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EXPLORATION 3-D SEISMIC FIELD TEST NATIVE TRIBES INITIATIVE

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BDM-Oklahoma, Inc.
Bartlesville, Oklahoma

National Petroleum Technology Office
U. S. DEPARTMENT OF ENERGY
Tulsa, Oklahoma

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1.0 INTRODUCTION

Three-dimensional (3-D) seismic is being used extensively worldwide to provide a more detailed structural and stratigraphic image of subsurface reservoirs to improve efficiency in exploration, development, and management of petroleum resources. 3-D seismic work began as an expensive, large-scale tool that was used almost exclusively on complex seismic prospects by major oil companies, but it is now used also on smaller prospects and by large independent oil companies. Acceptance of 3-D seismic has accelerated during the last 5 years based on its proven track record, a record that continues to grow. Increased 3-D expenditure has been justified during this period when budget cuts were made throughout the oil industry. 3-D is being used as an exploration tool to reduce drilling risk in structurally complex areas and to predict reservoir quality in undrilled areas. The 3-D payout has been measured by increased reserve estimates, cost savings from more accurate positioning of delineation and development wells, improved reservoir characterization leading to better simulation models, and the ability to predict more accurately future opportunities and problems during the production history of a field. These benefits can be applied to all operating areas, including remote exploration regions and mature producing areas, to improve efficiency and reduce risk and cost.

Many seismic operators believe that current costs for 3-D work have dropped to the point where 3-D surveys can now be run efficiently and cost-effectively by small operators in areas where the land is relatively open and where there are few permitting problems. In rough terrain and thickly vegetated areas, any seismic acquisition program becomes much more expensive, making it more difficult to justify for smaller, thinner reservoirs. The BDM/NIPER program is being designed to search for thin, shallow targets in a typical open country environment, to determine actual operating costs, and to identify areas of potential cost savings in program design.

To determine current acquisition procedures and costs and to further the goals of the President's Initiative for Native Tribes, a seismic-survey project is to be conducted on Osage tribal lands. The goals of the program are to demonstrate the capabilities, costs, and effectiveness of 3-D seismic work in a small-operator setting and to determine the economics of such a survey. For these purposes, typical small-scale independent-operator practices are being followed and a shallow target chosen in an area with a high concentration of independent operators. The results will be analyzed in detail to determine if there are improvements and/or innovations which can be easily introduced in field-acquisition procedures, in processing, or in data manipulation and interpretation to further reduce operating costs and to make the system still more attractive to the small-scale operator.

1.1 Project Description

The work will focus upon the development of practical and efficient technologies which could be used, cost-effectively, by independent operators. Several work elements will be required to achieve the objectives of the project:

- A review of the geology of the Osage reservation for prospect development.
- The development of a comprehensive plan to test and evaluate 3-D seismic technology for use in identifying shallow exploration targets.
- A 3-D seismic pilot test.
- An evaluation of the survey design and test results and a determination of the technology's usefulness for shallow-formation prospecting from several aspects, including economics, suitability for small operators, exploration appropriateness, and success of the field test.
- Technology transfer to operators, including representatives of the Osage Tribe.

2.0 3-D SEISMIC FIELD TEST PLAN

2.1 Development of the 3-D Seismic Field Test Plan

The plan develops the procedures and methodologies required to delineate subtle stratigraphic and structural traps in relatively shallow reservoirs which are the primary targets for independent operators and native tribes. The critical work segment in planning a 3-D survey is the selection of the site where hydrocarbon traps are expected to be present, and where structural and stratigraphic information is available for identifying the traps. Principal elements of the strategy include the following:

- Compliance with environmental regulations (including generation of assessments and impacts).
- Obtaining of permits from state agencies, Indian councils, and other agencies for the survey.
- The development of survey procedures and methodologies, including energy sources, recording equipment, pattern design, and data processing.

Each phase of the survey will be planned in detail, based on the availability of geologic information, previous 2-D surveys, the availability of equipment, and economics.

2.2 Implementation of the 3-D Seismic Field Test

A determination will be made of the required environmental tests and documentation which will be necessary to conduct the field test. The required environmental documentation, assessments, impacts, and reporting requirements will be developed and submitted. Generally, conventional vibroseis sources cause little environmental damage but, when shear-wave vibroseis is employed, the damage produced can increase. In shear-wave vibroseis, transverse seismic waves are generated. Damage can increase in this type of survey because extra coupling is needed between the vibrating plate and the ground to generate the transverse waves.

Survey specifications have been developed for a 9-mi^2 test, and procurements drafted for a seismic contractor to perform the survey and to record the data. Many seismic contractors have high-fidelity data recording equipment that can record more than 1000 channels of data simultaneously. Additional channels allow closer spacing of receiver stations. Closer spacing helps preserve the continuity of reflections and accommodates longer spreads, which help to distinguish between primary reflections and multiples. Considering that the designed depth-of-investigation will be about 4,500 ft. and that the survey area will cover 9-mi^2, the optimum number of channels for data acquisition will be decided after careful consideration of the density of data points required, the availability of equipment, etc.

Tentatively, a 9-mi^2 field layout plan for data acquisition using the so-called swath method will be used. Instead of shooting along individual lines (as in a 2-D survey) data in a 3-D survey are collected over a broad area. In the swath method, several parallel geophone lines (commonly four or six) are laid out simultaneously. Multiple parallel shot sources or vibroseis energy input stations (commonly six or eight) are located at one end of these geophone lines. After moving 2, 3 or 4 geophone groups, the series of shots is repeated. The number of geophone groups which are moved between the sets of shots will establish the fold of multiple coverage. Tentatively, a geophone group interval of 82.5 ft. and shotpoint or vibroseis source-point interval of 330 ft. will give the desired multiplicity of coverage. Each geophone group will consist of about 12 geophones deployed in a pattern (an array) to provide attenuation of noise waves. The output of all geophones in a group is fed into one data channel, that is, one recording trace. The geophone group interval of 82.5 ft. should scan subsurface points at every 41.25 ft. It is imperative in the collection of high resolution seismic data that all unnecessary noise is minimized or that this noise is cancelled out.

Accurate surveying is critical in collecting usable 3-D data. The purpose of surveying is to determine X-Y coordinates and elevations for each source and receiver station, and to tie this information to the corresponding CMP (common-midpoint) seismic trace. Although the contractor conducting the seismic survey will conduct the survey, it is very important to monitor and maintain proper quality control in this phase of the work.

The raw data collected on magnetic tapes in the field will be processed, and various corrections will be applied in order for the recorded data to actually represent reflection times from subsurface points. Various types of noise present in the raw seismic data be suppressed. This suppression requires sophisticated data-processing software. "Noise" is anything in the data not related to subsurface structure. The object of data processing is to accurately identify the true seismic-reflection signal in the presence of noise, and to maximize the S/N (signal-to-noise) ratio.

The final result of data processing will be magnetic tapes containing the seismic data. The data on these tapes will be in several formats, so that analysis and interpretation can be conducted on different workstations.

2.3 Analysis and Interpretation of Data

After the tape containing the seismic data has been formatted and downloaded for processing on a workstation, the analysis and interpretation phase of work will begin. Synthetic seismic traces (seismograms) will be generated from available sonic and density log data. Next, model studies of different trap geometries will be conducted to determine if field data indicate the presence of structural or stratigraphic traps of interest. Time slices will be obtained at various orientations to highlight the presence of structural features of interest. Research will be conducted with the combined interpretation of compressional and shear wave data for the identification of fractured and faulted zones, lithologic variations, etc.

Detailed structural mapping will be conducted on reflectors of interest. Isopach mapping of formations of interest will commence after integrating available geological, wireline-log, and production information.

2.4 Technology Transfer

The survey design will be evaluated in a comparative study for technical and economic efficiency. The program and results will be compared to other tests published in the literature.

Workshops and meetings will be conducted and reports will be submitted as requests are received. Also, producers on Osage leases will have access to the results and will serve to transfer technology to other independents.

3.0 PROSPECT DEVELOPMENT

Prospects in Osage County for the seismic field test required a thorough background study of the geology and geophysics of the Osage Mineral Estate. Several publications were reviewed to develop a better insight into the topography, stratigraphy, and structural aspects of the area.

3.1 Topographical Description

Osage County is located on the Northeast Oklahoma platform in the "Cherokee basin" of northeastern Oklahoma. The county is immediately east of the Nemaha anticline and north of the McAlester basin, an extension of the Arkoma basin. The Anadarko basin to the southwest, Seminole arch to the south, and Chautauqua arch to the northeast are tectonic features which have influenced the development of the structures and strata of Osage County throughout the Paleozoic (Figure 3–1).

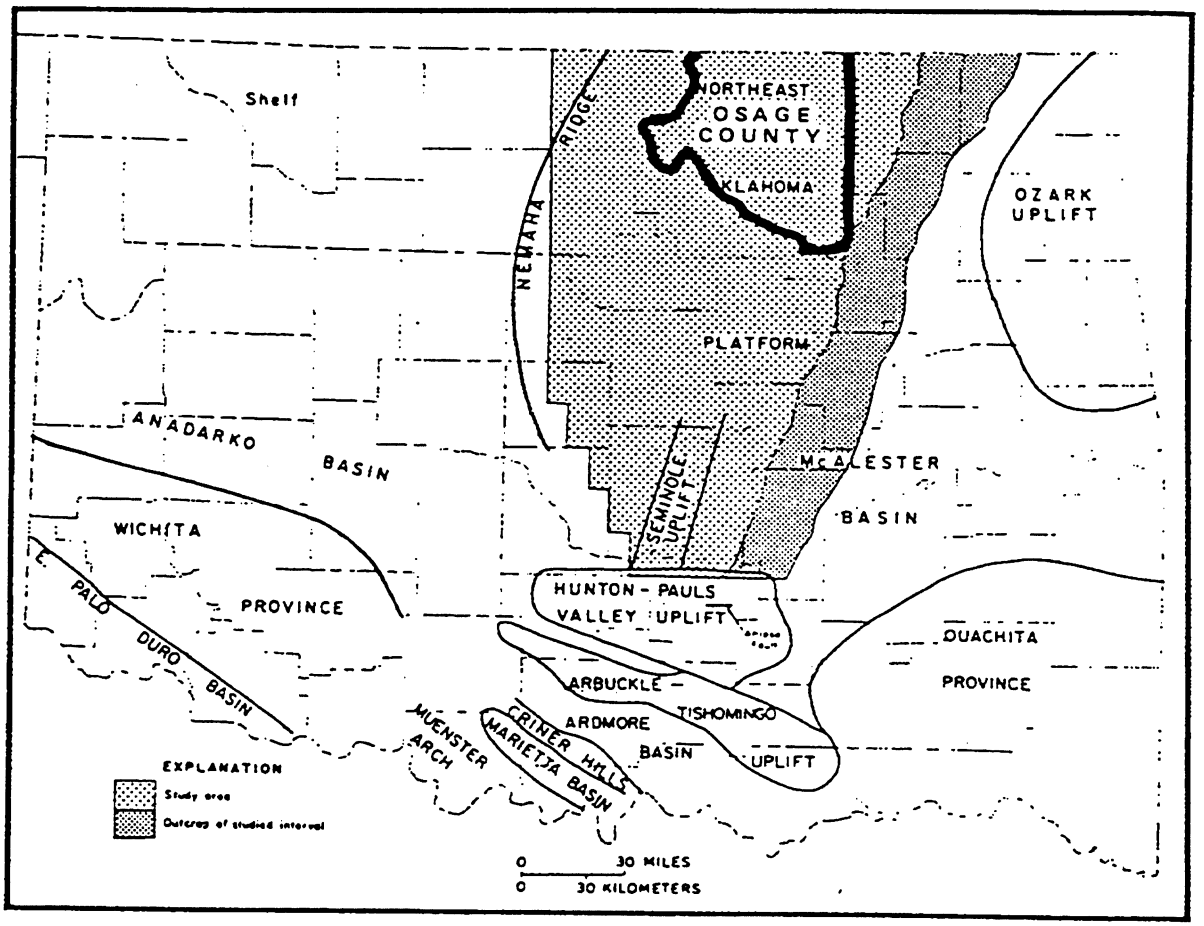

Figure 3–1 Map showing major structural features and provinces of Oklahoma (from Krumme, 1981).

Two major physiographic provinces are represented in Osage County: the Northern Limestone Cuesta plains in the western half of the county, and the Eastern Sandstone hills in the eastern half (Jones, 1960). Both provinces are dominated by surface exposures of Pennsylvanian rocks that dip westward 40–50 ft./mi. Differential weathering and dendritic drainage have developed a rough topography of ledges and hills etched into the relatively flat prairie. These ledges are formed in sandstone on the east which grades westward into limestone. Surface rocks in the eastern half of the county have been deformed by numerous low-offset normal faults, small domes, anticlines, and synclines that are expressed topographically as low wooded ridges. The terrain in the west appears less structurally deformed on the surface, preserving open rolling prairie. Irregularly wooded and agricultural vegetative cover in the eastern portion of the county grades to the west into low scrub and grassland. Surface elevations across the county generally range around 1000 ft., with little regional riation.

3.2 Geological Analysis of the Osage Reservation

3.2.1 Stratigraphy

Middle and upper Pennsylvanian (Desmoinesian, Missourian, and Virgilian) rocks are exposed throughout Osage County, except for a limited exposure of Permian red beds in the western part of the county. The oldest Pennsylvanian rocks are exposed in the southeast, with the exposures becoming younger to the northwest.

Subsurface rocks are dominated by Desmoinesian rocks deposited unconformably above a deformed sub-Pennsylvanian section. The entire Paleozoic section, with two major unconformities, lies on top of a severely eroded basement. The total sedimentary thickness ranges from around 2,000 ft., over basement highs, in the southeast part of the county to around 5,000 ft. in the west. Approximately half of this section was deposited in the Pennsylvanian. Individual units, with emphasis on petroleum productive formations, are discussed later. A generalized stratigraphic column of the Northeast Oklahoma platform is shown in Figure 3–2.

3.2.2 Late Precambrian Geology and Geomorphologic Features

The Osage County area formed a portion of a broad lowland which extended cross much of the southern Mid-Continent region at the end of the Precambrian era. A few deep test wells in this area have reached basement. All of these wells in or around Osage County have cut a reddish or pink granite at total depth. No upper Proterozoic sediments have been reported from this immediate area.

Upper Proterozoic sediments have been reported in wells to the north, in northern Kansas, where thick clastic accumulations formed in the Mid-Continent rift, but this feature apparently did not extend into the immediate Osage County region. Organic-rich sediments have been identified in several portions of the Mid-Continent rift. Some of these sediments have been

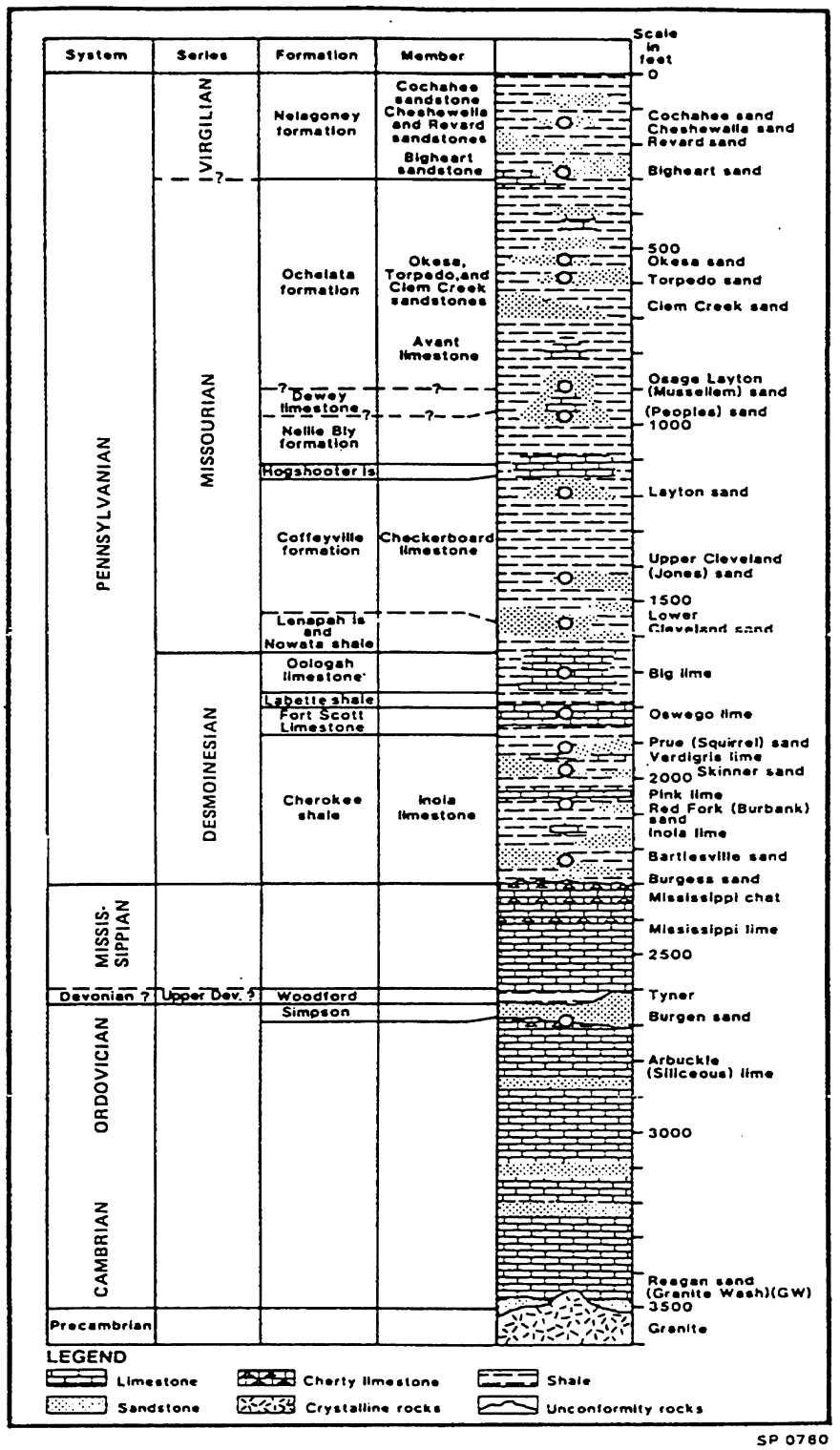

Figure 3–2 Stratigraphic Column Showing Position of Strata that Produce Hydrocarbons Within the Northeast Oklahoma Platform (from Assessment of the Oil nad Gas Potential of Osage County, Oklahoma Based on Remote Sensing: Final Report. Prepared for Osage tribal Council. Undated [c. 1984]).

identified as potential hydrocarbon source beds. Precambrian-age hydrocarbon shows and oil seeps have been documented at various locations along the length of the Mid-Continent rift, but the rift was apparently located to the north and west of the Osage County region.

The granite which underlies much of northern Oklahoma had been deeply weathered in the lowland areas by the end of the Precambrian, and a thick layer of rotten debris apparently covered the barren Late Precambrian lowlands. A thick granite wash is known from several wells around the region. There are no remnants of eroded or reworked sedimentary debris reported in these detrital granite washes, supporting the concept that the Mid-Continent rift did not extend into this area and that there were no significant nearby Precambrian sedimentary troughs or basins near the Osage County region.

The granite washes are often highly porous but, without any local source materials for hydrocarbon generation, the washes generally have proven to be barren where they can be shown to be of late Precambrian origin.

Although much of the late Precambrian landscape was a low-relief surface, occasional monadnocks apparently rose several tens to hundreds of ft. above the regional surface. Some wells have encountered granite at much shallower depths than would be expected if the late Precambrian erosion surface had really been peneplained. These wells show very thin to absent lowermost Cambrian-Ordovician sedimentary sections. In some cases, Devonian and, occasionally, Mississippian or Pennsylvanian sediments were deposited directly on the granite.

These highs apparently are ancient hills which rose above the surrounding Precambrian plains. These hills would have formed islands in the early Paleozoic seas. As the islands slowly eroded away, they contributed sandy material into the carbonates which dominate many of the lower Paleozoic sedimentary sequences.

Erosion of the Precambrian hilltops during the Paleozoic era produced localized younger granite wash deposits. These washes occur in structurally high positions, such as on the flanks or crests of the ancient Precambrian hilltops. These beds are surrounded by Paleozoic sediments, and frequently are charged with hydrocarbons. The source beds for these reservoir wash deposits are lower Paleozoic sediments which occupy the valleys surrounding the ancient monadnocks.

Neither the basement nor the ancient, deeper granite washes hold much potential for oil production in the prospect area, although any younger granite washes encountered on the structurally higher monadnocks should be tested thoroughly.

3.2.3 Lower Paleozoic Setting

The Osage County region formed part of the Cherokee shelf, a broad area, generally with very low relief during the early Paleozoic, except for scattered Precambrian granite monadnocks or islands. A succession of quartose sandstone and carbonate sediments accumulated in a shallow sea or on a lowland plain which covered this shelf during much of the early Paleozoic. Tectonic

activity was minimal until a series of regional disturbances warped the shelf area during the Mississippian period. The majority of the lower Paleozoic formations are widespread across the region. There are few fine-grained or organic-rich sediments in the lowermost Paleozoic section.

Basal Cambrian. A basal Upper Cambrian clastic unit, the Reagan Sandstone, spread across the topographically lowest portions of the ancient Precambrian erosional surface. Across the southern Kansas–northern Oklahoma region, this unit includes quartose, dolomitic, feldspathic, arkosic, and quartz-glauconite sandstones at various locations and in different parts of the formation. Accessory minerals are found in greater quantities in the direction of the Mid-Continent rift, where a greater variety of Precambrian rock types was available for erosion. The Reagan either is absent or is very thin in several of the deep holes in Osage County. Thin Reagan beds have been reported in a few Osage County wells. The unit thickens in many of the surrounding areas and is several tens of ft. thick in some of the deep wells in nearby counties in Oklahoma and Kansas.

The Reagan Sandstone is petroliferous in many places in Kansas, but its oil-reservoir potential has not been demonstrated in Osage County. The Reagan sandstones generally have high porosity and permeability values and possess excellent reservoir parameters in many parts of the south-central Mid-Continent, but they are quite thin across most of Osage County. More importantly, no lowermost Paleozoic source rocks have yet been identified which could have produced hydrocarbons to charge the deepest Paleozoic sediments in the Osage County region. No shales or other potential source beds are known in the region above or below the Reagan in the deeper Cambrian or in the Precambrian section around the area of the Kansas-Oklahoma border.

Lowermost Paleozoic rocks have not produced large quantities of hydrocarbons in the south-central Mid-Continent region. The open, shallow Reagan sea may have supported abundant life forms; however, if early Cambrian life-forms were prolific, conditions in the southern Mid-Continent obviously were not favorable for the preservation of organic material or kerogens and the formation of hydrocarbon reserves.

Cambrian oil production is known from the Reagan several tens of miles to the north, in Kansas. Studies of these beds suggest that the oil found there has migrated downward through fractures from overlying shaly source beds. The same process of migration could have occurred in the Osage County region, but the Paleozoic section above the Reagan Sandstone in the study area contains very little to no shaly sediments.

Cambrian-Ordovician. The period of Reagan deposition ended with the retreat of the early Cambrian sea and the formation of an unconformity surface above the Reagan Sandstone. The shelf was soon submerged again, however, and a thick carbonate sequence began to accumulate across the region. Deposition continued through the Late Cambrian and into the Early Ordovician.

The sedimentary section laid down in Osage County at this time was dominated by dolomites. The rocks making up these units are known as the Arbuckle Formation. The section typically begins with a basal unit that consists mostly of dolomite, sandstone, and sandy dolomite. In many cases, the lowermost Arbuckle beds, which were deposited on the shores of the Precambrian islands, are feldspar- and quartz-rich. These units contain large quantities of granite detritus, derived form the old monadnocks. The basal beds range from find to coarse in texture.

The basal dolomites/sandy dolomites are overlain by vuggy dolomites that range in color from light tones, generally whites or grays, to buff and light browns. These units range from fine- to coarse-grained. In the region around Osage County, the Arbuckle sediments are about 1000 ft. thick. The uppermost Arbuckle beds are generally sandier than the middle section and often contain chert. The Arbuckle sequence contains almost no shale in the region along the northern Oklahoma border. There is no obvious potential source for hydrocarbons in the Arbuckle in this area.

Early Ordovician deposition ended with the retreat of the shallow sea and the exposure of the Arbuckle to subareal erosion. An unconformity developed at the top of the dolomite. A broad, gentle warping of the south-central Mid-Continent produced large, regional-scale ripples across northern Oklahoma and southern Kansas, and large quantities of dolomite were eroded from high-standing areas like the Central Kansas uplift. As the topographically higher areas were eroded, some minor shales were deposited in depressions on the top of the Arbuckle dolomites across northern Oklahoma and southern Kansas.

As the period of mild tectonism and flexure ended, seas once again advanced across northern Oklahoma. Following the deposition of the minor shale section just above the Arbuckle, carbonates once again began to accumulate. These Middle Ordovician rocks are known as the Simpson Group.

The Simpson rocks in Osage County are primarily dolomites, although many sandstones and shales are scattered through the section in surrounding areas. The Simpson shales are generally considered to be good source rocks. Compared to Reagan and Arbuckle fields, Simpson oil production is relatively widespread throughout the area of Oklahoma and Kansas.

Analysis of Osage County well logs shows that there is little contrast in rock densities or sonic velocities within the Cambrian-Ordovician section. The density and sonic curves tend to be relatively straight and featureless from the top of the Simpson to the top of the basement. This featureless geophysical character will make it difficult to identify individual units on even the best-quality seismic section in Osage County.

Following the deposition of the Simpson, the sea retreated once again, there was another period of erosion, and another unconformity developed. There is no known Silurian section in Osage County.

Devonian. During the late Middle and Late Devonian, a sea once again advanced into Osage County. Waters spread across the region from the east, and a shale unit, the Woodford, was laid

down. The Woodford Shale varies greatly in thickness from one area to another across northern Oklahoma and southern Kansas. Even in a small, localized area, like Osage County, the thickness is highly variable over short distances.

The Woodford Shale forms a distinctive marker on most logs, although it is quite thin in some places in southern portions of the county, and it can be hard to recognize in a few holes in that area. Total thickness generally ranges from a few ft., in places where little Woodford was originally deposited or at locations where it was later eroded, to low-lying areas, where the Woodford is several tens of ft. thick. The Woodford is usually dark to black in color and rich in organic material. It is believed that the Woodford forms an excellent petroleum source rock in many areas of the southern Mid-Continent region.

Mississippian. The shallow-water shelf environment persisted across northern Oklahoma well into the Mississippian period. During the Mississippian, however, a number of continental-scale sags and shoal areas developed on the south-central margin of North America as the shelf began to warp. Positive structural features formed in the region of the Ozarks and in central Texas at this time.

The Mississippian section is typified by quiet, shallow-water sediments and by shore deposits. At the end of the Mississippian period, there was a major retreat of the seas from the southern Mid-Continent region, and a significant unconformity developed across Oklahoma.

3.3 SURFACE FRACTURE ANALYSIS

Surface fracture analysis has been used to develop exploration leads in Osage County as a part of the prospect development for the 3-D seismic survey. The objective of this analysis was to identify priority locations for potential subsurface oil and gas traps. The validity of surface fracture analysis rests on the assumption that fractures at depth are propagated upward to the surface, either at the time of their formation or at a later time, and that these sites form the loci of major folding and, frequently, of facies changes, the fractures have exerted some control on the entrapment of oil and gas.

It is generally assumed that the primary fracture orientations at depth correspond to those mapped at the surface. This has been documented in some areas by mapping fractures in vertically exposed sections. It has also been observed during hydraulic fracturing that fractures at depth are often parallel to certain surface fractures. Orientation analysis did show that the surface lineaments, fracture traces, anticlines, and domes are strikingly consistent and on trend with mapped subsurface structures in Osage County, Oklahoma. It is this observation, as well as other geological considerations, that made it attractive to use surface fracture analysis as a tool for inferring potential locations of subsurface oil and gas traps.

Factors considered during the selection of fractures for exploration leads included:

- Similarity to features associated with established production in Osage County.

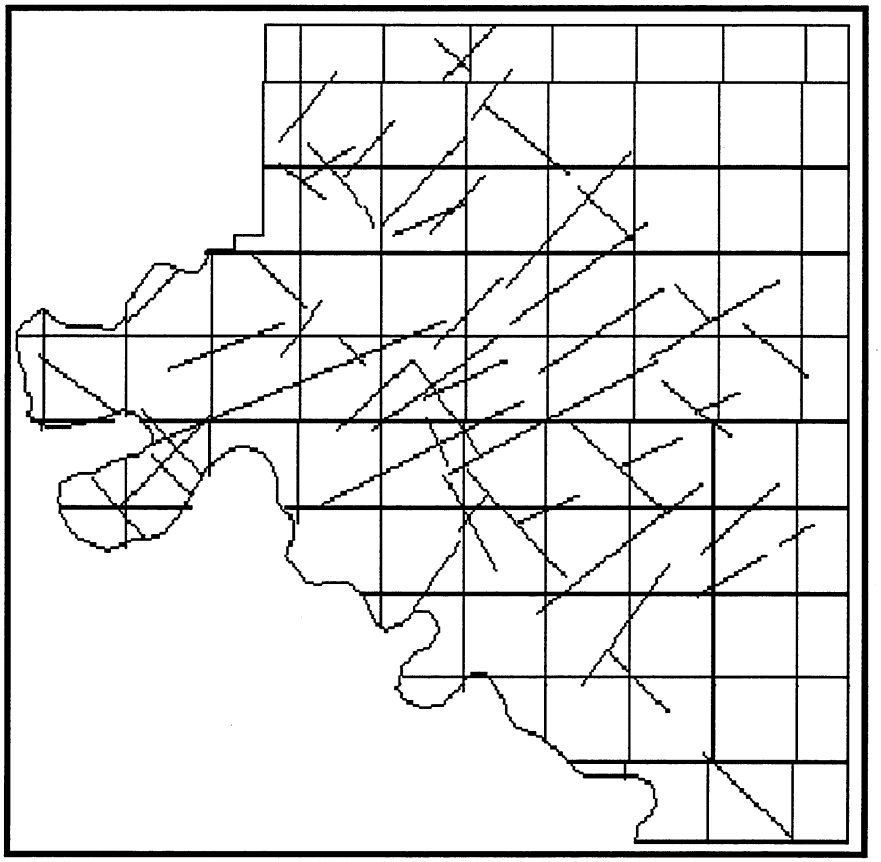

Figure 3–3 The 56 Surface Lineaments in Osage County, Oklahoma

- Strength of the features on the imagery and conformance to postulated exploration models.
- Proximity to established production, location with respect to known reservoir, source, and seal lithologies, or general geological location.
- Supporting evidence from the literature or from regional maps.
- Size and clarity of the area on the imagery.

The surface fracture analysis technique used consisted of mapping and digitizing surface and subsurface features, investigating the correlation between surface and subsurface features, identifying subsurface-structure indicators, and delineating priority locations for the 3-D seismic program.

Landsat images were used to map the regional-scale surface lineaments, whereas the small-scale surface fracture traces and the circular and arcuate features were interpreted from color-infrared high-altitude aerial photographs. In addition, the subsurface producing structures from the Mississippian Chat Formation were mapped from existing geological maps, as were surface anticlines and domes in the county. The orientations and extent of these surface and subsurface features were subsequently digitized. They are graphically displayed in Figures 3–3–3–8.

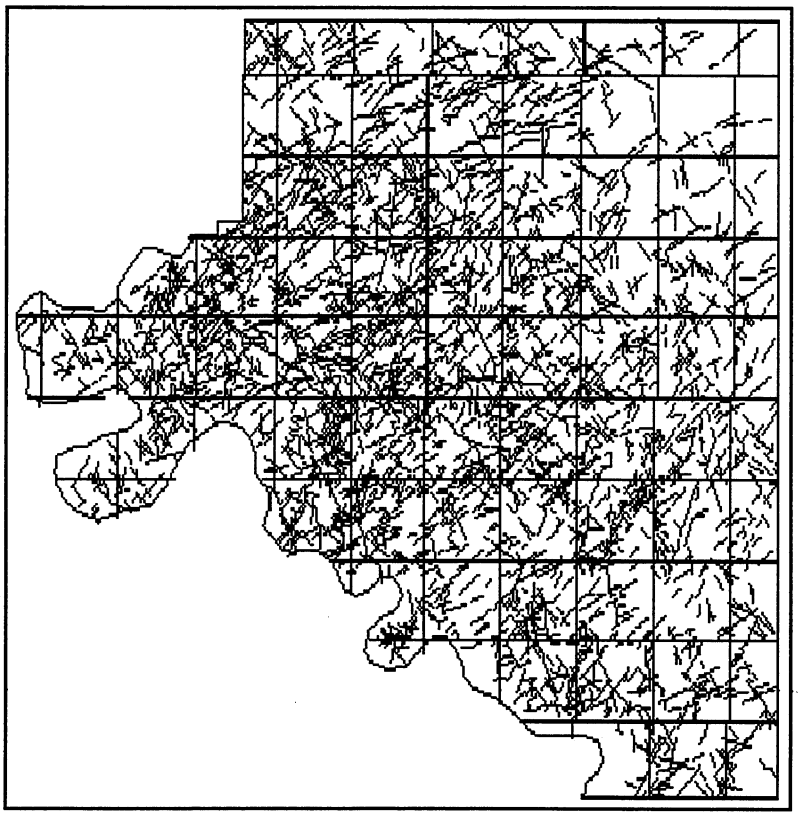

Figure 3–4 The 3,368 Surface Fracture Traces in Osage County, Oklahoma

An orientation analysis was performed by generating rose diagrams of the surface lineaments, fracture traces, anticlinal axes, and the strikes of subsurface structures. Figure 3–9 displays these data as rose diagrams. Figure 3–9 shows that surface and subsurface features in Osage County can be grouped into two sets (one oriented northwest-southeast, the other northeast-southwest), clearly demonstrating a consistency in trends between the surface and subsurface features.

Further analysis showed that the correlation between surface and subsurface features in Osage County exists not only in orientation, but also in position. Figure 3–10 shows the overlap of major surface lineaments and subsurface structures, whereas that of surface lineaments and subsurface stratigraphic traps is shown in Figure 3–11. One can see from Figure 3–10 that subsurface structures are closely associated in position with the surface lineaments, especially in the south-central, east-central, and southeastern parts of the county. In Figure 3–11, pools in the Burbank Sandstone are approximately aligned with the northwest-trending surface lineaments in the western half of the county. The major part of Burbank field appears to lie between two northwest-trending surface lineaments, perhaps as a result of a graben in the basement. Oil and gas pools in the Bartlesville Sandstone appear to be associated with both northwest- and northeast-trending surface lineaments in the eastern half of the county. However, a closer association was found between surface lineaments and structural traps than between surface lineaments and stratigraphic traps in the county.

The alignment of subsurface structures and stratigraphic traps along the surface lineaments, as well as the consistency in orientation, strongly suggests that the major surface lineaments in Osage County closely follow regional-scale fractures above basement weakness zones or fault zones, and that these faults, during their propagation to the surface, controlled the formation of oil and gas traps in the county.

A mathematical analysis was performed to investigate the association between subsurface structures and the characteristics of surface-fracture traces and circular and arcuate anomalies. The objective was to identify additional criteria for inferring subsurface traps. The study showed that surface-fracture orientation, frequency, and density, as well as circular and arcuate features could be used as indicators of subsurface structural complications.

In total, five quantitative subsurface-structure indicators were identified in this study. They are: (1) major surface lineaments, (2) analyses of the complexity of surface-fracture orientation (rose diagrams), (3) local residual surface-fracture frequencies, (4) local residual surface-fracture densities, and (5) the presence and density of surface circular and arcuate features. Potential subsurface oil and gas traps in Osage County were then identified using these indicators.

Figure 3–10 shows the correspondence between the surface lineaments and the known subsurface producing structures in Osage County. Any section along and/or adjacent to the surface lineaments was considered as anomalous. Any of those anomalous sections not

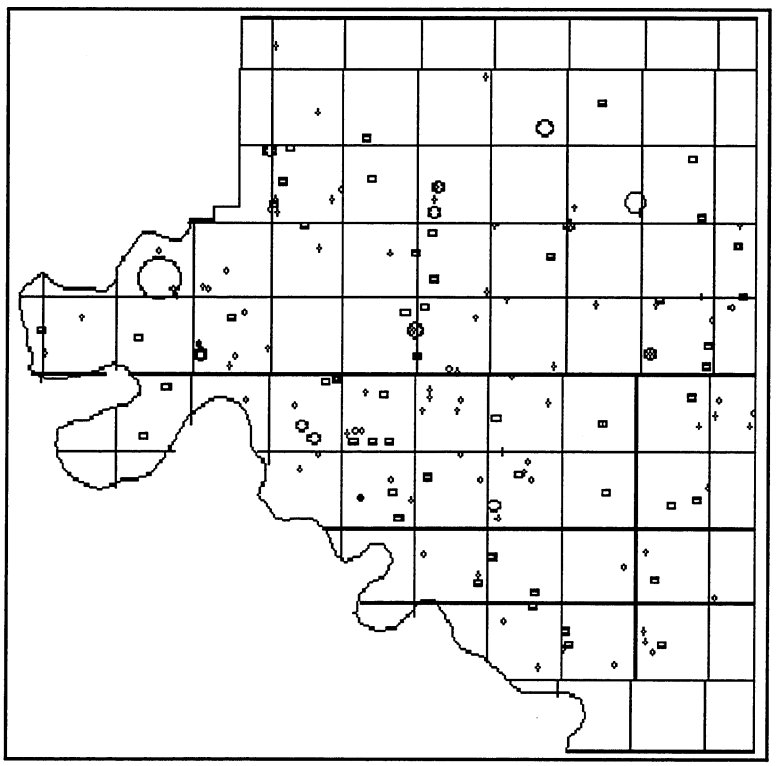

Figure 3–5 The 156 Surface Circular Features in Osage County, Oklahoma

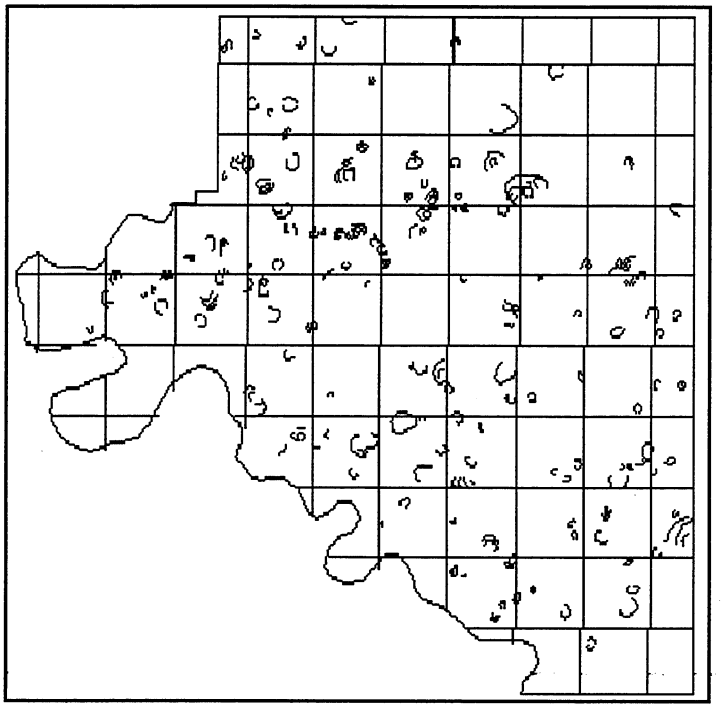

Figure 3–6 The 235 Surface Arcuate Features in Osage County, Oklahoma

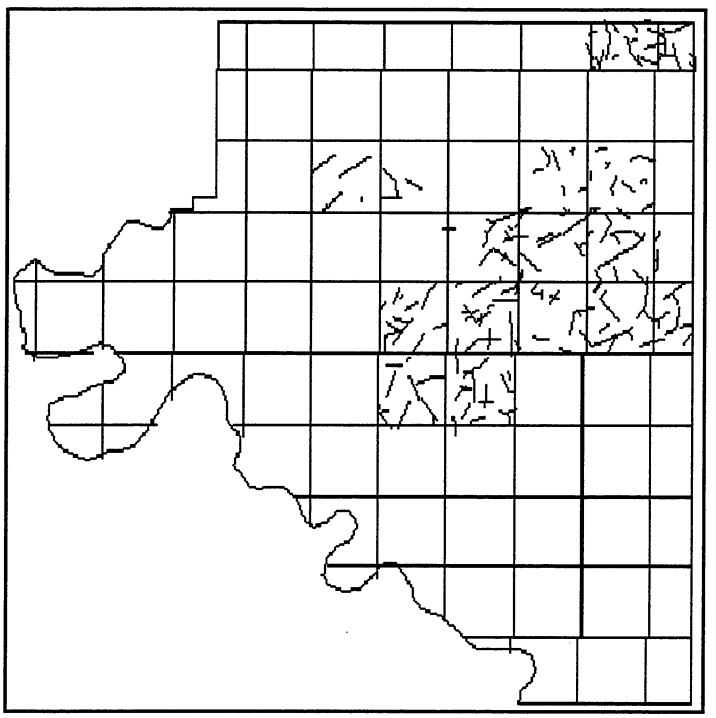

Figure 3–7 Crests of 207 Surface Anticlines and Domes in 16 Townships in Osage County, Oklahoma

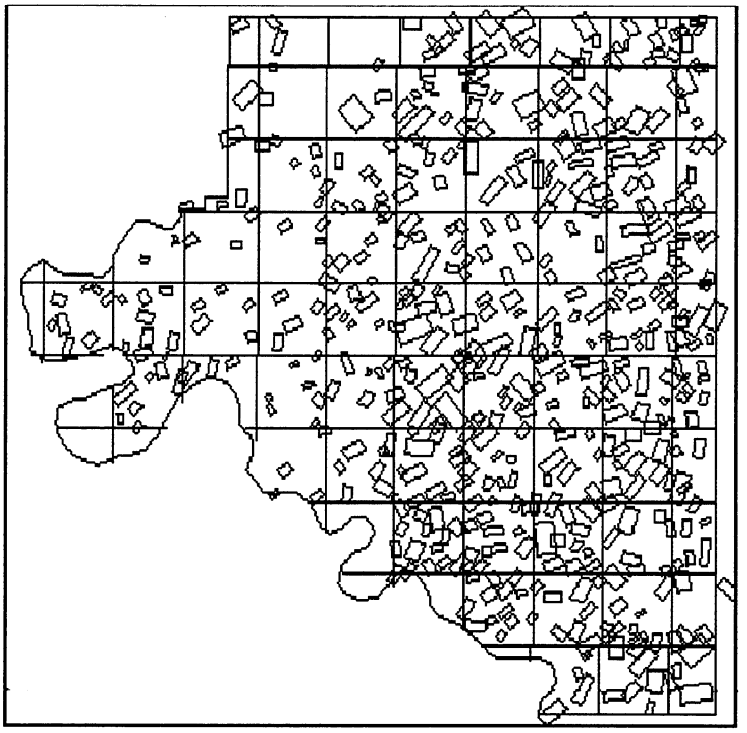

Figure 3–8 The 499 Subsurface Structures from the Mississippian Chat Formation in Osage County, Oklahoma

associated with the subsurface producing structures should be considered as priority locations for potential, previously unidentified oil and gas traps.

The anomalous sections defined by the complexity of surface-fracture orientation and their relationship to the existing subsurface structures are displayed in Figure 3–12. Similarly, the anomalous sections defined by the other three indicators (local residual surface-fracture frequency, local residual surface-fracture density, and surface circular and arcuate features), as well as their corresponding relationship to the existing subsurface structures, are shown in Figures 3–13–3–15. Any of those anomalous sections which were not associated with existing subsurface structures were also considered as priority locations for potential, unidentified oil and gas traps. Priority locations which correspond to and are identified by all five indicators should be considered the most favorable for subsurface oil and gas entrapment and additional exploration work and drilling.

The identification of priority locations through this surface fracture analysis procedure provided several candidate location areas for the site of the 3-D seismic program. Subsurface geological mapping and producing-trend analysis were used to further pinpoint the final site.

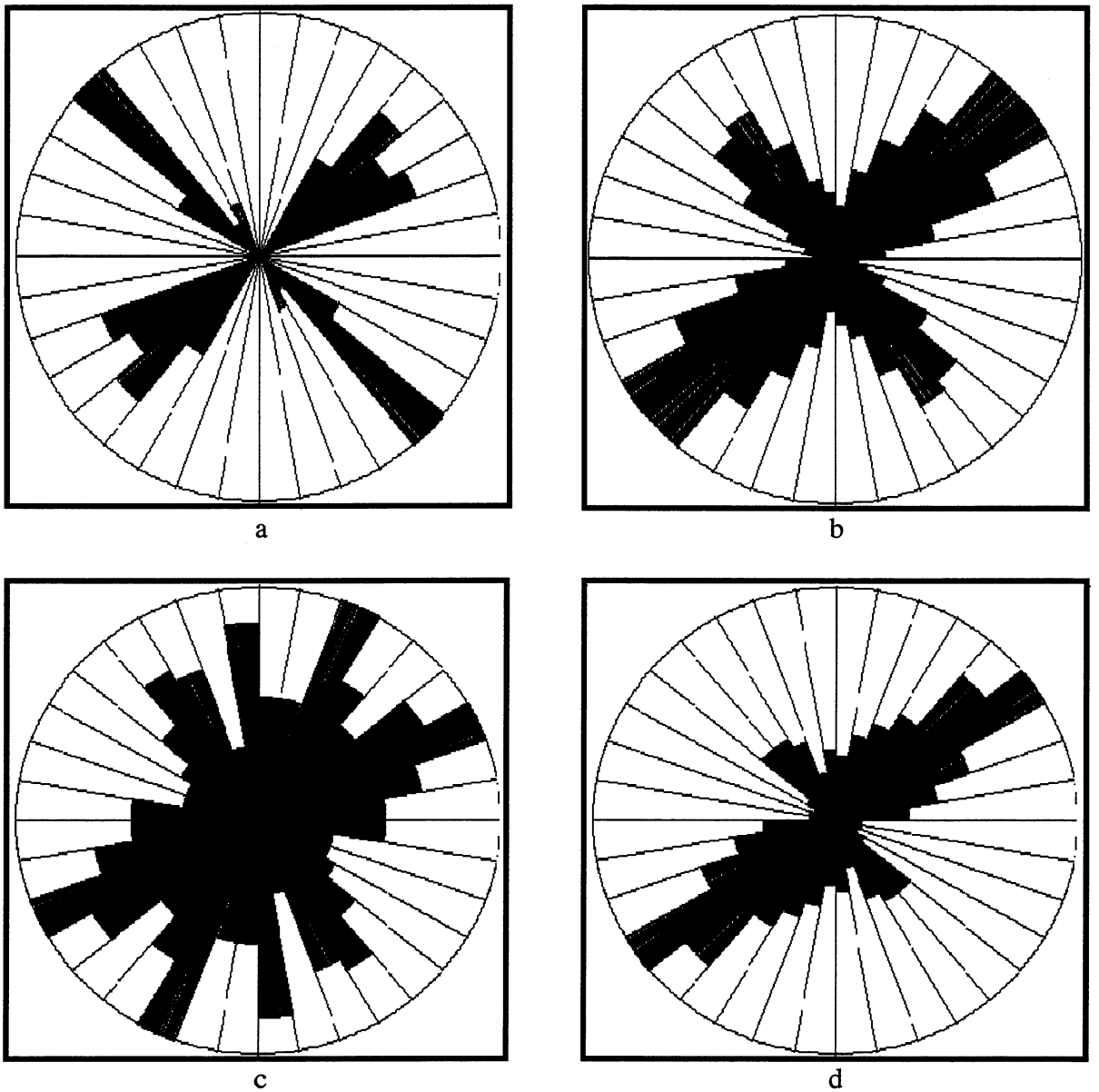

Figure 3–9 Rose Diagrams of Surface and Subsurface features in Osage County, Oklahoma: (a) The 56 Surface Lineaments, (b) the 3,368 Surface-Fracture Traces, (c) the 207 Surface Anticlines and Domes, (d) the 499 Subsurface Structures.

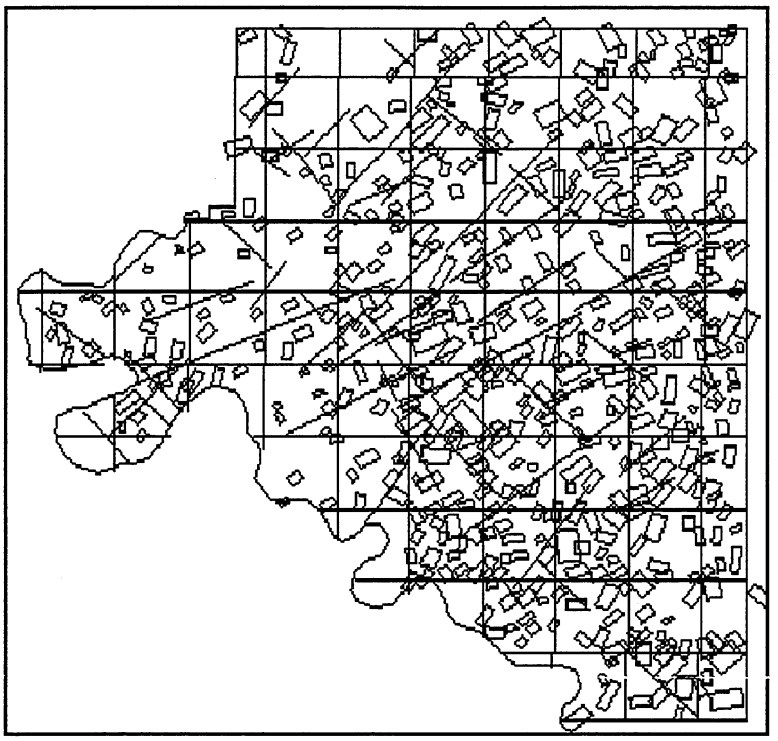

Figure 3–10 Overlap of Surface Lineaments (Lines) and Subsurface Structures (Rectangles) in Osage County, Oklahoma.

3.4 Producing Trend Analysis

Hydrocarbon exploration sites were identified for the 3-D seismic test program a through the identification of shallow structures, stratigraphic traps, and/or combination structural/ stratigraphic traps that have the potential for accumulations of producible hydrocarbons. Shallow potential hydrocarbon-bearing formations which fall along established trends and trend extensions have been targets for identification with these seismic surveys. All of the trapping mechanisms mentioned above are associated with economic hydrocarbon-producing accumulations in Osage County. It is possible that all of the three prospect areas identified by subsurface control and 2-D seismic data will be the selected locations for detailed high-resolution 3-D seismic surveys.

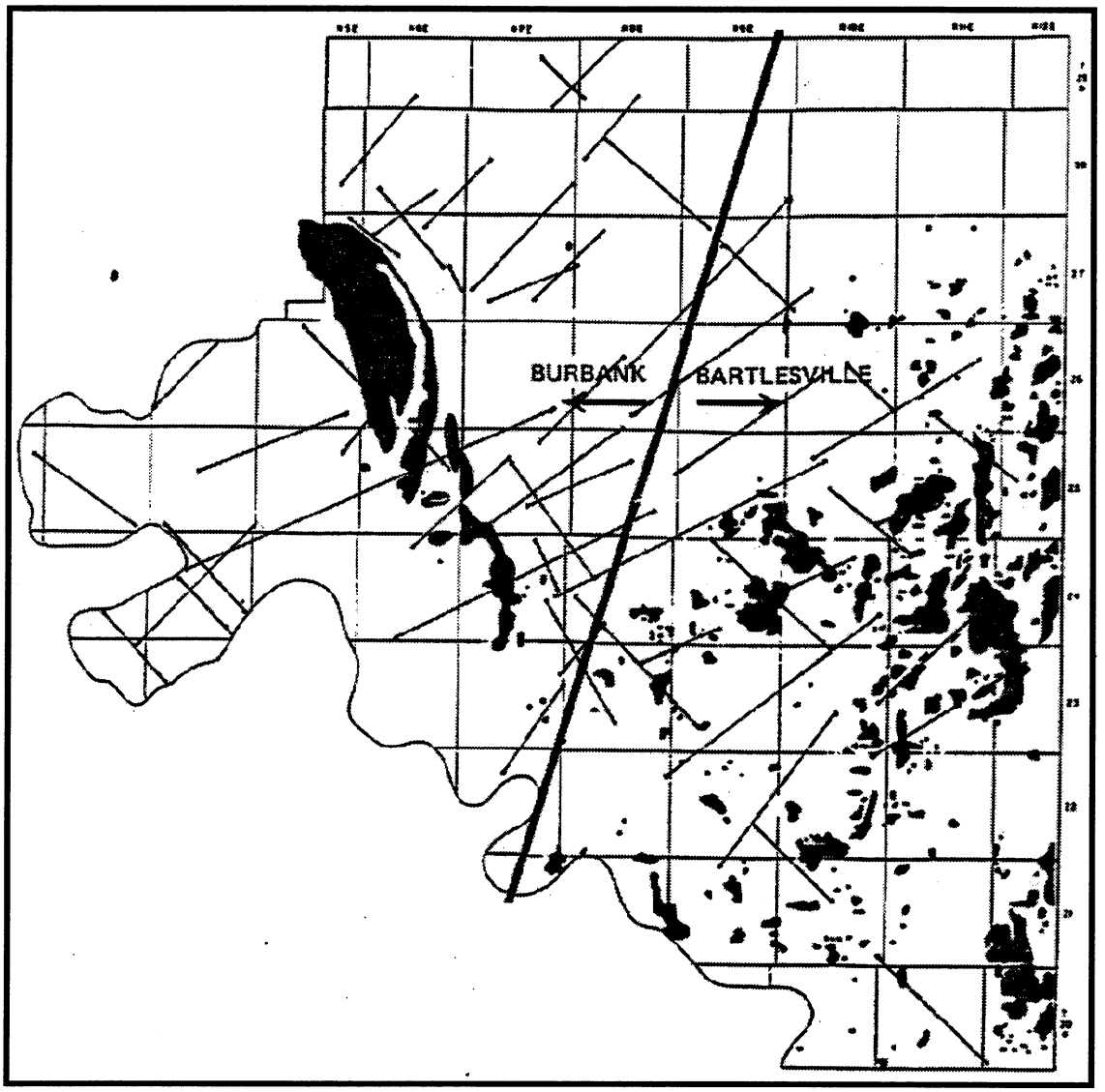

Figure 3–11 **Overlap of Surface Lineaments (Lines) and Subsurface Stratigraphic traps (Shaded Areas) in Osage County, Oklahoma.**

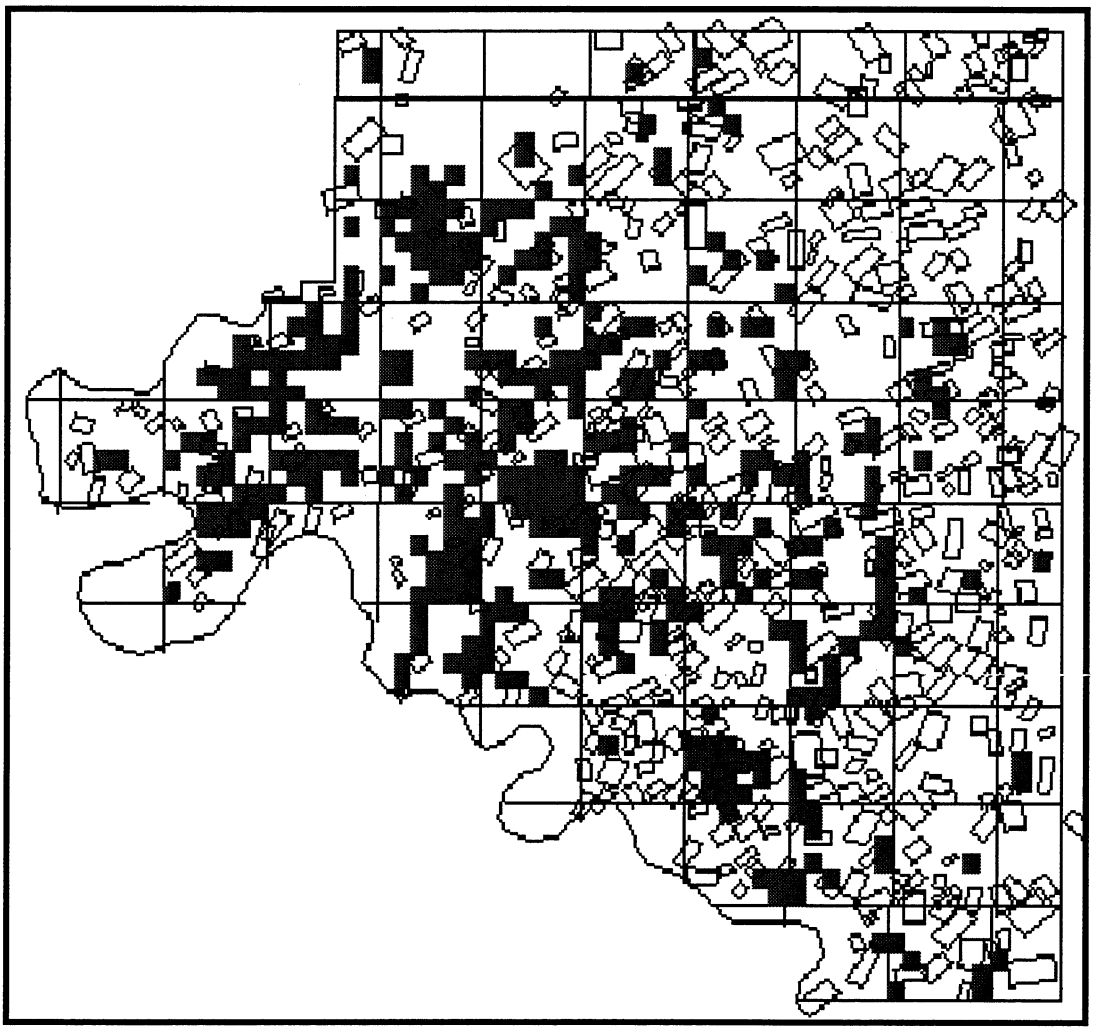

Figure 3–12 **Overlap of Subsurface Structures (Rectangles) and Anomalous Sections (Shaded Areas) in Osage County, Oklahoma, Indicated by Irregular Rose Diagrams.**

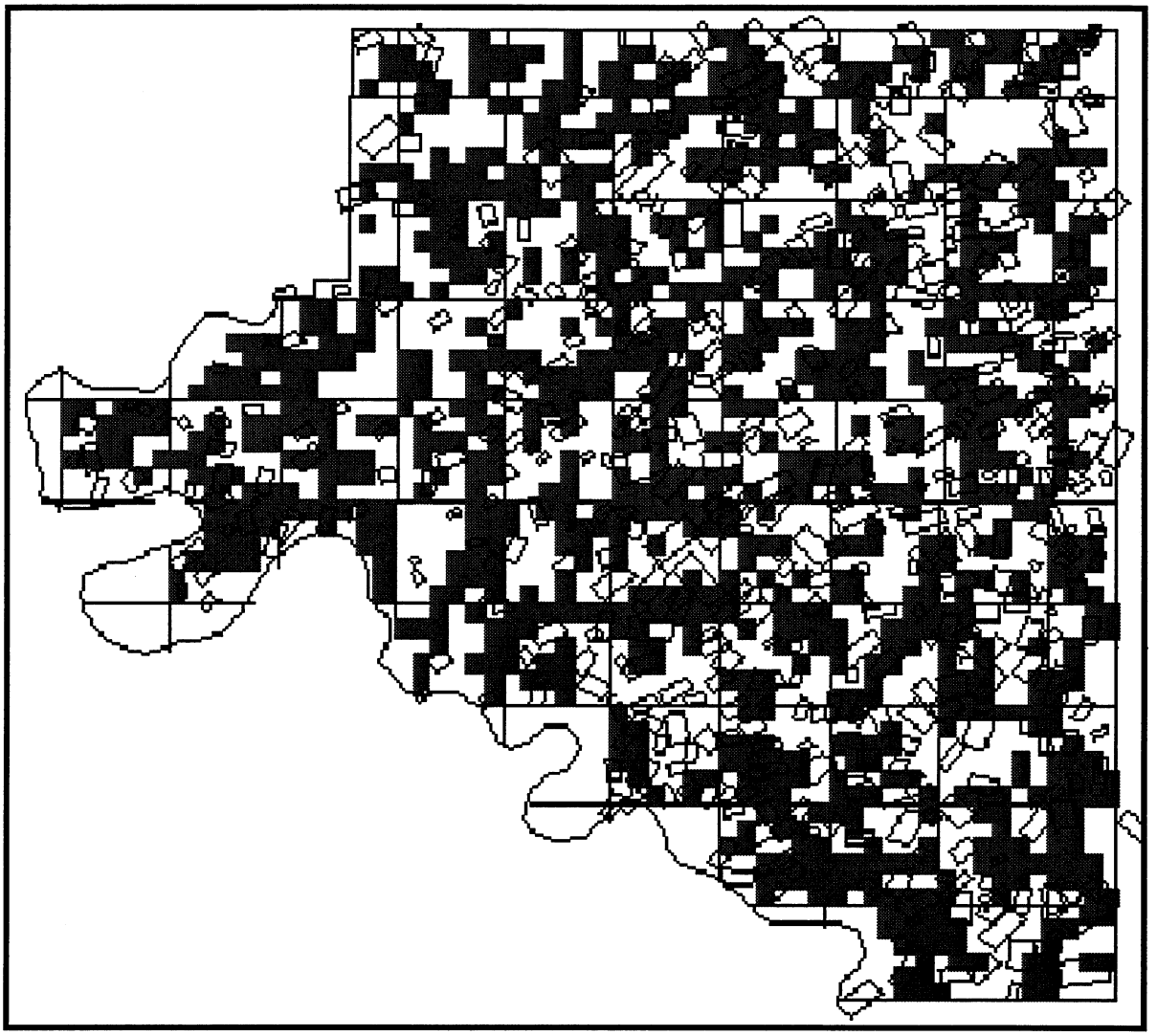

Figure 3–13 **Overlap of Subsurface Structures (Rectangles) and Anomalous Sections (Shaded Areas) in Osage County, Oklahoma, Indicated by the Local Residual Surface-Fracture Frequency Distribution.**

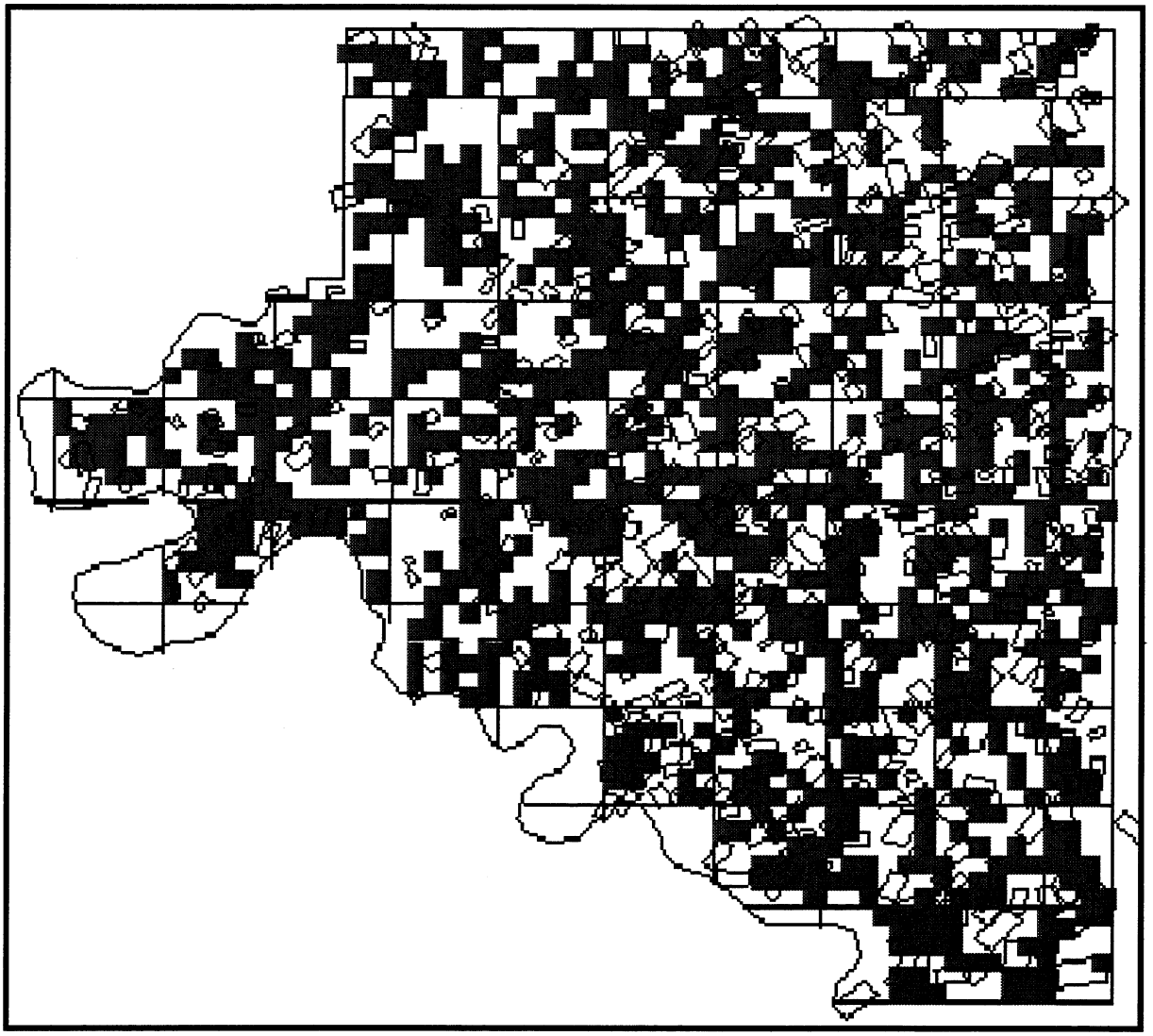

Figure 3–14 **Overlap of Subsurface Structures (Rectangles) and Anomalous Sections (Shaded Areas) in Osage County, Oklahoma, Indicated by the Local Residual Surface-Fracture Density Distribution.**

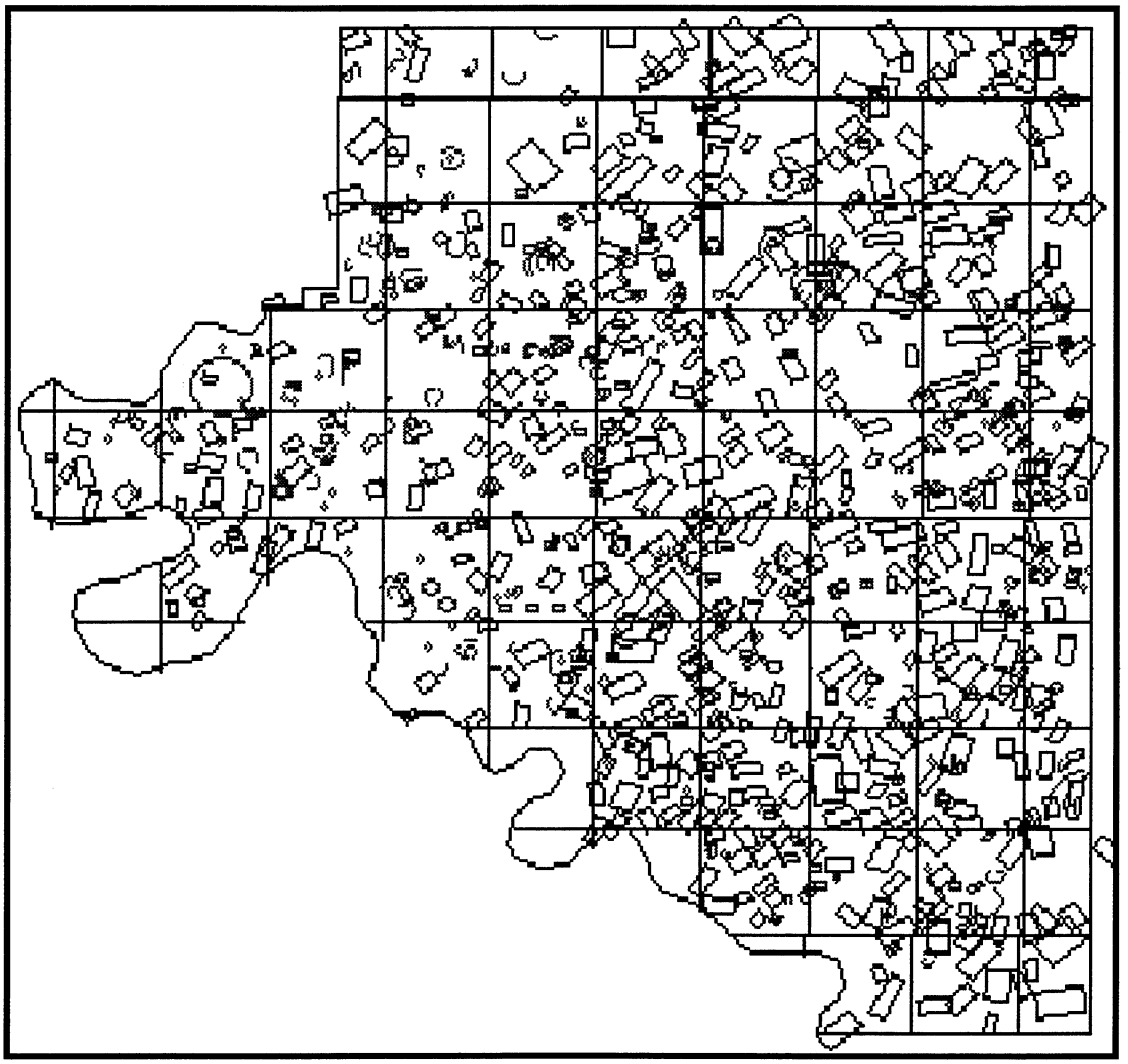

Figure 3–15 **Overlap of Subsurface Structures (Rectangles) and Anomalous Sections (Shaded Areas) in Osage County, Oklahoma, Indicated by Surface Circular and Arcuate Features.**

4.0 GENERATION OF PROSPECTS

BDM-Oklahoma staff generated subsurface structural prospects in four areas of Osage County for selection of a 9-mi^2 area for a 3-D seismic field test and data acquisition. Before mapping was started, 2-D seismic maps and records, subsurface-structure maps, producing-sand maps, stratigraphic trends, surface-fracture analyses, production records by field, and producing trends were reviewed and evaluated. These records and maps were obtained from several sources, including the Bureau of Indian Affairs (BIA) at the Osage Agency Branch of Minerals, in Pawhuska, Oklahoma. The process of prospect generation began with exploration leads developed from a fracture and lineament analysis performed on Landsat data purchased from the BIA. Structure maps from the BIA were analyzed for indications of structural trends that matched the results of the fracture–lineament Landsat study. The BIA maps were constructed without benefit of the Landsat data and do not reflect the structural orientation of older Paleozoic structures as identified in the BDM-Oklahoma study.

Producing trends were analyzed throughout the county by fields. Producing formations, cumulative production, and other field data were tabulated and graphed (Figure 4–1; Table 4–1). Figure 4–2 is a map of Osage County showing the location of all of the hydrocarbon-producing fields, corresponding to the tabulation of production data in Figure 4–1. These figures and the table provide an analysis of producing trends and production data for the county. Cumulative hydrocarbon production data by lease, was taken into consideration in analyzing the production trends in the county.

There are 367 hydrocarbon reservoirs in the county that produce from Pennsylvanian, Simpson, and/or Arbuckle sediments. The Pennsylvanian (Cherokee Group) Bartlesville Sandstone is productive in 80 fields in the county and is the most productive Pennsylvanian sandstone reservoir, out of a total of 367 Pennsylvanian-sandstone reservoirs. There are 134 Mississippian reservoirs, with 77 of these in the Mississippian Chat and 57 in Mississippian limestones. There are a total of 266 older Paleozoic reservoirs in Mississippian, Simpson, and Arbuckle sediments.

Analysis of the fracture system in Osage County led to the conclusion that the northwest-southeast fracture orientation is older than the northeast-southwest fracture orientation. There is an exception in western Osage County, along the Pennsylvanian (Cherokee Group) Burbank Sandstone trend, where the major fracture pattern has a northwest-southeast orientation. Northwest-southeast fractures probably bounded the stream valley and floodplain when the Cherokee Group sediments were deposited in the western part of Osage County. Elsewhere in the county, Pennsylvanian sediments, which accumulated as stream valley-fill deposits, show a northeast-southwest orientation, the major direction of the primary fracture trend.

Structural trends were also investigated and analyzed for the older Paleozoic reservoirs (the Mississippian Sands, Simpson, and Arbuckle) in Osage County, Oklahoma, and adjoining Chautauqua County, Kansas. The older structural trend in this region also runs northwest-

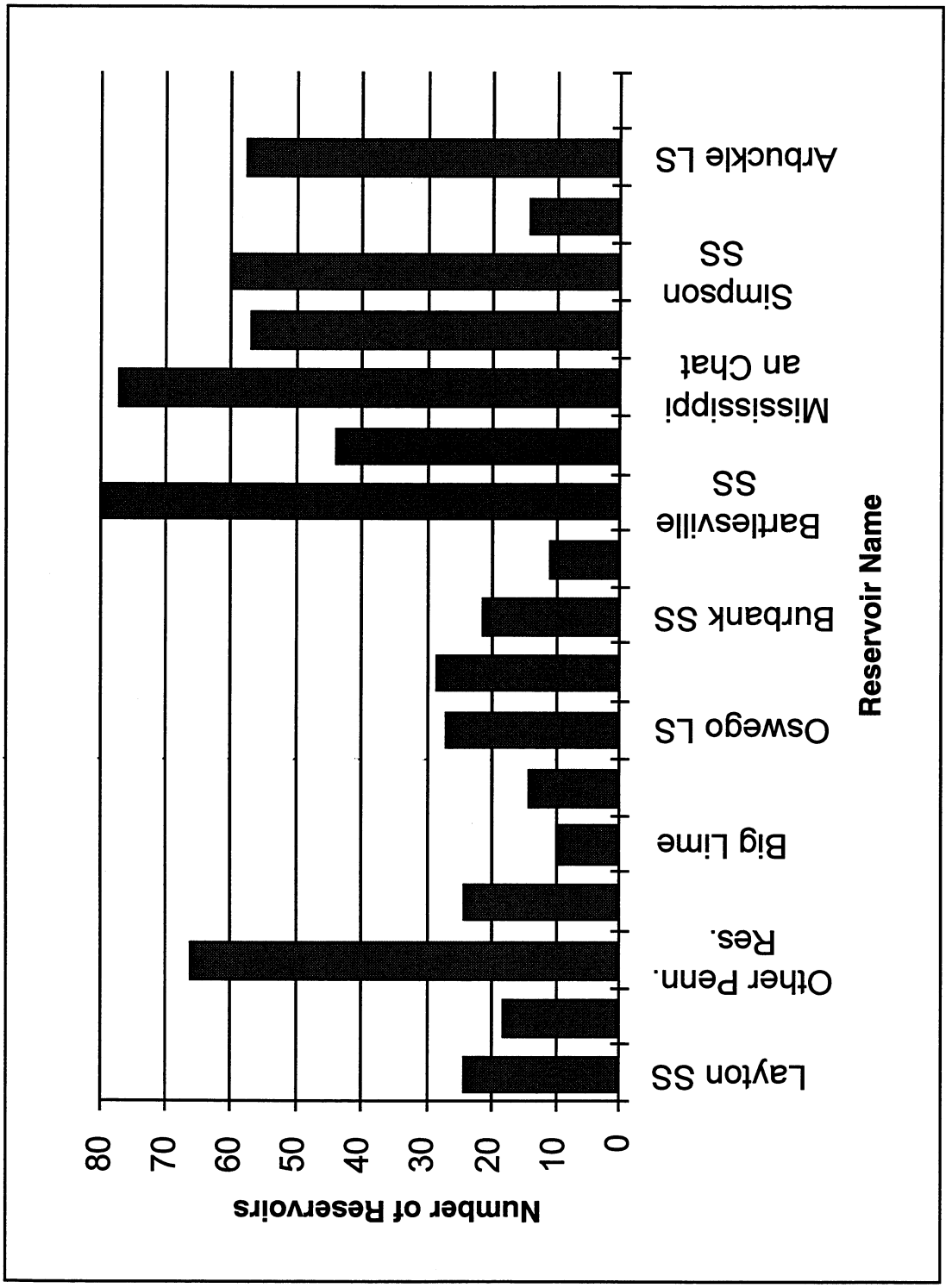

Figure 4–1 Producing Trends in Osage County, Oklahoma, by Numbers of Reservoirs.

Figure 4–1 Producing Trends in Osage County, Oklahoma, by Numbers of Reservoirs.

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
41	Alko	23N-9E	7/50	1328		Cleveland SS	1					
45	Almeda	26N-11&12E	1913	1500	10	Bartlesville SS	186	33	2,792,279		450,385	408,804
						Burgess SS						
				1700	20	Mississippian LS (Gas)						
			1/75	1941	3	Arbuckle (Gas)						
	Almeda NW		1/58	830	10	Wayside SS						
89	Apperson SW	26N-5E	8/46	2372	13	Layton SS		35	11,261			
			7/64			Mississippian LS		42	47,036,804		279,320	1,929,638
126	Atlantic	25N-7E	1924	1600	10	Wayside SS	495	36				
		25N-8E		1850		Bartlesville SS						
		25N-9E		2000		Blurgess SS						
		26N-8E		2100		Skinner SS						
		26N-9E				Mississippian Chat						
				2419	21	Mississippian LS						
				2640		Arbuckle						
				2750	15	Silicious LS (Arbuckle)						
	Atlantic E		1924				1		4,296		25,551	
127	Atlantic N	25N-8E	7/56	2382	12	Mississippian Chat		36	1,707			
145	Avant	23&24N-11E	1904	1400	65	Bartlesville SS	440	36	109,144,845		869,971	947,318
		23&24N-12E		1450	150	Burgess SS						
146	Avant W	22N-11E	1905	1162	10	Big Lime	551	32	4,681,869	637	2,111,554	249,158
		23N-10E		1697	12	Bartlesville SS						
		23N-11E		1844	9	Burgess SS						
	Backius		1919	1050		Wayside SS	75	34	961,327			
				1500		Bartlesville SS						
				1700		Mississippian LS						
173	Bandwheel	24N-9E	1921	700			207		5,995,922		159,105	948,269
				2050		Penn. SS		34				
				2200		Mississippian LS						
177	Barker	23N-7E	1/32	1029	3	Penn. SS	162	36	6,139,805		140,790	
		23N-8E				Ordovician						
		24N-7E				Cambrian						
		24N-8E		1610	9	Layton SS						
				2055	2	Big Lime						
				2178	20	Oswego LS						
				2386	16	L. Skinner SS						
						Mississippian LS						
				2872	24	Hominy SS (L. Simpson)						
			1941	2870		Arbuckle						
			8/68	2343	15	Skinner SS						
			8/68	2567	7	Mississippian Chat						

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
184	Barnsdall	24N-10E	1916	1100	79	Bartlesville SS	332	33	8,234,314		2,430,155	1,041,178
		24N-11E		1200	20	Penn. SS						
						Mississippian LS						
				1900		Arbuckle						
185	Barnsdall S	23&24N-10E	1921	1800	30	Bartlesville SS	249	34	2,226,287	1,335	464,107	444,309
		23&24N-11E				Burgess SS						
			7/67	2047	4	Arbuckls (Gas)						
186	Barnsdall W	24N-10E	1922	1900	60	Bartlesville SS	143	36	4,723,095			207,819
				1450	20	Big Lime						
187	Bartlesville	26N-12E	4/1897	1303	17	Bartlesville SS	152	36	874,914			
		27N-12E		260	9	Dewey SS						
				650	70	Big Lime						
				700	30	Peru SS						
				900	80	Oswego LS						
				1050	25	Skinner SS						
				1500	35	Burgess SS						
			2/70	1447	19	Mississippian LS						
			2/70			Arguckle (Gas)						
205	Belford NW	24N-4E	4/56	3710	13	Wilcox SS (Simpson)	25	44	1,168,579		795,264	125,526
			1/57	1464	6	U.Tonkawa SS						
				3410	20	Mississippian Chat						
				3249	5	U. Skinner SS						
				3326	3	L. Skinner SS						
				3506	14	Mississippian Chat		40				
				3650	30	Mississippian LS						
224	Big Bend	25N-3E	4/43	2850	25	L. Layton SS	34	41	4,004,687		46,497	
225	Big Bend E	25N-3E	10/49	2649	20	Layton SS	8		304,691			
226	Big Bend N	25N-3E	5/60	3832	22	Mississippian Chat	14	39	592,805			295,853
			11/60	4156	10	Wilcox SS (Simpson)						
						Layton SS						
	Big Bend S	25N-3E	2/62	2756	4	Cottage Grove	4	40	110,708			
227	Big Bend W	25N-2E	4/55	2739	12	Osage Layton SS	6	40	103,979			
			3/66	3818	19	Mississippian Chat		41				
	Big Horse	27N-12E	1927	1700	40	Bartlesville SS	84	47	930,055			
				1900	10	Mississippian LS						
				1050	20	Wayside SS						
231	Big Horse NE	27N-12E	4/68				44		390,312			
	Bighorse NE	27N-12E	4/68				91		633,846		99,726	349,650
247	Birch Creek	24N-10E	1920			Bartlesville SS	81	36	2,553,885		102,209	162,769
						Burgess SS						
						Mississippian LS						
				1950	40	Cleveland SS		35				
			1/75	2041	6	Bartlesville SS		35				
			1/75	2070	24	Mississippian Chat						

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
249	Birch Creek W	24N-10E	4/53	1360	7	Cleveland SS	6		18,177		10,249	459,47
259	Black Dog	22N-8E	1951	2603		Hominy SS (L. Simpson)	16		386,111		110,654	
	Black Dog E	22N-8E	8/75				3		104,986			
261	Black Dog S	22N-8E	12/55	2750		Arbuckle	17		145,167			391,528
				2290	20	Red Fork SS						
260	Black Dog W	22N-8E	6/45	2531	16	Burgess SS	24	40	849,115	1,847	78,645	50229
				2828	15	Arbuckle						
			1/75	1950	26	Oswego LS						
			1/75	2023	5	Peru SS						
			1975	2222	8	L. Skinner SS						
			1975	2294	36	Red Fork SS						
			1975	2518	27	Hominy SS (L. Simpson)						
			1975			Oil (?)						
253	Blackburn	22N-7E	4/67	2909	8	Tyner SS (Simpson)	8	37	366,459			11,927
			1967	2810	4	Wilcox SS (Simpson)						
255	Blackburn N	22N-7E	7/55	3023	187	Arbuckle	11	42	787,434		109,685	6,093
			5/68	2846	10	Wilcox SS (Simpson)						
			5/75		6	Peru SS(Gas)						
256	Blackburn NE	22N-7E	7/55	2952	20	Arbuckle	25	39	705,824			259,660
			2/63	2541	6	Burgess SS		38				
			4/75			Gas (?)						
262	Blackland	27N-7E	9/45	2487	10	Burgess SS	39	37	3,523,721			317,870
				2489	10	Mississippian Chat						
				2504	16	Mississippian LS						
263	Blackland NE	27&28N-8E	10/41	2570	10	Mississippian Chat	44		1,224,163			1,380,585
264	Blackland SW	27N-7E	7/56	2491	12	Burbank SS	1	38	5,177			
291	Boar Creek	22N-9E	1939	510	11	Okesa SS	39		273,017			62,580
						Clam Creek SS						
292	Boar Creek East	22N-9E	10/53			Skinner SS	19	38	128,429		34073	
305	Boston	21N-7E	1904	1500		Penn. SS	308	37	1,203,520		6,279	1,269,754
		22N-7E				Mississippian LS						
		21N-8E	1960			Arbuckle						
		22N8E				Cambrian						
306	Boston E	22N-8E	8/29	2117	13	Peru SS	6		7,732			
307	Boston N	22N-7E	1921			Wilcox (Simpson)	15		740,475		226,922	
		22N-8E	1935		40	Arbuckle		36				
			9/69	2938	4	1st L. Hominy SS (L. Simpson)						
308	Boston W	22N-7E	10/41	3032	24	Hominy SS (L. Simpson)	12	38	438,411			
			4/60	2736	9	Wilcox SS (Simpson)						
			4/62	2901	7	Tyner SS (Simpson)						
			8/76	2488	8	Skinner SS						

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
309	Boulanger NW	29N-10E	7/68	1986	6	Mississippian Chat (Gas)						
	Bowring	28N-11E	1921	800	60	Layton SS (Gas)	49		332,279		93,936	
				1275	20	Peru SS		34				
						Oswego LS						
				1800	20	Mississippian LS						
312	Bowring E	28N-11E	11/48	765	13	Penn. SS	2		4,230		347,450	
313	Bowring SE	27N-12E	8/75	1596	8	Bartlesville SS	49		359,498		272,604	
329	Branstetter	22N-11E	1928			Bartlesville SS	38	38	502,279		222,282	116,610
			1/35			Burgess SS						
						Mississippian LS						
	Breene		1950			Taneha (?)			109			
389	Buell	23N-9E	1922	2000		Penn. SS	25	37	742,739			957,626
						Mississippian LS						
				330	12	Okesa SS						
			1/77	1908	10	Skinner Sandstone						
				2092	8	Bartlesville SS						
399	Bulldog	24N-9E	1920	1775	80	Penn. SS	57	34	2,225,211			45,857
				1830	15	Oswego LS						
				2200	15	Bartlesville SaS						
						Mississippian LS						
400	Bulldog N	24N-9E	10/55				16		122,722			77,724
		25N-9E	4/56	2498	10	Mississippian LS						
401	Burbank	25N-6&7E				Burbank SS						
		26N-5,6&7E										
		27N-5&6E										
	Burbank S					Burbank SS		38				
						Skinner SS						
402	Burbank SW	25N-5E	3/57	3088	10	Mississippian Chat	6		112,220			
403	Burbank Townsite	26N5E	9/61	3004	5	Burbank SS	1		715			
464	Candy Creek	24N-12E	1920	1700	20	Bartlesville SS	144	36	2,008,233		11,809	696,287
				2770	10	Arbuckle (Gas)						
465	Caney	28N-12&13E	8/62	1060	14	Wiser SS	107		285,641		1,015,527	361,278
		29N-12&13E		1149	8	Pawnee LS						
466	Caney NW	29N-12E	10/60	1055	10	Big Lime						
470	Canyon Creek	23N-10E	1923		10	Bartlesville SS	56	39	5,093,639		3,934	176,049
						Blurgess SS						
			1963			Arbuckle						
471	Canyon Creek South	23N-10E	11/55	2125	12	Bartlesville SS	1	39	25,998			
631	Cleveland E	21N-8E	1/50	483	8	Buzzard (?)			381,346			
			2/50	501	11	Okesa SS						
			8/50	1868	45	Oswego LS						
			3/55	2234	10	Bartlesville SS						
			6/64	300	42	Topeka SaS						
				1156	18	Cleveland SS						

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
	Country Club	1923				Red Fork SS	25	33	1,217,059			
						Penn SS						
						Ordovician						
						Mississippian LS						
			8/60	2008	3	Bergen SS (Simpson)						
756	Dalton	24N-7E	1926			Bartlesville SS	52	38	1,438,334			189,511
		24N-8E		2430	40	Burgess SS						
					20	Mississippian LS						
					30	Ordovician						
				2794	4	Simpson SS		36				
				2842	1	Burgess SS		38				
				2814	63	Arbuckle		41				
				2509	8	Mississippian Chat						
				2832	6	Hominy SS (L. Simpson)						
				1600	10	L. Layton SS		37				
				2384	13	L. Skinner SS		42				
757	Dalton NE	25N-8E	1/58	2493	9	Mississippian Chat	1	40	62			
	Dalton S		1941	2500		Arbuckle	3		201,664			
758	Dalton W	24N-7E	7/33	2890	30	Siliceous LS (Arbuckle)	15		447,759			
			12/46	2926	1	Hominy SS (L. Simpson)						
	Dog Creek		5/56	2440	10	Mississippian Chat	13		222,129			167,371
806	Dog Creek N	28N-8E	8/56	2438	18	Mississippian Chat	1	27	204			
807	Dog Creek NE	28N-8E	12/60	2338	5	Mississippian Chat	4	33	143,145			70,776
808	Dog Creek S	28N-8E	10/75				81		4,497,082			3,154,133
809	Dog Creek SE	28N-8E	9/81				1		30			
810	Dog Creek SW	28N-7E	4/80				5		38,281	947	364,243	75,125
		28N-8E										
811	Dog Creek W	28N-8E	4/56				7		46,906			1,179,008
812	Doga E	24N-5E	4/51	2942	12	Skinner SS	3	40	73,349			
813	Doga N	24N-5E	12/51	3163	30	Mississippian LS	25	37	671,068			358,538
814	Doga NW	24N-5E	8/61	3221	8	Mississippian Chat		40				
817	Doga SW	24N-4E	7/52	3336	12	Mississippian Chat	5	38	496,293			
822	Domes SW	26N-10E	7/56	1962	5	Mississippian LS	7	36	396,200		124,453	405,039
				1736	10	Bartlesville SS						

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
823	Domes-Pond Creek	26N-10E	1917	1510	67	Stray SS	1435	36	25,294,826	14,184	4,556,414	8,664,596
		26N-11E		1680	100	Bartlesville SS						
		27N-10E		1880	45	Mississippian LS						
		27N-11E		2175	15	Ordovician						
		27N-12E		1050		Wayside SS						
		28N-10E		800	60	Layton SS						
		28N-11E		1275	20	Peru SS						
		28N-12E		1500		Oswego LS						
		29N-10E		500	15	Musselman SS						
		29N-11E		1800	5	Burgess SS						
		29N-12E				Mississippian Chat						
						Peru SS						
			7/73	1891	3	Arbuckle						
835	Drum Creek	25N-4E	9/46	2852	28	Cleveland S	33	42	954,326			
				3470	15	Mississippian Chat						
836	Drum Creek N	25N-4E	10/51	3432	38	Mississippian LS	40	43	1,947,062			11,631
837	Drum Creek, NW	25N-4E	7/59	3503	6	Mississippian Chat	4	44	148,721			
838	Drummond Ranch	26N-8E	12/45	2300	28	Peru SS	1		32,441			
839	Drummond Ranch, N	26N-8E	4/58	2416	9	Mississippian Chat	40	38	181,941		1,018,010	1,560,556
880	Edgewood	21N-11E	1921	2000	7	Bartlesville SS	11	35	55,250		201,598	98,435
		22N-11E				Burgess SS						
						Mississippian LS						
881	Edgewood S	21N-11E	1924			Bartlesville SS	31		232,431			
			2/60			Cleveland SS						
893	Elgin S	29N-9E	1915			Ramsey SS	236	33	3,386,561	542	10,035,204	
						Penn SS						
						Oswego LS						
				2100		Mississippian Chat						
894	Elgin SW	29N-9E	5/75	2025	10	Red Fork SS	11		97,752		33,866	
912	Enfisco	26N-7E	1921		10	Stray Penn SS	8	36	1,201,722		57,379	494,615
		27N-7E	11/56			Oswego LS						
				2530	4	Mississippian LS						
913	Enfisco W	27N-7E	4/80				2		4,325			
915	Enterprise	23N-7E	4/68	3044	6	Simpson SS	4	42	209,298			
			4/68	3082	10	Arbuckle		41				
			11/68	2638	9	Burbank SS		34				

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
916	Enterprise N	23N-7E	8/53	2740	4	Mississippian Chat	2		4,061			
	Fairfax		1925			Oswego LS		38				
						Burbank SS						
						Wilcox SS (Simpson)						
937	Fairfax NW	24N-5E	9/79				1		115			
	Falls Dome		1920	1850		Oswego LS		36				
						Bartlesville SS						
				2300		Burgess SS						
965	Flat Rock	20N-12E	1906	1110	95	Bartlesville SS	1119	36	3,897,555		624,360	936,860
		21N-11E		1345	20	Burgess SS						
		21N-12E	4/58	2014	44	Arbuckle						
966	Flat Rock W	20&21N-11E	3/51	2045	6	Hominy-Wilcox SS (L. Simpson)	44	40	586,349		211,957	
970	Flesher	22N-9&10E	1919		40	Bartlesville SS	10	35	199,950			
			10/55			Mississippian LS						
971	Flesher E	22N-10E	1/51	2238	26	Mississippian LS	4	38	37,547			
			5/34	2425	10	Arbuckle						
988	Foraker	28N-7E	1920	1100		Cleveland SS	65		1,985,745		63,986	297,984
			1922	1250		Oswego LS						
			1942	1800		Burbank SS						
				2700	10	Mississippian LS		33				
989	Foraker N	28N-7E	1/71	2805	10	Mississippian Chat	5		15,959			
996	Foraker NE	29N-7E					3		622	7,276	210,884	10,082
991	Foraker S	27N-7E					6		28.296		595,737	
992	Foraker SW	27N-7E					2		16,355			
1011	Forty-Five	25N-12E	1916			Oswego LS	72	34	2,913,266	850	656,562	442,649
		26N-12E		1400		Skinner SS						
				1500	35	Bartlesville SS						
			6/74	1995	4	Arbuckle (Gas)						
	Frankfort		1920	2040	50	Peru	6		414,429			
				2905	40	Mississippian LS						
1023	Frankfort E	29N-6E	10/83				1		7,372			
1024	Frankfort S	29N-6E	5/67	2866	5	Mississippian LS	1		180			
	G I Joe		12/45	1604	18	Tucker SS	18		575,727			
1096	Gilliland	22N-7E	9/19	2800	20	Layton SS (Gas)	153		8,311915			238,010
		23N-7E			60	Oswego LS (Gas)						
		23N-8E			10	Prue SS		36				

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Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
					15	Bartlesville SS						
						Mississippian LS						
						Arbuckle						
				2222	4	Prue SS		40				
				2330	8	L. Skinner SS						
				2815	4	Arbuckle						
			1970	2741	1	Misener U. Hominy SS (L. Simpson)						
			1970	2771	1	M. Hominy SS (L. Simpson)						
			1970	2791	2	Tyner SS (Simpson)						
	Gilliland S		1945	2900	10	Hominy SS (L. Simpson)	26		455,318			
						Arbuckle						
1097	Gilliland W	23N-7E	7/56	2432	6	Skinner	2	37	770			
1129	Grainola SW	28N-6E	5/56	3045	4	Mississippian Chat	1	34	600			
1146	Grayhorse	24N-6E	6/58	2859	10	Mississippian Chat	6	36	59,183			
			9/58	2681	17	Burbank SS						
1143	Grayhorse N	24N-6E	6/50	2705	10	Cherokee SS	1		18,499			
1144	Grayhorse SE	23N-6E	11/76	3147	6	L. Hominy SS (L. Simpson)	2	31	7,774			
1145	Grayhorse W	24N-6E	8/56	2886	14	Mississippian Chat	2	41	18,280			
1160	Greenup N	22N-7E	4/60	2728	18	Wilcox (Simpson)	6	40	292,762		6,180	30,399
	Happy Hollow		1919	1945	15	Oswego	95	36	1,982,354			
				2200	20	Bartlesville SS						
				2392	6	Burgess SS						
			10/58	2736	20	Arbuckle						
				2416	10	Mississippian Chat						
1220	Happy Hollow NE	25N-8E	3/79				3		111,628			
1234	Hardy	25N-3E	1934	2567	20	Layton SS	48		3,997,819		4,605	2,585,119
				2359	8	Perry (Gas)						
			5/62	3376	16	Skinner SS		46				
			2/64	3521	7	Mississippian Chat		42				
	Hardy SE		11/54	2555	12	Osage-Layton SS	5	40	204,664			
	Hardy SW		1/56	3468	20	Skinner SS	1	38	522			
	Herd District		1919	500	15	Musselman SS						
				1100	15	Wayside SS						
	Herd E		9/50	1416	12	Peru SS	16	37	86,273		1,096,557	
				2050	10	Mississippian Chat						
	Herd N		1955	1706	8	Mississippian Chat	14		61,759			
	Herd NW		10/53	1800	5	Burgess SS	85		1,157,209			
	Herd SW		10/54	2026	18	Mississippian	53	39	375,604			

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	Hickory Creek S		1939	1050	20	Wayside SS	91	36	1,160,443			
1324	Hominy	22N-8E	1916			Penn SS	34	34	311,543		67,166	
		22N-9E				Mississippian						
						Ordovician						
						Cambrian						
			10/64	2546	66	Arbuckle		40				
1325	Hominy E	22N-9E	1918		30	Bartlesville SS	23	34	652,487			
			4/47			Mississippian LS						
						Hominy SS (L. Simpson)						
						Arbuckle						
			10/75	2535	48	1st Wilcox (Simpson)		38				
1328	Hominy Falls	21N-11E	1919		20	Bartlesville SS	42	36	414,420		165,344	2,959
		21N-12E			55	Taneha SS						
		22N-11E			10	Burgess SS						
		22N-12E			20	Mississippian LS						
			1/75	2178	2	Arbuckle						
1329	Hominy Lake S	22N-8E	7/52	2851	8	Red Fork SS	22	40	441,102		42,632	
				2864	37	Hominy SS (L. Simpson)						
				2974	23	Arbuckle						
1326	Hominy S	22N-9E	6/40			Oswego LS	7	37	48,857			
1327	Hominy W	22N-8E	1982				17		339,354	442	217,611	329,559
	Horn SW		8/63	1768	16	Bartlesville SS	12	31	50,942			
1361	Hulah	28N-12E	1979				2				454,568	
1362	Hulah N	29N-12E	8/62	1060	14	Wiser SS	2		13,081			
			8/62	1149	3	Pawnee LS						
1414	Javine	22N-11E	1919	1750	12	Burgess SS	59	36	1,792,782			
		22N-12E	2/46			Tucker SS						
1427	Johnson W	26N-10E	8/69	866	33	Musselman SS	6		22,517		437,911	
			1/73	2421	38	Arbuckle (Gas)						
	Kasishke		1921			Burbank SS		40	436,314			
				2480	10	Mississippian Chat						
			1956	2800	10	Ordovician						
	Kasishke S		11/25	2816	68	Hominy SS (L. Simpson)	25					
				2880	10	Arbuckle						
				2790	25	Mississippian Chat						
1443	Kaw S	25N-4E	2/47	3304	41	Mississippian LS	44	41	6,594,531			
		25&26N-5E		2350	10	Layton SS						
	Kaw SW		10/58	3194	7	Skinner SS	1	37	118			

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1471	Keystone E	19N-10E	1948	2550	30	Wilcox SS (Simpson)	13		60,046			
		20N-10N	9/75	1960	20	Bartlesville SS						
			12/73	1935	9	Red Fork SS						
	Keystone N		6/74	2530	4	1st Hominy SS (L. Simpson)		38				
	Keystone SE		1953	2613		Hominy SS (L. Simpson)	4		111,675			
						3rd Simpson SS		38				
1534	Landon	28N-9E	1914			Prue	109	35	601,824			
			1919			Oswego LS						
						Bartlesville SS						
						Wayside SS						
1535	Landon E	28N-9E	7/74	2021	8	Mississippian Chat	2		39,823		137,411	
			1/75	1991	5	Pink LS						
			8/75	2003	17	Mississippian Chat						
			5/75	1328	4	Wayside SS						
1536	Landon N	29N-9E	4/61	1605	13	Wayside SS	3	35	43,621			
1537	Landon NE	28N-9E	3/73	1916	22	Mississippian Chat	1					
1538	Landon NW	28N-9E	7/53	1620	19	Wayside SS	92		1,137,273			861,993
			1/74			Mississippian Chat (Gas)						
1539	Landon SW	28N-9E	5/56	2286	39	Mississippian LS	7	39	31,031	3,013	111,772	
1540	Landon W	28N-9E	6/56	1590	12	Wayside SS	34	35	101,143			79,932
	Lee Dome		1926	1940	30	Oswego LS						
				2200	35	Bartlesville SS		36				
				2320	20	Burgess SS						
				2525	15	Ordovician						
	Little Chief NE		4/52	2701	14	Red Fork SS		39				
				2814	20	Burbank SS						
				2882	10	Mississippian Chat						
	Little Chief NW		5/54									
	Little Chief SE		10/53	2811	25	Burbank SS		40	19,973			
	Little Chief W		9/53			Burbank SS						
	Lone Spring E		1/52	2585	16	Arbuckle	1	30	13,266			
1624	Lone Spring N	23N-9E	10/55	1567	18	L. Cleveland SS	17	37	166,230		205,576	39,080
1655	Lucy Creek	25N-5E	1/57	2176	6	Osage-Layton SS	1	35	2,206			
			1/69	3212	6	Mississippian Chat		37				
1656	Lucy Creek E	25N-5E	8/66	1851	3	Avant SS	9		265,397			
			9/67	3238	6	Mississippian LS						
1657	Lucy Creek N	25N-5E	2/58	3273	10	Mississippian Chat	1					

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1679	Madalene	21N-10E	1920	1562	19	Prue SS	48		695,350			72,964
					65	Oswego LS		35				
					35	Bartlesville SS						
1680	Madalene E	21N-10E	1923			Bartlesville SS	46	35	1,160,779	929	150,082	
1693	Manion	23N-8E	1/18			Layton SS	75		2.969,317		40,912	134,530
		23N-9E	1927			Oswego LS		38				
					17	Bartlesville SS						
					30	Burgess SS						
						Okesa						
	Manion N		1920	2050	40	Bartlesville SS	81	38				
						Wilcox SS (Simpson)						
1694	Manion S	22N-9E	6/55	2621	4	Wilcox Hominy SS (L. Simpson)	5	41	125,486			
1737	Masham NW	22N-04E	10/57	3536	21	Mississippian Chat	13	38	192,391			442,269
1772	McCord SW	25N-2&3E	12/64	2748	14	1st Osage Layton SS	30		1,364,410			
1776	McInnis	25N-8E	6/57	2813		Arbuckle	22	39	402,110			55,156
1777	McInnis W	25N-7E	1156	3033	13	Arbuckle	2	37	7,660			
	Me-Gra-To-Moie		1939									
1894	Mud Creek SE	20N-10E	1943	2150	15	Tucker SS	12		36,294			
			4/51	358		Penn SS						
1920	Myers	26N-8E	1916	2101	6	Mississippian Chat	56		847,732		727,776	344,576
				2280	4	Mississippian LS						
				1400	10	Layton SS (Gas)						
						Skinner SS						
				2700		Simpson SS						
1921	Myers NE	27N-9E	9/55	2304	12	Mississippian Chat	4	33	22,924			
1922	Myers S	26N9E	1928	1600	10	Wayside			917,728			
				2110		Skinner						
				2364		Mississippian Chat						
1931	Naval Reserve	23&24N-7E	4/28	2940	110	Bartlesville SS	335	38	60,388,703		182,888	343,719
		24N-6E		3000	10	Arbuckle						
		25N-6&7E		2670	40	Burbank SS						
						Mississippian Chat						
1932	Naval Reserve E	24N-7E	8/52	2570	8	Mississippian Chat	10		148,416			
	Naval Reserve NW		5/51	2695	15	Burbank SS	104	39	2,103,193			
1933	Naval Reserve S	23N-7E	2/38	2944	28	2nd Wilcox SS	16	38	1,538,080			
				2987	96	Hominy SS (L. Simpson)						
						Burbank SS						
	Naval Reserve W		6/55	2767	35	Mississippian Chat	27	40	803,184			
				3008	5	Wilcox (Simpson)						

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1940	Nelagoney	25N-10E	1917	1200	15	Skinner SS	41		349,067		749,402	111,682
		25N-11E	8/77	1400	15	Bartlesville SS		34				
				2350		Arbuckle (Gas)						
	New England		1920			Bartlesville SS		34				
						Burgess SS						
						Arbuckle						
						Mississippian Chat						
2009	Ochelata N	25N-12E	1910	1154		Prue SS	232		4,038,421			
				1650	40	Bartlesville SS						
2012	Ohio-Osage	21N-9E	1932			Cleveland SS	14		394,319			
						Bartlesville SS						
			4/56			Layton SS						
			6/59	2788	28	Tyner SS						
	Okesa		1904			Prue SS	46		1,017,115			
				1575	35	Bartlesville SS		35				
				1700	20	Mississippian LS						
	Okesa N			1345	19	Peru SS	4	37	23,934			
				1625		Bartlesville SS						
2027	Okesa W	26N-10E	3/17	1926	34	Mississippian LS (Gas)	4		43,051			
			12/19	1693	15	Bartlesville SS						
2081	Osage City	21N-8&9E	11/04			Burbank SS	253	37	9,324,716	332	215,184	261,626
		22N-8&9E				Burgess SS						
						Arbuckle						
2082	Osage City E	21N-9E	1920	1620	25	Cleveland SS	85	37	1,231,972		232,800	
		22N-9E		2250	30	Bartlesville SS		38				
				2597	18	Arbuckle						
2084	Osage-Hominy	23N-8E	1917			Layton SS	254	37	13,605,381			1,068,590
		24N-8E				Oswego LS (Gas)						
						Bartlesville SS						
						Burgess						
			2/56	2613	2	Arbuckle						
2111	Page	20N-11E	1918			Penn SS	90		1,115,945	262	1,885,904	175,425
						Ordovician		33				
						Cambrian						
2123	Pappin	26N-9E	2/56	2000	27	Mississippian LS	2		711			
				1946		Bartlesville SS						
				1575		Peru SS						
2124	Pappin NW	27N-9E	8/66	2206	10	Mississippian Chat	6	36	47,718		104,944	1,884
2125	Pappin W	26N-9E	1/56	2204	5	Mississippian Chat	3	39	879			

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
2146	Pawhuska	25N-9E	10/19	1850	20	Bartlesville SS	134	35	3,365,165		219,285	211,726
		26N-9E		2000	20	Burgess SS						
						Burgen SS (Simpson)						
						Arbuckle						
				2272	10	Arbuckle (Gas)						
2147	Pawhuska N	26N-9E	5/72	2376	9	Arbuckle (Gas)	18		81,157		1,442,115	678,297
			6/72	980	18	Osage Layton (Gas)						
			6/72	308	44	Nelagoney Stray SS						
			10/72	648	31	Stray SS (Gas)						
			9/73	2018	3	Burgess SS						
			9/73	2048	26	Mississippian LS						
2148	Pawhuska NE	26N-9&10E	6/48	2090	62	Mississippian Chat	25		519,469			1,828,141
2149	Pawhuska NW	26N-9E	11/57	2201	6	Burgess SS	9	36	112,940			1,224
			1/58	2022	7	L. Skinner						
	Pawhuska W		1919	2200	10	Bartlesville SS	60	36	763,995			
				2400	20	Burgess						
						Burgen SS (Simpson)						
						Arbuckle						
						Mississippian LS						
2159	Paxton E	22N-8E	4/50	2520		Prue (Gas)	30		725,482		169,984	369,502
						Red Fork SS		39				
2160	Paxton SE	22N-8E	4/52	2425	16	Skinner SS	8	41	126,749		294,244	84,207
						Red Fork SS (Gas)						
			10/67	2949	18	M. Hominy SS (Simpson)						
2165	Pearsonia	27N-7E	8/19			Layton SS	67	36	5,933,607		8,105	11,202
		27N-8E				Oswego						
						Burgess						
				2410	40	Mississippian LS						
2167	Pearsonia NE	27N-9E	7/69	2254	1	Mississippian Chat	1	34	810,834		222,833	5,117,629
	Pearsonia S		10/45									
			5/74	2054	12	Big Lime						
2168	Pearsonia SE	27N-8E	4/65	2480	10	Burgess SS	13	38	150,097			
2183	Penn Creek	23N-8E	1922			Bartlesville SS	21	35	486,241			106,446
						Mississippian LS						
			11/57	2410	12	Burbank SS						
2201	Pershing	24N-9E	3/17	2033	30	Bartlesville SS	430	35	5,928-740	496	266,838	1,215,008
		24N-10E	1/57	2072	14	Burgess SS						
		25N-9E		1400	10	Wayside SS						
		25N-10E		1520	10	Big Lime						
				1700	10	Oswego LS						

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
2202	Pershing E	25N-10E	7/49	1982	21	Bartlesville SS	28		165,295	9,527	5,427	
2203	Pershing NE	25N-10E	1950	1906	37	Bartlesville SS	1		562			
2206	Pettit SE	23N-8E	12/61	1368	6	Peoples SS	1		1,036			
2207	Phillips Lake E	22N-6E	3/58	3212	4	Burgen SS (Simpson)		41	27,377			
	Piggot		1924			Burgess SS			9,776			
2225	Pioneer	20N-11E	1920			Bartlesville SS	26	34	308,175			
		21N-11E				Simpson SS						
2226	Pioneer E	20N-11E	3/49	2259	28	Hominy SS (Simpson)	2	39	127,849			
		21N-11E		2349	15	Arbuckle						
2227	Pioneer S	20N-11E	1951	2057	16	Bartlesville SS	1		3,386			
				2181	10	Burgess SS						
				2195	5	Mississippian LS						
	Platter		1939									
2254	Ponca City SE	25N-2E	7/65	3835	4	Mississippian Chat	3	40	56,516		12,487	
	Pond Creek		1912	1600	10	Penn SS	78		2,251,686			
						Mississippian LS						
2257	Pond Creek NW	29N-10E	3/56	1800	27	Mississippian Chat	7	33	1,292,608			
	Pond Creek SW		1/56	1760		Mississippian Chat			24,028			
2287	Prairie Springs NW	29N-8E	11/79				14		81,238			
2288	Prairie Springs SW	29N-9E	6/58	1597	8	Wayside SS	30	34	386,630			190,812
			8/73	2050	33	Mississippian Chat (Gas)						
2289	Prairie Springs W	28&29N-8E	8/79				19		140,986		22,586	1,525
2297	Prue	21N-10E	1920	1990	25	Bartlesville SS	29	36	217,775		427,216	22,105
				1648	20	Prue (Gas)						
				1495	20	Oswego LS						
				2450	20	Simpson SS						
2307	Quapaw	24N-11E	1914	1420	10	Oswego LS	269	34	2,001,591		1,228,333	1,163,090
		25N-10E		1600	20	Skinner SS						
		25N-11E		1630	50	Bartlesville SS						
			6/1967	2105	10	Arbuckle						
2320	Ralston NE	24N-6E	9/56	2867	7	Skinner SS	2	34	54,670			
2324	Ramona	24N-12E	1911	934	100	Big Lime	157	33	1,708,240	221	3,281,281	154,239
				1687	20	Bartlesville SS						
				1753	20	Burgess SS						
2346	Red Bluff	12N-11E	7/50	1904		Burgess SS	1	36	109,976			
						Mississippian LS						
						Hominy SS (Simpson)						
2348	Red Bluff N	21N-11E	1924	1863	2	Bartlesville SS	8		108.979			2,264
2347	Red Bluff NE	21N-11E	8/60	1896	10	Tucker SS						

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
2367	Remington	25N-5&6E	1/49	2970	10	Mississippian Chat	40	41	2,930,604			
				2820	15	Blurbank SS						
						Burgess SS						
	Burbank N		8/61	3004	5	Burbank SS	2		1,886.071			
	Remington NW		1/56	3094	8	Mississippian Chat						
	Remington SW		1/57	2176	6	Osage-Layton SS	1	35	2,206			
	Revard S		2/57	1640	12	Bartlesville SS	9	38	38,342			
2405	Ritberger E	26N-8E	7/59	2441	3	Mississippian Chat	5	38	71,828			
2406	Ritberger SE	26N-8E	9/58	2300	10	Skinner SS	1	39	389			
2407	Ritberger SW	26N-8E	6/56	2540	10	Mississippian Chat	8	38	99,388			
	Ross Day		9/51	3374	10	Mississippian LS	2	40	5,777			
2442	Ross Day E	24N-4E	5/56	3375	8	Mississippian Chat	25		992,862			
2443	Ross Day N	24N-4E	6/73	3484	4	Mississippian Chat						
2444	Ross Day NE	25N-4E	2/67	2432	12	L. Layton SS	1		19,824			
2445	Ross Day S	24N-4E	5/58	3510	4	Mississippian Chat	3	42	10,970			
2446	Ross Day SE	24N-4E	6/77	3230	47	Mississippian Chat						
2447	Ross Day SW	24N-4E	10/77	3465	21	Burbank SS						
			11/77	3544	16	Mississippian Chat						
2569	Shall Lake N	20N-11E	2/50	2249	16	Burgess SS	2	39	19,155		165,251	
2570	Shell Lake NW	20N-10E	10/47	2193	20	Tucker SS	13		411,173			
				1935	9	Red Fork SS						
				1960	20	Bartlesville SS						
				2550	30	Wilcox SS (Simpson)						
2572	Shidler E	27N-6E	1/55	2714	12	Prue SS	1	36	14,450			
	Shidler NW		12/80				2		8,166			
2574	Shidler SE	27N-7E	3/72	2899	10	Mississippian Chat	4	39	22,914		24,024	
2582	Signal Hills	23N-9E	4/44	430	20	Okesa SS	23		306,346		849,176	670,620
						Cleveland SS						
						Hominy SS (Simpson)						
						Arbuckle						
2602	Skiatook	22&23N-12E	2/11	1370	20	Bartlesville SS	46	34	479,022		355,477	266,877
						Burgess SS						
						Mississippian LS						
	Solomon Creek		1939	2722	37	Skinner SS	1	30	18,980			
2643	St Johns N	25N-7E	8/55	2466	6	Skinner SS	4	37	7,785			
	St Johns W		6/52	2657	66	Burbank						
2692	Strohm	25N-7E	8/56	2693	13	Mississippian Chat	6	40	291,007			
2693	Strohm E	25N-7E	6/55	2645	8	Mississippian Chat	3	39	34,303			
2694	Strohm N	25N-7E	5/54	2550	16	Skinner SS	11	40	259,671			
				3010		Ordovician						
				2620	10	Mississippian Chat						
2695	Strohn NW	26N-7E	2/64	3088	5	Arb Lime (?)	2		1,883			
2714	Sundown SW	22N-10E					3		235			

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
2715	Sunny Slope NE	23N-6E	8/57	3170	11	Simpson SS	14	39	592,528			5,136
			12/57	2726	20	Skinner SS						
				3138	11	Wilcox SS (Simpson)						
2716	Sunny Slope SW	22&23N-6E	6/58	3152	5	Wilcox SS (Simpson)		43				
2717	Sunset	22&23N-9E	1919			Bartlesville SS	39	36	311,817			8,730
						Hominy SS (Simpson)						
						Arbuckle						
2718	Sunset NE	23N-9E	6/28	2524	3	Simpson SS	8	39	224,481			1,145
			7/55	2130	8	Bartlesville SS						
2719	Sunset W	22N-9E	8/77				4		36,897			
2765	Tidal-Osage	24N-8&9E	1916	2450	10	Ordovician	294	36	13,840,963			942,207
				460	20	Okesa SS						
				1600	20	Big Lime						
				1700	15	Peru SS						
				1800	20	Oswego LS						
				2150	40	Bartlesville SS						
				2250	15	Burgess SS						
			7/60	2168	15	Mississippian LS						
2808	Turkey Creek	29N-10E	1917	1080	15	Wayside SS	102	33	470,919		174,589	
			2/52	1720	10	Burgess SS						
						Mississippian LS						
						Stray SS						
	Turkey Creek W		1917	1100	20	Wayside SS	57		294,476			
2819	Twin Creek	21N-9&10E	11/28	2071	27	Bartlesville SS	34		553,826			
	Unnamed Osage		3/76				4		27,368		2,265,247	
	Watkins						4					
2999	Whitetail	26N-9E	1919			Stray SS	218		3,394,742		273,671	278,724
		26N-10E				Bartlesville SS						
		27N-9E		1735	20	Mississippian Chat						
		27N-10E		1750	20	Mississippian LS						
			1/56	2093	3	Arbuckle						
			12/56	1526	13	Big Lime						
			12/56	880	12	Layton (Gas)						
	Whitetail N		6/35	2106	24	Mississippian Chat	24	39	53,684			
3000	Whitetail NW	28N-9E	4/60	1556	14	Wayside SS	5	38	46,251			
	Whitetail S		6/54	1927	15	Mississippian Chat	12	40	18,866			
				2612	8	Mississippian LS						
3001	Whitetail W	27N-9E	12/59	2060	14	Mississippian Chat	7	36	5,205	1,786	302,763	
3007	Widlcat Hill	21N-7E	6/38	1932		Bartlesville SS (Gas)	36		188,472		1,683,194	26,666
			8/45	2445	15	Tyner SS (Simpson)		35				
			9/45	2000		Hominy Wilcox SS (Simpson)						

Table 4-1 Osage County, Oklahoma, Producing Trends

Fld. No.	Field Name	Location (twp., rge.)	Disc. Date	Top of Pay (ft)	Net Pay (ft)	Producing Formation	No. Wells	API Grav	Cum. Oil Production (BBL)	Cum. Cond. (BBL)	Dry Gas Cum. (MCF)	Csghd. Gas Cum. (MCF)
3008	Wildhorse	21N-10E	8/12	3550		Penn SS	639	36	11,206,282			62,704
		22N-10E				Orcovician						
		22N-11E	6/75			Burgess SS						
						Bartlesville						
						Taneka SS						
						Mississippian Chat						
						Red Fork SS						
3009	Wildhorse N	22N-10E	1919			Penn SS	24	35	80,878		327,399	76,109
						Ordovician						
			9/75		34	Bartlesville SS						
3010	Wildhorse NE	22N-10E	5/72	1703	15	Bartlesville SS	13		348,428			
			3/66	2240	6	Arbuckle		40				
3011	Wildhorse S	21N-10E	1923			Penn SS	27	35	703,004			610,430
						Tyner SS (Simpson)						
						Arbuckle						
	Wildhorse SE		12/85				1		97,546			148,372
3012	Wildhorse W	22N-9E	8/40			Arbuckle	1		97,546			148,372
3055	Woolaroc	24&25N-11E	1917	1720		Skinner SS	203	36	7,592,912		1,274,660	926,790
		25N-12E		1800	40	Bartlesville SS						
3063	Wynona	24N-9E	1905	2050	100	Bartlesville SS	171	35	20,901,234		32,197	542,737
		24N-10E	1917	1600	60	Miss-Oswego LS						
				1050	30	Layton SS						
				1375	20	Wayside SS						
			1919	1520	30	Big Lime						
				2281	20	Mississippian LS						
				2506	20	Ordovician						
			1/69	2267	5	Mississippian Chat						
3064	Wynona S	23N-10E	11/51	2129	15	Bartlesville SS	13	36	11,176			
	X-686		11/48	2542		Hominy SS (Simpson)	6	236,276				

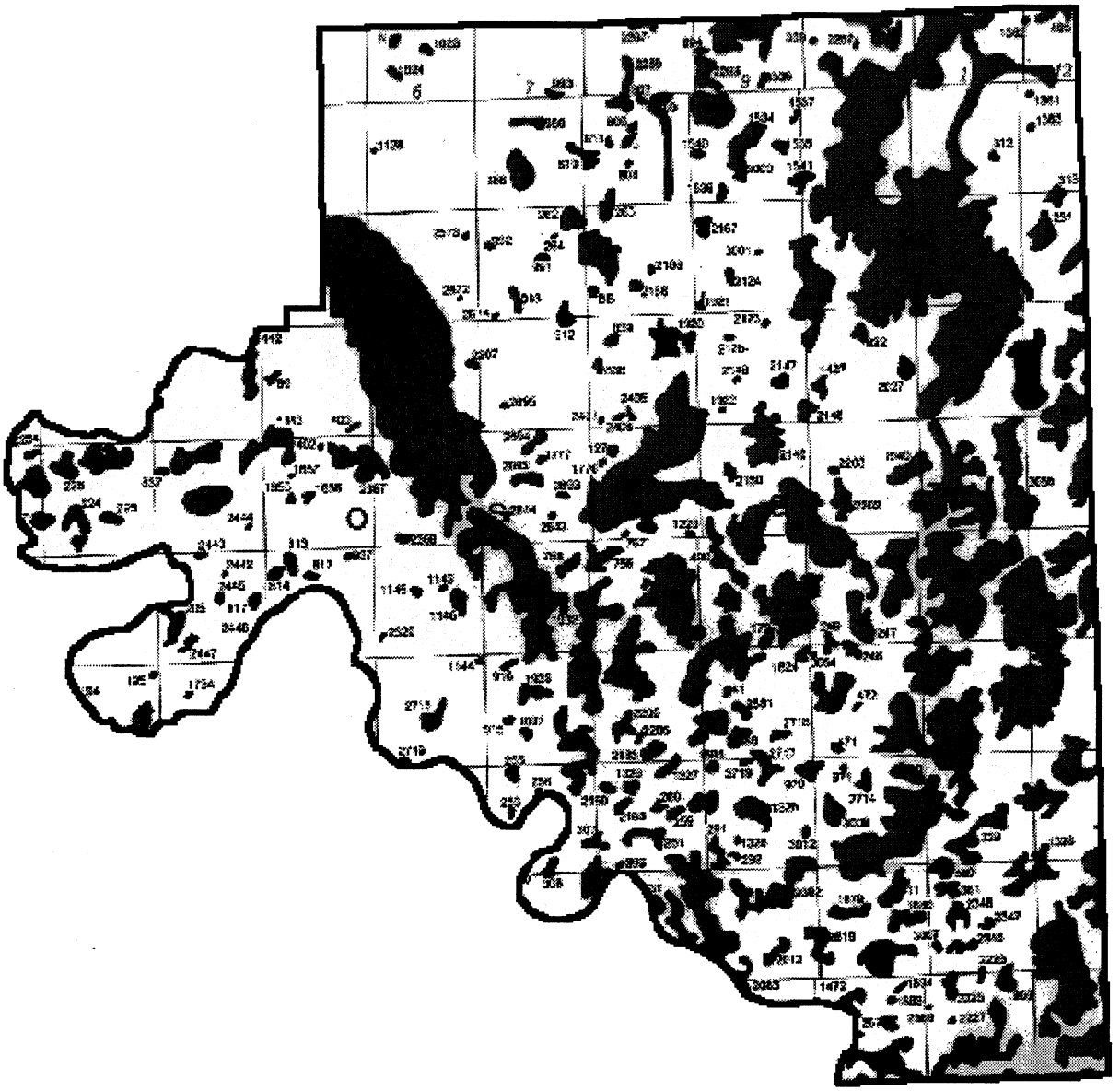


Figure 4–2 Map of Osage County, Oklahoma, Showing the Locations of All Hydrocarbon-Producing Fields.

southeast. The orientation of the older producing units in this region strengthens the conclusion that the northwest-southeast fracture orientation is the older set of structures and most likely to be associated with older trends in the region.

Regional stratigraphic trends were investigated and analyzed by examination of electric logs, driller's logs, and production data. Cross sections were constructed from the electric logs and

driller's log data to show regional and local stratigraphy and trends. Pennsylvanian sediments make up approximately 60% of the stratigraphic section in the study area, with Mississippian, Ordovician (Simpson), Ordovician-Cambrian (Arbuckle), and granite wash sediments making up the rest.

The regional cross sections show that Pennsylvanian sandstones vary rapidly in thickness across the county and that individual beds are largely discontinuous (Figures ~~4–3–4–4~~). Pennsylvanian sandstones generally produce hydrocarbons from stratigraphic traps in Osage County. These sandstones are largely valley-fill, channel sandstones deposited by streams. Reservoirs in these sandstones are commonly multiple-stacked point-bar units which were deposited in a fluvial-dominated deltaic environment. Continuity in these sands can be variable because they are point-bar deposits.

Local cross sections (e.g., Figure 4–5) were constructed using driller's logs and electric logs. The cross sections that extend across the prospect areas show that Pennsylvanian sandstones thin onto high structures and thicken off the flanks of these structures. This is to be expected because valley-fill, channel sandstones attempt to fill the low areas between structures or on the flanks of structures. In a similar manner, older Paleozoic sediments thin over basement structures. Precambrian granite hills and ridges form the core of the older structures in this region. The granite was highly eroded, but had not been fully peneplained, leaving a series of hills and ridges at the end of the Precambrian. Further erosion occurred during the Cambrian, forming a highly variable cover of granite wash which lapped up on the erosional hills and became thickest in the valley areas adjacent to the hills. Arbuckle and Simpson carbonates and clastics, as well as Mississippian carbonates and cherts, thin over the granite hills. These sediments also thicken off structure. Pinch-outs in the older Paleozoic sediments and in structures formed over eroded granite hills commonly trap hydrocarbons, creating prolific petroleum producing reservoirs.

Ten potential study areas were preliminarily selected for review and analysis prior to subsurface mapping. Four final areas were then selected for mapping and prospect development based on the initial review and analysis of the data, combined with requirements for lease availability, sufficient well control, availability of electric and driller's logs, and the presence of hydrocarbon shows in older Paleozoic sediments (Mississippian Sands, Simpson, and Arbuckle units). The six areas not selected will be re-evaluated for 3-D seismic data acquisition in the future because they still have potential for having older structures. Of the four final study areas, one has well control that includes penetration of the Precambrian granite basement. This area was mapped on three horizons (the top of Mississippian, Simpson, and Arbuckle). Two study areas has enough well control for mapping the top of the Mississippian and the Simpson formation, and the final area had sparse Simpson control, but excellent information of the Mississippian and may hydrocarbon shows. This area was mapped on top of the Mississippian.

Electric logs were correlated, and the tops of the older Paleozoic sediments (Mississippian, Simpson, and Arbuckle) were selected for mapping. Driller's logs were used in conjunction with electric logs to pick tops of the older Paleozoic units. It was sometimes difficult to pick the contact between the base of the Simpson carbonates and the top of the Arbuckle carbonates on

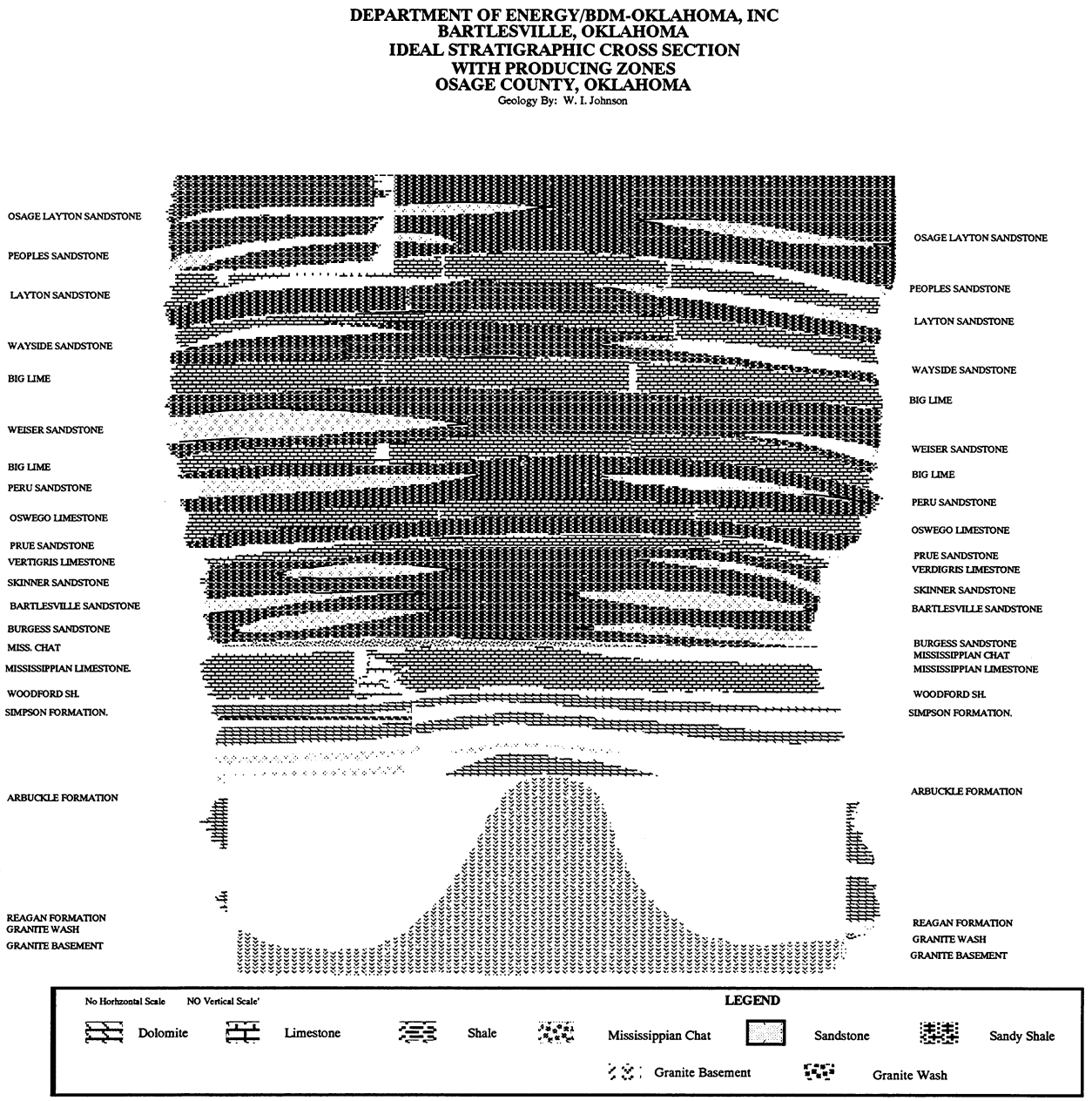


Figure 4–3 **Ideal West-East Stratigraphic Cross section with Producing Zones, Osage County, Oklahoma.**

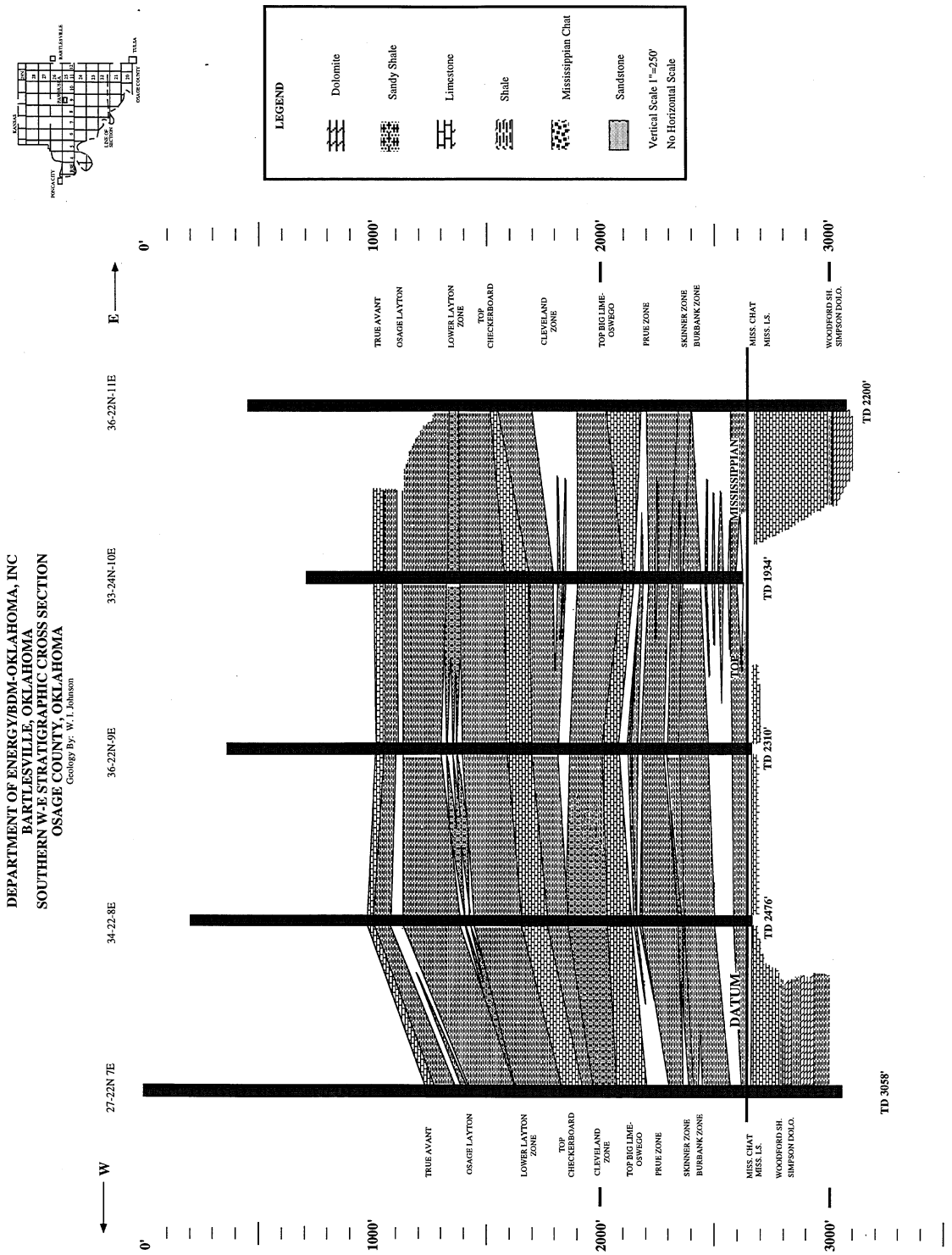


Figure 4–4 Southern West-East Stratigraphic Cross Section, Osage County, Oklahoma.

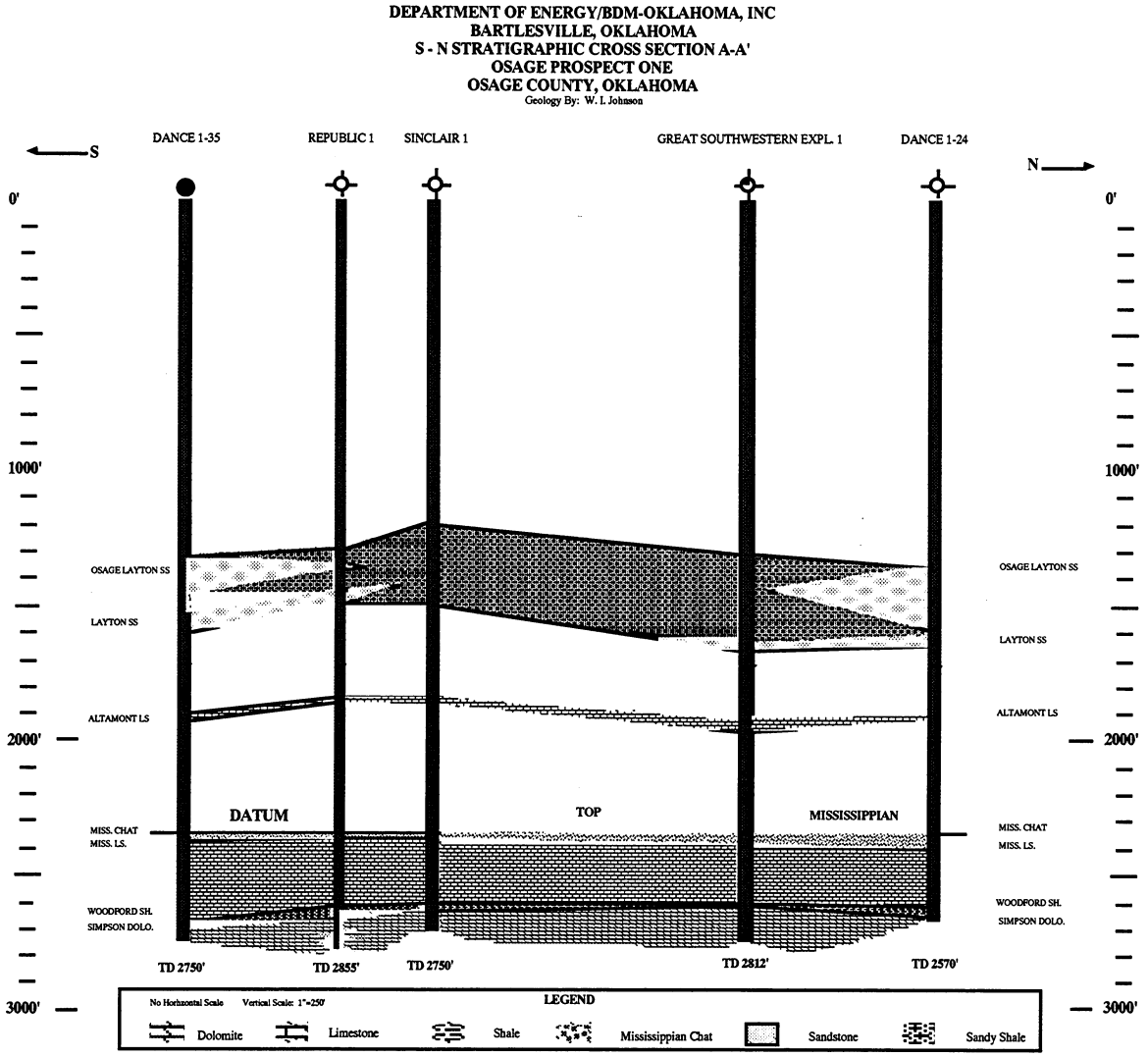


Figure 4–5 South-North Stratigraphic Cross Section A-A′, Osage prospect One, Osage County, Oklahoma.

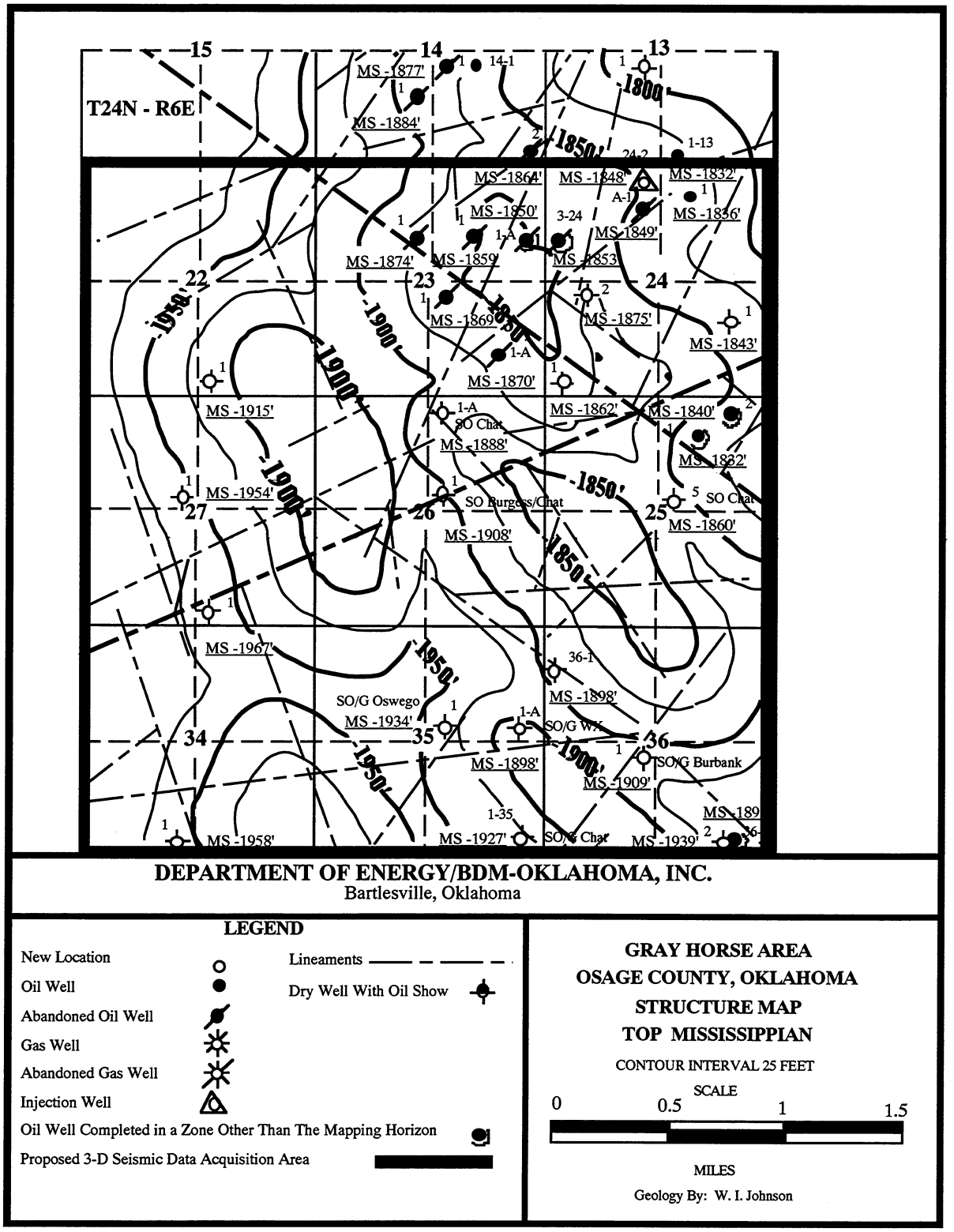
electric logs because they have approximately the same sonic velocity and electric log signature, and both are dolomite. In these cases, driller's logs were used along with the electric logs to pick tops. In some cases, the operators of the wells mistakenly identified the first dolomite below the Woodford Shale as the top of the Arbuckle, when the unit should have been identified as Simpson. The Woodford Shale, immediately overlying the Simpson, has a distinct signature on a gamma ray log and is made up of black shale. In most cases, the Woodford Shale was an easily recognizable log marker.

The top of the Mississippian Chat is used as the mapping marker for the top of the Mississippian. The Chat is made up of limestone and chert. When the Chat is encountered by a drillbit, the drillpipe bounces and shakes, and the rig can rattle and shake because the brecciated chert and limestone present an irregular drilling surface made up of both soft and hard rock. It is this "chatter" which gives the formation its name. The contact between the base of the Chat and the top of the main body of the Mississippian limestone can also be difficult to distinguish. Driller's logs used in conjunction with electric logs make correlations and picking the contact between the Chat and the main body of the Mississippian limestone much easier.

Sub-sea formation tops for the mapping horizons were posted on base maps of each area, fractures and lineaments from the previously discussed BDM-Oklahoma analysis were plotted on the same base maps, and structure maps were constructed by BDM-Oklahoma staff. The structure maps are an interpretation of all of these data, including the results of the fracture/lineament analysis.

BIA maps of the four final study areas show some structure on top of the Mississippian, but are based on out-of-date information and concepts and do not show the structural trends developed by the fracture and production analyses of the region. For this reason, new structure maps (Figures 4–6–4–8) were constructed on top of the Mississippian, Simpson, and Arbuckle in the selected areas where sufficient subsurface control was available. Fractures in each of the selected areas were plotted on the structure maps based on the fracture/lineament study and analysis performed by BDM-Oklahoma staff. Lineaments and fractures in the selected areas generally demonstrate multiple intersections of northwest-southeast fractures with other fractures of varying orientations. Hydrocarbon shows and production in Pennsylvanian, Mississippian, Simpson, and/or Arbuckle sediments were noted by wells on the maps.

After the completion of the mapping of the four selected areas (Figures 4–9–4–13), an analysis was performed to select the area with the highest potential for having multiple structures that may contain commercial quantities of hydrocarbons in older Paleozoic sediments, structures that can be mapped by a 3-D seismic survey, over the structures, topography that allows easy access by vehicles used in 3-D and a relatively unwooded area. A 9-mi^2 area in the Gray Horse area (Sect. 22–27, 34–36, T25N, R6E) was selected for the 3-D seismic data acquisition based on the selection criteria. The three lower-ranked prospect areas not selected for 3-D seismic data acquisition in the FY-95 program will be re-evaluated at a later date for data acquisition in future 3-D seismic data research programs.



DEPARTMENT OF ENERGY/BDM-OKLAHOMA, INC.
Bartlesville, Oklahoma

LEGEND

New Location
Oil Well
Abandoned Oil Well
Gas Well
Abandoned Gas Well
Injection Well
Oil Well Completed in a Zone Other Than The Mapping Horizon
Proposed 3-D Seismic Data Acquisition Area
Lineaments
Dry Well With Oil Show

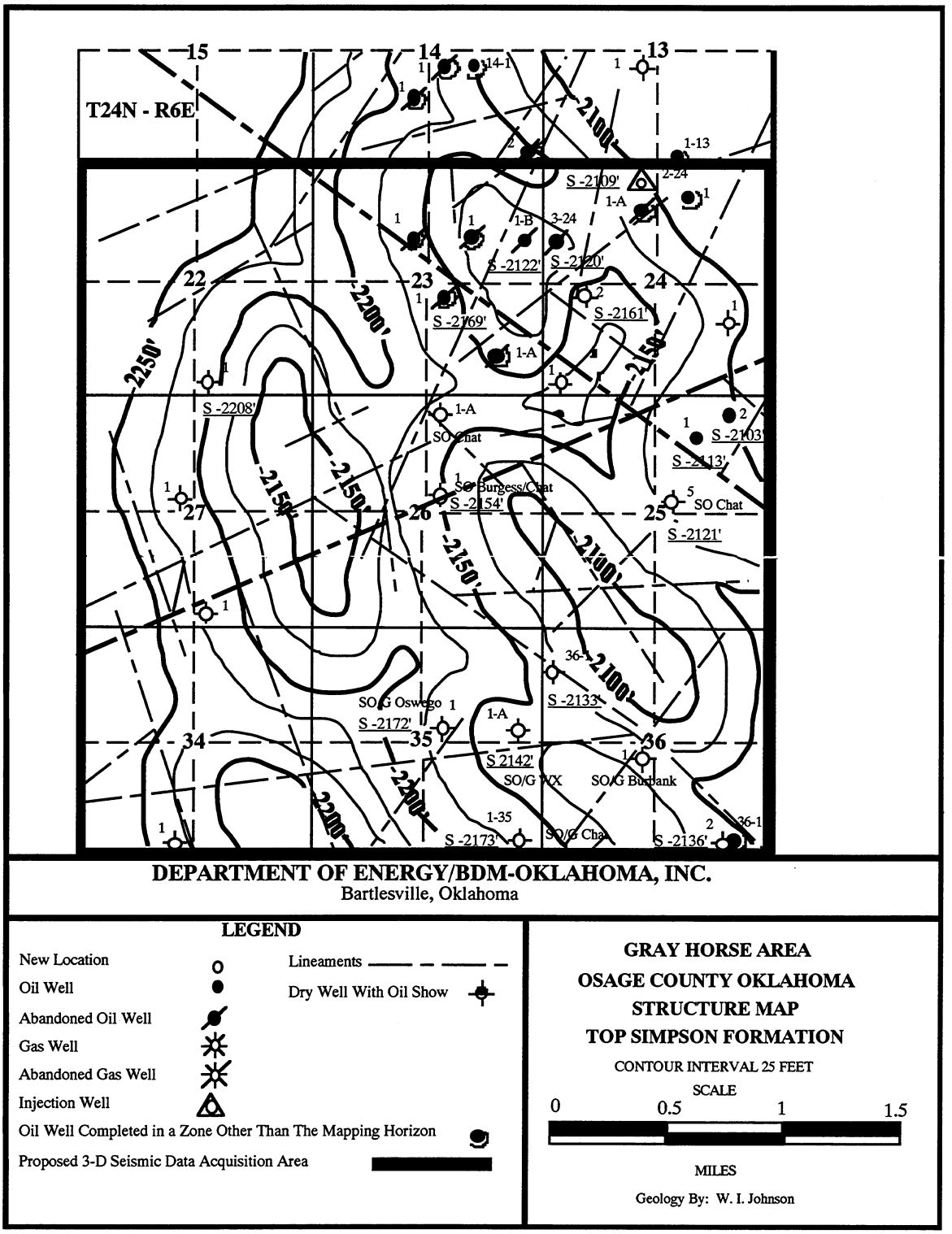
GRAY HORSE AREA
OSAGE COUNTY, OKLAHOMA
STRUCTURE MAP
TOP MISSISSIPPIAN

CONTOUR INTERVAL 25 FEET

SCALE
0 0.5 1 1.5
MILES

Geology By: W. I. Johnson

Figure 4–6 Structure Map of the Top Mississippian, Gray Horse Area, Osage County, Oklahoma.



DEPARTMENT OF ENERGY/BDM-OKLAHOMA, INC.
Bartlesville, Oklahoma

LEGEND

New Location
Oil Well
Abandoned Oil Well
Gas Well
Abandoned Gas Well
Injection Well
Oil Well Completed in a Zone Other Than The Mapping Horizon
Proposed 3-D Seismic Data Acquisition Area
Lineaments
Dry Well With Oil Show

GRAY HORSE AREA
OSAGE COUNTY OKLAHOMA
STRUCTURE MAP
TOP SIMPSON FORMATION
CONTOUR INTERVAL 25 FEET
SCALE
0 0.5 1 1.5
MILES
Geology By: W. I. Johnson

Figure 4–7 **Structure Map of the Top Simpson Formation, Gray Horse Area, Osage County, Oklahoma.**

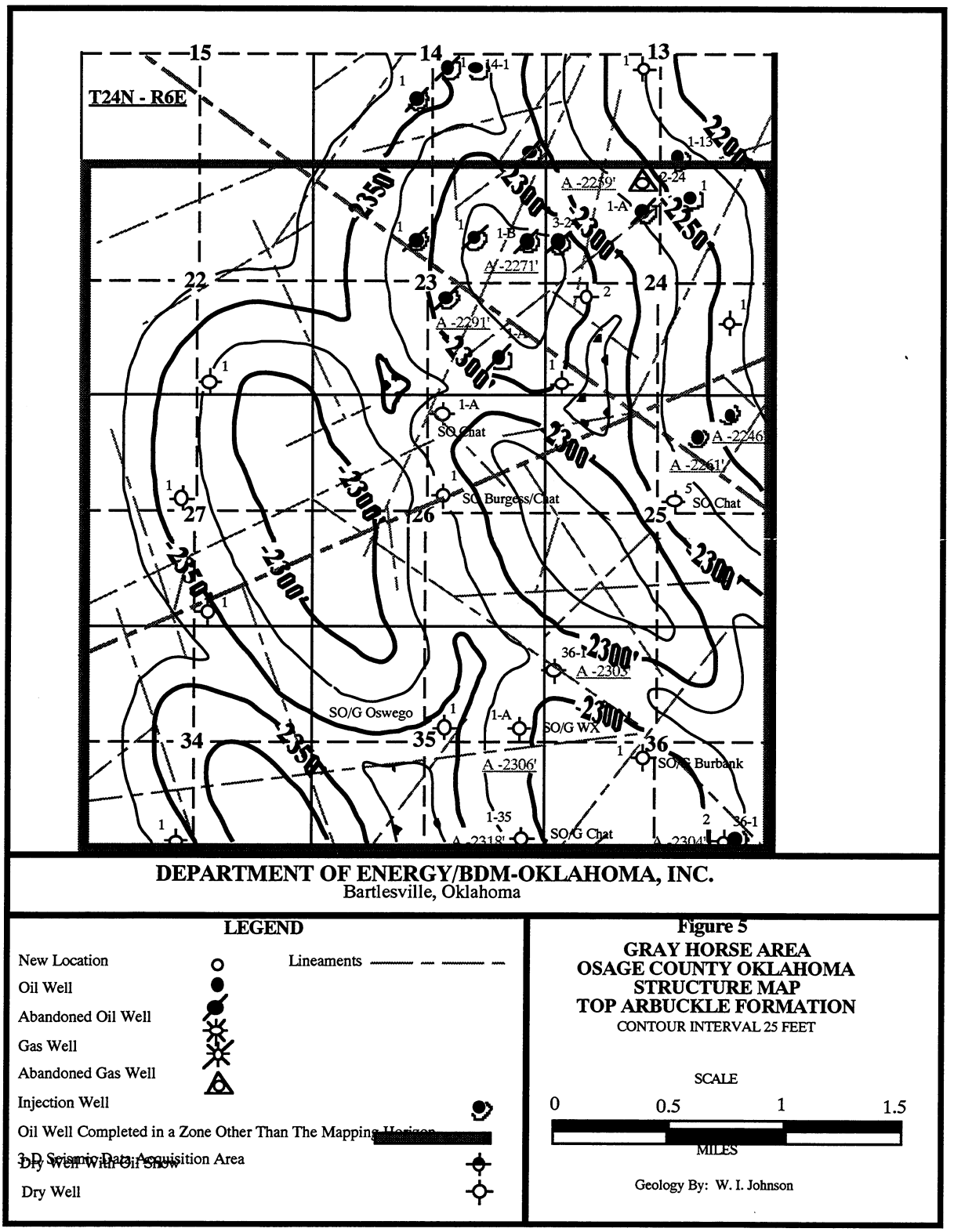


Figure 4–8 Structure Map of the Top Arbuckle Formation, Gray Horse Area, Osage County, Oklahoma.

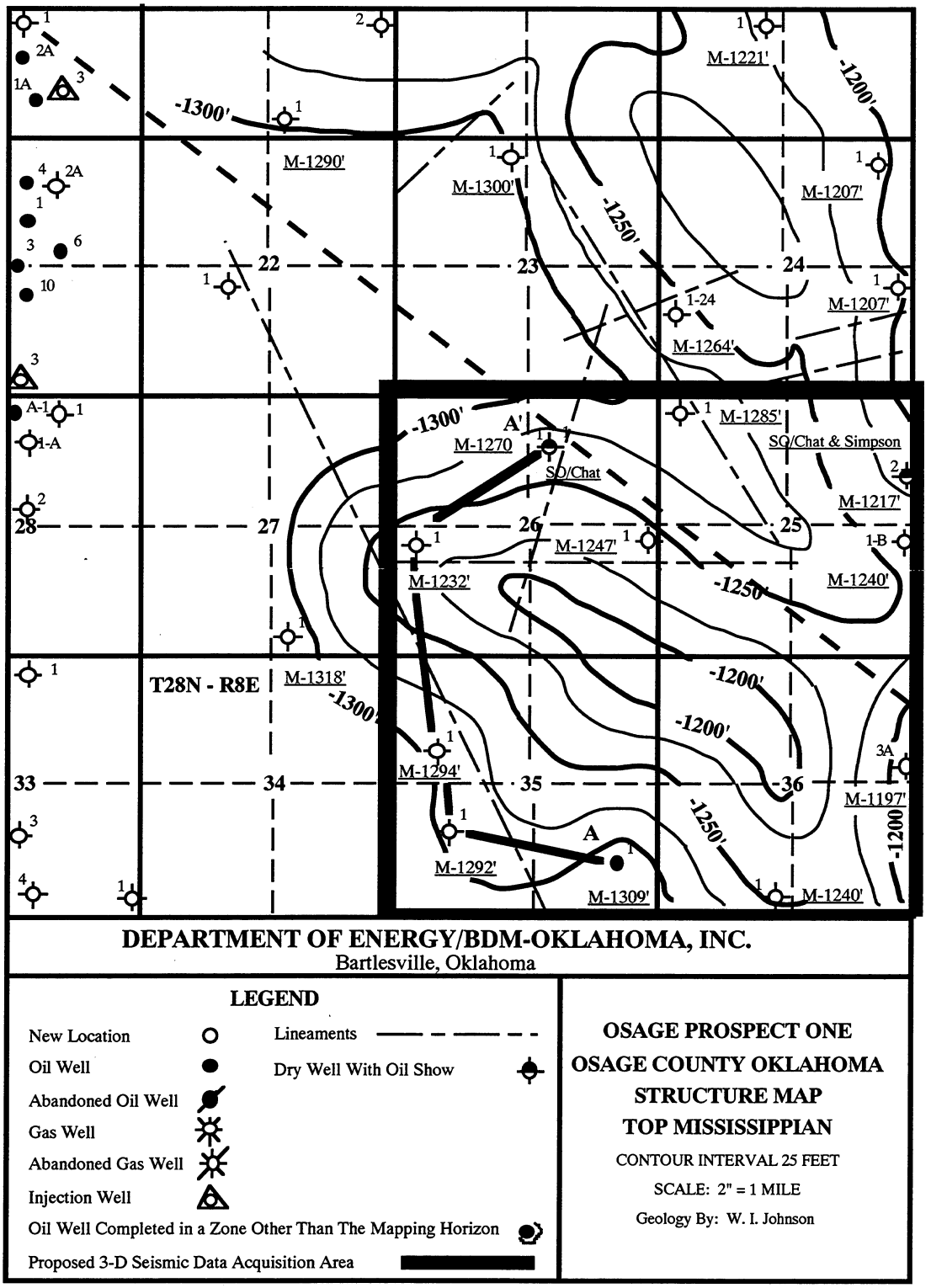


Figure 4–9 Structure Map of the Top Mississippian, Osage Prospect One, Osage County, Oklahoma.

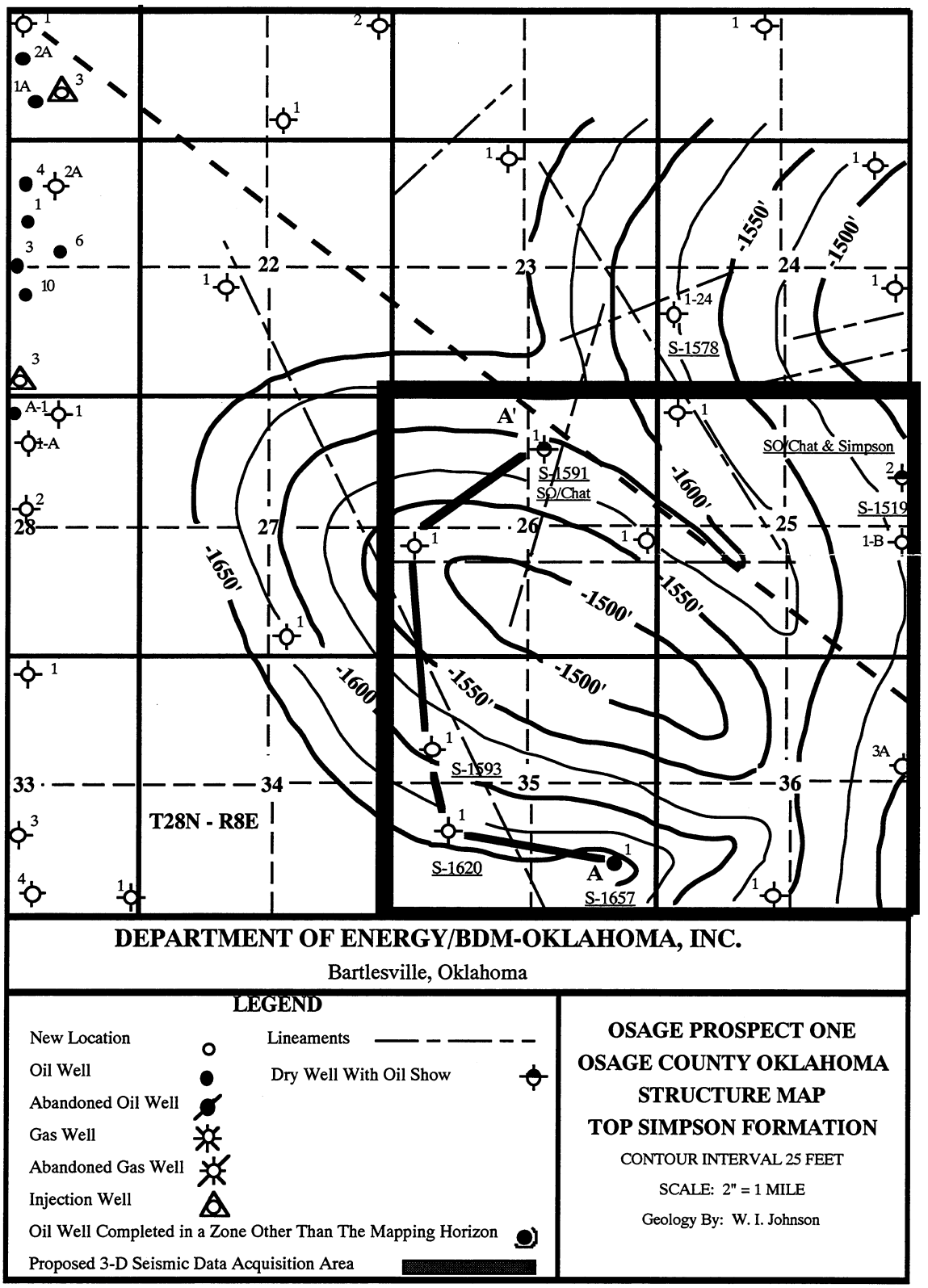


Figure 4–10 Structure Map of the Top Simpson Formation, Osage Prospect One, Osage County, Oklahoma.

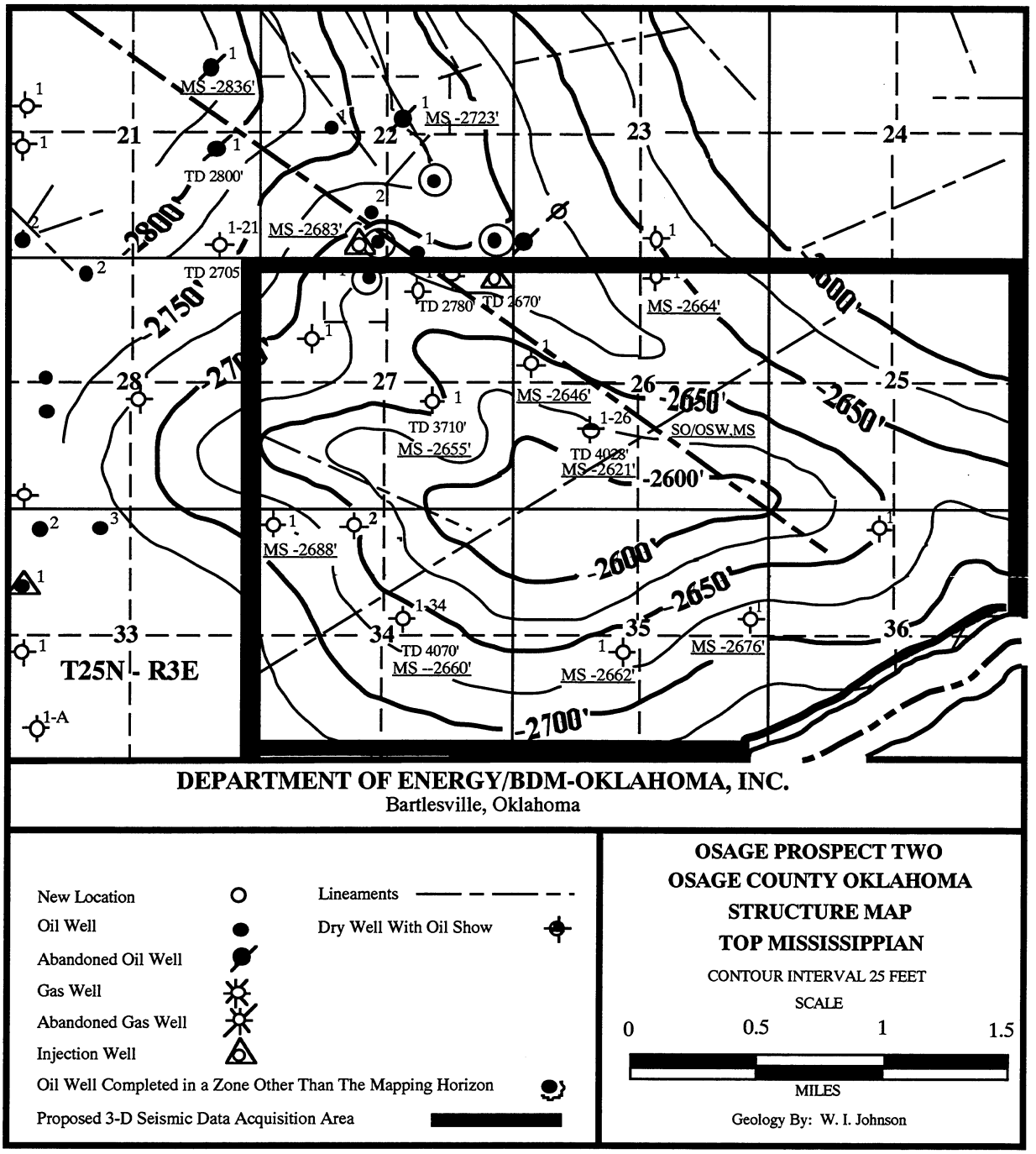


Figure 4–11 Structure Map of the Top Mississippian, Osage Prospect Two, Osage County, Oklahoma.

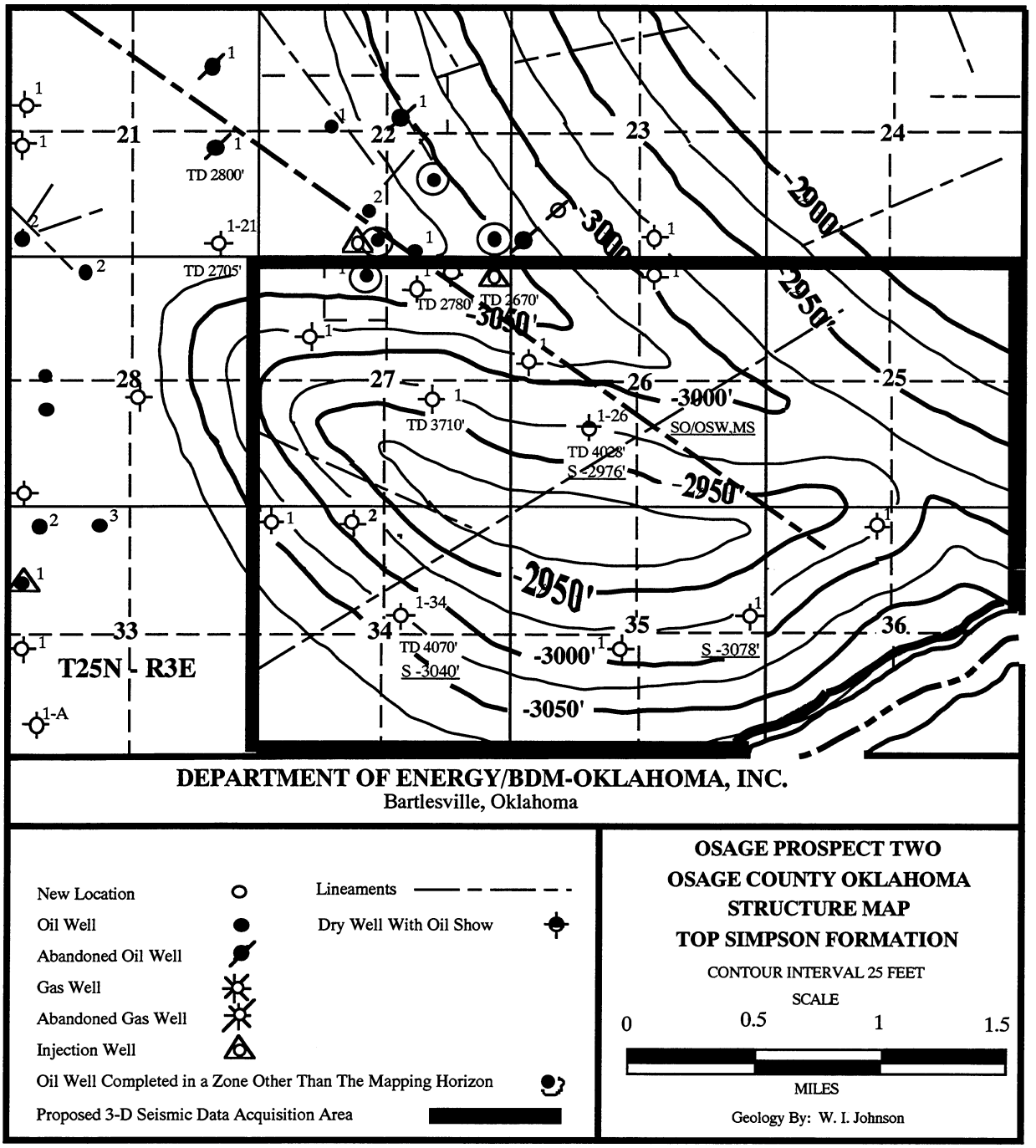


Figure 4–12 Structure Map of the Top Simpson Formation, Osage Prospect Two, Osage County, Oklahoma.

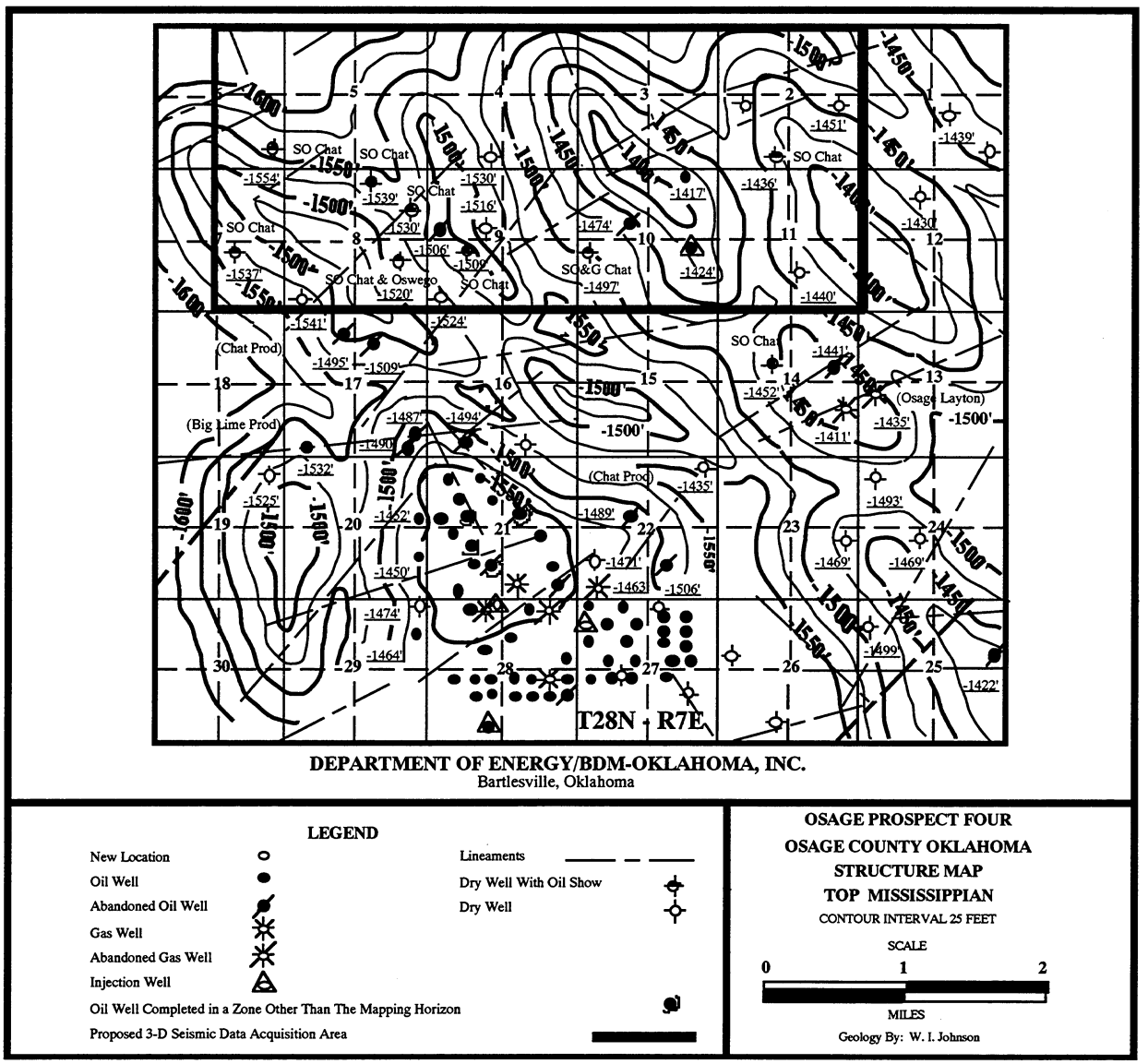


Figure 4–13 Structure Map of the Top Mississippian, Osage Prospect Four, Osage County, Oklahoma.

5.0 SEISMIC SURVEY DESIGN

The clastic and carbonate producing reservoirs in the Mississippian in Osage County are similar to those typically encountered in the highly productive Pennsylvanian cyclic sedimentation. 3-D seismic data will be used for the identification of subtle structural and stratigraphic traps (including sand pinch-outs, unconformities, and channel sandstones) expected to be present in the prospect area. The shallow lithology in the study area will be predominately a mix of sandstone, limestone, and shale. Depths to the shallowest targets, in the Mississippian section, will be about 1,500 ft. The deepest targets will be pinch-outs of granite wash and basal Cambrian sandstones against highs on the Precambrian basement at various depths down to approximately 3,900 ft.

Fracture studies from aerial photographs indicate two dominant directions of fracture alignment: one extending northeast-southwest and the other northwest-southeast. The later direction correlates with the alignment of deeper structures that are the primary exploration targets. The seismic lines will be aligned at right angles to this direction (i.e., northeast-southwest). The target formations generally have low dips (less than 5°).

Critical components in the recording of high-resolution seismic data include:

- Amplifiers with low system noise and a large dynamic range (around 120 dB and a precision of 12 or more bits)
- Filters which condition the signal (such as the preemphasis filter for suppression of high-amplitude, low-frequency noise to boost low-amplitude, high-frequency signals)
- A good A/D converter and digital data storage devices
- An adequate number of recording channels for a high resolution, intensive survey

A critical element of the data recording system is the seismometer system. The seismometers must be capable of recording high-frequency, broad-band data with integrity. Detectors for this survey should have high natural frequencies to aid suppression of low frequencies, so that recorded ground roll can be reduced and the relative amount of high-frequency information increased.

Expected signal frequencies for the survey will be in the range of 20–100 Hz. Two important objectives will be to record a broad band of frequencies and to preserve very high frequencies for this investigation of subtle stratigraphic traps.

In order to record a broad band of frequencies with a very high frequency content, special attention must be given to certain critical aspects of field survey operations (such as geophone-ground coupling, accurate location surveying, etc.) that are crucial for the acquisition of high-resolution data. A short noise test will be carried out at the onset of the survey to determine the noise characteristics of the soil, shallow rock, and ambient environment in the area for designing

geophone and shot arrays for noise attenuation. Twelve geophones per group, with geophones laid out 6 ft. apart, achieved reasonable ground roll attenuation in one of the past seismic surveys in this area.

The primary survey parameters which have been selected thus far are:

- The bin size for the survey should be approximately 110 × 110 ft.
- The fold will be approximately 30.
- The target depths for the survey will range from a minimum of 1500 ft. to a maximum of 4000 ft.
- The sample rate will be 2 ms.
- The record length will be 3s.
- The offset ranges will be minimum of 75 ft. and a maximum of 5000 ft.
- The energy source will be vibroseis with a sweep frequency of 120–128 Hz (nonlinear downsweep 9 dB) and sweep length of 10s. The contractor should consider employing more than one vibrator to improve survey efficiency.

Design of geophone and shot arrays will be done after completion of the noise test, for noise attenuation and to maximize the signal-to-noise ratio.

The shot and receiver spacings will be approximately 300 ft., but other combinations of shot and receiver spacings are acceptable for the desired coverage if they can be used without sacrificing the details of coverage.

The source and receiver line spacings will vary, depending upon the number of channels available for recording. Since a system with a large number of channels will considerably reduce the number of shots per square mile, the availability of a larger number of channels will reduce the necessary survey time and the overall cost of survey. Therefore, at least 240 recording channels will be desirable.

A swath or a full-range 3-D template design or some variation is recommended, although this may be modified to have several source traverses in the true 3-D manner if this is necessary to get more azimuths and higher fold. However, other survey designs may be acceptable if they satisfy the data-resolution specifications mentioned previously.

6.0 SUMMARY

Many seismic operators believe that the current costs for 3-D seismic operations have dropped to the point where 3-D surveys can be run efficiently and cost-effectively by small operators in certain areas. To determine current acquisition procedures and costs and to further the goals of the President's Initiative for Native Tribes, a seismic-survey project is to be conducted on Osage tribal lands in Osage County, Oklahoma. The project will take place in five steps: (1) geological review, (2) development of a comprehensive plan to test and evaluate 3-D seismic, (3) the 3-D seismic pilot test, (4) evaluation of the survey design, test results, and usefulness (including economic usefulness), and (5) technology transfer to operators.

The geology of Osage County has been reviewed both in terms of structure and sedimentary history in order to guide the 3-D seismic program to favorable locations for unidentified hydrocarbon deposits.

An analysis of surface fractures and lineaments also was performed to see if surface fracture patterns could give an indication of subsurface trends and especially of the location of hydrocarbon deposits. The surface-fracture analysis consisted of mapping and digitizing surface and subsurface features, investigating the correlation between surface and subsurface features, identifying subsurface-structure indicators, and delineating priority locations for the 3-D seismic program. Regional-scale surface lineaments were mapped from Landsat images, whereas aerial photographs were used to map smaller-scale fracture traces. Rose diagrams of the surface lineaments, fracture traces, anticlinal axes, and the strikes of subsurface structures were then generated for the purpose of orientation analysis. This analysis and analysis of the lineament maps indicated a correlation between surface and subsurface features in Osage County. There also seems to be a correlation between these features and location of known hydrocarbon deposits. Priority indicators were then identified and used to select initial candidates for the site of the 3-D seismic program.

Using the information provided by the geological study and the surface fracture analysis, BDM-Oklahoma staff generated a series of maps and subsurface structural prospects in four areas of Osage County. The goal was the selection of a 9-mi^2 area for a 3-D seismic survey. Various maps and previous analyses were reviewed for indications of structural and producing trends. BDM-Oklahoma staff prepared maps showing the structure of producing formations and the outline of hydrocarbon-producing fields. Electric logs, driller's logs, and production data also were analyzed in order to produce cross sections showing regional and local stratigraphy.

Ten potential areas were selected for review and analysis prior to subsurface mapping. The final four areas selected for mapping and prospect development were chosen on the basis of the review and analysis of the data, unleased acreage in a 9-mi^2 area, good well control, the availability of electric and driller's logs, and hydrocarbon shows in older Paleozoic rocks

(including the Mississippian Sands, Simpson, and Arbuckle). A 9-mi^2 area near Gray Horse was selected for the first 3-D seismic acquisition based on the selection criteria.

Design of the 3-D seismic survey has begun. Survey parameters such as bin size, fold number, sampling rate, record length, offset ranges, and energy source are being established. A swath or a full-range 3-D template design or some variation of it, has been recommended. The final parameters will be selected once a contractor is chosen and initial field tests are performed.