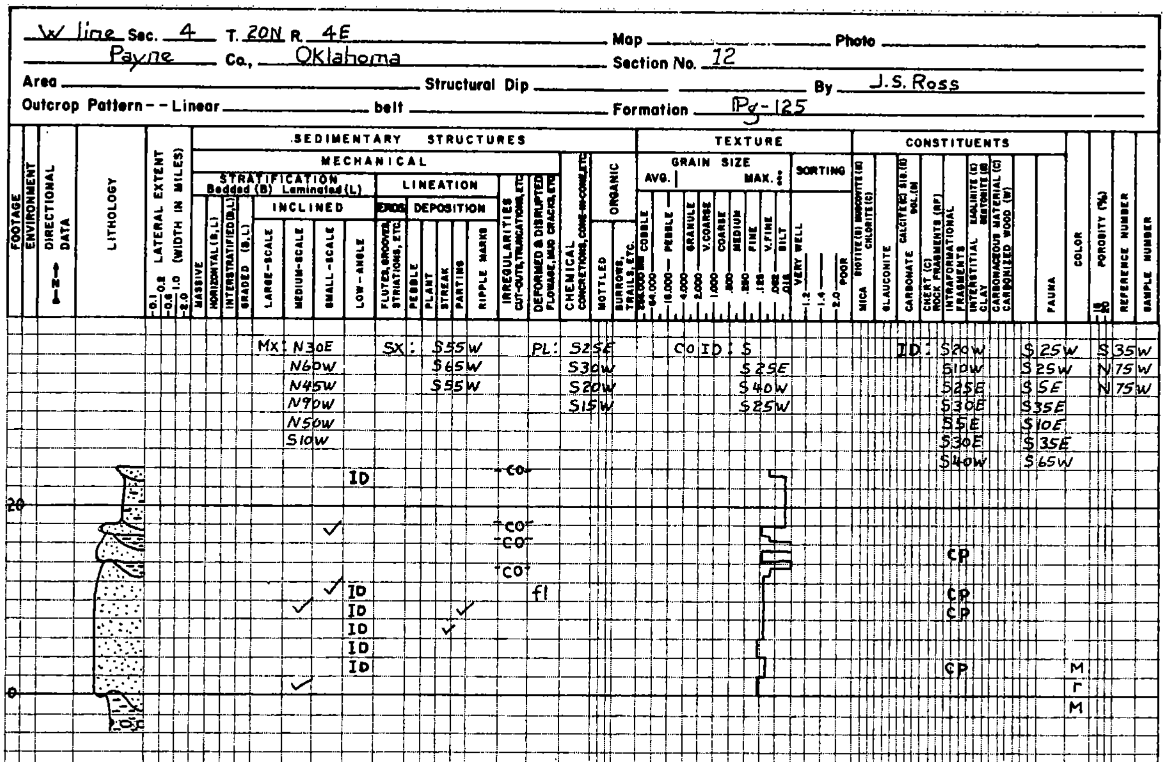
SE Corner Sec. 5 T. 19N R. 4E Map ____ Photo ____
Payne Co., Oklahoma Section No. 10
Area ____ Structural Dip ____ By J.S. Ross
Outcrop Pattern--Linear ____ belt ____ Formation Pg-40



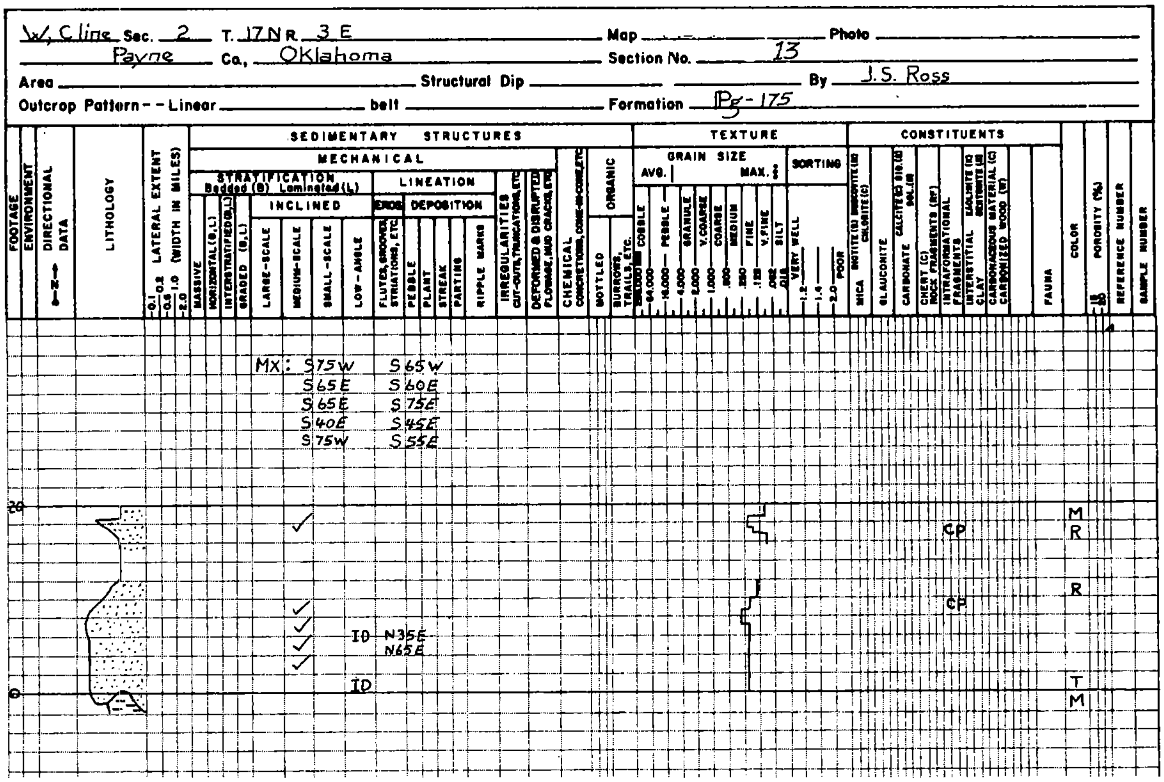
## 11. Sandstone in Garrison Shale



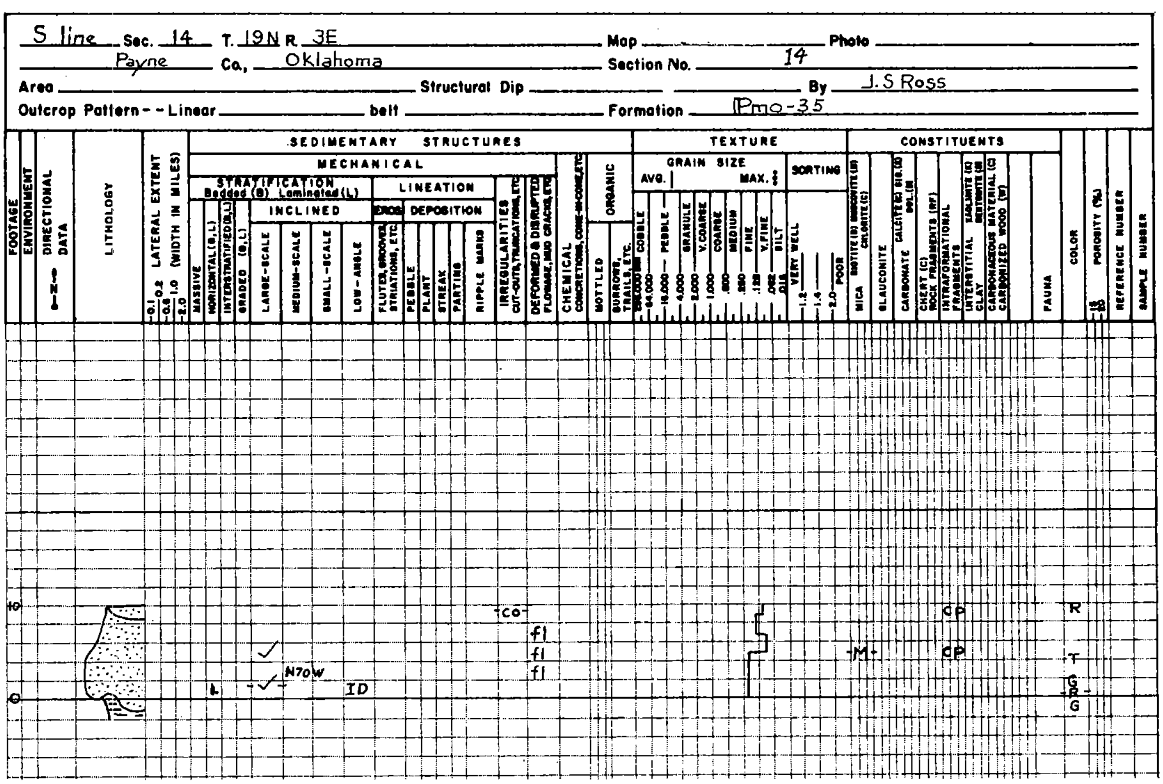

## 12. Sandstone in Garrison Shale



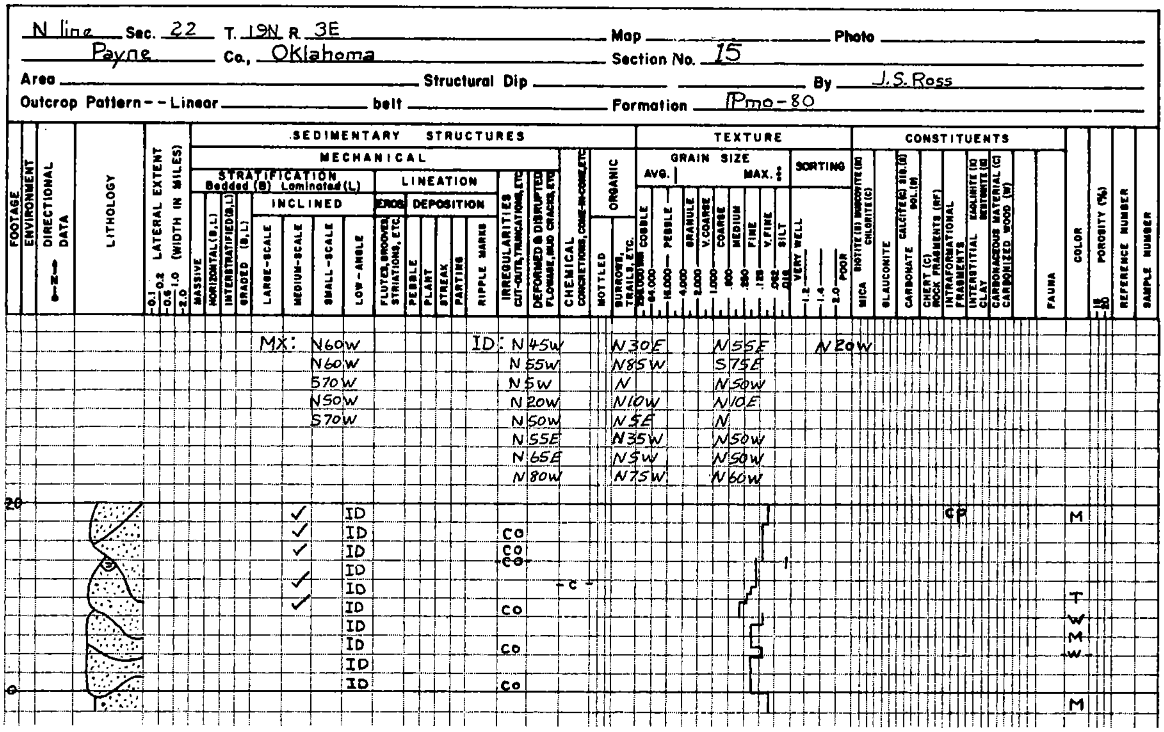
## 13. Sandstone in Garrison Shale



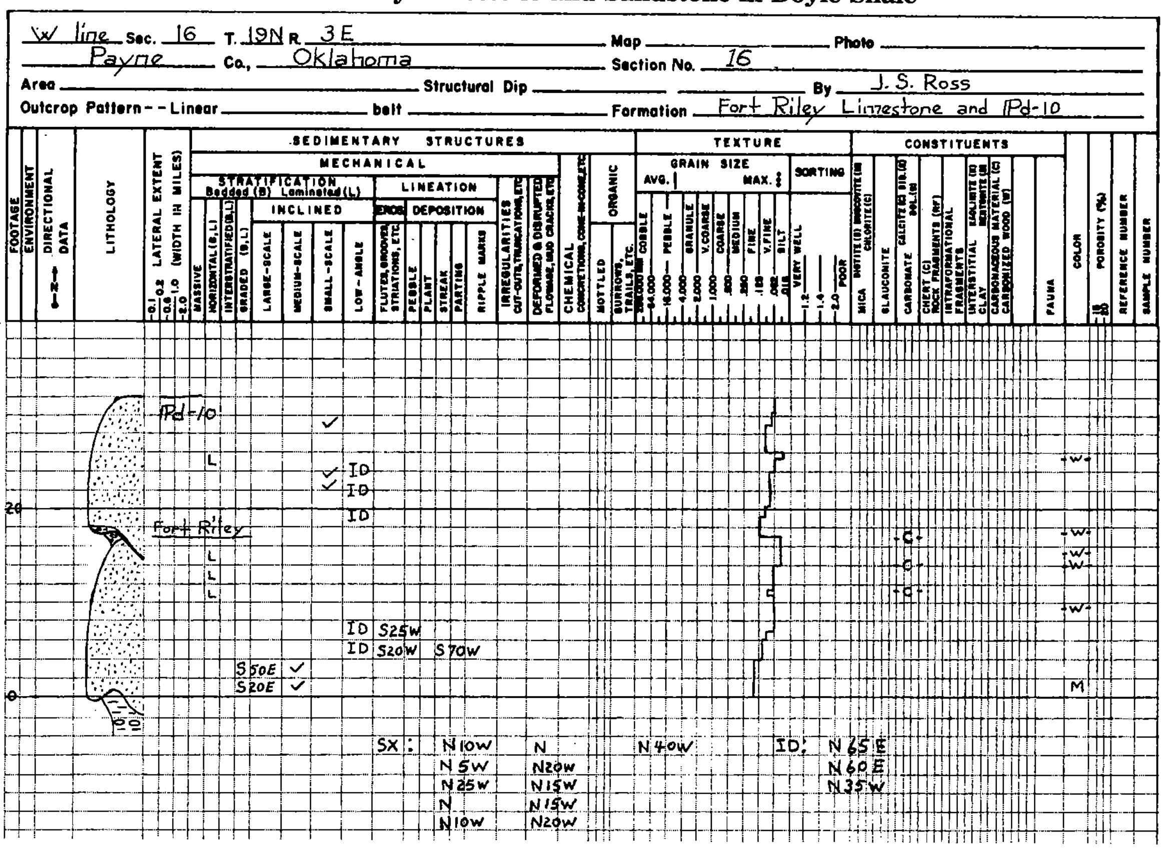

## 14. Sandstone in Matfield–Oketo Shale



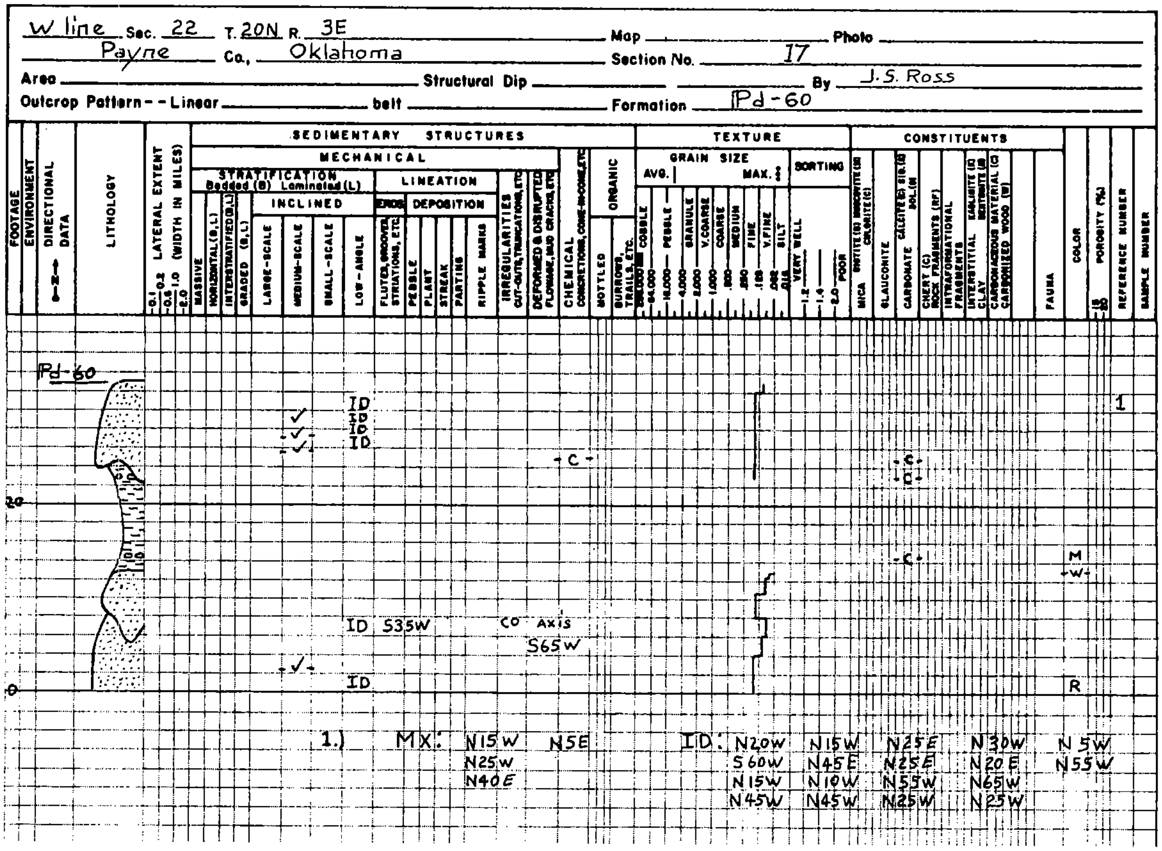
## 15. Sandstone in Matfield–Oketo Shale



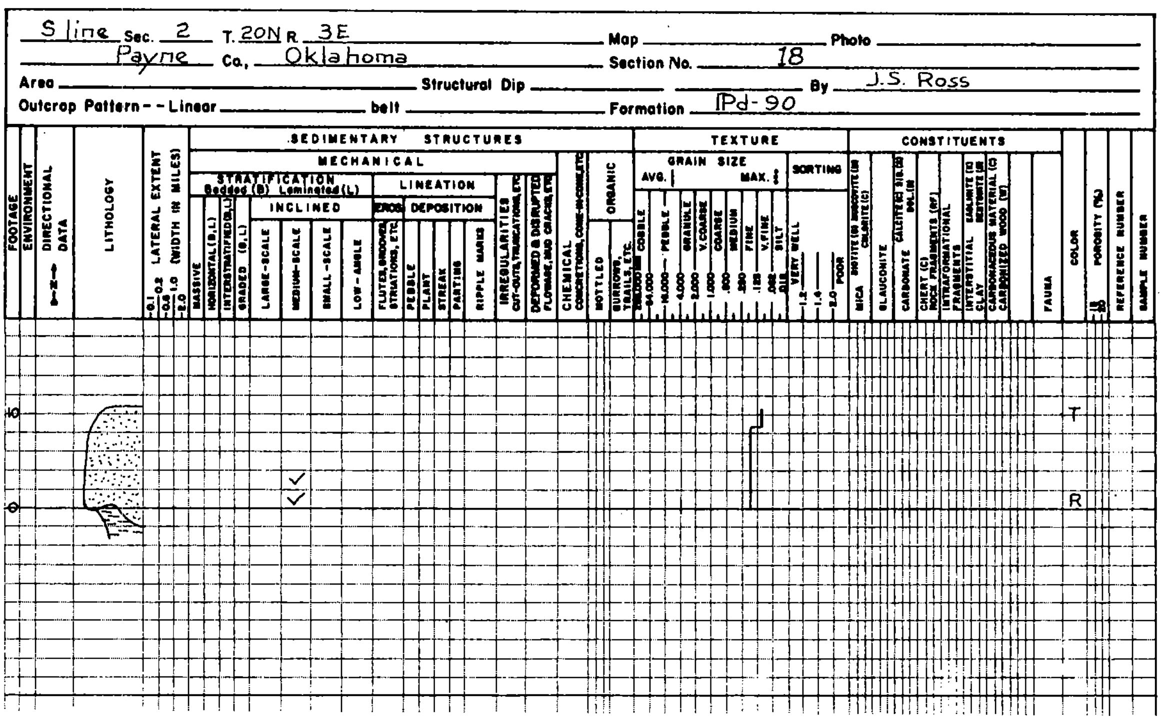

## 16. Fort Riley Limestone and Sandstone in Doyle Shale



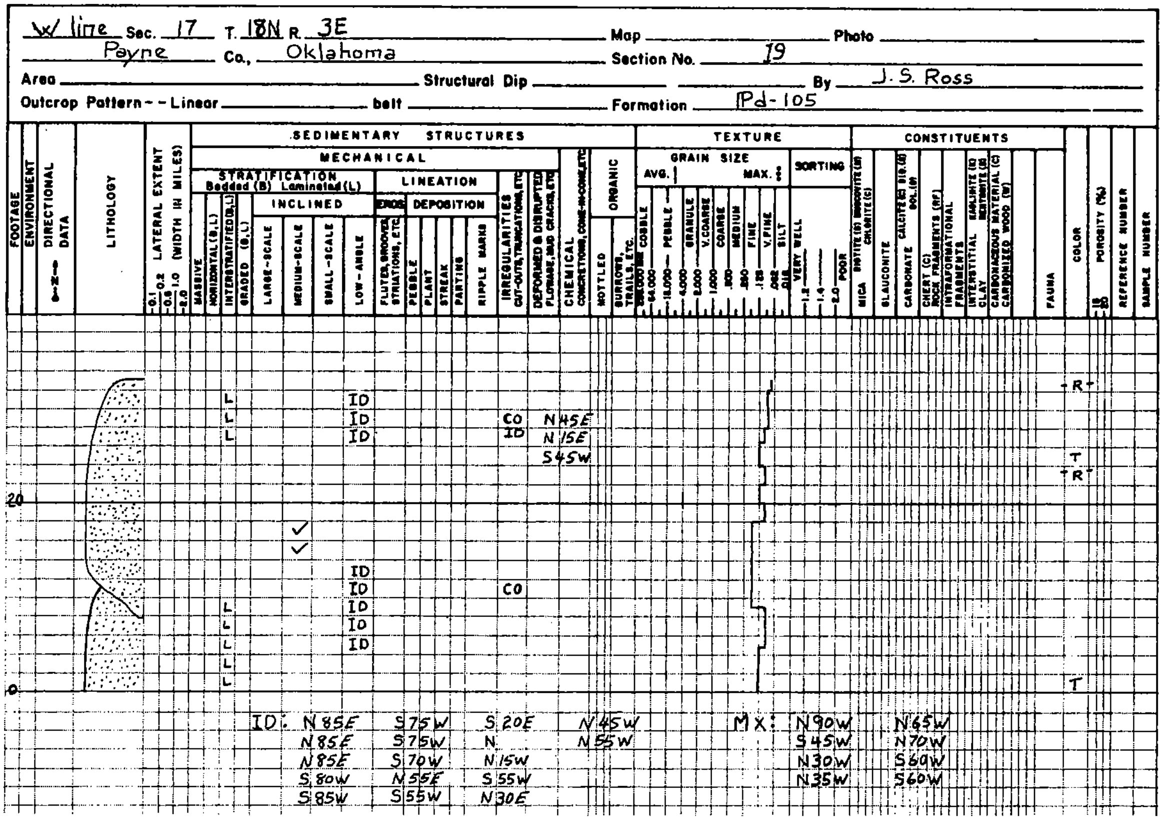
## 17. Sandstone in Doyle Shale




## 18. Sandstone in Doyle Shale



## 19. Sandstone in Doyle Shale



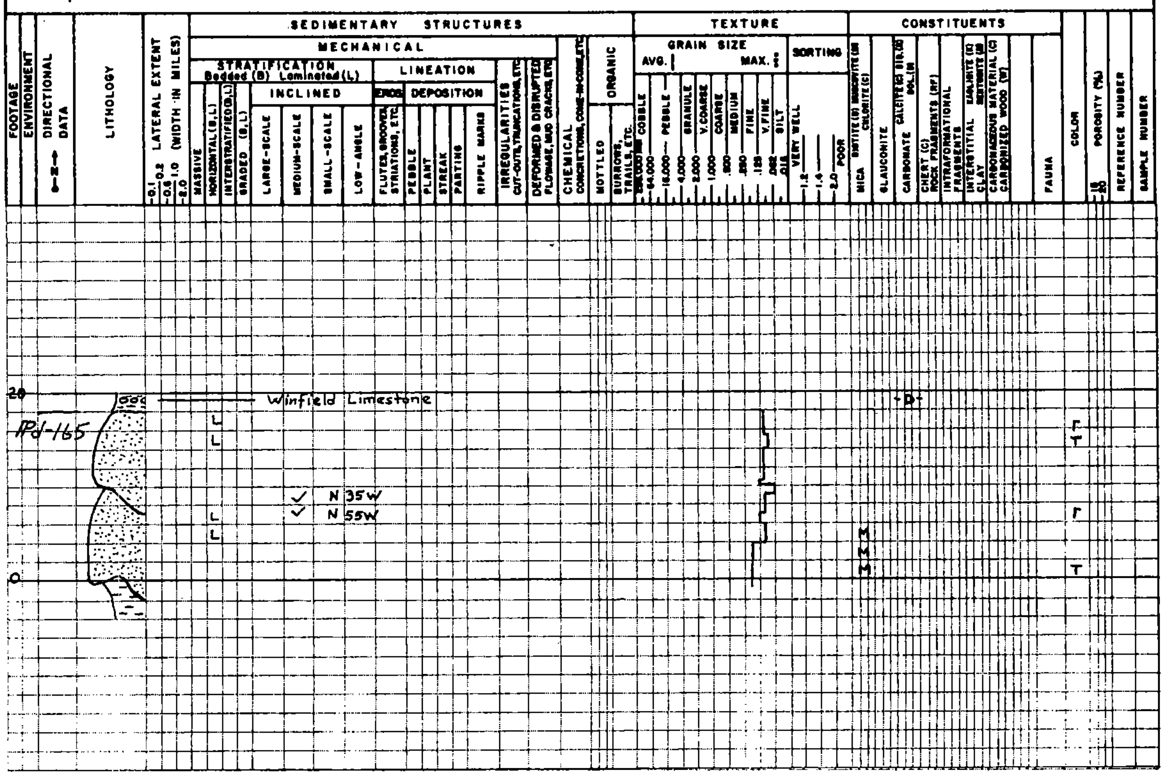
## 20. Sandstone in Doyle Shale and Winfield Limestone

N line Sec. 16 T. 20N R. 3E Map ______ Photo ______

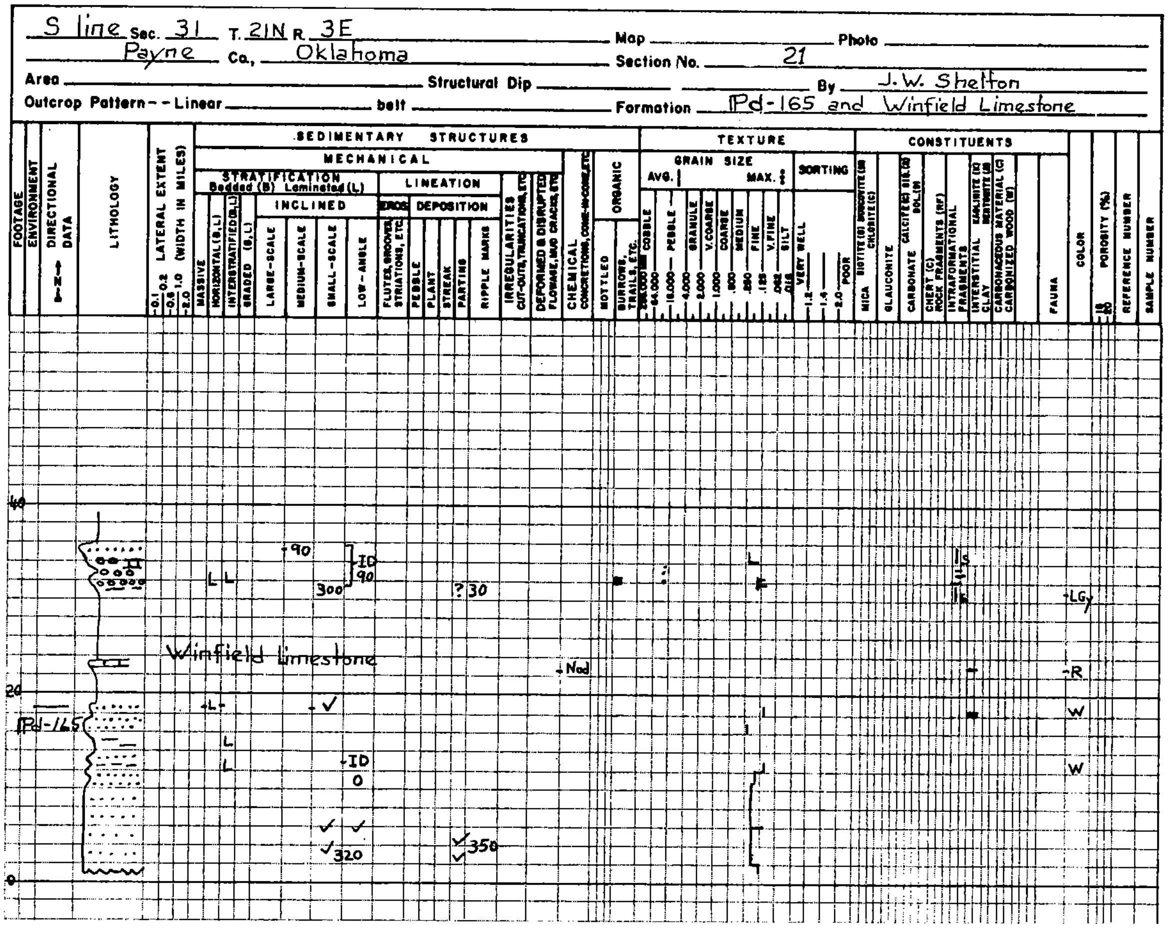
Payne Co., Oklahoma Section No. 20

Area ______ Structural Dip ______ By J.S. Ross

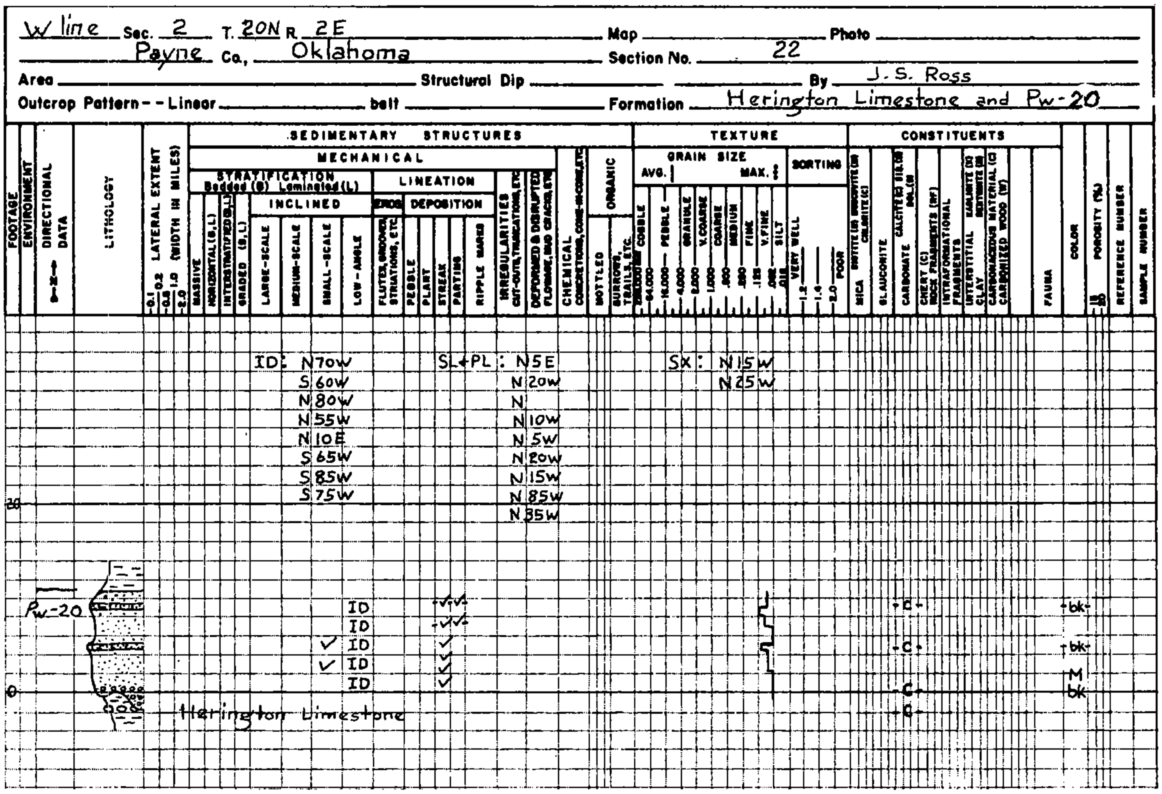
Outcrop Pattern - - Linear ______ belt ______ Formation IPd-165 and Winfield Limestone



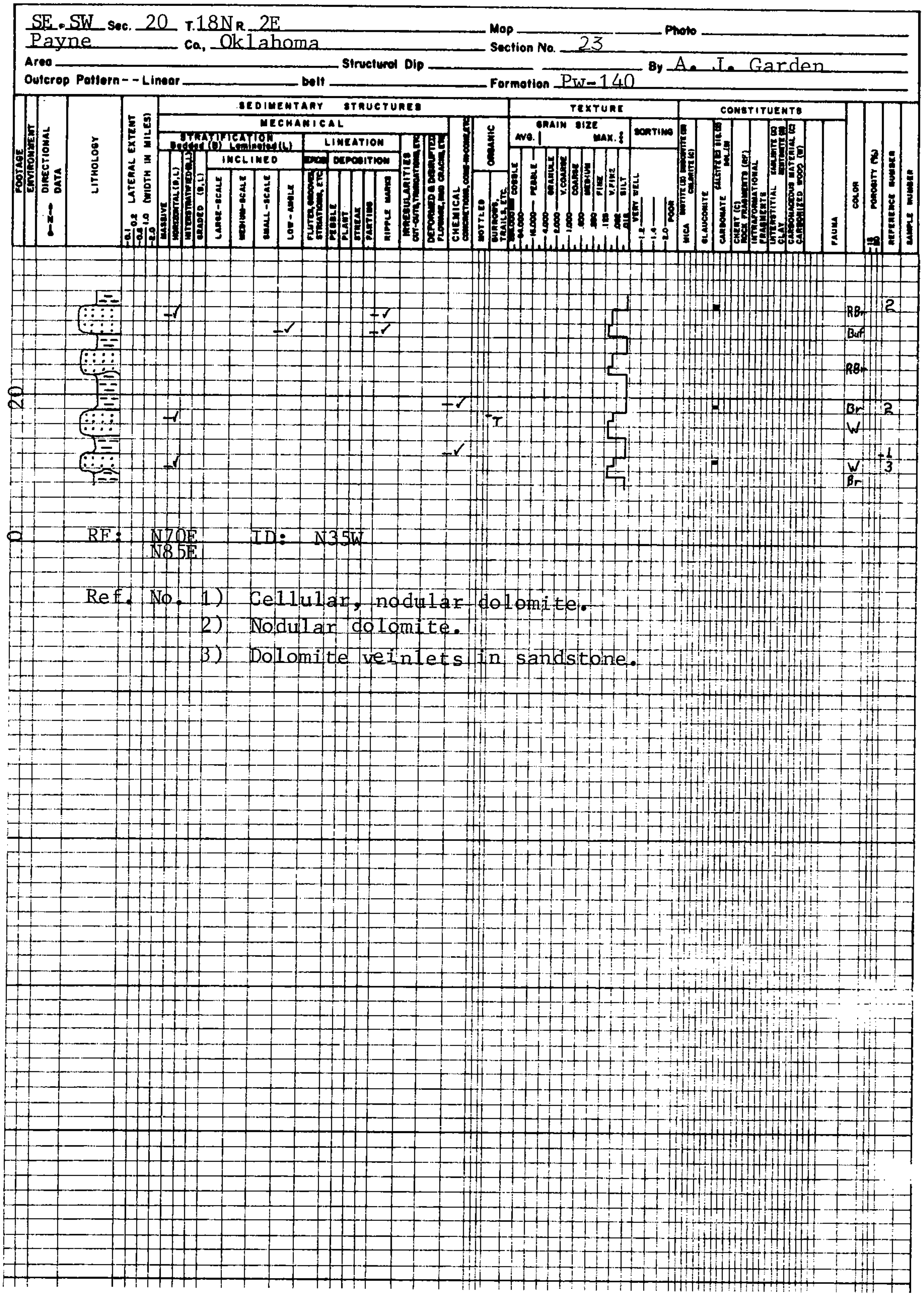
## 21. Sandstone in Doyle Shale and Winfield Limestone



## 22. Herington Limestone and Wellington Formation



## 23. Wellington Formation



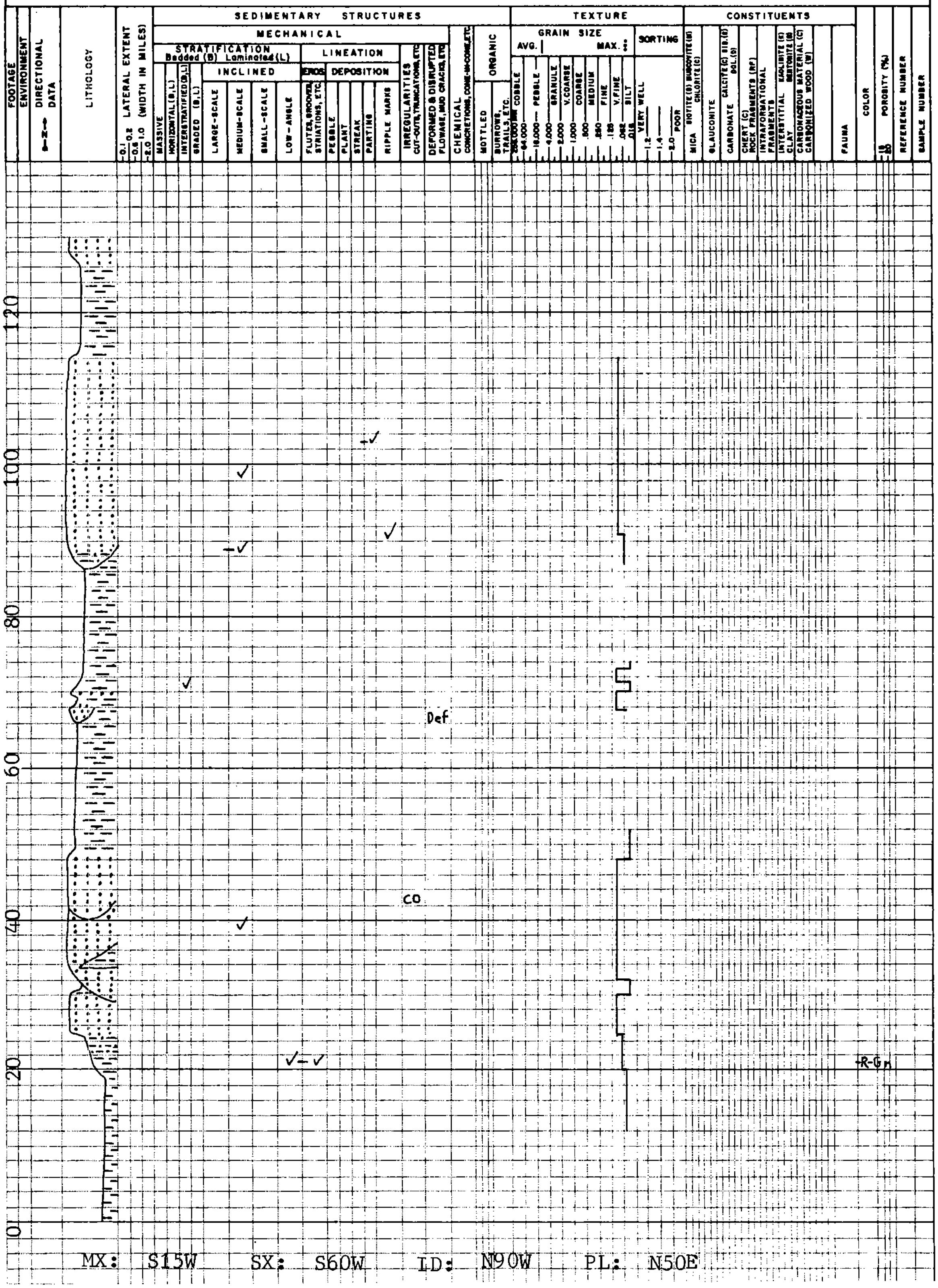
## 24. Wellington Formation

NW SW Sec. 32 T. 19N R. 2E Map ______ Photo ______

Payne Co., Oklahoma Section No. 24

Area ______ Structural Dip ______ By A. J. Garden and

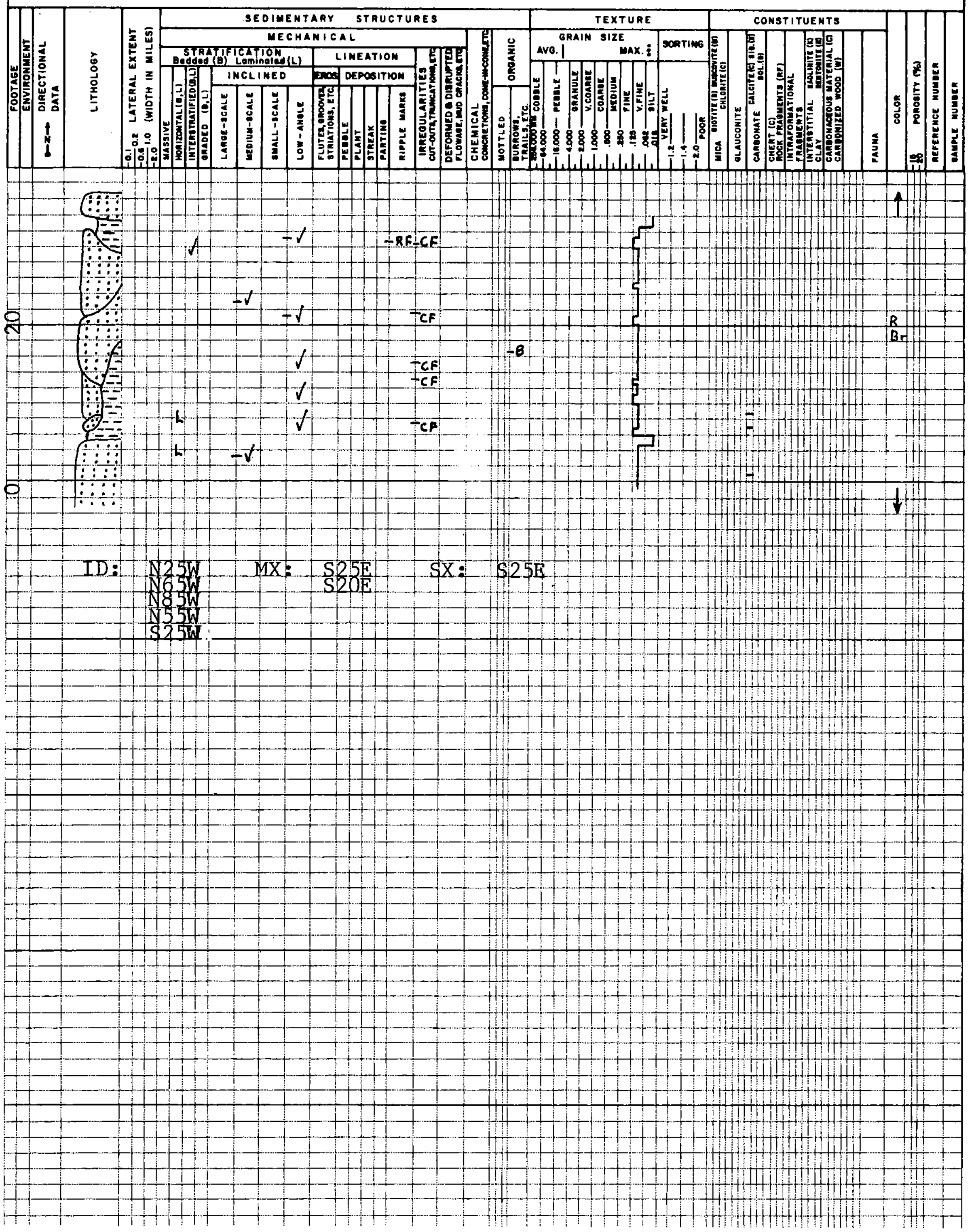
Outcrop Pattern--Linear ______ belt ______ Formation Pw-200 J. W. Shelton



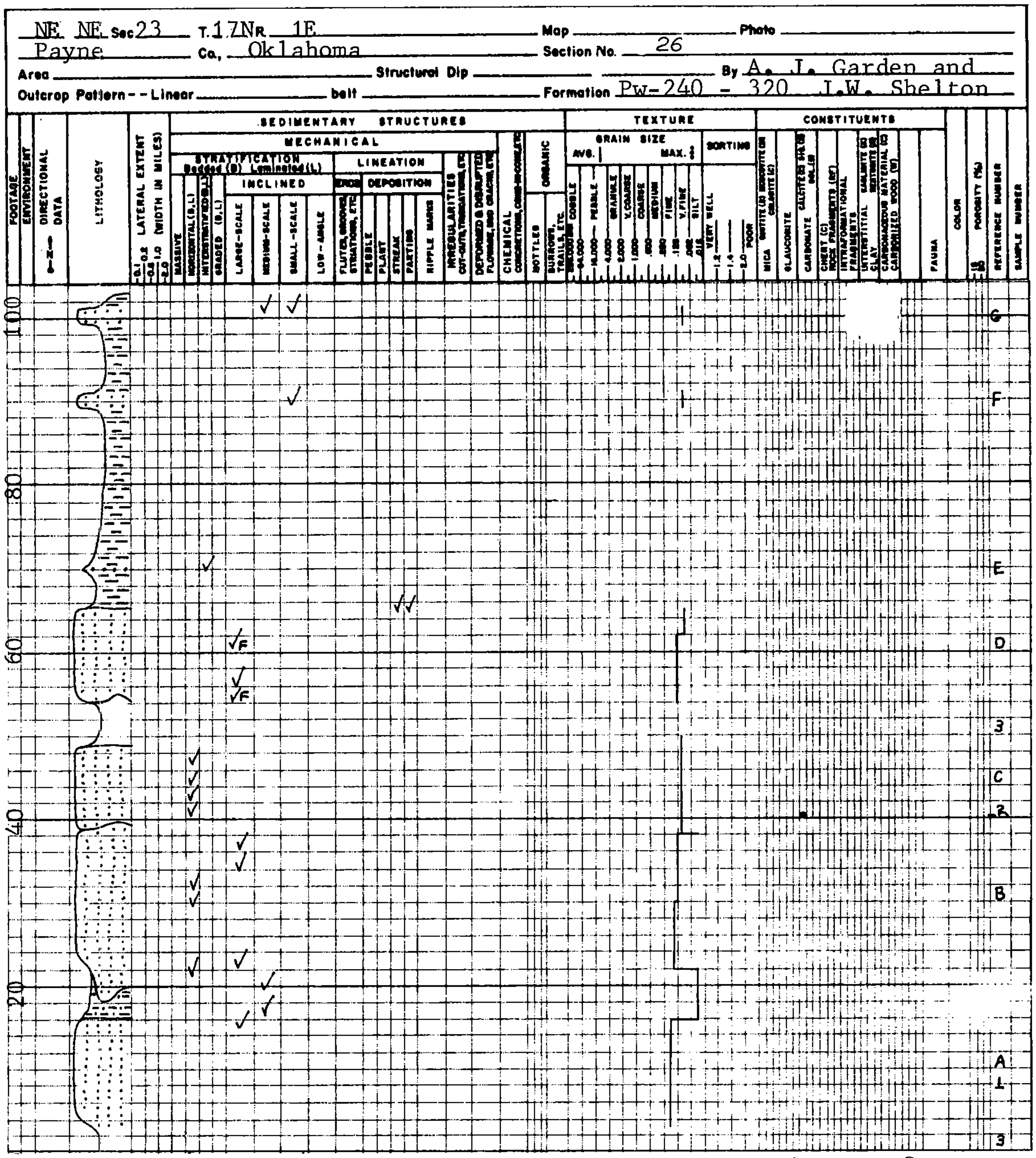

MX: S15W SX: S60W LD: N90W PL: N50E

## 25. Wellington Formation

SW SW Sec. 7 T. 18N R. 2E Map ______ Photo ______
Payne Co., Oklahoma Section No. 25
Area ______ Structural Dip ______ By A. J. Garden and
Outcrop Pattern--Linear ______ belt ______ Formation Pw-280 J. W. Shelton



## 26. Wellington Formation




MX: (A) N50W, N25W, N55W, N10W; (A) N20W, N55W, N50W, N50W; (B) N10E, N80E

ID: (A) N90W, N70W

SX: (A) N85W, N90W; (G) N85W, N50W, N90W

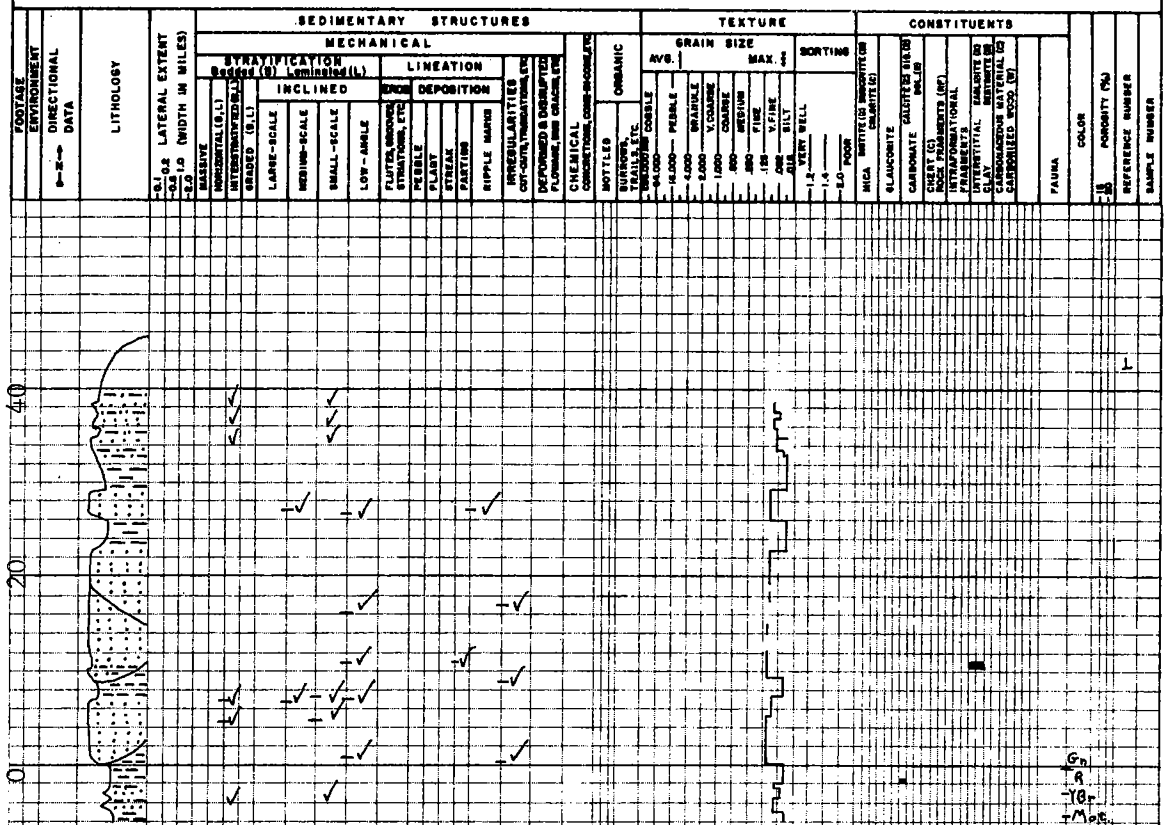
PL: (D) N75E, N70E; (D) N85E, N65E; (D) N70E, N70E

FMX: (D) N35E, N45E, N55E; (G) N75W

Ref. No. 1) Springs and seeps from lowermost sandstone.
2) $Fe_2O_3$ stains.
3) Mostly covered.

## 27. Wellington Formation

NW NE Sec. 3 T19N R. 1E Map ______ Photo ______
Payne Co., Oklahoma Section No. 27
Area ______ Structural Dip ______ By J. W. Shelton and
Outcrop Pattern--Linear ______ belt ______ Formation Pw-380 A. J. Garden




MX: N15W, N30W, S80W, N75E, N70W, N35W, S50W

ID: S85E, N90W, S60W, N60E, S85E, N90W

SX: N35W, S80W, N90W

RF: N20W, N15W

PL: S60W

CO Trend: N30E, N45E, S65W, N90W

Ref. No. 1) Mostly covered at top of hill.

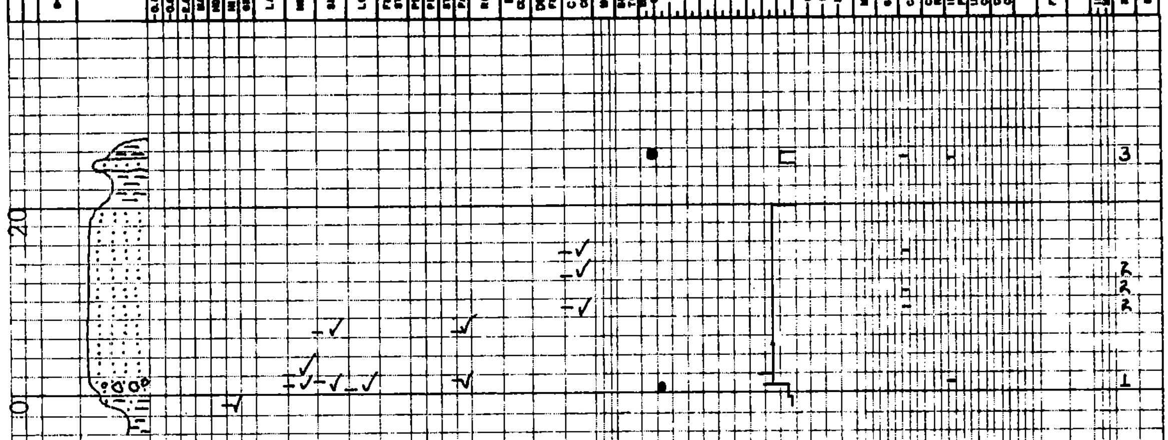
## 28. Wellington Formation

SW SE Sec. 35 T19N R 1E Map Photo

Payne Co., Oklahoma Section No. 28

Area Structural Dip By A. J. Garden

Outcrop Pattern--Linear belt Formation Pw-420




ID: S55W MX: S80W SX: S75W PL: S60W
N90W

Ref. No. 1) Clay-pebble conglomerate at base; largest pebble 50mm with calcite.

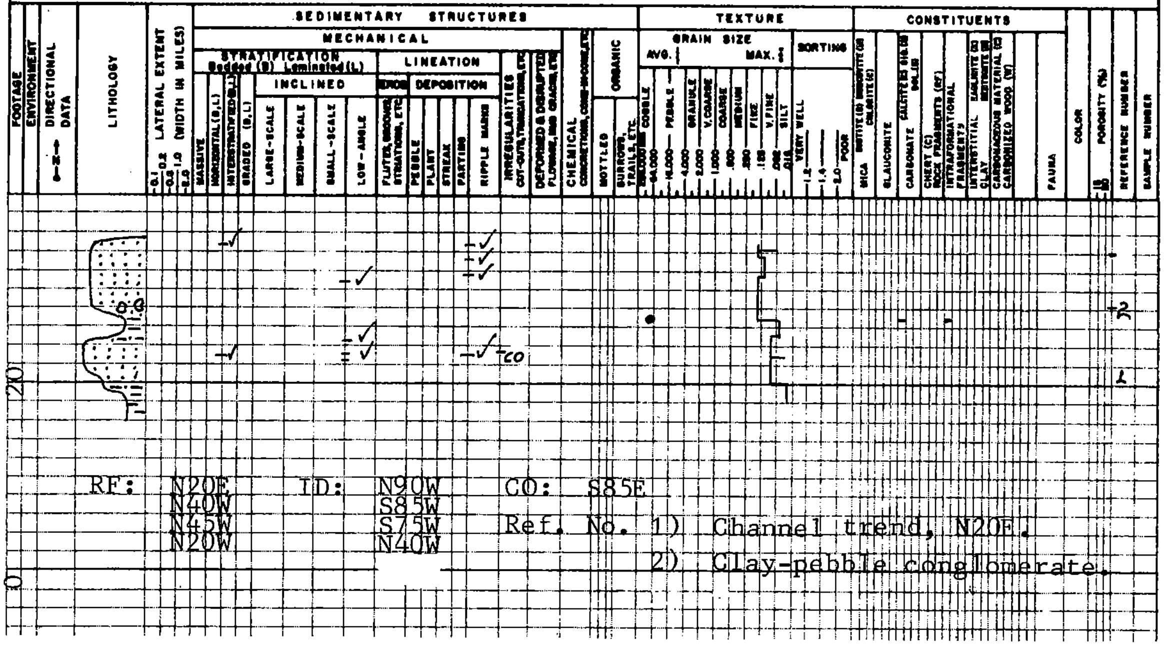
2) Dolomite concretions in sandstone up to 100mm and as veins; calcite present.

3) Clay-pebble conglomerate in sandstone; largest pebble 75mm with calcite.

Note: $Fe_2O_3$ cemented sandstone blocks along section.

## 29. Wellington Formation

SE SE Sec. 34 T. 19N R. 1E Map ______ Photo ______
Payne Co., Oklahoma Section No. 29
Area ______ Structural Dip ______ By A. J. Garden and
Outcrop Pattern--Linear ______ belt ______ Formation Pw-460 J. W. Shelton

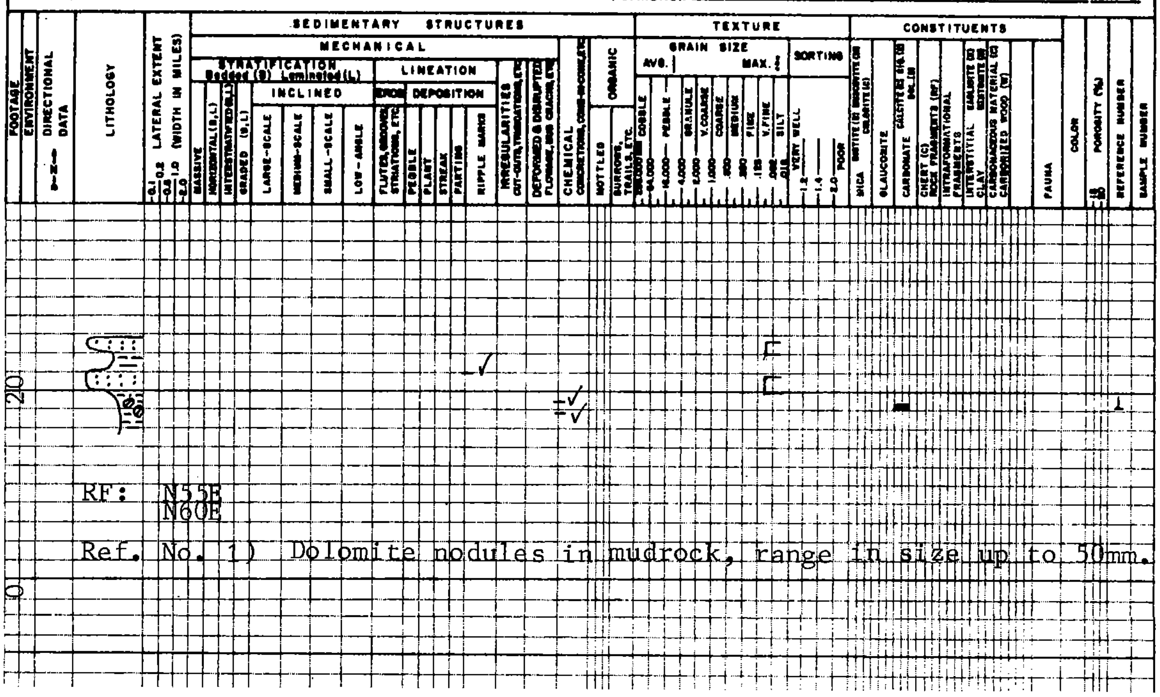


RF: N20E, N40W, N45W, N20W ID: N90W, S85W, S75W, N40W CO: S85E

Ref. No. 1) Channel trend, N20E.
2) Clay-pebble conglomerate.

## 30. Wellington Formation

SE NE Sec. 10 T. 19N R. 1W Map ______ Photo ______
Payne Co., Oklahoma Section No. 30
Area ______ Structural Dip ______ By A. J. Garden
Outcrop Pattern--Linear ______ belt ______ Formation Pw-500

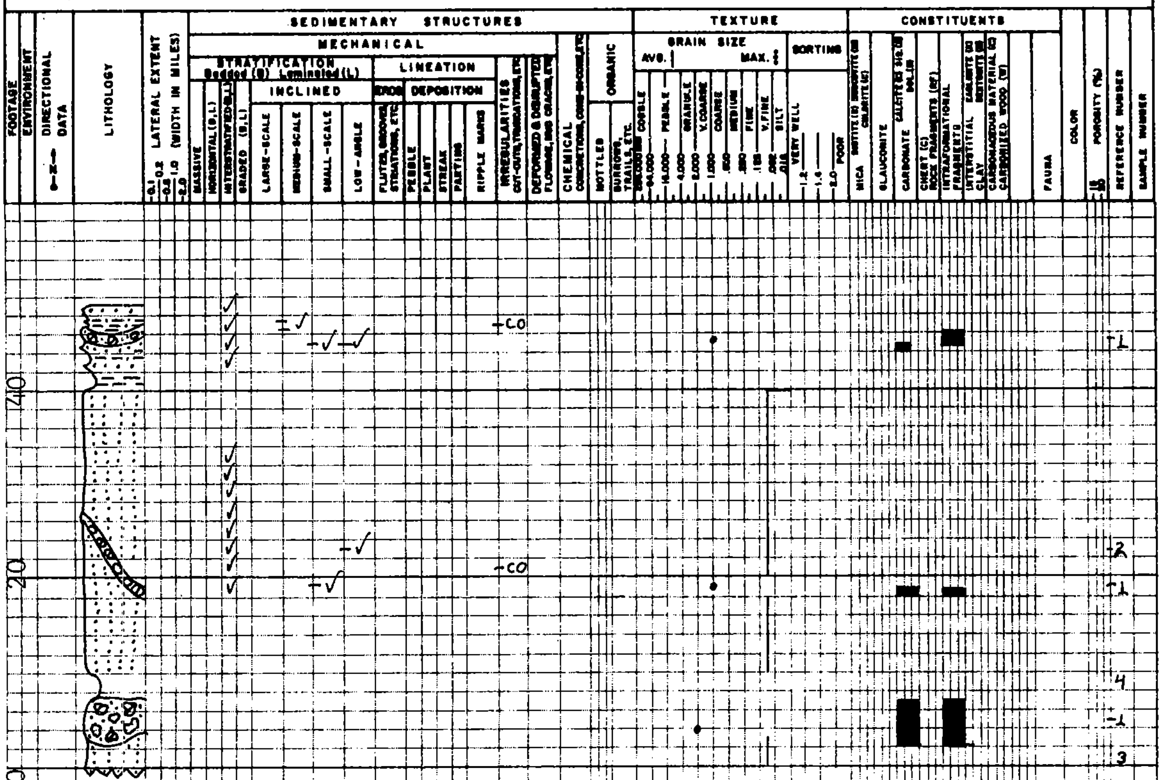


RF: N55E, N60E

Ref. No. 1) Dolomite nodules in mudrock, range in size up to 50mm.

# 31. Wellington Formation

SE NE Sec. 31 T. 18N R. 1E Map ____ Photo ____
Payne Co., Oklahoma Section No. 31
Area ____ Structural Dip ____ By A. J. Garden and
Outcrop Pattern--Linear ____ belt ____ Formation Pw-500 J. W. Shelton




ID: N05W N15E CO: S10W
N20E S05W N65W
N

Ref. No. 1) Dolomite, clay-pebble conglomerate.
2) ID or LX.
3) Base of sandstone questionable.
4) Mostly covered.

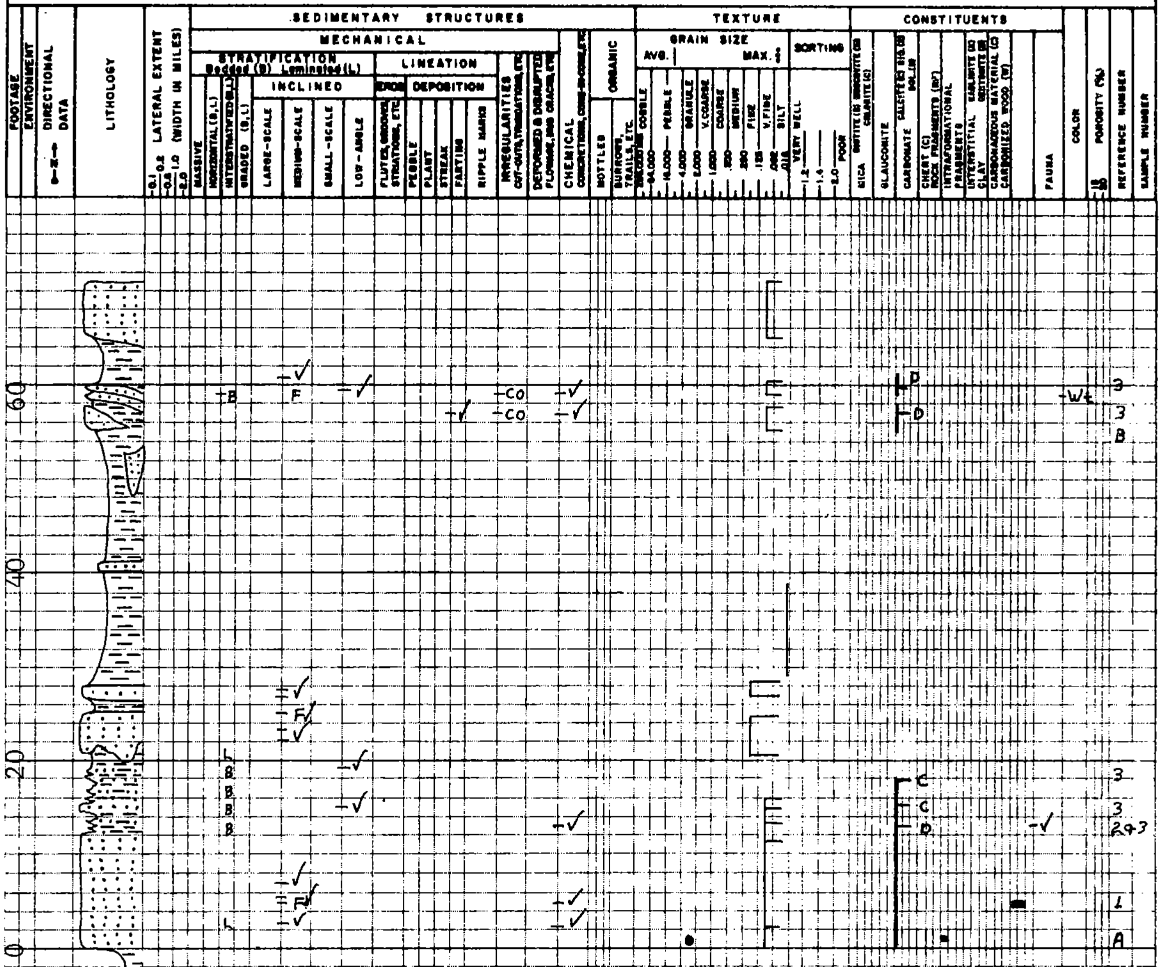
## 32. Wellington Formation

SE SE Sec. 17 T. 18N R. 1E Map ______ Photo ______

Payne Co., Oklahoma Section No. 32

Area ______ Structural Dip ______ By A. J. Garden and

Outcrop Pattern--Linear ______ belt ______ Formation Pw-500 & 560 J.W. Shelton




| | A | B | | B | | A | B |
|---|---|---|---|---|---|---|---|
| MX: | S85W<br>S30E<br>S65E<br>S70W<br>S80W<br>S85W | S70W<br>S60W<br>N65W | FMX: | S10W<br>S20E<br>S15W<br>N20W<br>N<br>N60E | ID: | N15W<br>S10E<br>S25W | N50W |

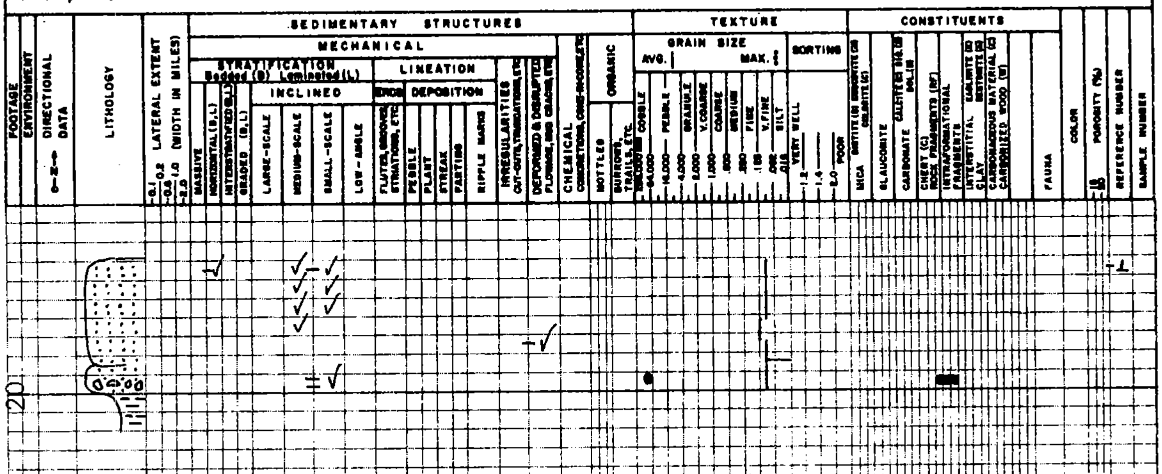
PL: N30E, N15E, N25E

CO Trend: N70W

Ref. No. 1) Iron-oxide concretions replacing wood fragments.
2) Fossil fragments.
3) Dolomite-calcite conglomerate.

## 33. Wellington Formation

SW SW Sec. 2 T. 18N R. 1W Map ______ Photo ______
Payne Co., Oklahoma Section No. 33
Area ______ Structural Dip ______ By A. J. Garden and J. W. Shelton
Outcrop Pattern--Linear ______ belt ______ Formation Pw-580




SX: N20W N40W MX: S50W S25W S55W
S65W S25W S75W N15W S60W
S45W S70W

Ref. No. 1) Local iron-oxide stain at top of sandstone.

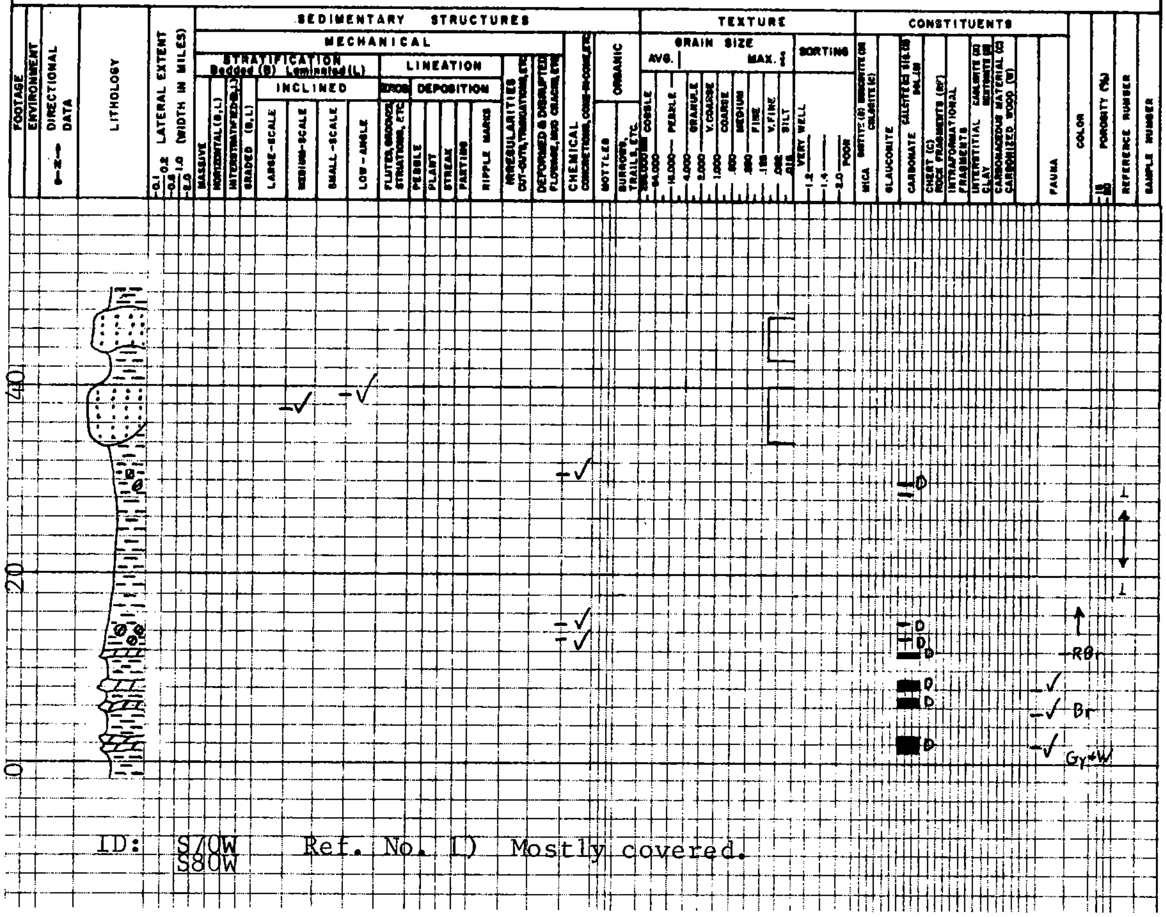
## 34. Wellington Formation

NE NW Sec. 15 T. 19N R. 1W Map ______ Photo ______

Payne Co., Oklahoma Section No. 34

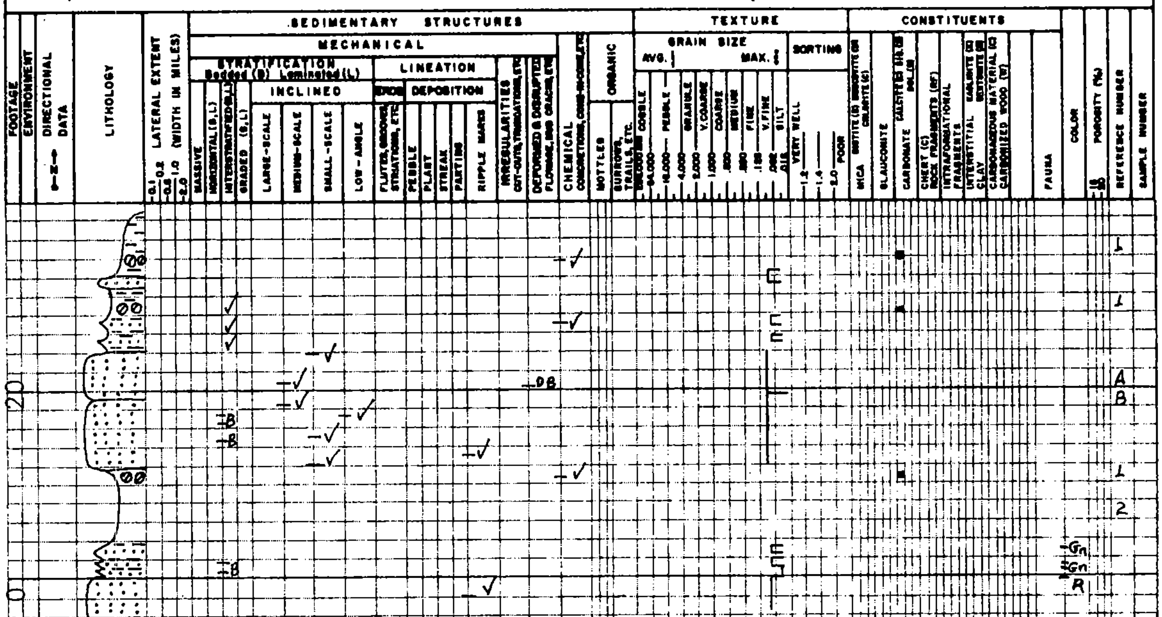
Area ______ Structural Dip ______ By A. J. Garden

Outcrop Pattern - - Linear ______ belt ______ Formation Pw-600



## 35. Wellington Formation

SW SE Sec. 5 T. 19N R. 1W Map ______ Photo ______
Payne Co. Oklahoma Section No. 35
Area ______ Structural Dip ______ By A. J. Garden and J. W. Shelton
Outcrop Pattern--Linear ______ belt ______ Formation Pw-620



| | A | B | | | |
|---|---|---|---|---|---|
| MX: | N75W | N85W | RF: N60W | Ref. No. | 1) Dolomite nodules, ranging in size up to 100 mm, in mud-rock. |
| | N65W | N70W | | | |
| | N45W | N85W | | | |
| | N50W | S30W | | | |
| | N65W | S10E | | | |
| | S75W | N90W | | | 2) Mostly covered. |

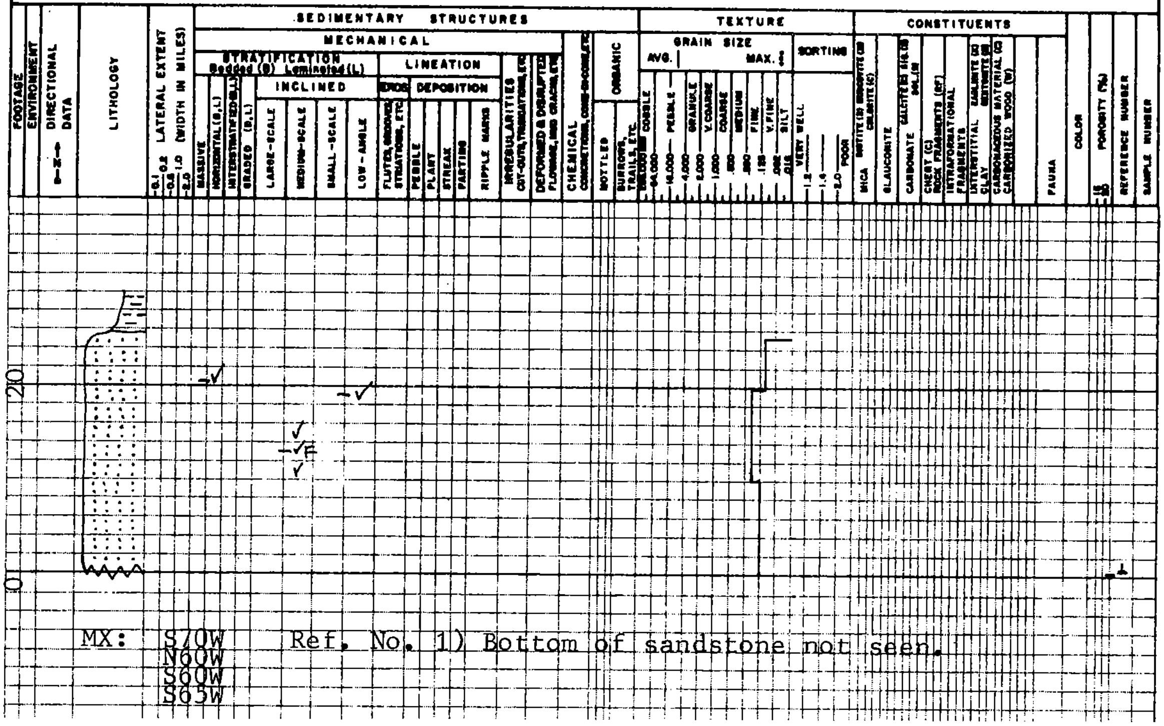
## 36. Wellington Formation

SW SW Sec. 4 T. 18N R. 1W Map ____ Photo ____

Payne Co., Oklahoma Section No. 36

Area ____ Structural Dip ____ By A. J. Garden and J. W. Shelton

Outcrop Pattern--Linear ____ belt ____ Formation Pw-620



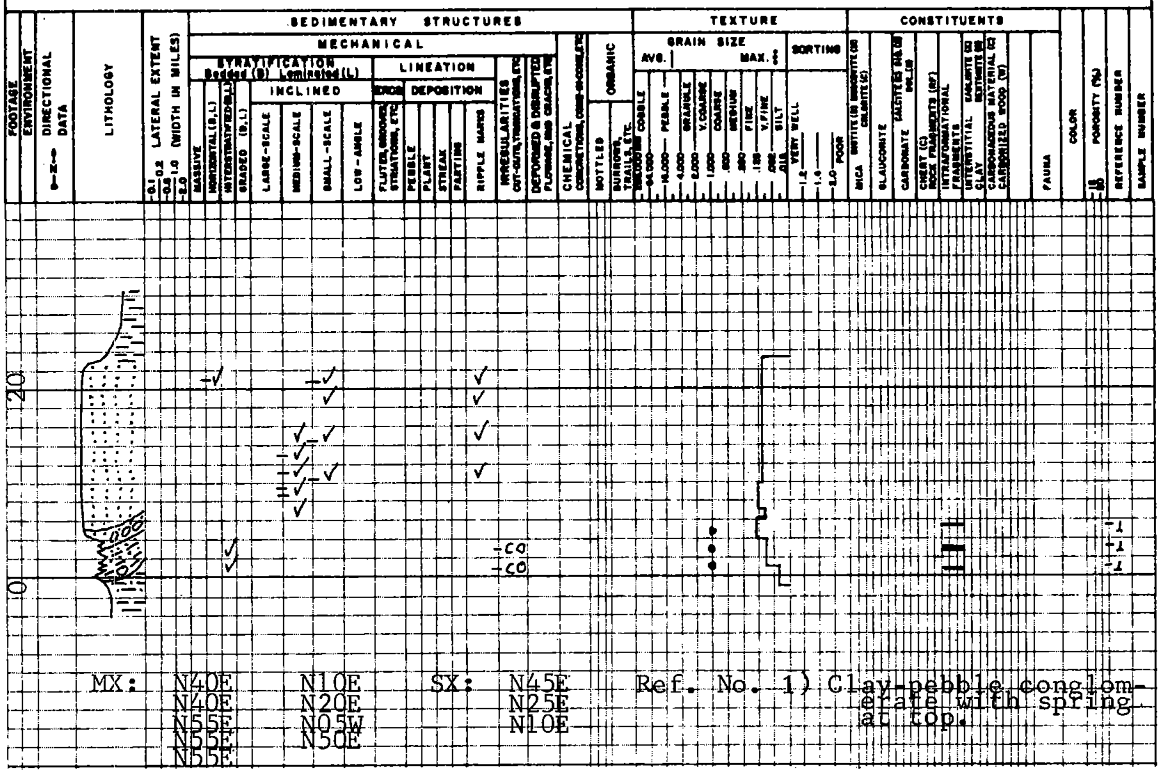
## 37. Wellington Formation

NE NE Sec. 17 T. 18N R. 1W Map ______ Photo ______

Payne Co., Oklahoma Section No. 37

Area ______ Structural Dip ______ By A. J. Garden

Outcrop Pattern - - Linear ______ belt ______ Formation Pw-620



## 38. Wellington Formation

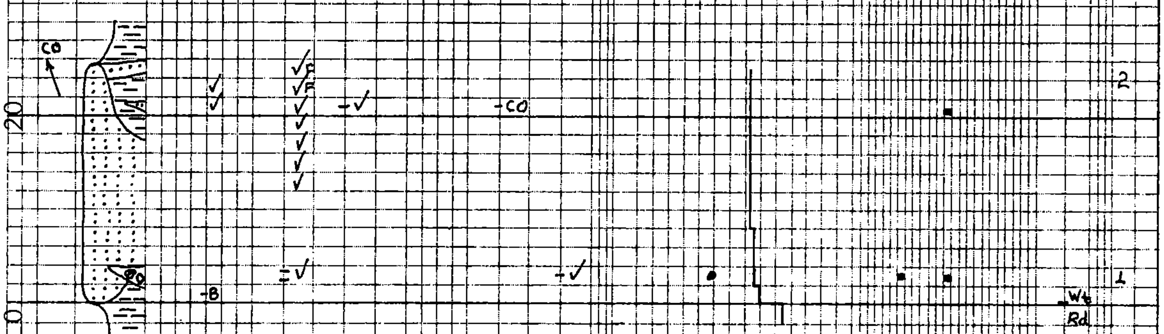
SW SE Sec. 17 T. 18N R. 1W Map ______ Photo ______

Payne Co., Oklahoma Section No. 38

Area ______ Structural Dip ______ By A. J. Garden and J. W. Shelton

Outcrop Pattern--Linear ______ belt ______ Formation Pw-640

SEDIMENTARY STRUCTURES — MECHANICAL: STRATIFICATION Bedded (B) Laminated (L); INCLINED; LINEATION; EROS. DEPOSITION; IRREGULARITIES; CHEMICAL; ORGANIC — TEXTURE: GRAIN SIZE AVG., MAX.; SORTING — CONSTITUENTS — FAUNA — COLOR — POROSITY (%) — REFERENCE NUMBER — SAMPLE NUMBER




MX: N50W N40E N45W N45W S65E N70E N85E N45E

N30E N20E S25E N10E N25E S20W N85E N45E

FMX: S10W N85E S65E N75E N10E N50E N20W

ID: S30W S55W

Ref. No. 1) Carbonate, clay- pebble conglomerate, base of sandstone at intersecting road.

2) FMX trends are NE to NW.

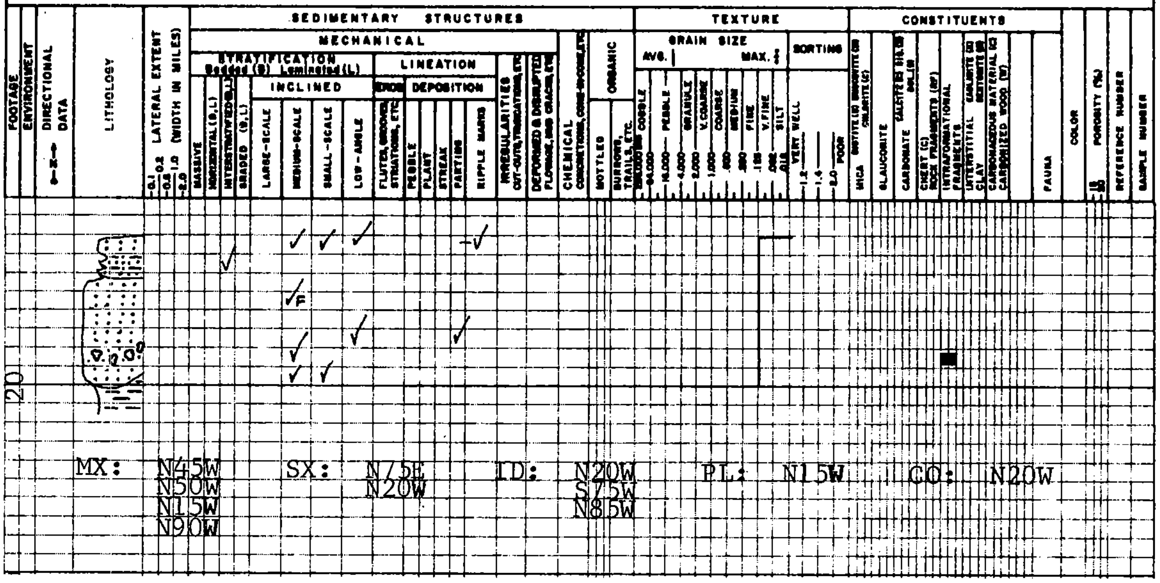
# 39. Wellington Formation

NW NW Sec. 17 T. 19N R. 1W Map ______ Photo ______

Payne Co., Oklahoma Section No. 39

Area ______ Structural Dip ______ By A. J. Garden and J. W. Shelton

Outcrop Pattern--Linear ______ belt ______ Formation Pw-700



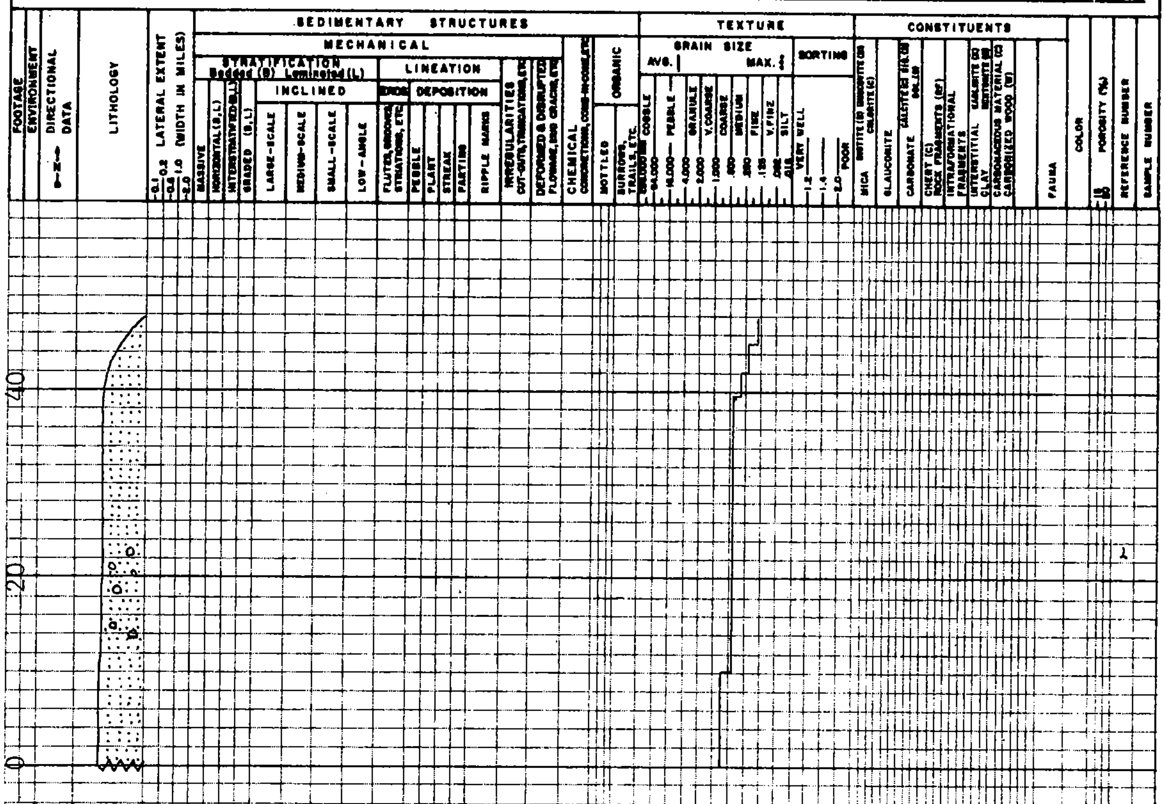
## 40. Terrace Deposit

NE NW Sec. 24 T. 18N R. 1W Map ______ Photo ______

Payne Co., Oklahoma Section No. 40

Area ______ Structural Dip ______ By A. J. Garden

Outcrop Pattern--Linear ______ belt ______ Formation Terrace




Ref. No. 1) Clay layers are present throughout section. Pit exposes 20 ft; other exposed on slope above pit.

# INDEX

(**Boldface** numbers indicate main references; parentheses indicate page numbers of figures)

**Type faces:** Text in 9- and 8-pt. Century Schoolbook, with 1-pt. leading
Heads in 10- and 9-pt. Century Schoolbook bold and italic
Figure captions in 8-pt. Helvetica, with 1-pt. leading
Running heads in 8-pt. Century Schoolbook bold

**Presswork:** Miller 38-in. 2-color; covers on 23 by 29 Harris

**Binding:** Smyth sewn

**Paper:** Text on 70-lb. Patina

**Covers:** Hardbound on Gane GB58 blue linen on 160-pt. binder's board
Softbound on 65-lb. Hammermill gray, antique finish