THE DISTRIBUTION AND DEPOSITIONAL ENVIRONMENT OF THE SPIRO SANDSTONE, ARKOMA BASIN, HASKELL, LATIMER, AND PITTSBURG COUNTIES, OKLAHOMA

By

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CHAPTER I

ABSTRACT

The Spiro Sandstone in the area of study is thought to be a shallow marine sand deposited on the stable platform prior to the rapid subsidence of the Arkoma basin. This interpretation is based on the presence of fossils, limestone, burrows and bioturbation, and chamosite. The Spiro occurs in both channel and blanket-like geometries and is characterized by three groups of deposits: 1) sandstones with fossils and/or limestone bed(s), 2) medium- to coarse-grained sandstone with no visible fossils or limestone, and 3) limestone and a fossiliferous sandstone. In general the Spiro is thicker to the south and east in the area of investigation.

Porosity in the Spiro is both primary and secondary. Primary porosity was preserved in medium- to coarse-grained rocks due to chamosite grain coatings. Secondary porosity is due mainly to dissolution of chamosite pellets, with some dissolution of fossils and shale and siltstone clasts.

The Spiro is one of the main gas producing sandstones in the Oklahoma part of the Arkoma basin. In the area of study, as of January, 1988, the Spiro had produced 517 BCFG in the Kinta field, 590 BCFG in the Wilburton field, and 91

BCFG in the Red Oak-Norris field.

CHAPTER II

INTRODUCTION

The Spiro Sandstone is one of the main gas producing sandstones in the Oklahoma part of the Arkoma basin. The area of investigation includes 27 townships in the Arkoma basin north of the Choctaw fault (T4, R16 - 18E, T5 - 8N, R16 - 21E, including parts of Haskell, Latimer, and Pittsburg counties, Oklahoma)(Fig. 1). In the study area the Spiro is the main producer in the Wilburton and Kinta gas fields and a secondary producer in the Red Oak-Norris field.

Objectives and Methods

The purpose of this investigation is to determine the distribution, geometry, depositional environment, and diagenetic overprints of the Spiro Sandstone.

Subsurface information was obtained from induction logs, formation density logs, compensated neutron-formation density logs, sonic logs, and gamma ray logs from approximately 650 wells. This information was entered into a computerized data base and used in preparation and interpretation of various correlation sections, structural maps, and isopach maps. Base maps were generated by the

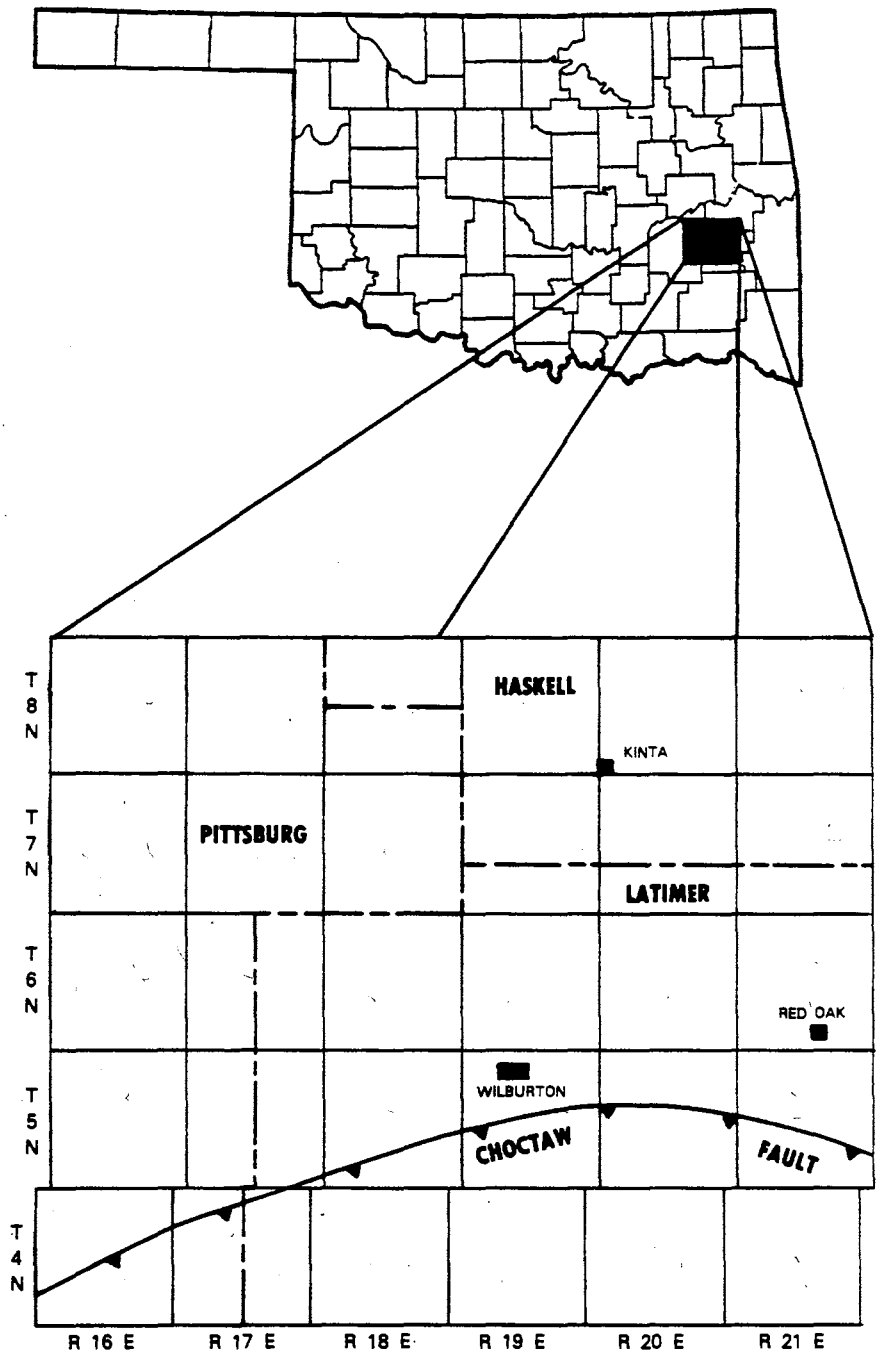


Figure 1 Location map showing study area and location of the Choctaw fault.

computer.

Internal features of the Spiro were determined through a detailed examination of 9 cores (Table 1), including the study of 46 thin sections, X-ray diffraction, and scanning electron microscopy. An estimate of the depositional environment was made from the integration of internal features, sandstone geometry, stratigraphic framework, and structural framework.

Previous Investigations

The Spiro Sandstone is named after the town of Spiro in LeFlore County, Oklahoma (Jordan, 1957). Production from the Spiro was first discovered in 1951 in the Superior Oil Company Allred No. 1 in Sec.18, T.8N., R.20E., Haskell County, Oklahoma (Woncik, 1962).

In his discussion of the Kinta gas field Woncik (1962) described the Spiro as a white, medium-grained, subangular sandstone with varying amounts of porosity due to different types of cement. Six (1962) discussed the Red Oak-Norris field and concluded that the Spiro was deposited over a large area and contains approximately 10% more calcite and dolomite and less clay than the Red Oak sand. Berry and Trumbly (1968) described the Spiro Sandstone in the Wilburton field as a shallow marine sandstone with an average thickness of 47 feet and a range from 31 tO 120 feet. Pittman and Lumsden (1968) used the Spiro to study the relationship between chlorite coatings on quartz grains

TABLE 1

SPIRO CORES INCLUDED IN THIS STUDY

LOCATION	NAME	CORED INTERVAL (feet)
10-4N-16E	Pan American Smallwood Unit No.1	11,678 - 11,736
9-4N-18E	Shell Mabry No.1-9	5,830 - 5,952 13,129 - 13,172
3-5N-19E	Pan American Reusch Unit No.1	11,467 - 11,523
25-6N-19E	Tenneco Arkansas Kraft No.1-25	13,840 - 13,896
21-6N-20E	Shell Jankowsky No.1-21	13,717 - 13,758
27-6N-21E	Mustang Lyons No.1-27	12,213 - 12,244
11-6N-21E	Midwest Free Unit No.1	11,818 - 11,890
32-7N-20E	Shell Jankowsky No. 1-32	9,799 - 9,839
31-8N-21E	Humble Burge No.1	6,623 - 6,677

and porosity. Lumsden et al. (1971), in their study of the sedimentation and petrology of the sandstone in the Oklahoma part of the Arkoma basin, divided the Spiro into eight separate facies with limestone, shale, and sandstone as end members and named the Foster Sand (within the Spiro-Wapanucka interval) as a separate channelized sandstone. Sutherland and Manger (1979) discussed the differences between Late Mississippian and Early Pennsylvanian rocks in the Ozark dome and Ouachita Mountain regions and concluded the Spiro is a blanket sand formed in a shore zone complex. Grayson (1980),in his study of the Wapanucka Formation in the Ouachita Mountains included the Spiro Sandstone as part of the upper sandstone-limestone member of the Wapanucka Formation. Houseknecht (1987) studied the Atoka Formation of the Arkoma basin and suggested that the Spiro was deposited in three main environments: 1) river-dominated channel, 2) tide-dominated channel, and 3) interchannel sand flat.

CHAPTER III

STRUCTURAL FRAMEWORK

Regional Structure

The Arkoma basin is one of several foreland basins formed during the Ouachita orogeny. The Ouachita Orogenic Belt extends from east-central Mississippi through Arkansas, Oklahoma, Texas, and into northern Mexico. Prior to deformation the entire foreland along the orogenic belt experienced the same history of rifted margin sedimentation followed by foreland basin development caused by convergent tectonics. In the final stages of orogeny the foreland region segmented into separate basins including the Arkoma, Black Warrior, Fort Worth, and Marathon basins (Houseknecht, 1987).

The Arkoma basin extends beyond central Arkansas in the east to the Arbuckle Mountains in the west. In Oklahoma, it is bounded on the north by the Ozark dome and the northwest by the northeast Oklahoma platform. In Oklahoma, on the surface the Arkoma basin is separated from the Ouachita Mountains to the south by the Choctaw fault.

During Cambrian to Early Pennsylvanian time the Arkoma basin was a stable shelf located north of the Ouachita trough. Throughout this time shallow-water sediments

accumulated in the basin area while deep-water sediments accumulated in the trough. In late Morrowan and early Atokan time the basin began to subside along a series of down-to-the-south syndepositional faults. These faults become progressively younger northward and resulted in the formation of a foredeep probably associated with thrust loading. They offset both the basement and sedimentary rocks; their development is evidence of gradiation from stable-shelf sedimentation to fully basinal sedimentation (Houseknecht, 1987). By Desmoinesian time the compressional conditions that resulted in formation of the Ouachita Mountains and the Arkoma basin had ended. Although the Choctaw fault marks the surface boundary between these two structural features, folds and thrusts extend northward into the basin as a series of long, linear east-trending, faulted anticlines and synclines (Berry and Trumbly, 1968).

Local Structure

Structural Styles

Sediments in the Arkoma basin were affected by both compressional and extensional tectonics. Compressional features are present in the Wilburton area, where thrust faults represent the northernmost edge of the Ouachita system (Fig. 2). Extensional features are represented by down-to-the-south syndepositional faults that appear to

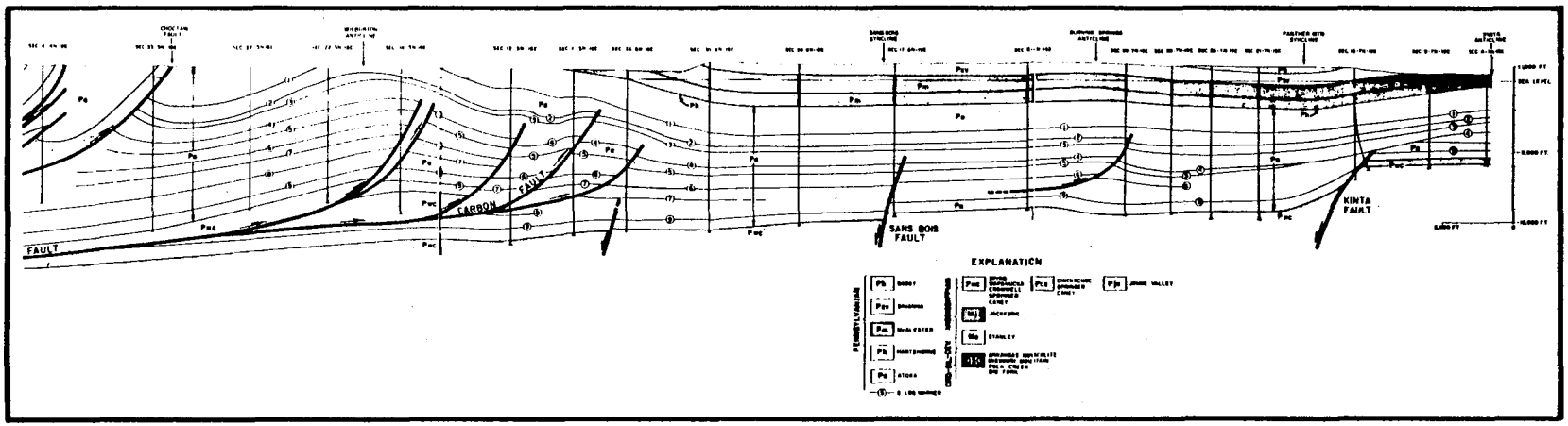


Figure 2 Regional cross section through the central part of the Arkoma basin illustrating compressional and extensional structures (after Berry and Trumbly, 1968).

extend under the leading edge of the thrusted terrain. Overall, both types of structures are east- to east-northeast-trending and subparallel to the overall basin trend (Plate I). Some normal faults, however, show a northeast trend. Several normal faults show a northeast to north-northeast trend.

In the Wilburton area compressional anticlines are asymmetric to the north and are thrust faulted at depth. These thrust faults are foothill-like imbricates of the Choctaw fault to the south, where Morrowan strata are at the surface. Structures related to extension formed as the basin subsided by growth faulting. The growth faults apparently offset the Wapanucka and older strata. They were active during deposition of lower Atokan, but fault movement ceased before Hartshorne sedimentation (Koinm and Dickey, 1967).

Local Features

Discussion of structures within the area of investigation is divided into two categories: compressional and extensional. In each category the order of discussion is from south to north. Evidence of the structures is based on a structural map constructed on the top of the Wapanucka Limestone (Plate I).

The Carbon fault, located in T5N, R16 through 19E, is an imbricate of the Choctaw fault. The Carbon fault extends to the surface across part of the area where it is

developed. Related faults associated with the Wilburton anticline apparently are subsurface features. At the horizon mapped these associated faults are responsible for several east-trending structures. These faults and folds generally trend from west to east.

The Brazil anticline is a large fold located in T5 and 6N, R20 and 21E; it extends east of the study area. Though no faults were mapped at the level of the top of the Wapanucka, Berry and Trumbly (1968) suggest that the lower Atokan and Wapanucka dip southward in this area and are cut by several thrust faults.

The Sans Bois fault system is the first syndepositional fault north of the Carbon fault. It is thought that splays of the fault extend underneath the Carbon thrust fault. The Sans Bois fault zone generally trends from west-southwest to east-northeast and has several smaller faults associated with it. One of these faults located in T5 and 6N, R19E, trends north-northeast before intersecting the main fault. Throw along the Sans Bois fault zone ranges from approximately 400 feet in T6N, R19E, to approximately 6800 feet across the zone in T7N, R21E.

The Sans Bois syncline, located north of the Brazil anticline and above the Sans Bois fault, is a broad syncline (Fig. 2). It appears the fold may be related to compression after extensional tectonics. In a tilted fault block the Wapanucka is as deep as 14,000 feet.

The Kinta fault zone is the northernmost named fault

zone in the study area. It is a syndepositional fault system that trends west-to-east overall, but extends north-northeast in T8N, R21E. The fault is downthrown to the south with vertical separation of approximately 4000 feet in T7N, R18E and only 500 feet in T8N, R21E.

The fault block between the Sans Bois fault zone and Kinta fault zone is characterized by generally broad, gentle folds. Faulted anticlines are present in T6N, R16E, and T7N, R19 and 20E. A broad gentle nose extends from T7N, R21E, to T6N, R18E.

North of the Kinta fault zone the rocks dip gently to the southwest. In T8N, R18E a normal fault shows separation of 400 to 1000 feet. It apparently is not a branch of the Kinta fault. In T8N, R19E, a small syncline is present and in T8N, R20 and 21E is a west-to-east-trending anticline.

CHAPTER IV

STRATIGRAPHIC FRAMEWORK

Regional Stratigraphy

The Lower and Middle Pennsylvanian rocks in the Arkoma basin are subdivided into the Morrow, Atoka, and Desmoines Series (Table 2). This study is of upper Morrowan and basal Atokan age sediments but a brief overview of Pennsylvanian age rocks will be given.

The Morrowan Series consists of the Springer Formation and Lower Dornick Hills Group. The Lower Dornick Hills Group includes the Union Valley Formation and Wapanucka Formation. The Wapanucka Formation, included in this study, appears to thicken from north to south. The Morrowan rocks in the Arkoma basin consist of shales, siltstones, sandstones, and massive shelf limestones.

The Atokan Series is represented by the the Upper Dornick Hills group. The Spiro Sandstone is the basal unit of this group. Atokan rocks are alternating sandstones and shales deposited in nonmarine, shallow marine, and deep marine environments (Houseknecht and Kacena, 1983).

The Desmoinesian Series is divided into the Krebs, Cabaniss, and Marmaton Groups. Desmoinesian rocks in the Arkoma basin are dark shales, sandstones, thin coals, sandy

TABLE 2

LOWER AND MIDDLE PENNSYLVANIAN STRATIGRAPHY

Desmoinesian Series	Marmaton Group	Holdenville Sh. Wewoka Fm. Wetumka Sh. Calvin Fm.
	Cabaniss Group	Senora Fm. Stuart Sh. Thurman Ss.
	Krebs Group	Boggy Fm. Savanna Fm. McAlester Fm. Hartshorne Fm.
Atokan Series	U. Dornick Hills Group	Atoka Fm.
Morrowan Series	L. Dornick Hills Group	Wapanucka Fm. Union Valley Fm. Springer Fm.

limestones in lenses, and siltstones (Branson, 1956). They were deposited in alluvial and shallow marine environments (Houseknecht and Kacena, 1983).

North from the Ouachita Mountains an unconformity at the base of the Pennsylvanian separates Pennsylvanian and Mississippi rocks (Moore, 1979), and the hiatus associated with the unconformity increases northward. North of the Arkoma basin, basal Pennsylvanian rocks change from Atokan to Desmoinesian. There is also an unconformity in the area of study separating the Morrowan and Atokan strata; it is most prominent in the northeast. Local unconformities separate the Spiro and the Wapanucka in the area of thick sandstone trends.

Relationship to Adjacent Units

The Spiro Sandstone is lowermost Atokan in age and is overlain by the Atoka Formation and underlain by the Morrowan Wapanucka Formation (Fig. 3). The Spiro represents the youngest deposits on the stable platform prior to significant subsidence of the Arkoma basin.

The Spiro has both a conformable and an unconformable contact with the underlying Wapanucka. Rowland (1974) divides the Wapanucka into four members: 1) the lower shale and limestone member, 2) the limestone member, 3) the middle shale member, and 4) the upper sandstone member. Grayson (1980) divides the Wapanucka in much the same way: 1) the Chickachoc Chert Member, 2) the lower limestone

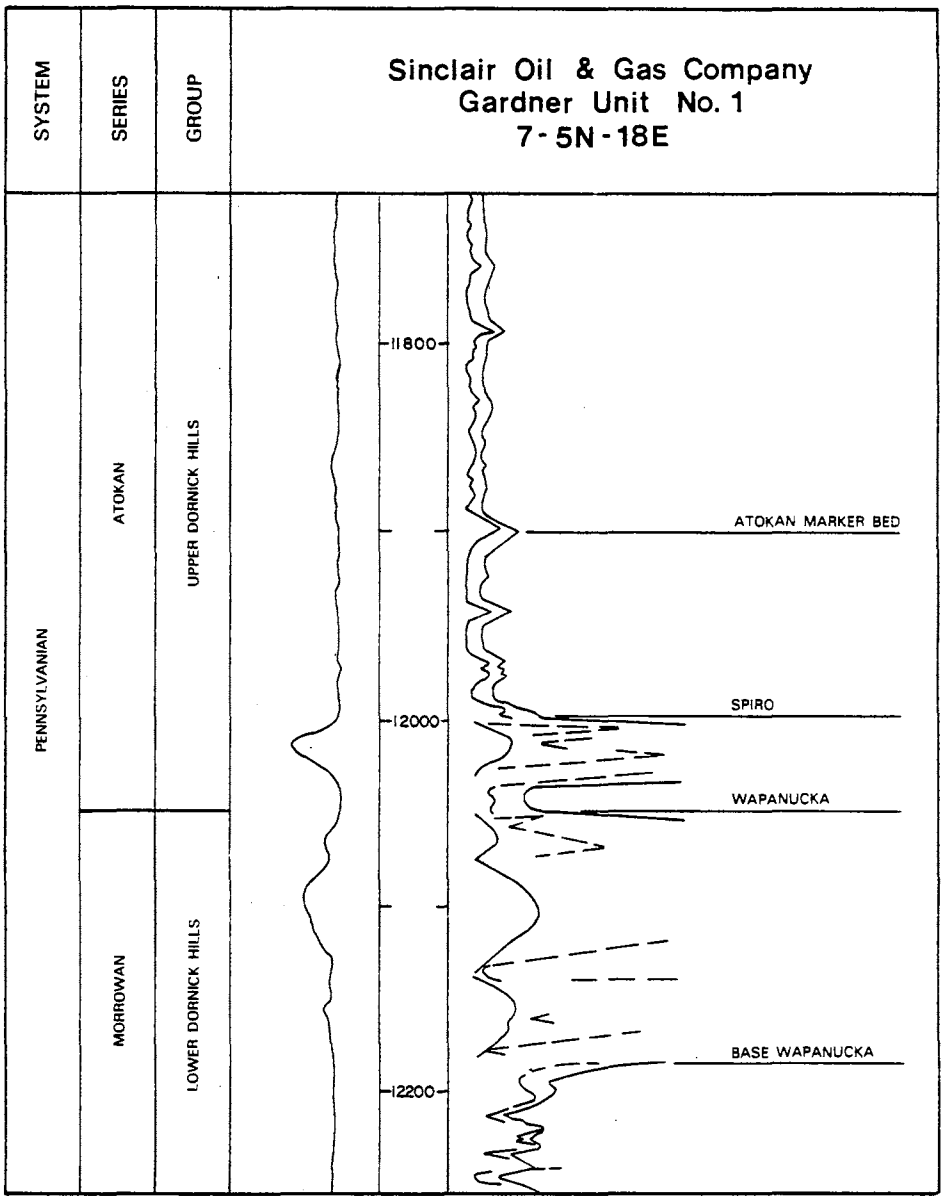


Figure 3 Type log of the Spiro Sandstone interval and adjacent units.

member, 3) the middle shale member, and 4) the upper sandstone limestone member. Grayson (1980) includes the Spiro as part of the upper sandstone-limestone member.

Throughout most of the study area sandstone of the Spiro is separated from the Wapanucka by shale (Plate II). In the southern part of the area the interval is 5 to 20 feet in thickness. To the northeast in T7N, R21E, and T8N, R21E, thickness of the shale averages 50 feet. In the Kinta area the shale is either very thin, from 2 to 5 feet, or the Spiro is unconformable upon the Wapanucka (Fig.4).

The Atoka Formation is characterized by alternating dark shale, siltstone, and fine-grained sandstone; it is as thick as 10,500 feet adjacent to the Choctaw fault. The Atoka, which is conformable upon the Spiro, was deposited as the basin was rapidly subsiding by movement of a series of down-to-the-south syndepositional faults.

In the northern part of the study area an unconformity exists between the Spiro and Wapanucka. According to Lumsden et al. (1971) the Spiro and Wapanucka are separated by a slight disconformity. Additionally a local unconformity is developed where the Foster "sand", a channelized sandstone body, has cut into the sub-Spiro shale.

Evidence of an unconformity is most clearly seen in the northeast part of T8N, R21E. In this area the Wapanucka is very thin or absent with no apparent change in thickness of the sub-Spiro shale (Fig. 4). Also in sections 1 and 12 both the Wapanucka and sub-Spiro shale

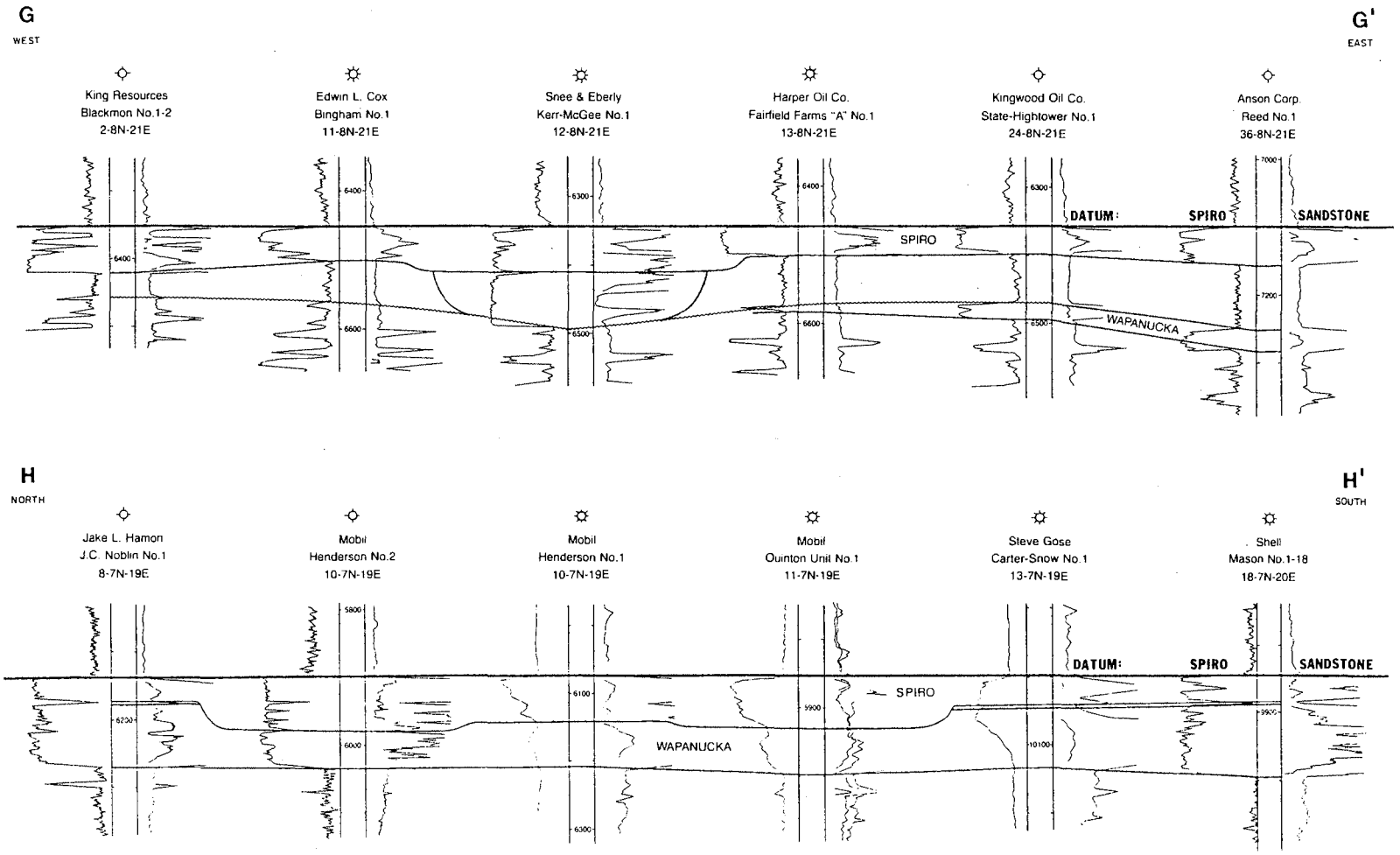


Figure 4 Correlation cross sections illustrating unconformities in the study area. Section G-G' shows an unconformity at the base of the sub-Spiro shale where the Wapanucka has been eroded. Section H-H' shows channelized units in the Spiro and a local uncomformity at the base of the channelized sandstone.

apparently were eroded before deposition of an anomalously thick Spiro interval (Fig. 4).

Lithology/Facies of the Spiro Sandstone Interval

In the area of study the Spiro Sandstone interval ranges in lithology from sandstone to limestone; sandstone being the dominant lithology. Based on the nine cores studied, the Spiro can be divided into three groups: 1) dominantly sandstones with fossils and/or a limestone unit, 2) medium- to coarse-grained sandstone with no visible fossils or limestone, and 3) limestone and fossiliferous sandstone.

In the southwestern part of the study area (T4 and 5N, R16 and 17E) the Spiro mainly consists of limestone and fossiliferous sandstone (Fig. 5). The limestone facies is not restricted to any part of the interval. Using compensated neutron-formation density logs thickness of limestone was mapped in the southwestern part of the area (Fig. 6). At some localities limestone composes almost the whole interval.

The Spiro interval thickens to the east, and the sandstone content increases to the north and east. In the Wilburton area and parts of the Red Oak area the Spiro is dominantly sandstone with fossils and/or a limestone unit (Fig. 7). The limestone unit, appears generally to occur in the lower part of the interval; it is not present north

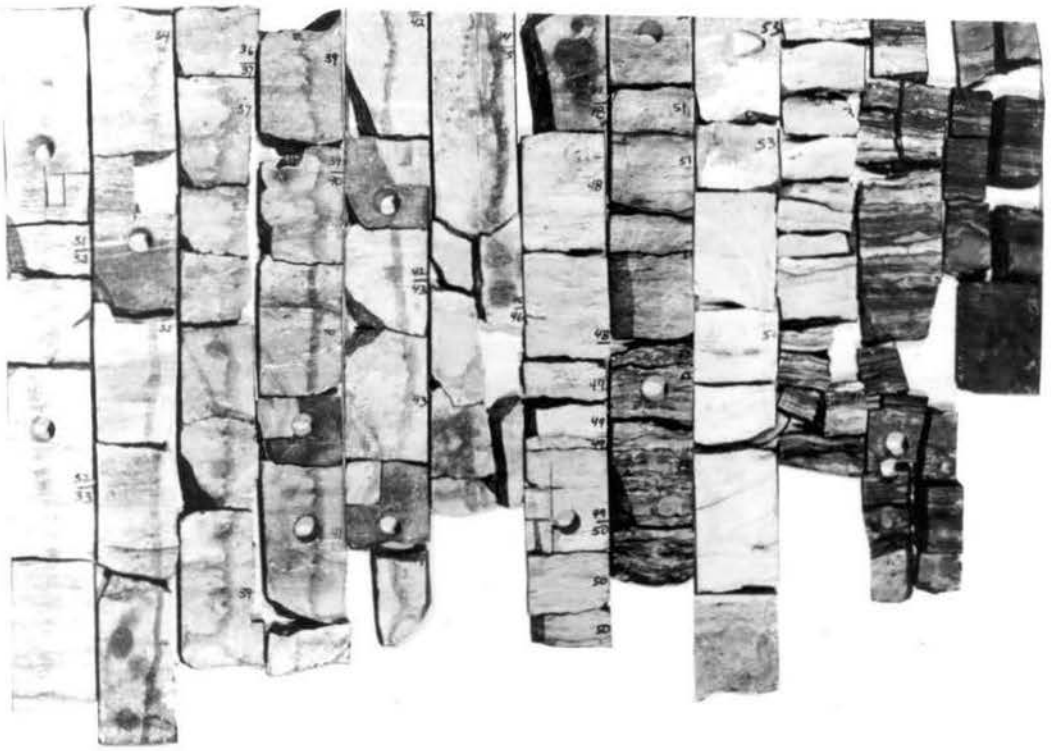


Figure 5 Photograph of the Shell Mabry No.1-9 core. Depths from 13,129' to 13,172'.

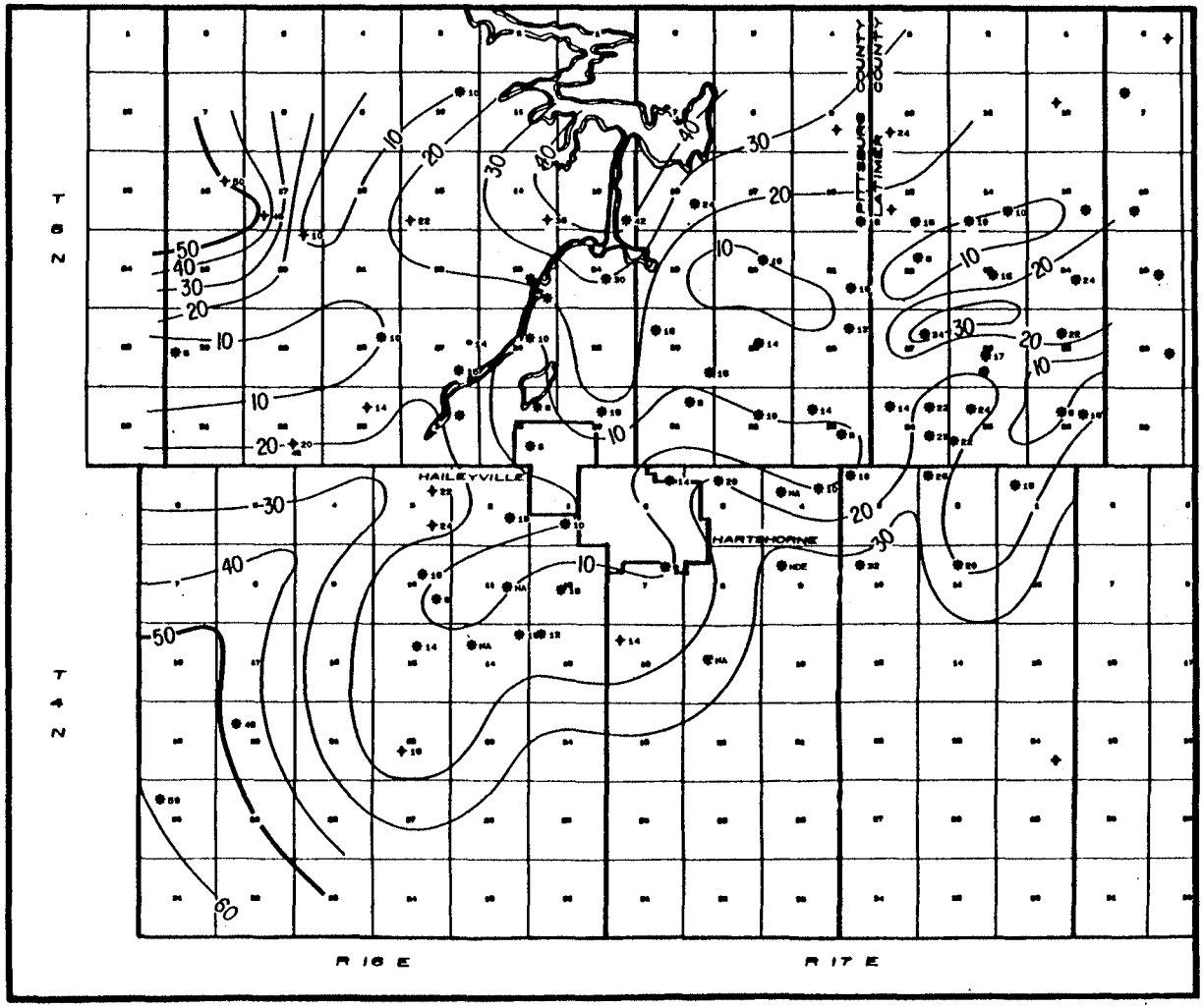


Figure 6 Isopach map of limestone in the Spiro in the southwest portion of the study area.

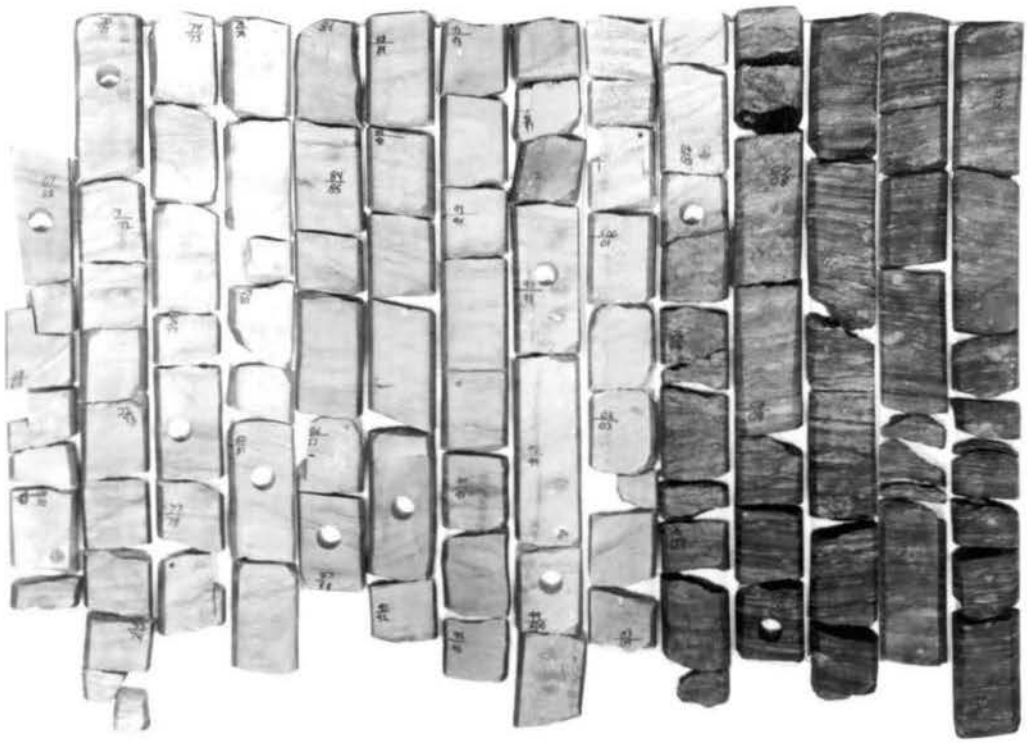


Figure 7 Photograph of the Pan American Reusch No.1 core. Depths from 11,467' to 11,523'.

of the Wilburton area. Limestone occurs in parts of the Red Oak area but contains a high percentage of quartz sand grains. The Humble Burge No.1 in T8N, R21E contains fossiliferous sandstone but no limestone.

In the Kinta area and parts of the Red Oak area where major thick sandstone trends exist, unfossiliferous, medium- to coarse-grained sandstone is dominant (Fig. 8). In these areas fossils and limestone are uncommon.

Porosity Distribution

Distribution of porosity in the Spiro Sandstone is generally related to the three groups of lithologies (Plate III). Where the Spiro is thick and sandstone is medium- to coarse-grained, porosity is highest. Where the Spiro is dominated by limestone and fossiliferous sandstone, porosity is generally lowest. In the areas where sandstone with fossils and/or a limestone unit occurs, porosity varies according to the amount of carbonate present.

Correlation Cross Sections

Six correlation cross sections are included with this study (Fig. 9) (Plates IV and V). The datum used is an Atokan shale bed present throughout the area of investigation. The logs were selected to show local and regional variations of thickness and trends that exist in the study area.

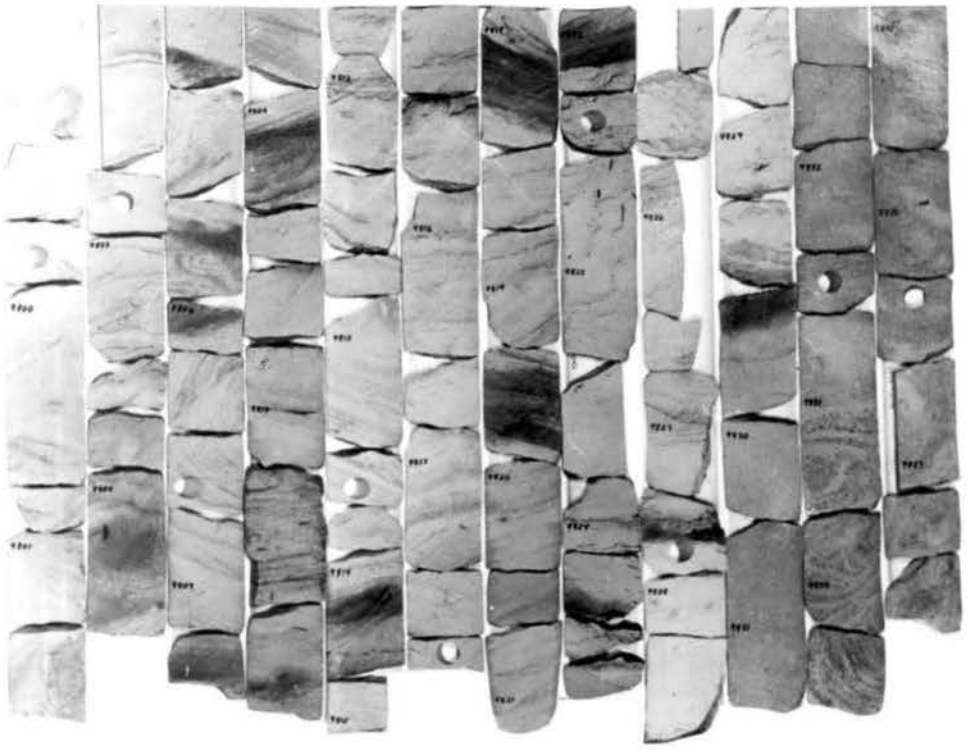


Figure 8 Photograph of the Shell Jankowsky No.1-32 core. Depths from 9,799' to 9,839'.

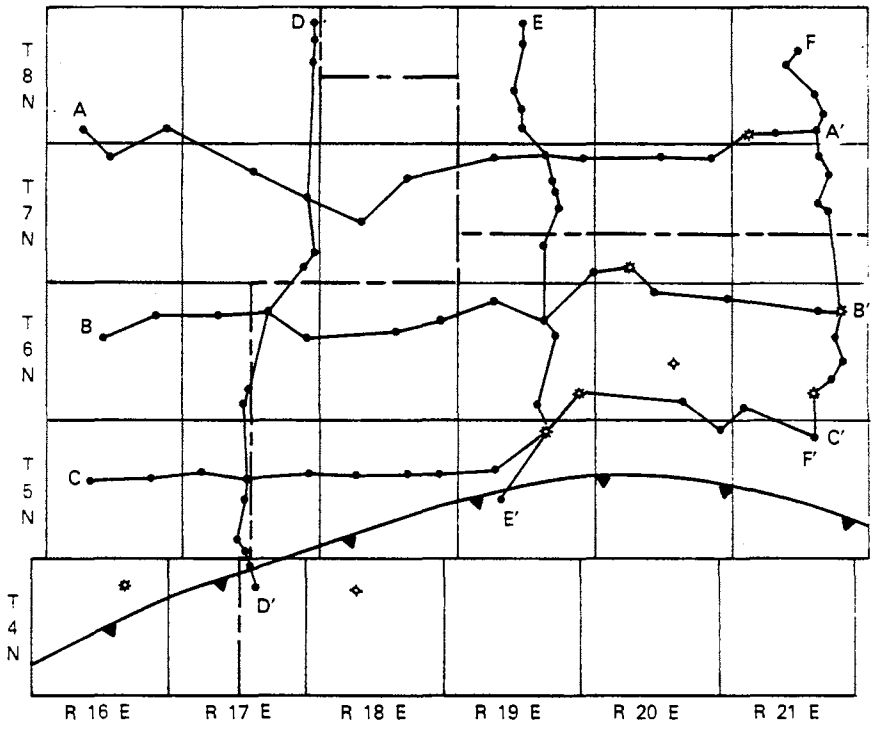


Figure 9 Index map showing core locations (well symbols) and lines of cross sections.

Cross Section A-A'

Cross section A-A' is a west-to-east section that extends from T8N, R16E, to T8N, R21E (Plate IV). The interval between the Atokan marker bed and Spiro Sandstone is not consistent along this line of section. It contains local variations in thickness from 175 feet thick to 56 feet. The Spiro interval is thin in the west but is markedly thicker in T7N, R19E, and T8N, R21E. The sub-Spiro shale averages 10 to 20 feet in thickness in the west. In T7N, R19E, the shale is very thin to absent; however, it thickens abruptly to 40 feet in section 34, T8N, R21E. In general the Wapanucka Limestone thins east along the line of section.

Cross Section B-B'

Cross section B-B' is a west-to-east section that extends from T6N, R16E, to T6N, R21E (Plate IV). The interval between the Atokan marker bed and Spiro Sandstone is fairly constant along this section with some local variations. The Spiro interval increases eastward with noticeably thicker sections in T7N, R20E, and T6N, R20E. The sub-Spiro shale thickness varies along the line of section. The thickness of the Wapanucka Limestone appears to show local variations but it is difficult to determine because many wells do not penetrate the whole section.

Cross Section C-C'

Cross section C-C' is a west-to-east correlation section that extends from T5N, R16E, to T5N, R21E (Plate IV). The interval from the Atokan marker bed to the Spiro Sandstone is consistent along the line of section. The Spiro interval shows local variations and marked thickening in T5N, R21E. The sub-Spiro shale is also characterized by local variations in thickness, but it apparently averages between 10 and 20 feet thick. The Wapanucka Limestone thickness is fairly consistent.

Cross Section D-D'

Cross section D-D' is a north-to-south section that extends from T8N, R17E, to T4N, R17E (Plate V). In general, the interval between the Atokan marker bed and Spiro Sandstone thins southward. One major variation is in section 25 of T7N, R17E, where the interval is thinnest. In contrast, the Spiro interval thickens from north to south. This is most noticeable from T6N, R17E, to T5N, R17E. In general the thickness of the sub-Spiro shale is consistently 5 to 20 feet thick. The Wapanucka thickens from north to south along the line of section.

Cross Section E-E'

Cross section E-E' is a north-to-south section that extends from T8N, R19E, to T5N, R19E (Plate V). As along section D-D', the interval from the Atokan marker bed to

Spiro Sandstone thins from north to south. This trend is interrupted locally in T7N, R19E, where the interval is relatively thin. The Spiro interval is thin to the north, but there is marked thickening in section 21, T8N, R19E. South of section 15, T7N, R19E the Spiro remains fairly constant. The sub-Spiro shale shows local variations; it is thin to absent from section 33, T8N, R19E, to section 15, T7N, R19E. In general, the Wapanucka Limestone thickens from north to south.

Cross Section F-F'

Cross section F-F' is a north-to-south section that extends from T8N, R21E, to T5N, R21E (Plate V). The interval between the Atokan marker bed and Spiro Sandstone thins from north to south with some local variations. The Spiro interval thins abruptly in section 22, T8N, R21E, and generally thickens southward. The sub-Spiro shale shows major variations in thickness from 60 feet to 5 feet. As in sections D-D' and E-E', the thickness of the Wapanucka increases to the south.

General Thickness Relations

Several regional trends are present in addition to local variations in stratigraphic thickness and trend. The total interval from the Atokan marker bed to the base of the Wapanucka shows general thickening to the east and south (Plate VI). The interval between the Atokan marker

bed and Spiro Sandstone is thickest in the northeast and is thinner to the south and west (Plate VII). The Spiro interval contains many local variations in thickness, but it generally increases from north to south and northwest to southeast (Plate VIII). The thickness of the sub-Spiro shale reaches its maximum in T7 and 8N, R21E (Plate II). The Wapanucka Limestone thickens consistently from north to south.

CHAPTER V

GEOMETRY OF THE SPIRO SANDSTONE

An isopach map of the Spiro was used to delineate the trends and distribution of the sandstone (Plate IX). Thickness was determined as the Spiro interval minus shale. Deflections of less than 80 A.P.I. gamma-ray units were considered to show sandstone. This measurement was determined from core-to-log comparisons and from averaging the maximum and minimum A.P.I. units of 50 gamma ray logs within the area of study.

Trends

Although the Spiro Sandstone is present throughout the area several distinct trends do exist, including three northwest-southeast trends. One trend extends from T5N, R16E, through the southern part of T5N, R17E, into T4N, R17E; a second trend can be traced from T8N, R17E, southwestward into T7N, R18E; a third trend extends from T8N, R19E, to T6N, R21E. One north-south sandstone trend is present from T8N, R21E, into T6N, R21E. It merges with the last trend mentioned above to form a single sandstone trend. The range in width is from 1 mile to 4 miles; length exceeds 18 miles. None of them originates within

the boundaries of the study area. Two sandstone trends in T6N, R16E, extend in a northeast-southwest direction and appear to be associated with the thick sandstone body present in that same area.

Sandstone distribution elsewhere apparently does not reflect specific trends. The Spiro is blanket-like in those areas.

Thickness

Thickness of the Spiro varies from zero in the north and northwestern extremity of the area to 143 feet in section 34, T5N, R17E. Sandstone thickness generally shows marked changes in areas of the sandstone trends discussed above.

Boundaries

Because the Spiro Sandstone is generally continuous over the whole area, abrupt lateral contacts are present mainly in association with the major sandstone trends. Basal contacts are generally gradational in the southern portion of the study area, but they are sharper in areas of major sandstone trends and in the northern part.

CHAPTER VI

INTERNAL FEATURES

Sedimentary Structures

Common sedimentary structures in the cores include massive bedding, nodular bedding (in limestones), small- and medium-scale crossbedding, interstratification (of sandstone and shale), flowage, bioturbation, and several types of vertical and horizontal burrows. Although a specific type of vertical sequence of sedimentary structures does not characterize the Spiro Sandstone, overall in the Spiro-Wapanucka interval a zone of interstratified shale and siltstone-sandstone commonly underlies an upper zone of sandstone (Spiro), which in some instances consists of sandstone and limestone.

Interstratification

Interstratification of shale and sandstone-siltstone is present in eight of the nine cores studied. Sandstone laminae in shale beds are more common than shale laminae in sandstone beds (Fig. 10). Both parallel and lenticular bedding characterize the interstratified interval. It is noteworthy that flaser bedding is not common. Although the parallel type is dominant, lenticular bedding is most

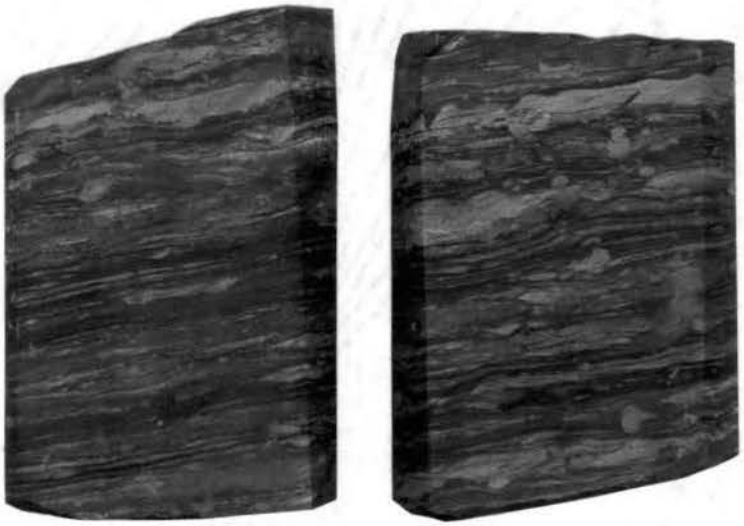


Figure 10 Interstratification of sandstone and shale in the Pan American Reusch No.1 core.

noticeable in the Pan American Reusch No.1 and Pan American Smallwood No.1 cores. Accompanying parallel interstratified shale in sandstone are sharp upper and lower contacts. In the Humble Burge No.1 and Shell Jankowsky No.1-21 cores an interstratified zone separates upper and lower sandstone units. In the upper core from Shell Mabry No.1-9 an interstratified zone is present within the sandstone and limestone interval.

Flowage

Flowage is present in seven of the nine cores included in this study, both in the sandstone facies and the interstratified zone (Fig. 11). Although flowage is best developed in the Shell Jankowsky No.1-32 core (Fig. 8), it is also quite noticeable in the Tenneco Kraft No.1 (Fig. 11) and Humble Burge No.1 cores. Micro-faulting and sand dikes are present but rare.

Small- and Medium-scale Crossbedding

Medium-scale crossbedding is the most abundant type of structure developed in the Spiro cores. It is especially characteristic of the sandstone intervals in the Pan American Reusch No.1 (Fig. 12), Humble Burge No.1, and Mustang Lyons No.1 cores. Though mainly confined to coarser grained sandstones, medium-scale crossbedding is also present in the fine-grained lower unit of the Humble Burge No.1 core. Small-scale crossbedding is not as common

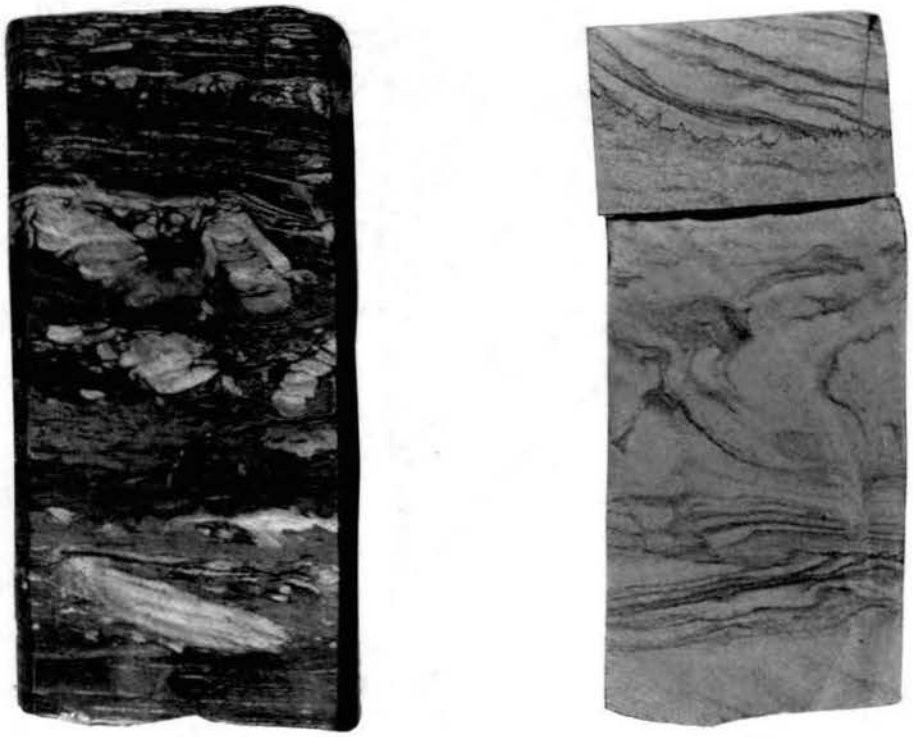


Figure 11 Flowage (A) in the interstratified zone at the base of the Mustang Lyons No.1-27 core and (B) in the Humble Burge No.1 core.

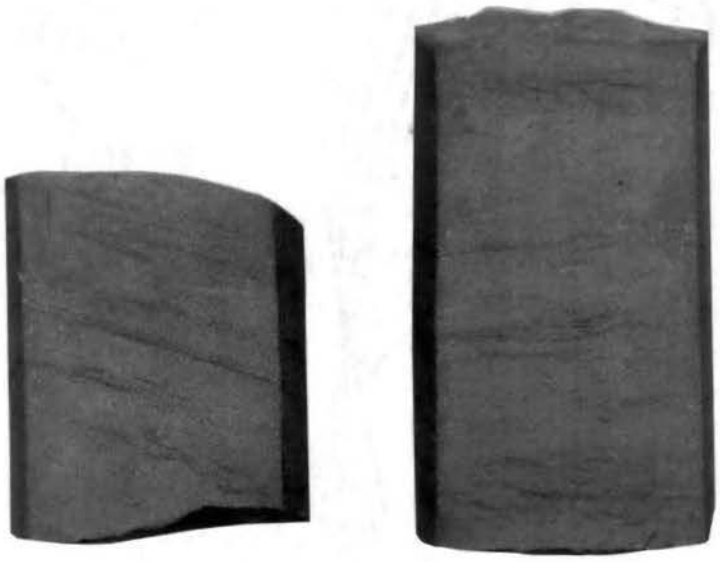


Figure 12 Medium-scale crossbedding in the Pan American Reusch No.1 core.

as the medium-scale types. It primarily occurs in the fine grained sandstone facies and is best developed in the lower sandstone unit of the Humble Burge No.1 core.

Massive Bedding

Although massively bedded sandstone occurs in six of the cores studied, it is not a dominant feature. Exceptionally in the Shell Jankowsky No.1-21 (Fig. 13) the majority of the core exhibits massive bedding.

Another exception is in the limestones developed within the Spiro section. Where a relatively thick limestone section exists, it is dominated by massive bedding (for example, Tenneco Kraft No.1-25 and Shell Mabry No.1-9 cores). In Pan American Reusch No.1 the limestone section is thick, but it is dominated by medium-scale crossbedding.

Bioturbation and Burrows

Bioturbation and burrows are common in the Spiro, and they occur in both the interstratified zone and sandstone zone. Horizontal and vertical burrows are developed best in the Midwest Free No. 1, Pan American Smallwood No.1 (Fig. 14), and lower Shell Mabry No. 1-9 cores. Bioturbation, though present in the sandstone facies, is most common in the interstratified zone.

Some burrows can be classified in terms of trace fossils. Small, dominantly horizontal burrows of the genus Planolites occur in the sandstone interval of the Pan

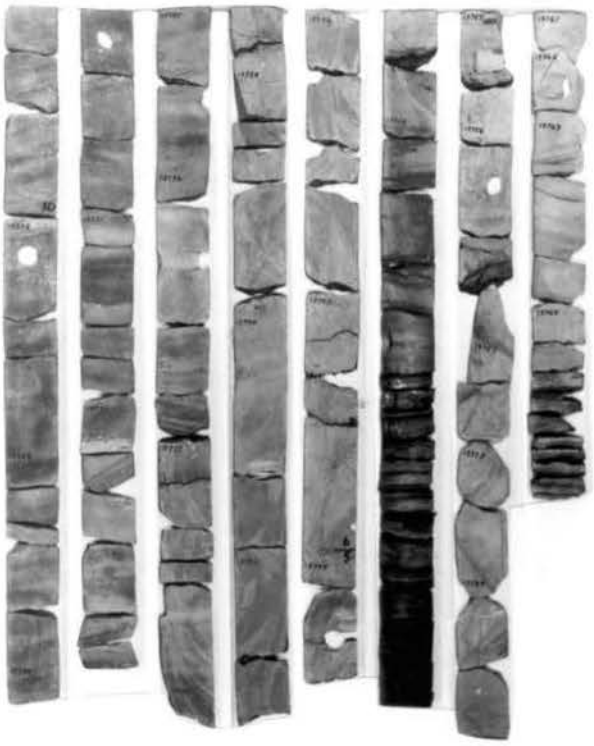


Figure 13 Massive bedding is the dominant feature in the Shell Jankowsky No.1-21 core.

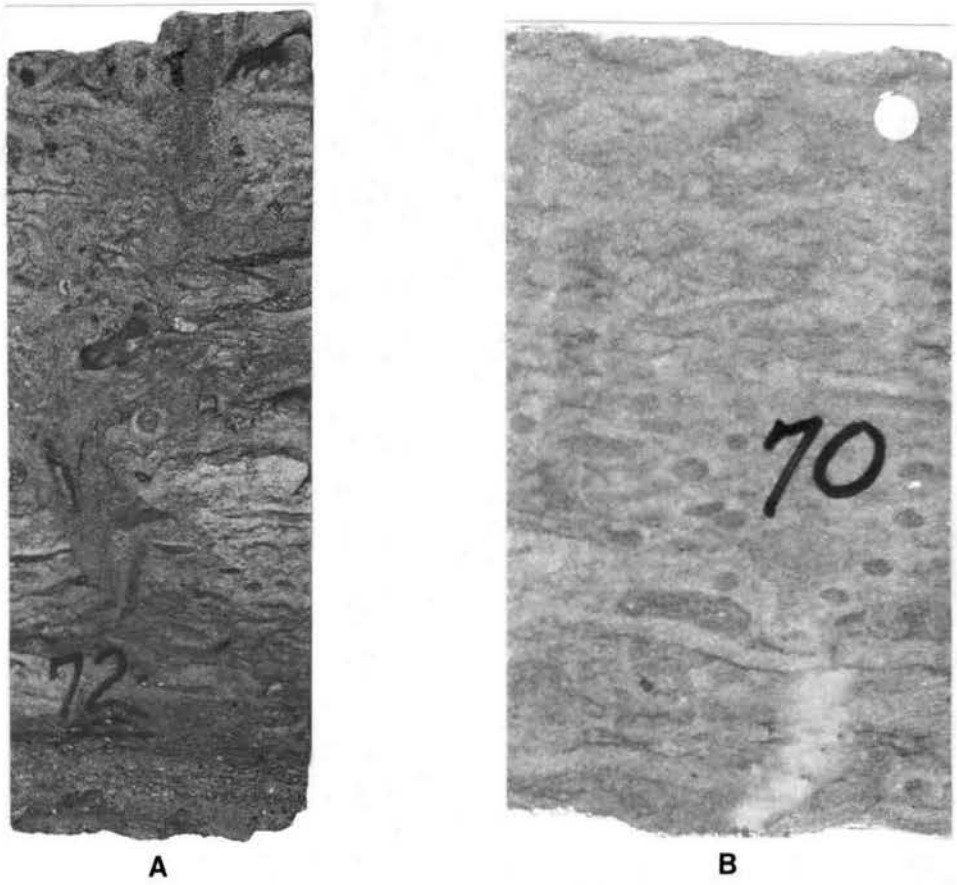


Figure 14 Burrows (A) in the Pan American Smallwood No.1 core and (B) Planolites in the Pan American Smallwood No.1 core.

American Smallwood No.1 (Fig. 14) and Humble Burge No.1 cores and in the Shell Mabry No.1 lower core. Burrows of the genus Zoophycus are less common; they occur in the interstratified zones of the Pan American Smallwood No.1 and Shell Mabry No.1 cores (Fig. 15).

Texture

The Spiro Sandstone is composed of sandstone, interbedded sandstone-siltstone and shale, and limestone. Excluding shale and limestone it ranges in grain size from very fine sand (.10mm) to coarse sand (.7mm). The average grain size is fine to medium. There are no uniform textural sequences in the Spiro, but areal variations in grain-size distribution within the study area do exist. In T4 and 5N, R16 and 17E, sandstones in the Spiro are generally very fine- to fine-grained. In the Wilburton area it is dominantly fine- to medium-grained. To the north in the Kinta area the Spiro is characteristically medium- to coarse-grained. The Spiro in T6 and 7N, R20E, and T6 to 8N, R21E, may range in grain size from fine to coarse. Overall, the Spiro is well sorted, but locally it may be moderately well or very well sorted. Sand grain shape is subangular to rounded.

Figure 15 Zoophycus in the Shell Mabry No. 1-9 upper core (from the thrust sheet).

CHAPTER VII

PETROLOGY AND DIAGENESIS

Because constituents from the Shell Mabry No.1-9 and Pan American No.1 cores differ from those of the other seven cores studied (Fig. 2 and 9), specific petrologic and diagenetic differences that occur in the Spiro interval within the area of investigation will be noted in the general description given below. The features of the Spiro were determined from examination of thin sections, X-ray diffraction, and scanning-electron microscopy (SEM) of representative samples from the nine Spiro cores.

Constituents

In general the Spiro Sandstone is a quartzarenite. Within the sandstone zones monocrystalline quartz is the dominant framework grain and is present in amounts ranging from 40 to 95 percent. The grains exhibit straight to slightly undulose extinction, and in some cases they are fractured due to compaction.

Other framework grains include fossil fragments, carbonate rock fragments, chert, metamorphic rock fragments, feldspar, chamosite clay pellets, glauconite, collophane, and intraformational clasts of clay, siltstone

and siderite. Of these types fossil fragments and chamosite pellets are the most abundant. In some samples fossils occur only as traces (e.g. Mustang Lyons No. 1-27); others contain as much as 44 percent. Echinoderms are the most abundant fossils; brachiopods, bryozoans, pelecypods, and foraminifera also occur. Chamosite clay pellets are present in all of the thin sections studied except those from the Shell Mabry No.1-9 and Pan American Smallwood No.1. They range in color from green to brown and go to extinction under crossed nicols (Fig. 16). Many grains of chamosite show deformation due to compaction (Fig. 17). Percentages range from trace to 12 percent. Glauconite occurs in thin sections from the Shell Mabry No.1-9 and Pan American Smallwood No.1 cores (Fig. 18). The grains are slightly deformed and exhibit a typical green sugary texture. Although found as a trace in some samples, metamorphic rock fragments compose 4 percent of sample S-11695 from the Pan American Smallwood No.1 core (Fig. 19). Carbonate rock fragments range in occurrence from a trace to 5 percent. Clay and siltstone clasts, present in various sizes and amounts, are most common in the lower unit of the Humble Burge No.1 core. Chert and feldspar occur in trace amounts. Dead oil is present in some rocks in amounts ranging from a trace to 10 percent (Fig. 20).

Accessory minerals include zircon, tourmaline, muscovite, pyrite, leucoxene, and hornblende. Muscovite and pyrite are the most common, but they only compose a

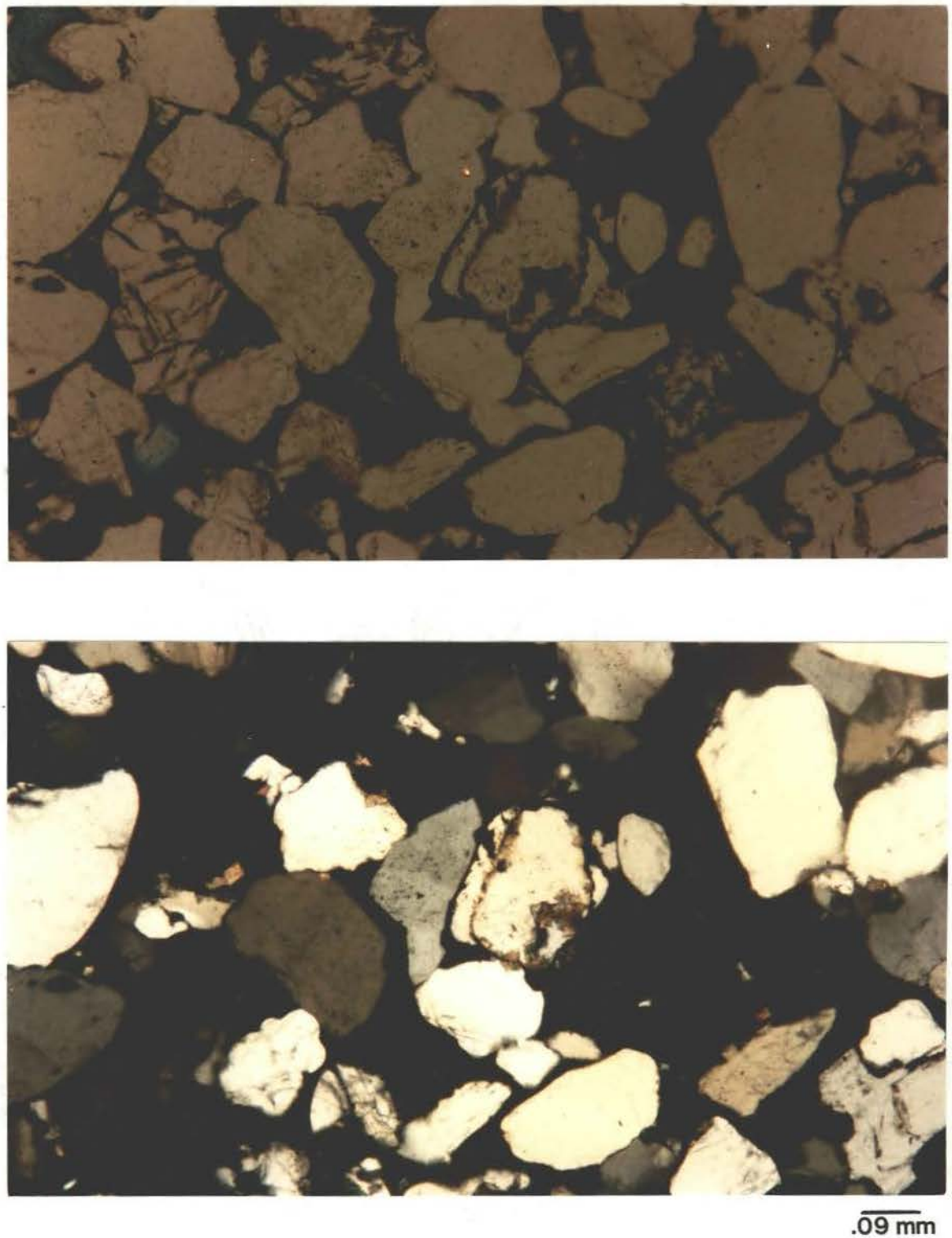
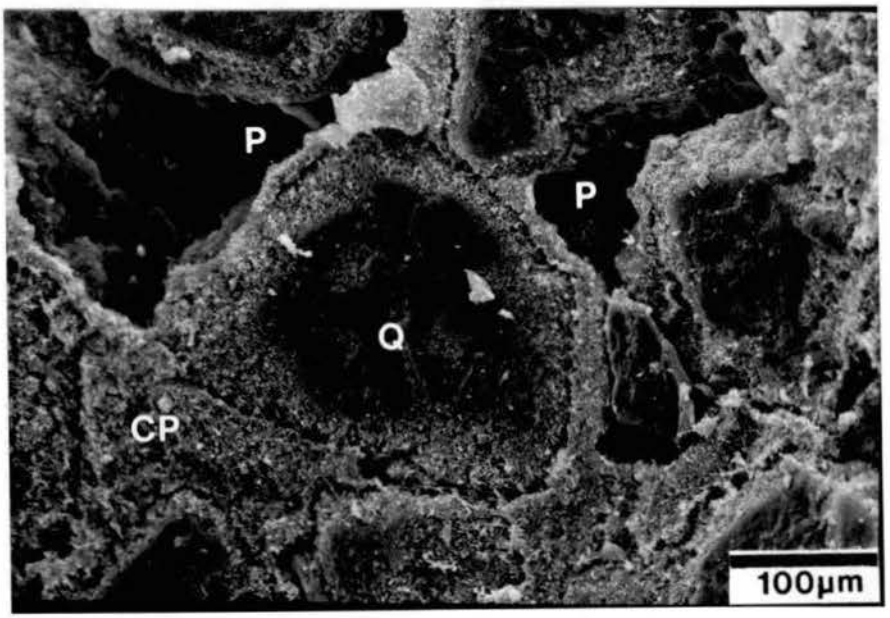
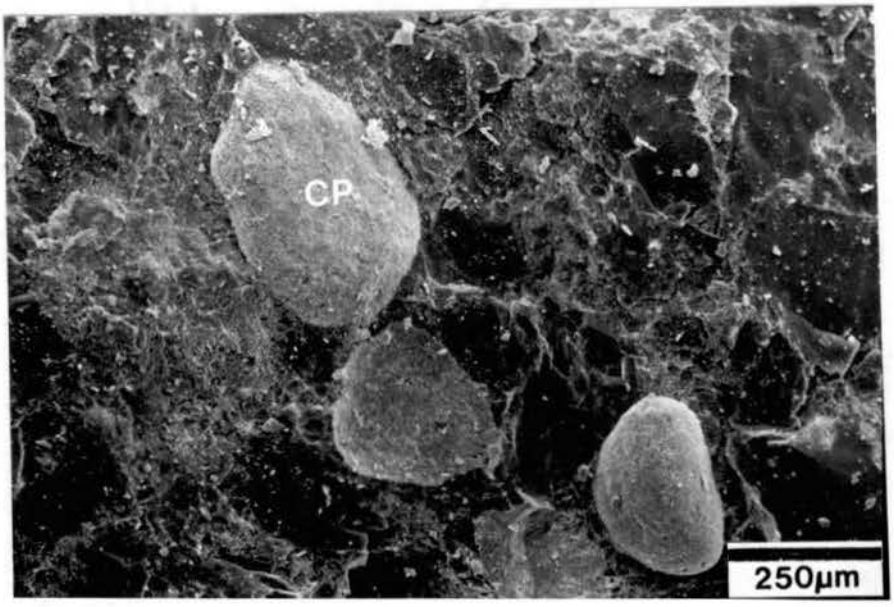


Figure 16 Chamosite as grain coatings and deformed pellets in plane polarized (above) and crossed-nicols. Also notice both primary and secondary porosity. (Shell Jankowsky No.1-21, 13,734').



A



B

Figure 17 A) SEM photomicrograph showing deformed chamosite pellets (CP) and grain coatings, quartz grains (Q), and primary porosity (P) preserved by grain coatings (Shell Jankowsky No.1032, 9,834'). B) SEM photomicrograph of chamosite pellets (CP) (Mustang Lyons No.1-27, 12,246').

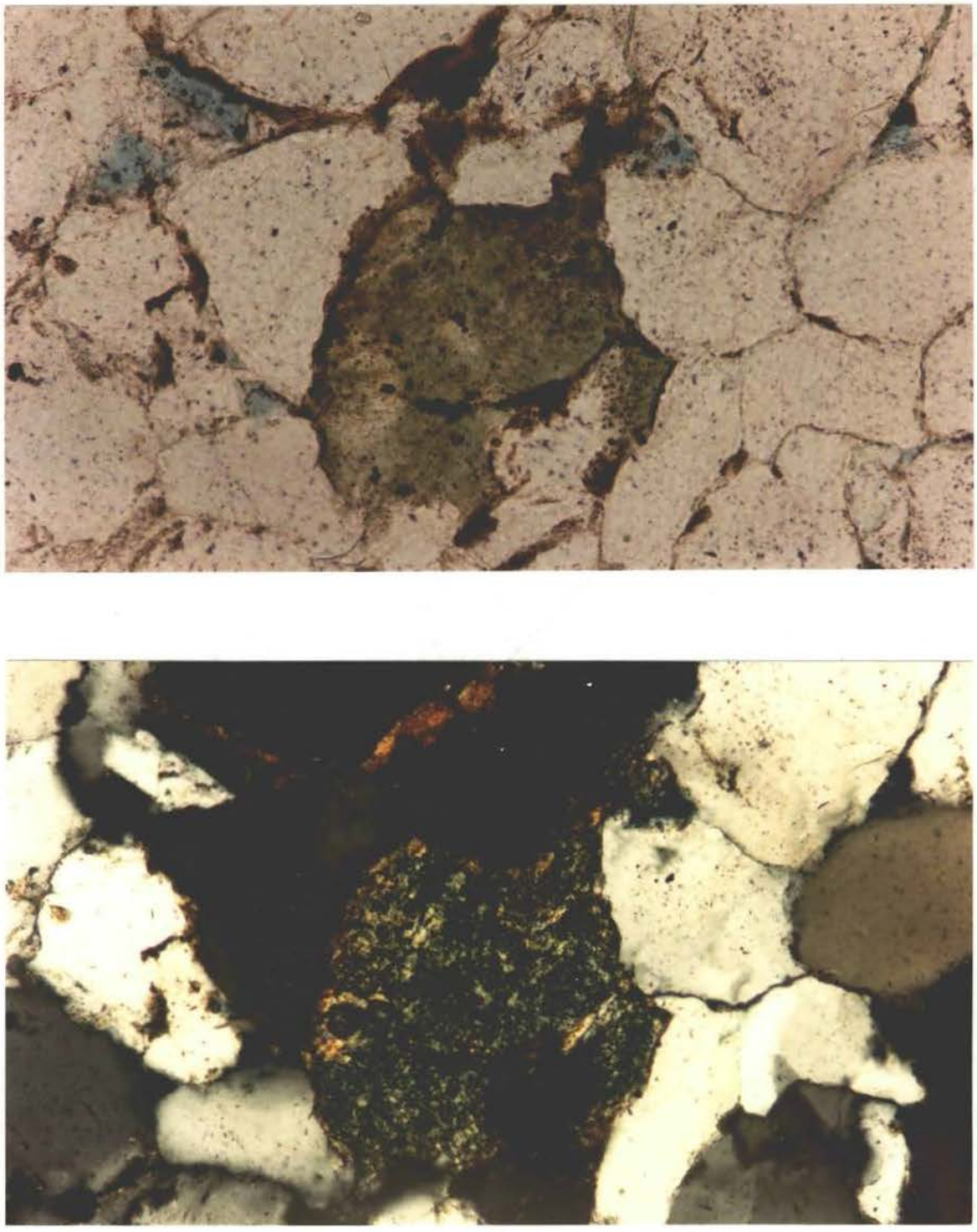


Figure 18 Deformed glauconite grain from the Shell Mabry No.1-9 core in plane polarized light (above) and cross-nicols (5,903').

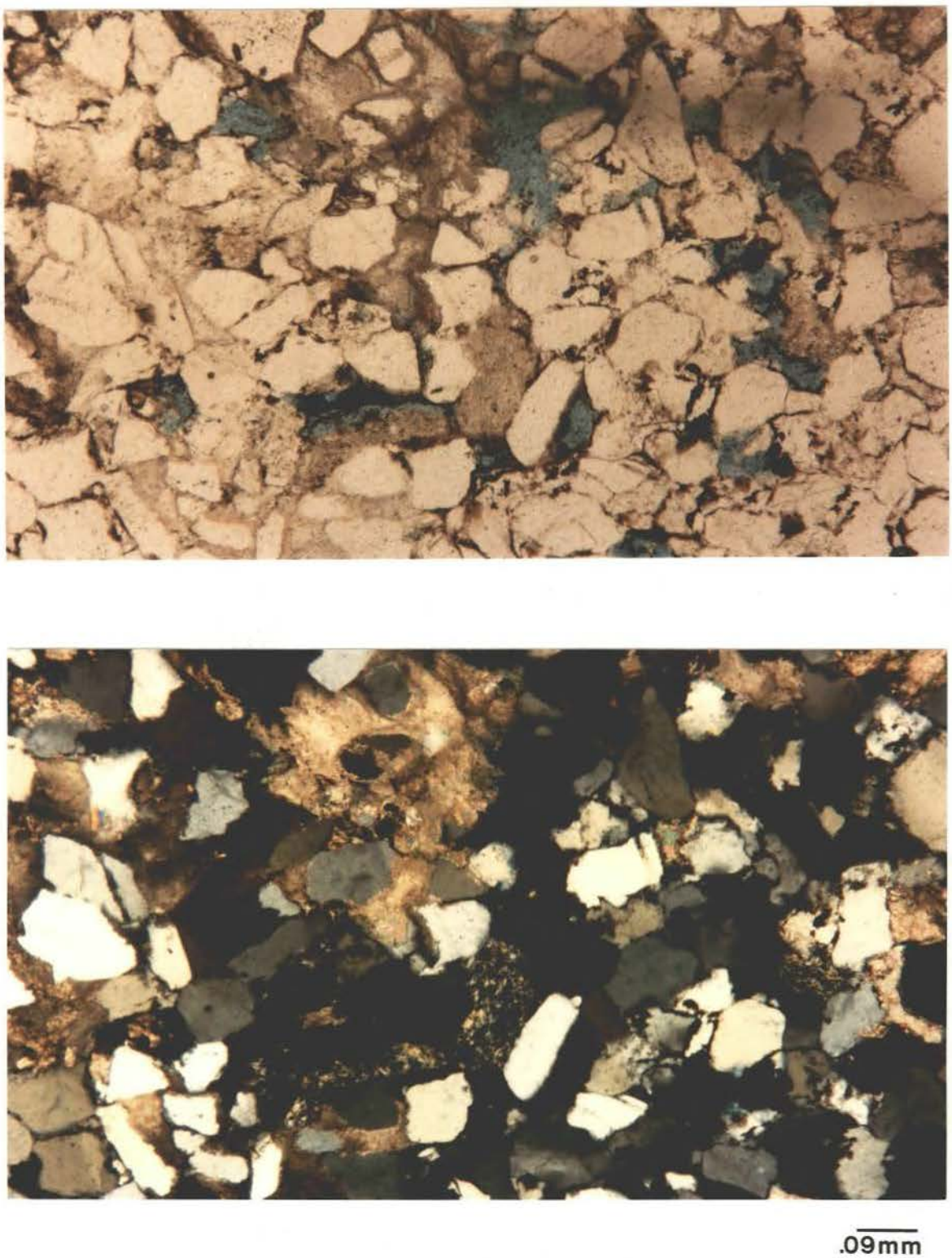


Figure 19 Metamorphic rock fragments and carbonate cement in Pan American Smallwood No.1 core in plane polarized light and cross-nicols. Also notice secondary porosity (11,695').

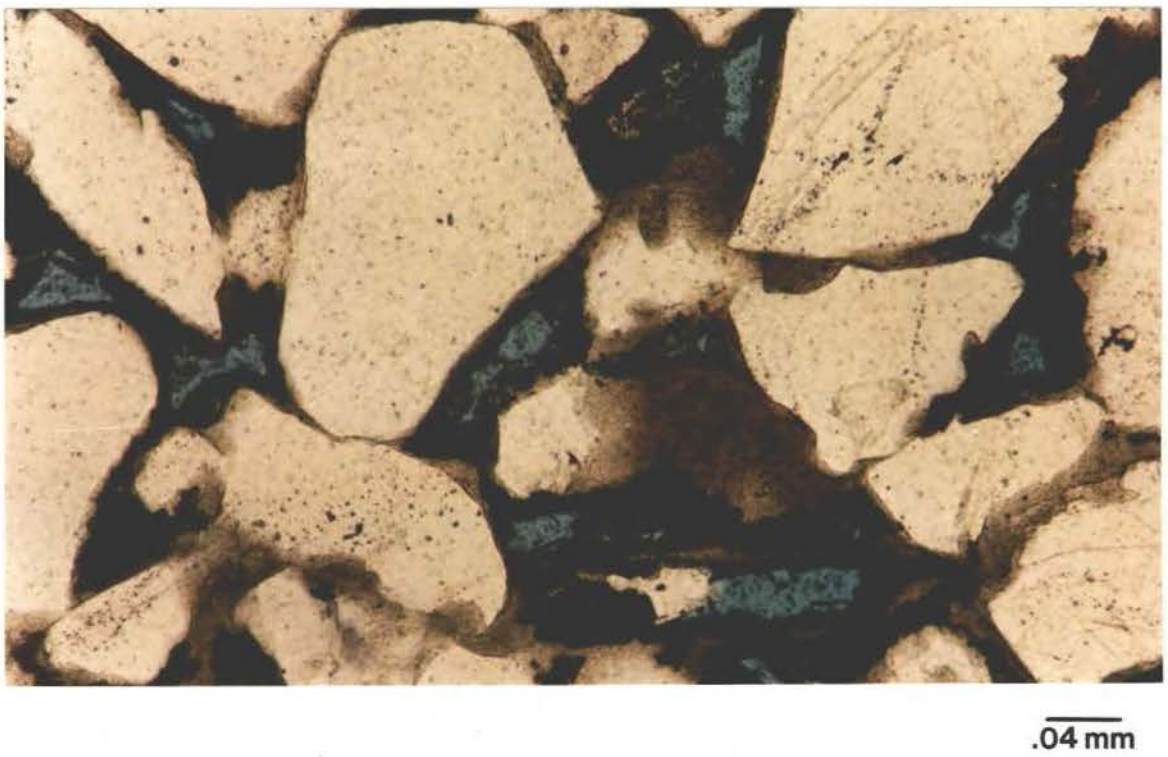


Figure 20 Dead oil along with chamosite coatings which aided in preservation of primary porosity (Midwest Free No.1, 11,861').

trace of a total sample. In sample S-11690 of the Pan Am Smallwood No.1 core, accessory minerals compose 3 percent of the thin section.

Diagenetic Constituents

Chamosite (iron-rich chlorite) is the dominant diagenetic constituent in the Spiro (Al-Shaieb, 1988). It occurs as grain coatings, oolite coatings, pore fillings, and clay pellets (Figs. 21 and 22). Chamosite is similar to regular chlorite in thin section but has a peak of 7Å or 14Å in X-ray diffraction. The 7A peak is similar to that of kaolinite. Also, the chamosite peak collapses when the clay sample is heated (Fig. 23). It occurs in amounts ranging from a trace to 22 percent. Chamosite is absent from the Pan American Smallwood No.1 or Shell Mabry No.1-9 cores.

Illite is common locally in some samples and present as a trace in most samples. Illite/smectite mixed layer clay is the only clay that is recognized in thin sections from the Pan American Smallwood No.1 and Shell Mabry No.1-9 cores (Fig. 24).

Quartz as overgrowths is the primary cement, and it composes as much as 10 percent of a thin section (Fig. 25). Calcite, siderite, and dolomite cements are common locally (Figs. 19, 26, 27, and 28). Chalcedony is present as a cement in one sample.

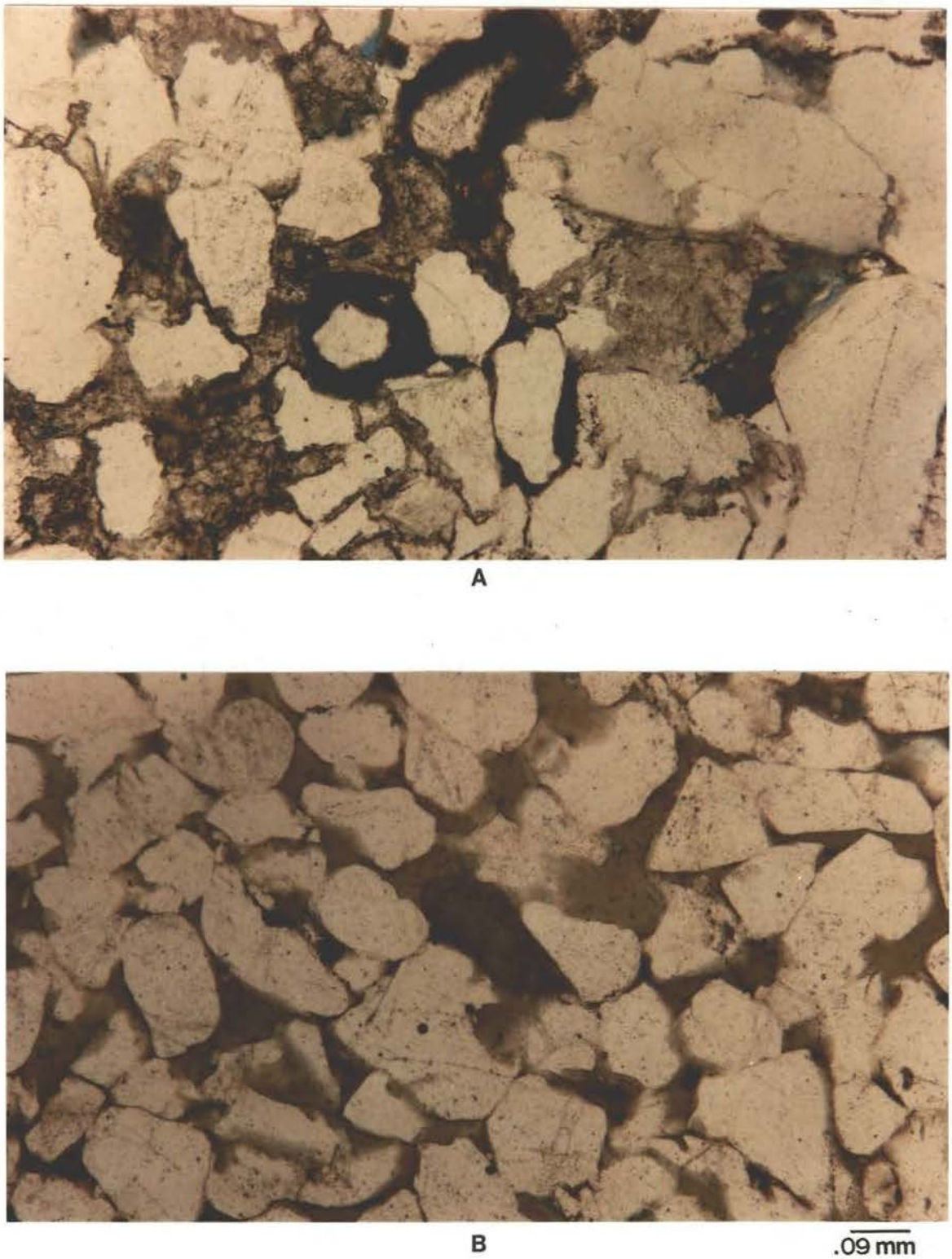
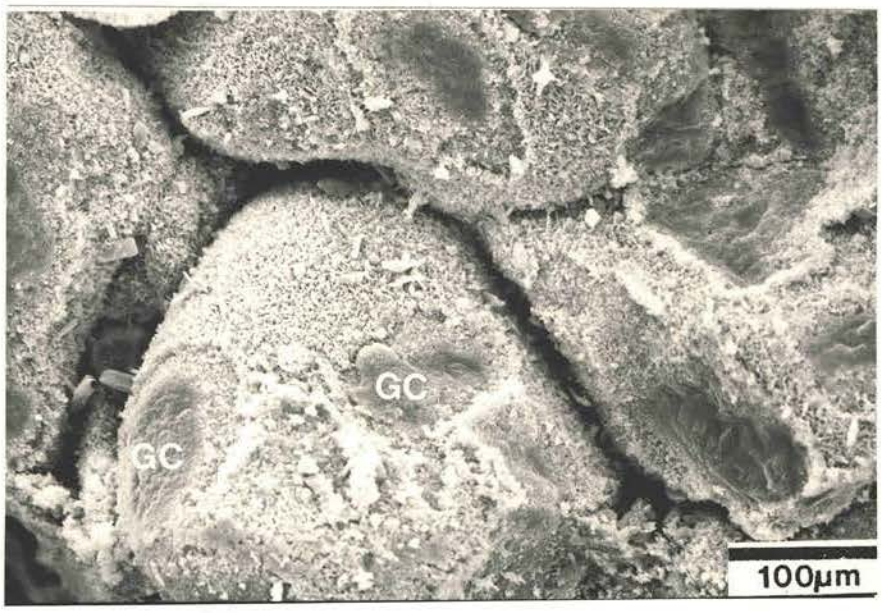


Figure 21 A) Chamosite as oolitic coatings on quartz grains (Tenneco Arkansas Kraft No.1, 13,855'). B) Chamosite as pore filler and pellets (Shell Jankowsky No.1-32, 9,812').

A



B

Figure 22 A) SEM photomicrograph of late-stage chamosite (Shell Jankowsky No.1-32, 9,812'. B) SEM photomicrograph of chamosite completely coating grains. Grain contacts (GC) (Midwest Free No.1, 11,870').

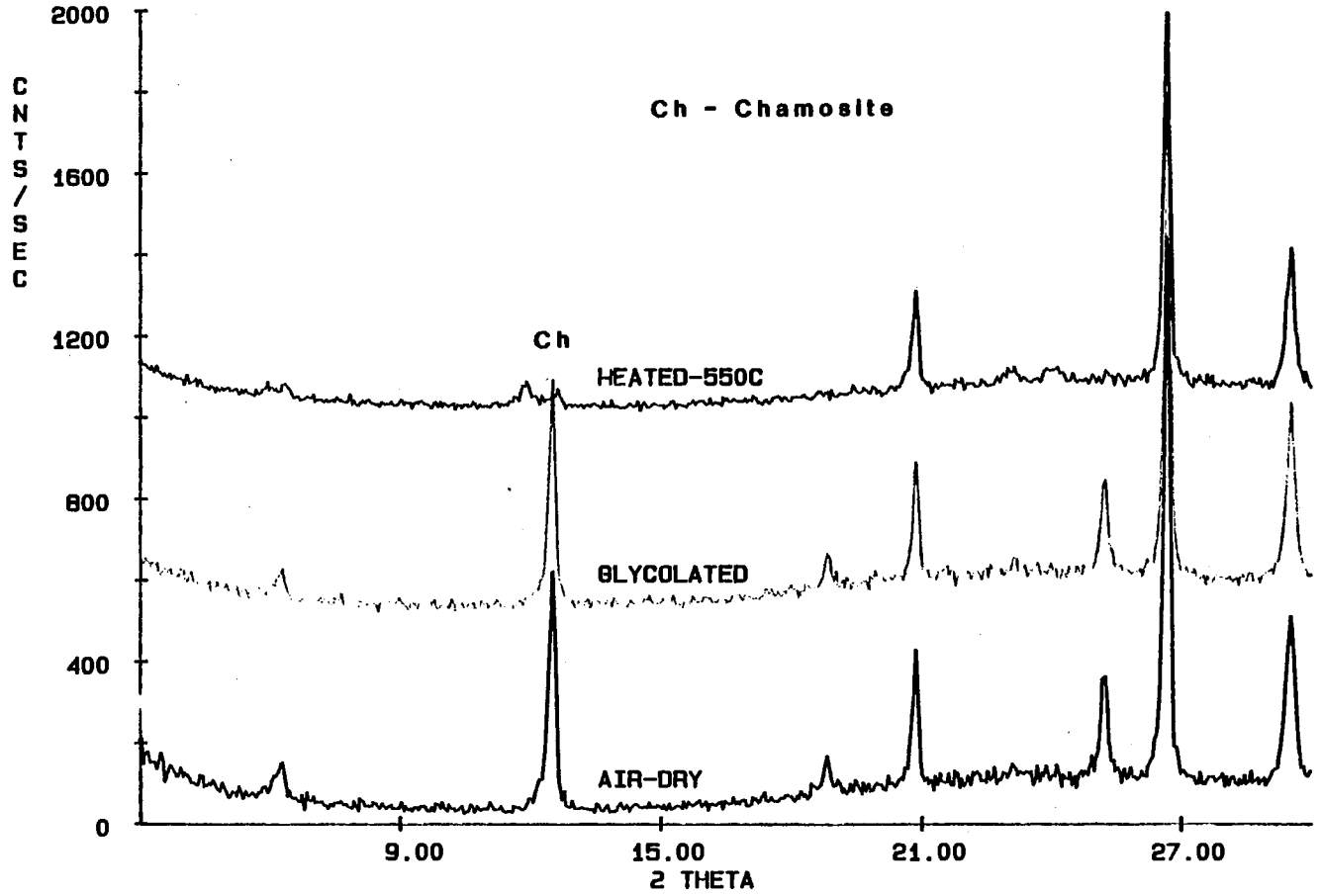


Figure 23 X-ray diffraction peaks of clays from the Pan American Reusch No.1 depth 11,469' showing 7Å peak of chamosite.

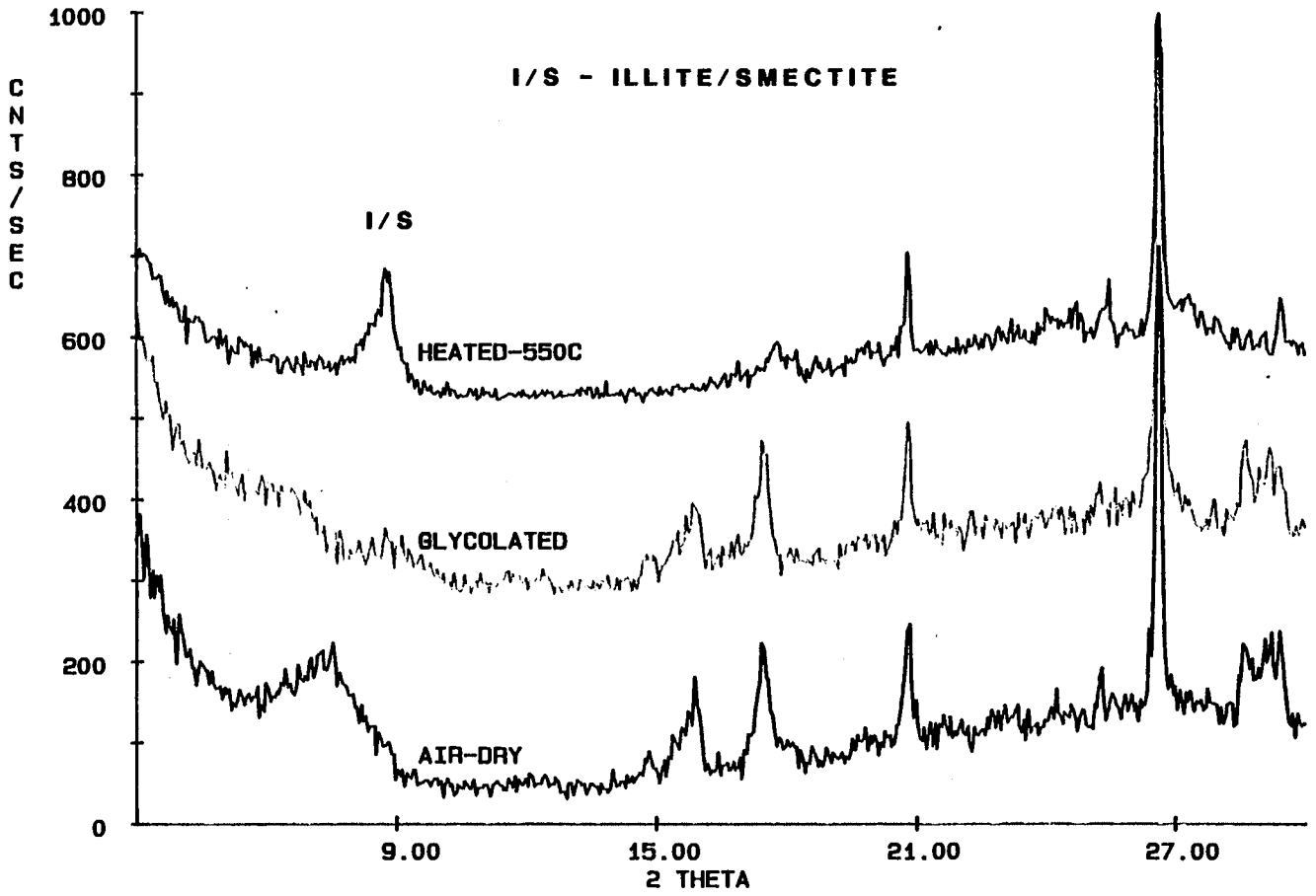


Figure 24 X-ray diffraction peaks of clays from the Shell Mabry No.1-9 depth 5,903'. This sample contains illite/smectite mixed layer and no chamosite.

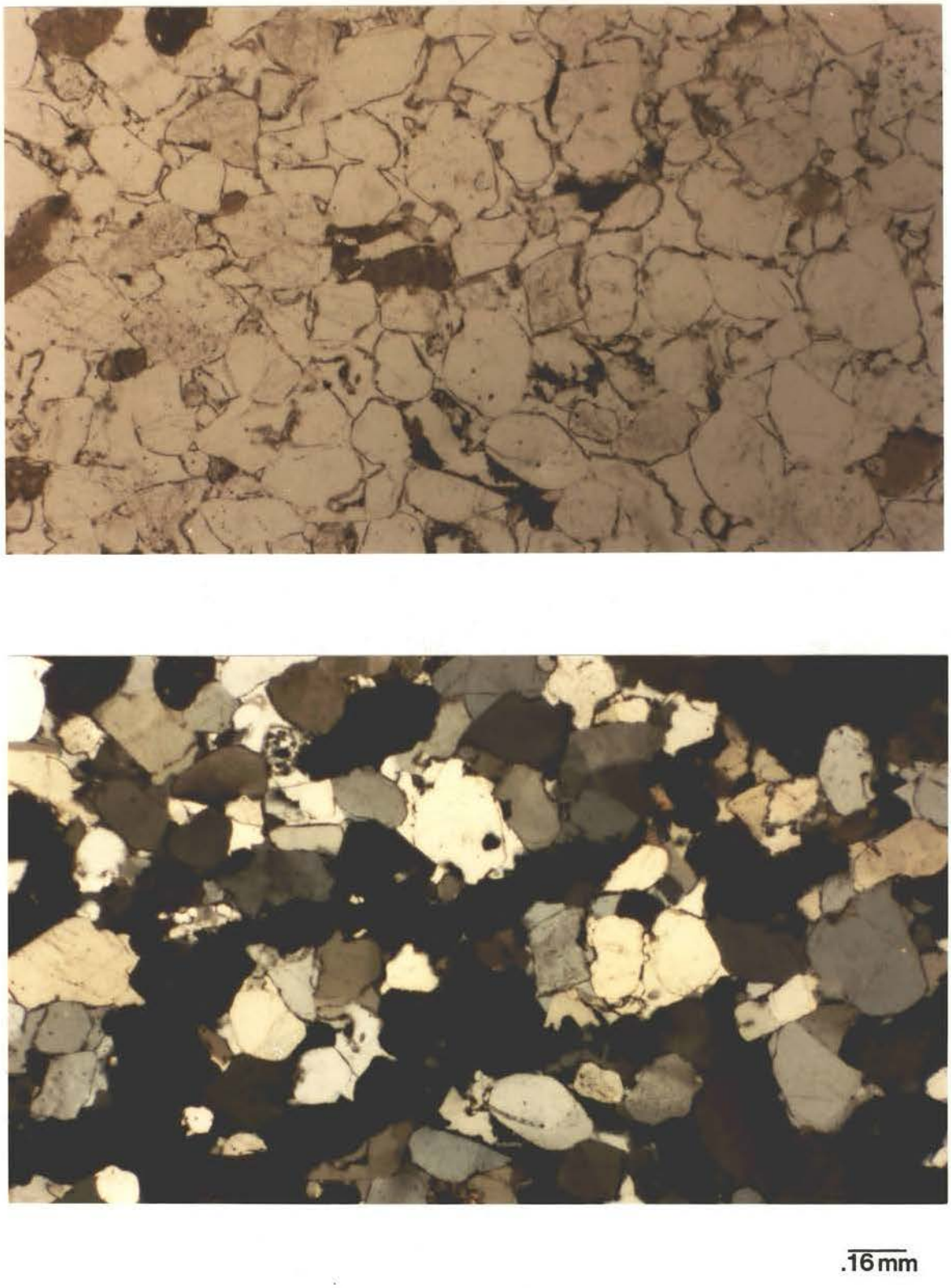


Figure 25 Quartz overgrowths with incomplete chamosite dust rims (plane polarized light and cross-nicols, Midwest Free No.1, 11,818').

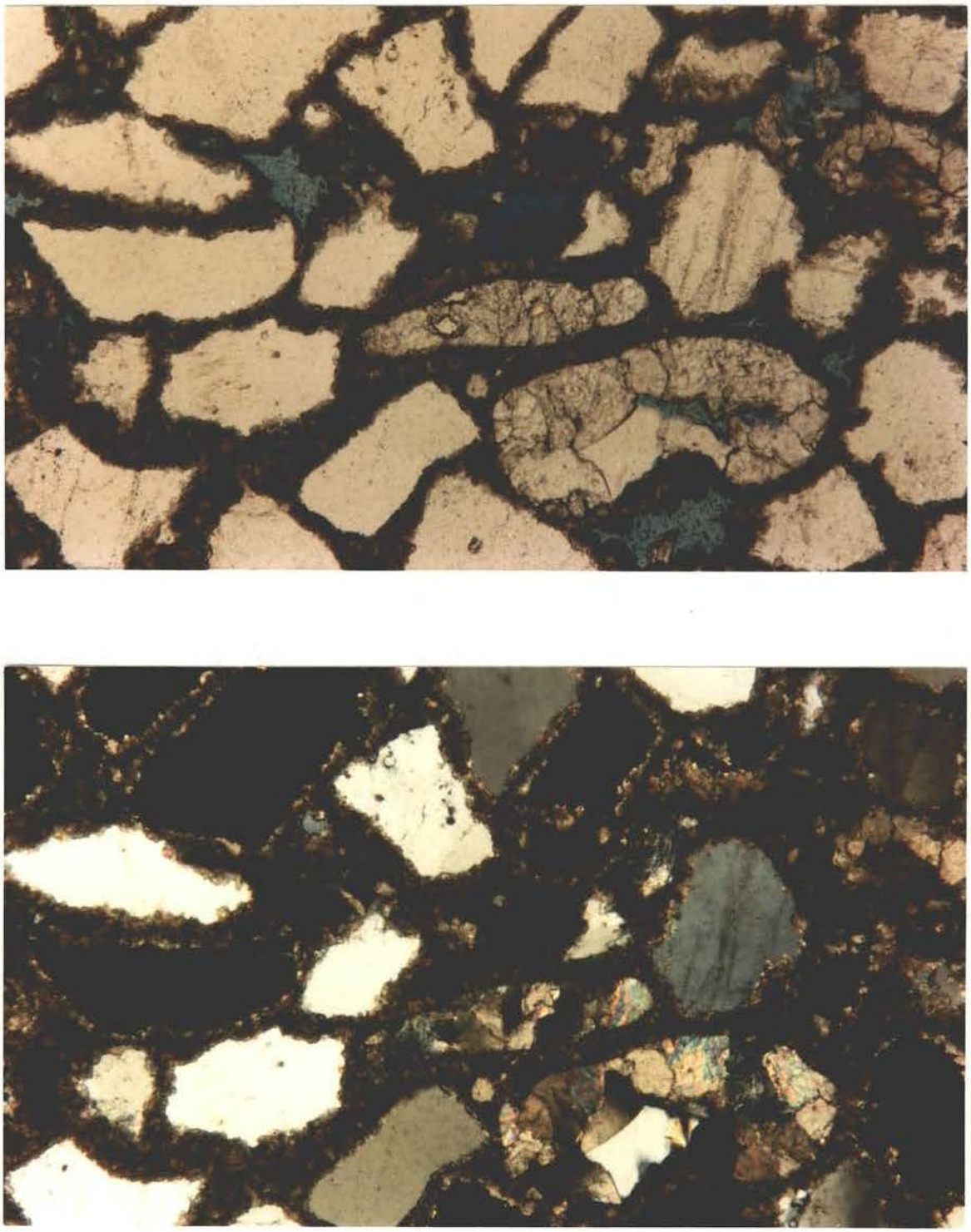


Figure 26 Siderite cement and preservation of some primary porosity (plane polarized light and cross-nicols, Midwest Free No.1, 11,870').

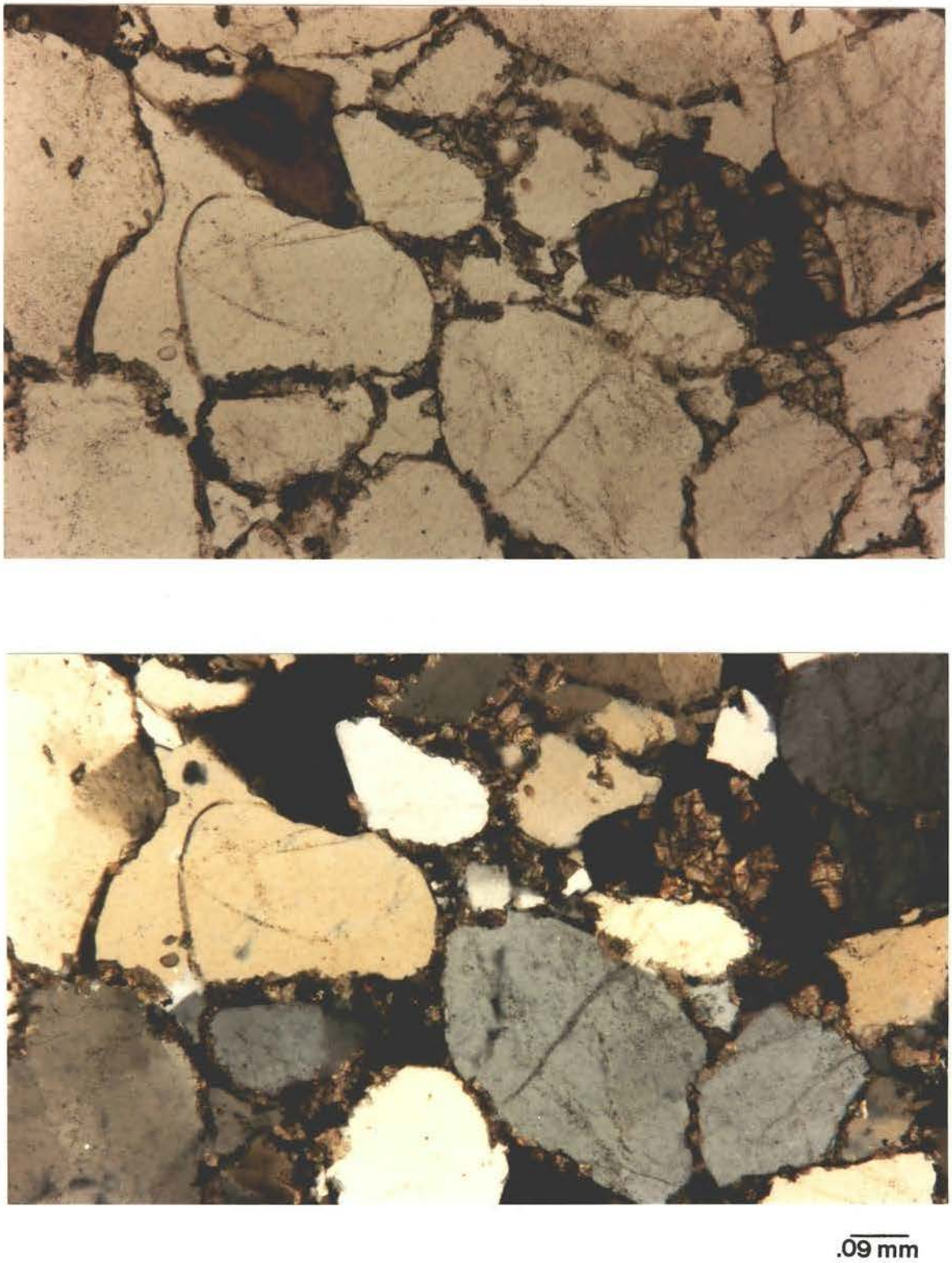
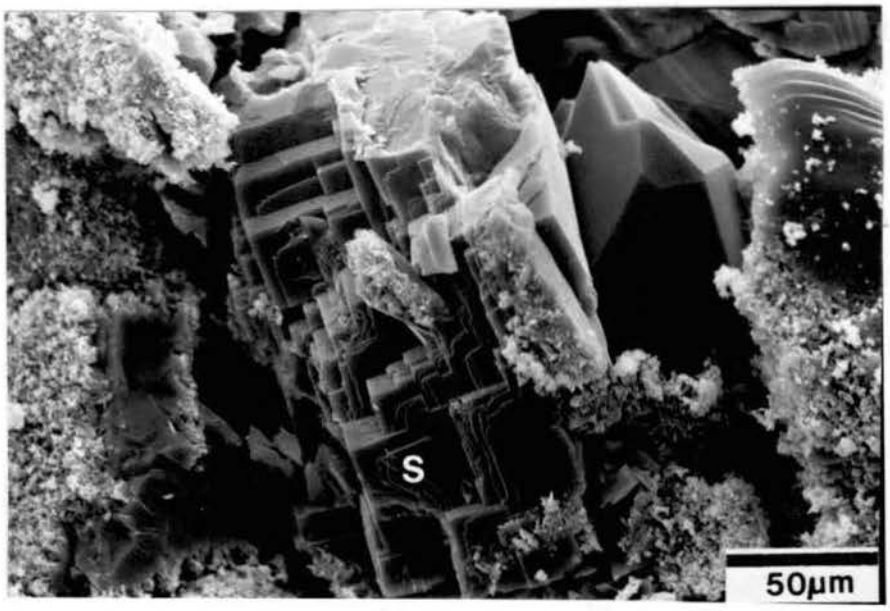
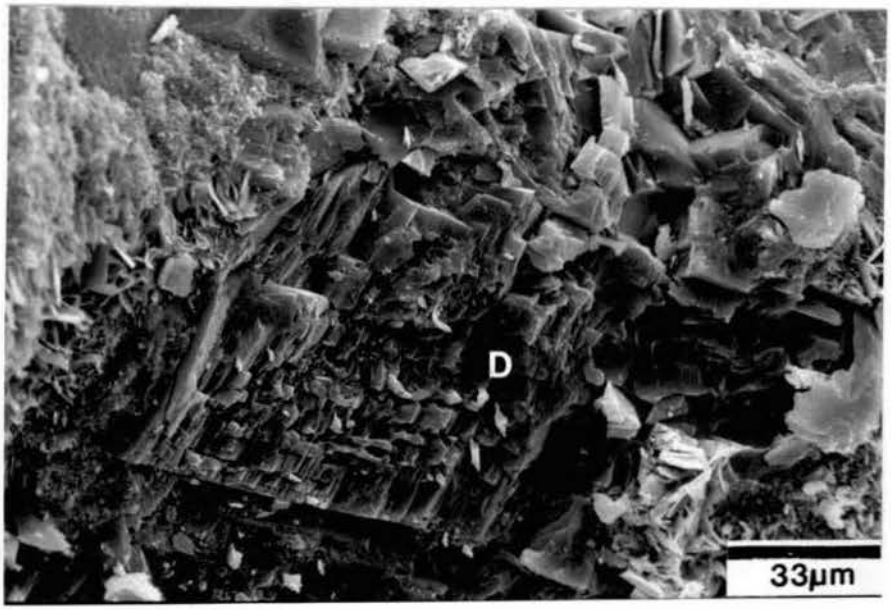


Figure 27 Dolomite cement formed around quartz grains and replacing chamosite pellets (plane polarized and cross-nicols, Shell Jankowsky No.1, 13,756').



A



B

Figure 28 SEM photomicrographs of siderite (A) and dolomite (B) (Midwest Free No.1, 11,870' and Shell Jankowsky No.1-21, 13,756', respectively).

Porosity

Porosity in the Spiro Sandstone is both primary and secondary. Where chamosite grain coatings are complete primary porosity is preserved (Fig. 16). The highest porosity in the Spiro occurs where primary porosity is preserved in the coarse-grained sandstones. Where chamosite did not completely coat the grains, quartz overgrowths formed (Fig. 29). In some thin sections porosity is completely occluded by quartz overgrowths. Secondary porosity was formed primarily due to dissolution of chamosite pellets (Fig. 30). Dissolution of fossils, shale clasts, and siltstone clasts also aided in forming secondary porosity. Most secondary porosity is in the form of enlarged pore spaces (Fig. 19).

Diagenetic History

A general paragenetic sequence is given in Figure 31. The sequence of events and diagenetic constituents may be different for a specific locality.

The first diagenetic event was the precipitation of chamosite as grain coatings. The chamosite pellets may have formed at the same time or they may have formed prior to deposition or they may be penecontemporaneous in origin. Al-Shaieb (1988) considers that both the coatings and pellets formed during this event, which he regards as post-deposition and pre-burial. The chamosite pellets and

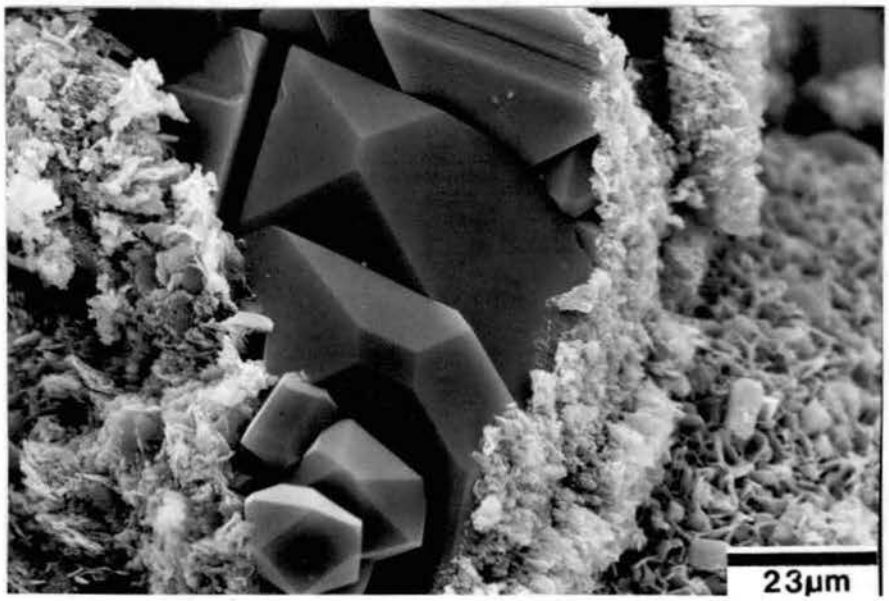
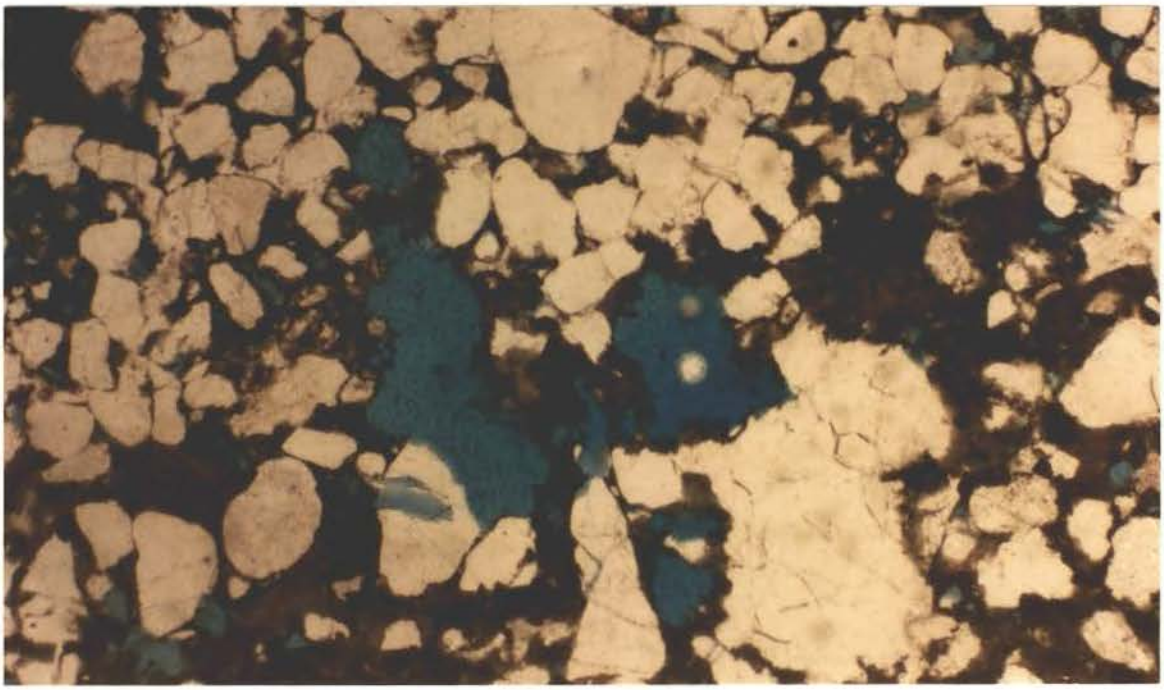
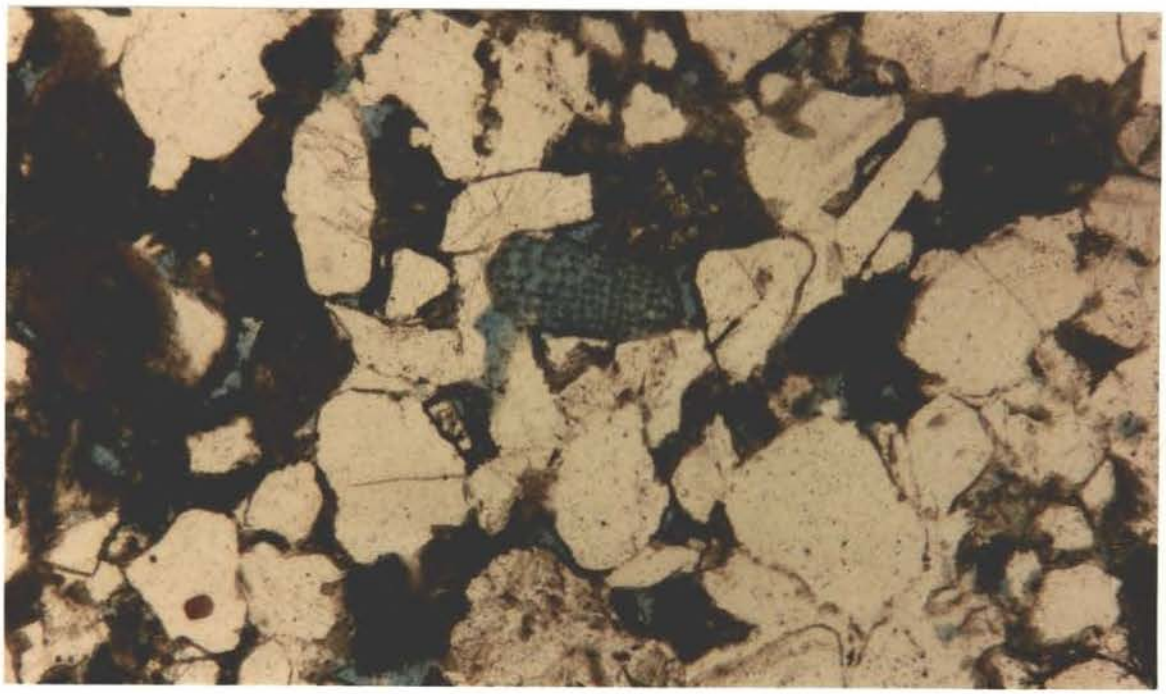


Figure 29 SEM photomicrograph of quartz overgrowth and incomplete chamosite grain coatings (Midwest Free No.1, 11,870').



A

.16 mm



B

.09 mm

Figure 30 Secondary porosity due to dissolution of chamosite pellets (A and B, Shell Jankowsky No.1-32, 9804').

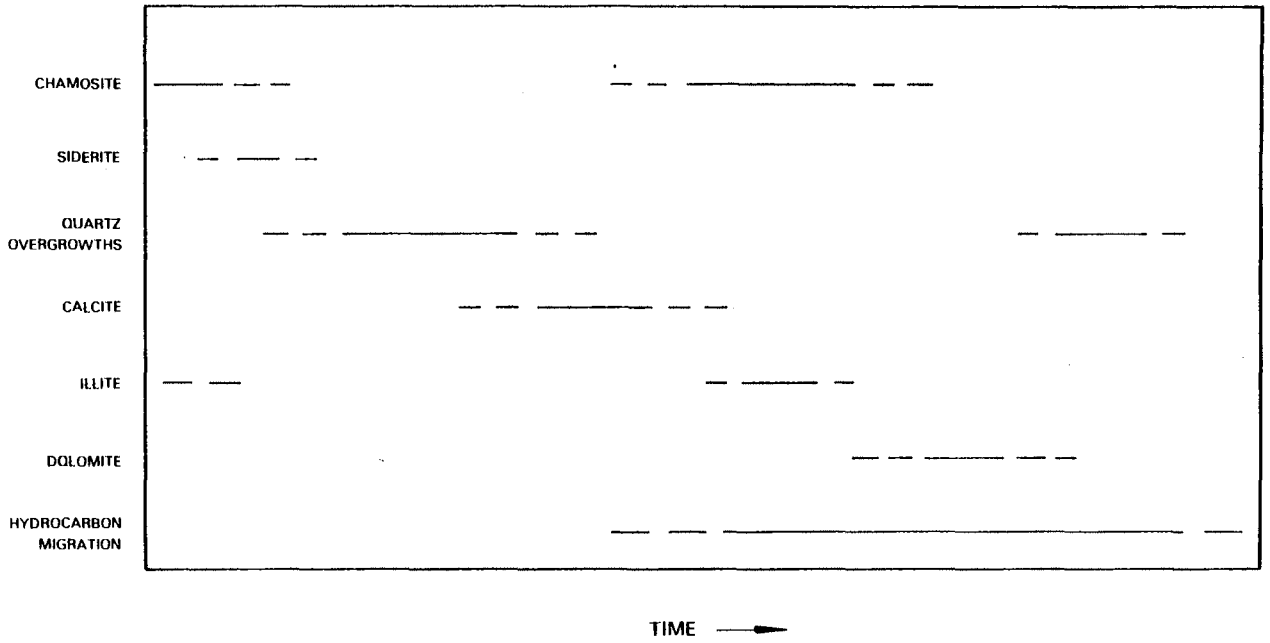


Figure 31 General paragenetic sequence of the Spiro Sandstone.

coating formed at this time are characterized by fine, somewhat randomly oriented crystals. Some illite was also precipitated during this time. This was followed by a short period of siderite cementation in some areas. Syntaxial quartz overgrowths then formed around quartz grains that were not completely coated by chamosite. Local calcite cementation followed, filling pore spaces and forming around fossil fragments. Another stage of chamosite and illite then occurred. Chamosite of the second stage is the more coarsely crystalline and more preferentially oriented (Fig. 22). Dolomite cementation was followed locally by a late stage of quartz cementation in some remaining pore spaces (Fig. 32). Hydrocarbon migration apparently began during late chamosite precipitation and ended following late quartz formation (Fig. 20).

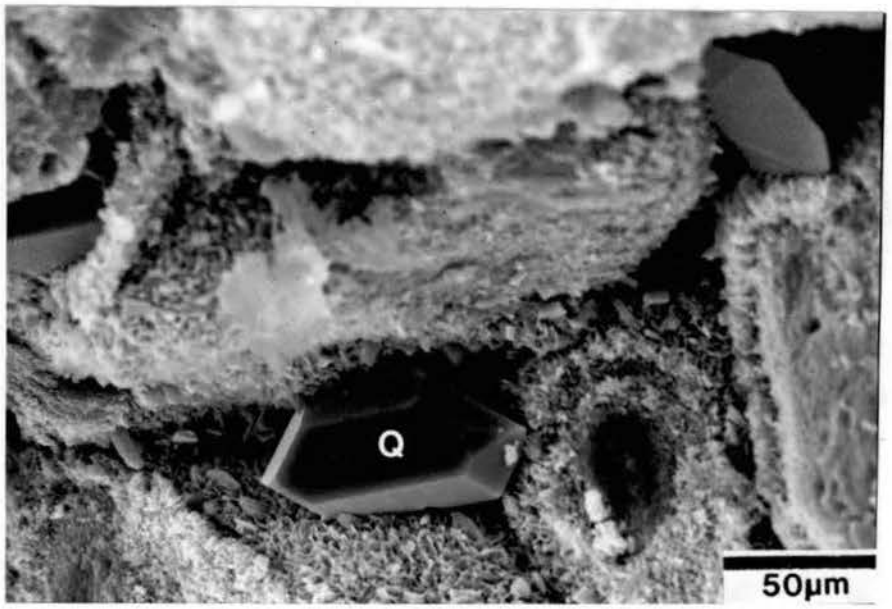


Figure 32 SEM photomicrograph of late stage quartz crystals (Midwest Free No.1, 11,870').

CHAPTER VIII

DEPOSITION OF THE SPIRO SANDSTONE

Depositional Environment

In the area of investigation the Spiro Sandstone was deposited in a shallow-marine environment. This interpretation is based on three primary marine indicators: fossils and/or limestone, burrows and bioturbation, and chamosite. Where the Spiro contains fossils, limestone, and/or burrows and bioturbation, it is easily determined as marine in origin.

Medium- to coarse-grained sandstones in the Spiro that do not contain fossils are also considered as marine deposits. Sharp lateral and lower boundaries of major sandstone trends and the associated coarser grain size are features that could suggest a fluvial origin. Lumsden et al. (1971) referred to these channelized deposits as the "Foster sand" and suggested they were deposited by stream channels. Houseknecht (1987) also discussed the presence of a fluvially dominated facies in the Spiro. However, because chamosite pellets in sandstone are developed only in shallow marine environments (Porrenga, 1967) and are unstable as allochthonous elements, it is thought that these thick, channelized sandstones were also deposited in

a shallow marine environment.

The Spiro Sandstone probably formed on a shelf with strong tidal influence. The channels may reflect subaerial incision with channel infilling after submergence, in an estuarine-like setting, or they may reflect localized nearshore current activity associated with an embayed coastline where tidal currents were particularly strong.

It should be noted that most internal features of the Spiro, such as crossbedding, interstratification, grain size, and sorting are not particularly diagnostic in determining environments. Also, the sequences of sedimentary structures and textures are of limited value in the environmental analysis.

Depositional slope during Spiro deposition apparently was to the south. This is indicated by the stable framework mineralogy and the foreland geologic setting. The common occurrence of flowage structures in Spiro cores suggests the possibility of locally unstable slopes.

Depositional History

Prior to deposition of the sub-Spiro shale the northeastern part of the study area (T8N, R21E) was exposed and the Wapanucka Limestone was partially to completely eroded (Fig. 4). This unconformity appears to be related to sea level fluctuations common during the Pennsylvanian.

Lumsden et al. (1971) show a local low-relief angular relationship between the Spiro and underlying strata in the

northwestern part of the study area. This discordance reflects erosion after deposition of the sub-Spiro shale.

The prominent local unconformity at the base of thick Spiro Sandstone may have formed during a second period of emergence. However, the transitional sections between the Spiro and sub-Spiro shale suggest that this prominent unconformity, as well as subsequent channel infilling, may have formed entirely in a marine environment. The thick sandstones reflect channels that cut through locally deposited Spiro sand into the sub-Spiro shale and, in some cases, into the Wapanucka Limestone (Fig. 4). Deposition of blanket-like Spiro in some areas preceded channeling, but this geometry developed best after channel infilling. Atokan shales were deposited conformably on the Spiro Sandstone as growth faults became active.

CHAPTER IX

PETROLEUM GEOLOGY

The Spiro Sandstone is one of the main gas producing sandstones in the Oklahoma part of the Arkoma basin. In the study area the Spiro is the main producer in the Wilburton and Kinta gas fields and a secondary producer in the Red Oak-Norris field (Fig. 33).

The Kinta gas field is located in the northern half of the study area and extends north and east out of the area of investigation. The field was discovered in 1951 by the Superior Oil Company. The initial test well was the Allred No.1 located in section 18, T8N, R20E; it tested 3 MMCFGPD (Woncik, 1962). The Kinta field also produces from other Atokan sandstones as well as the Morrowan Cromwell Sandstone. As of January of 1988 the field has a cumulative production of 517 BCFG from the Spiro Sandstone within the study area.

The Wilburton gas field, in parts of T5 and 6N, R17 to 19E, was discovered in 1960 by the Ambassador Oil Corporation. The Williams No.1 well, located in section 23, T5N, R18E was completed in the Spiro with a calculated open flow of 8.3 MMCFGPD (Berry and Trumbly, 1968). The trapping mechanism for gas in the Wilburton field is a series of

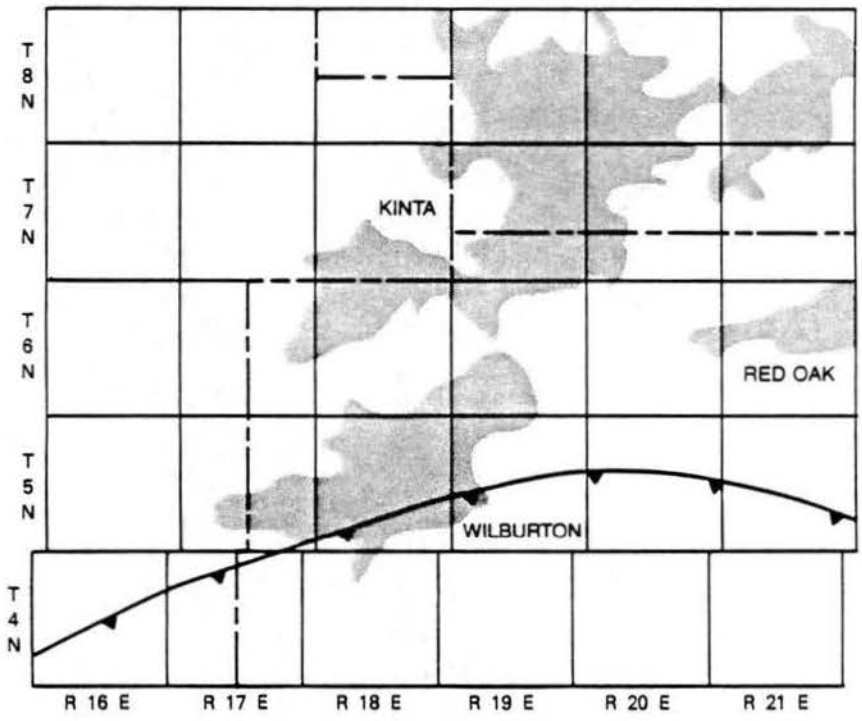


Figure 33 Index map showing location of major gas fields in the study area.

thrust-faulted anticlines that pass upward into the Adamson and Wilburton anticlines at the surface. Cumulative production as of January of 1988 was 590 BCFG from the Spiro Sandstone.

The Red Oak-Norris field is situated directly under the surface expression of the Brazil anticline in T6N, R21 to 23E. The field was first discovered in 1912 by Gladys Belle Oil Company by drilling a well in section 10, T6N, R21E. Production from this well came from the Desmoinesian Hartshorne Sandstone (Six, 1962). Later, production was established in the Atokan Red Oak and Spiro sandstones. The Spiro is a secondary producer in the Red Oak field, and in the study area it has produced 91 BCFG, as of January, 1988.

CHAPTER X

SUMMARY

The principal conclusions of this study are as follows:

1. The Spiro Sandstone thickens generally southward and eastward.

2. The Wapanucka Limestone thickens generally southward and westward.

3. Shale that separates the Wapanucka and Spiro in most areas is thickest in the northeast.

4. The sub-Spiro shale is very thin or absent locally due to pre-Spiro channeling.

5. The Wapanucka Limestone is thin or absent in the northeast due to erosion, possibly during sea-level fluctuations.

6. Local unconformities related to depositional processes exist where Spiro channelized sandstones overlie an anomalously thin shale and in some cases the Wapanucka Limestone.

7. The Spiro may be divided into three facies: 1) sandstones with fossils and/or limestone bed(s), 2) medium- to coarse-grained sandstone with no visible fossils or limestone, and 3) limestone and fossiliferous sandstone.

8. In the southeast the Spiro is mainly fossiliferous sandstone and limestone.

9. In the Wilburton area the Spiro is composed mainly of sandstones with fossils and/or a limestone unit.

10. In the Kinta area the Spiro contains no discernible limestone and is generally composed of unfossiliferous sandstone.

11. In the Red Oak area both unfossiliferous and fossiliferous sandstone occurs as well as sandy limestone beds.

12. The Spiro Sandstone is interpreted as having been deposited in a shallow marine environment, based on the presence of fossils, limestone, burrows and bioturbation, and chamosite pellets.

13. Chamosite pellets are present in the coarse-grained channelized sandstone suggesting it is also marine.

14. Trends of channelized Spiro generally extend to the south and southeast.

15. Where chamosite grain coatings are complete, primary porosity is preserved.

16. Secondary porosity is due mainly to the dissolution of chamosite pellets but also to dissolution of fossil fragments, shale clasts, and siltstone clasts.

17. Porosity is highest in the medium- to coarse-grained sandstones that contain no visible fossils.

18. Chamosite occurs as pellets, grain coatings, pore fillings, and oolitic coatings in the Spiro.

19. The Spiro is a gas-prone reservoir in the study area and is a producer in the Kinta, Wilburton, and Red Oak gas fields.

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APPENDIX

CORE DESCRIPTIONS

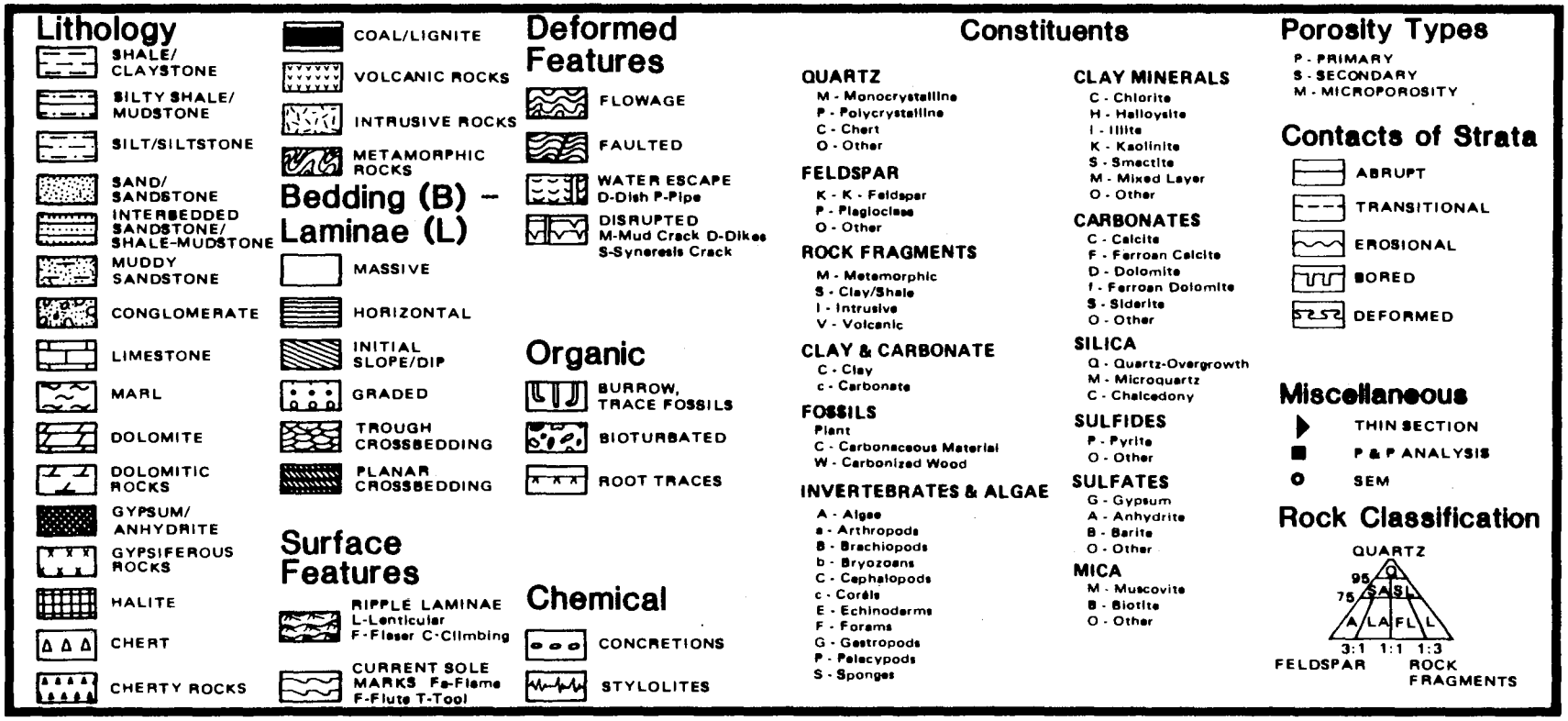

Lithology
SHALE/ CLAYSTONE
SILTY SHALE/ MUDSTONE
SILT/SILTSTONE
SAND/ SANDSTONE
INTERBEDDED SANDSTONE/ SHALE-MUDSTONE
MUDDY SANDSTONE
CONGLOMERATE
LIMESTONE
MARL
DOLOMITE
DOLOMITIC ROCKS
GYPSUM/ ANHYDRITE
GYPSIFEROUS ROCKS
HALITE
CHERT
CHERTY ROCKS
COAL/LIGNITE
VOLCANIC ROCKS
INTRUSIVE ROCKS
METAMORPHIC ROCKS
Bedding (B) – Laminae (L)
MASSIVE
HORIZONTAL
INITIAL SLOPE/DIP
GRADED
TROUGH CROSSBEDDING
PLANAR CROSSBEDDING
Surface Features
RIPPLE LAMINAE L-Lenticular F-Flaser C-Climbing
CURRENT SOLE MARKS Fe-Flame F-Flute T-Tool
Deformed Features
FLOWAGE
FAULTED
WATER ESCAPE D-Dish P-Pipe
DISRUPTED M-Mud Crack D-Dikes S-Syneresis Crack
Organic
BURROW, TRACE FOSSILS
BIOTURBATED
ROOT TRACES
Chemical
CONCRETIONS
STYLOLITES
Constituents
QUARTZ
M - Monocrystalline
P - Polycrystalline
C - Chert
O - Other
FELDSPAR
K - K - Feldspar
P - Plagioclase
O - Other
ROCK FRAGMENTS
M - Metamorphic
S - Clay/Shale
I - Intrusive
V - Volcanic
CLAY & CARBONATE
C - Clay
c - Carbonate
FOSSILS
Plant
C - Carbonaceous Material
W - Carbonized Wood
INVERTEBRATES & ALGAE
A - Algae
a - Arthropods
B - Brachiopods
b - Bryozoans
C - Cephalopods
c - Corals
E - Echinoderms
F - Forams
G - Gastropods
P - Pelecypods
S - Sponges
CLAY MINERALS
C - Chlorite
H - Halloysite
I - Illite
K - Kaolinite
S - Smectite
M - Mixed Layer
O - Other
CARBONATES
C - Calcite
F - Ferroan Calcite
D - Dolomite
f - Ferroan Dolomite
S - Siderite
O - Other
SILICA
Q - Quartz-Overgrowth
M - Microquartz
C - Chalcedony
SULFIDES
P - Pyrite
O - Other
SULFATES
G - Gypsum
A - Anhydrite
B - Barite
O - Other
MICA
M - Muscovite
B - Biotite
O - Other
Porosity Types
P - PRIMARY
S - SECONDARY
M - MICROPOROSITY
Contacts of Strata
ABRUPT
TRANSITIONAL
EROSIONAL
BORED
DEFORMED
Miscellaneous
THIN SECTION
P & P ANALYSIS
SEM
Rock Classification
QUARTZ
95
75
Q
SA
SL
A
LA
FL
L
3:1
1:1
1:3
FELDSPAR
ROCK FRAGMENTS

Figure 34 Core description of Pan American Smallwood No.1, NE 1/4, section 10, T4N, R16E; cored interval from 11,678 to 11,736 feet (right).

SUMMARY

Composed of fossiliferous sandstone and limestone, in four units or intervals, described from bottom to top.

1. From 11,710 to 11,729 feet, very fine-grained sandstone and interlaminated siltstone and shale. Zoophycus and bioturbation are very common. Some flowage is also present.

2. From 11,698 to 11,710 feet, limestone. The lower 8 feet are characterized by nodular bedding. The upper four feet are oolitic, grain-supported carbonate, with some quartz grains evident in thin section.

3. From 11,689 to 11,698 feet, very fine-grained sandstone with a thin bed of limestone. Planolites trace fossils are present as well as bioturbation, flowage, and crossbedding.

4. From 11,678 to 11,689 feet, interbedded sandstone, limestone, and shale. The sandstones are characteristically thin, very fine-grained, and fossiliferous.

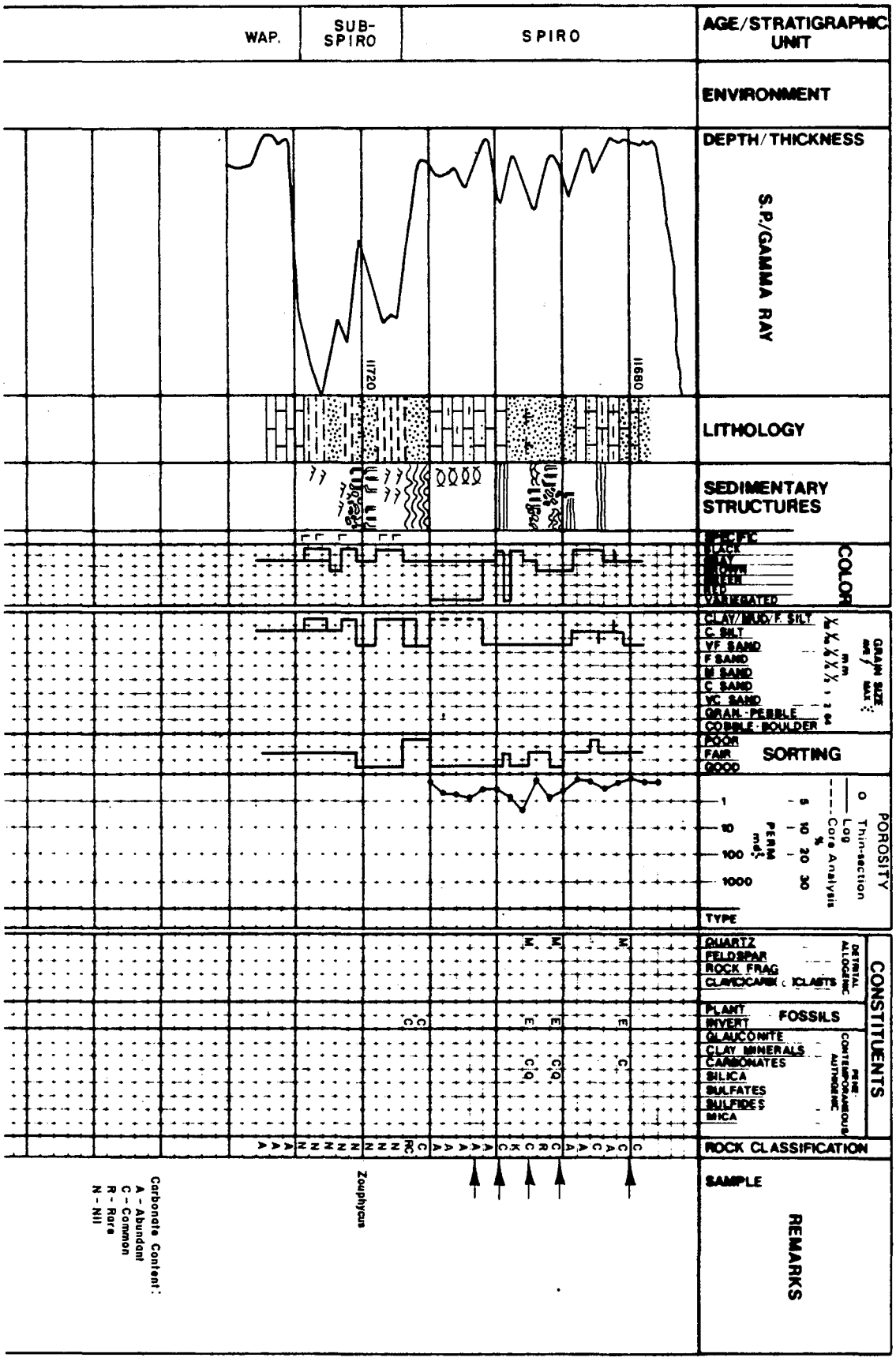

WAP.
SUB-SPIRO
SPIRO
AGE/STRATIGRAPHIC UNIT
ENVIRONMENT
DEPTH/THICKNESS
S.P./GAMMA RAY
11720
11680
LITHOLOGY
SEDIMENTARY STRUCTURES
COLOR
SPECIFIC
BLACK
GRAY
BROWN
GREEN
RED
VARIEGATED
GRAIN SIZE
CLAY/MUD/F. SILT
C. SILT
VF SAND
F SAND
M SAND
C SAND
VC SAND
GRAN.-PEBBLE
COBBLE-BOULDER
SORTING
POOR
FAIR
GOOD
POROSITY
Thin-section
Log
Core Analysis
PERM md.
TYPE
CONSTITUENTS
DETRITAL ALLOGENIC
QUARTZ
FELDSPAR
ROCK FRAG
CLAY/CARB CLASTS
FOSSILS
PLANT
INVERT
AUTHIGENIC
GLAUCONITE
CLAY MINERALS
CARBONATES
SILICA
SULFATES
SULFIDES
MICA
ROCK CLASSIFICATION
SAMPLE
REMARKS
Carbonate Content:
A - Abundant
C - Common
R - Rare
N - Nil
Zaphrycus

Figure 35 Core description of Shell Mabry No.1-9, SW 1/4, section 9, T4N, R18E; core interval from 13,129 to 13,173 feet (right).

SUMMARY

The core is composed of fossiliferous sandstone and limestone, in four units, described from bottom to top.

1. A transition unit of shale and interlaminated siltstone and shale. Flowage is the dominant sedimentary feature and a thin conglomerate is present.

2. From 13,147 to 13,155 feet, very fine-grained, well-sorted sandstone. Burrows, bioturbation, and crossbedding are common sedimentary features.

3. From 13,133 to 13,147 feet, fossiliferous, massive limestone.

4. From 13,129 to 13,133 feet, fossiliferous, fine-grained sandstone. Low-angle medium-scale crossbedding is the dominant sedimentary structure.

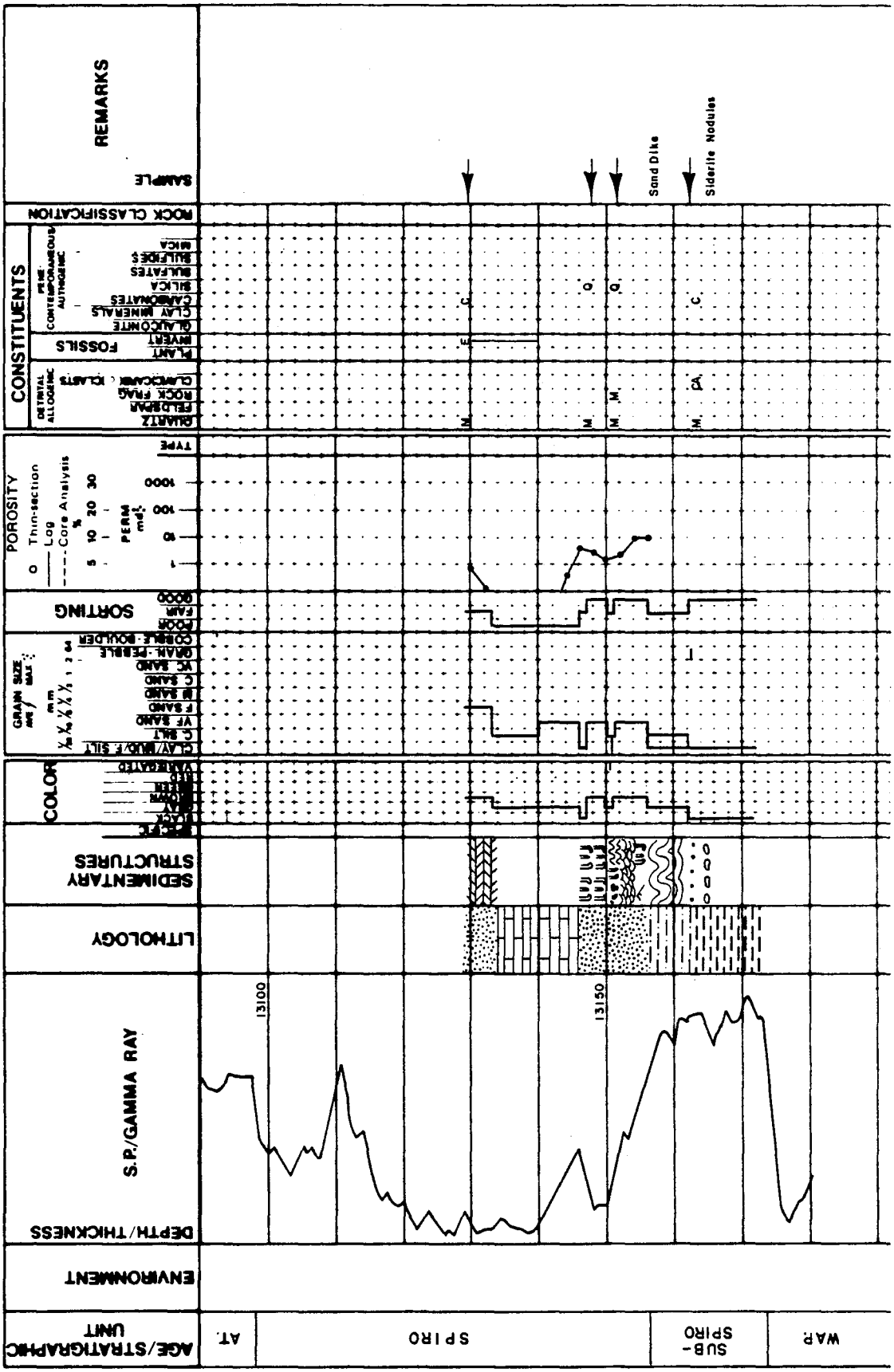

REMARKS
SAMPLE
Sand Dike
Siderite Nodules
ROCK CLASSIFICATION
CONSTITUENTS
DETRITAL ALLOGENIC
QUARTZ
FELDSPAR
ROCK FRAG.
CLAY/MICA FLAKES
FOSSILS
PLANT
INVERT.
FINE CONSTITUENTS AUTHIGENIC
GLAUCONITE
CLAY MINERALS
CARBONATES
SILICA
SULFATES
SULFIDES
MICA
POROSITY
Thin-section
Log
Core Analysis
PERM md.
TYPE
SORTING
GRAIN SIZE
CLAY/SILT
VF SAND
F SAND
M SAND
C SAND
VC SAND
GRAN.-PEBBLE
COBBLE-BOULDER
COLOR
VARIEGATED
BLACK
GRAY
BROWN
GREEN
RED
WHITE
SEDIMENTARY STRUCTURES
LITHOLOGY
S.P./GAMMA RAY
13100
13150
DEPTH/THICKNESS
ENVIRONMENT
AGE/STRATIGRAPHIC UNIT
AT.
SPIRO
SUB-SPIRO
WAR.

Figure 36 Core description of Shell Mabry No.1-9, SW 1/4, section 9, T4N, R18E; core interval from 5,830 to 5,952 (right).

SUMMARY

This core is composed of sandstone and limestone, in four units from bottom to top.

1. From 5,898 to 5,952 feet, fine-grained, well-sorted fossiliferous sandstone. Sedimentary structures include flowage, burrows, bioturbation, and crossbedding.

2. From 5,882 to 5,898 feet, limestone.

3. From 5,857 to 5,882 feet, bioclastic packstone, some interbedded shale. Highly bioturbated, very fine-grained sandstone at 5,868'.

4. From 5,930 to 5,857 feet, massive bedded limestone.

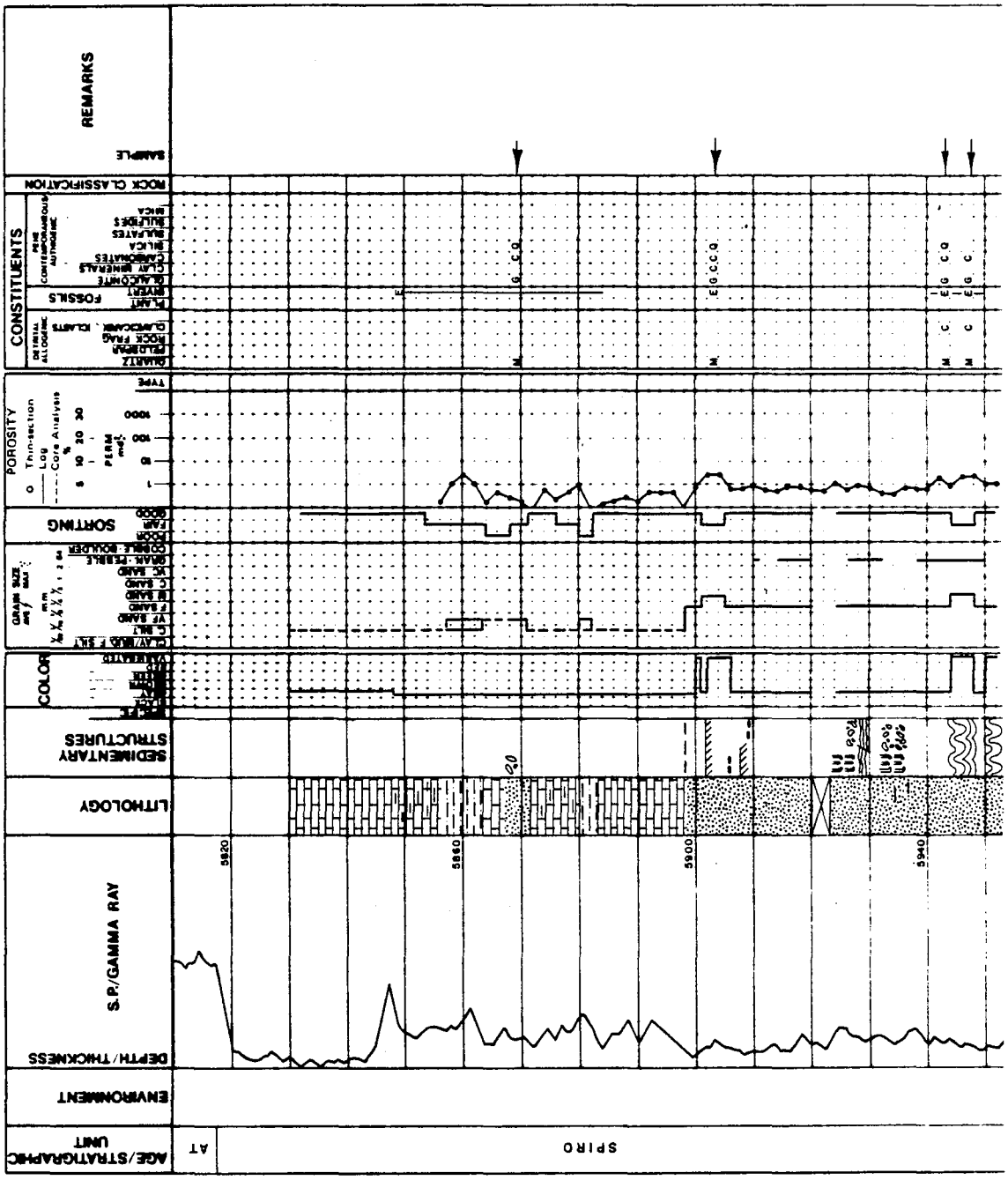

REMARKS
SAMPLE
ROCK CLASSIFICATION
CONSTITUENTS
POROSITY
SORTING
COLOR
SEDIMENTARY STRUCTURES
LITHOLOGY
S.P./GAMMA RAY
DEPTH/THICKNESS
ENVIRONMENT
AGE/STRATIGRAPHIC UNIT
AT
SPIRO
5920
5940
5960
5980
6000
6020

Figure 37 Core description of Pan American Reusch No.1, NW 1/4, section 3, T5N, R19E in the Wilburton gas field; cored interval from 11,678 to 11,736 feet (right).

SUMMARY

The core is composed of sandstone and limestone, in four units, described from bottom to top.

1. A transition unit of interlaminated siltstone and shale. Sedimentary features include bioturbation and lenticular bedding.

2. From 11,497 to 11,525 feet, crossbedded fossiliferous limestone. Abundant fossils include echinoids and crinoids. Quartz grains on the order of 33% are present in thin section.

3. From 11,478 to 11,497 feet, medium-grained quartzarenite. Medium-scale cross bedding is the dominant sedimentary feature. Log porosity averages 17%. Fossils are present in thin section, with a few visible in hand specimen.

4. From 11,467 to 11,478 feet, a fine-grained quartzarenite. Sedimentary features include crossbedding, burrows, and flowage. Porosity ranges from 3 to 10%. Fossils are visible in hand specimen.

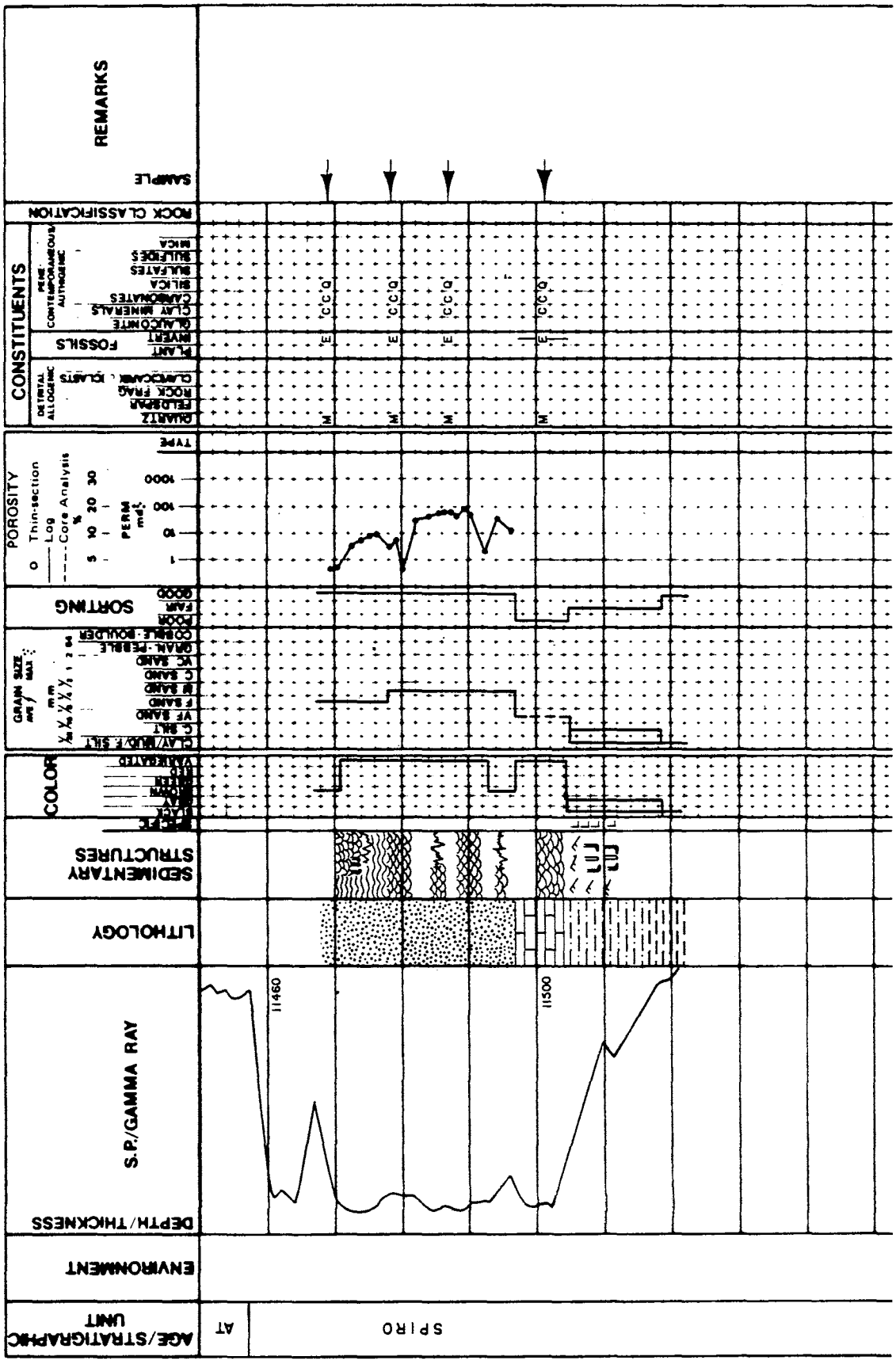

REMARKS
SAMPLE
ROCK CLASSIFICATION
CONSTITUENTS
DETRITAL ALLOGENIC
QUARTZ
FELDSPAR
ROCK FRAG.
GLAUCONITE
FOSSILS
PLANT
DIAGENETIC CONTEMPORANEOUS AUTHIGENIC
MICA
SULFIDES
SULFATES
SILICA
CARBONATES
CLAY MINERALS
GLAUCONITE
POROSITY
Thin-section
Log
Core Analysis
PERM md.
TYPE
SORTING
GRAIN SIZE mm
COLOR
SEDIMENTARY STRUCTURES
LITHOLOGY
S.P./GAMMA RAY
11460
11500
DEPTH/THICKNESS
ENVIRONMENT
AGE/STRATIGRAPHIC UNIT
AT
SPIRO

Figure 38 Core description of Tenneco Arkansas Kraft No.1-25, SW 1/4, section 25, T6N, R19E, in the Wilburton gas field; cored interval from 13,840 to 13,896 feet (right).

SUMMARY

This core consists of sandstone and limestone, in four units, described from bottom to top.

1. Limestone unit (13,885 to 13,896 feet) contains no quartz grains in thin section.

2. From 13,882 to 13,885 feet, interstratified sandstone and shale. Burrows occur locally.

3. From 13,860 to 13,882 feet, fine-grained quartzarenite. Stylolites are common throughout the unit and medium-scale cross-bedding is the dominant sedimentary structure. Porosity is low, averaging 2%, and permeability averages around 10 md but varies locally.

4. From 13846 to 13860 feet, a fine-grained sandstone dominated by flowage. Some burrows are also present. Porosity averages 8% and permeability averages a little greater than 100 md.

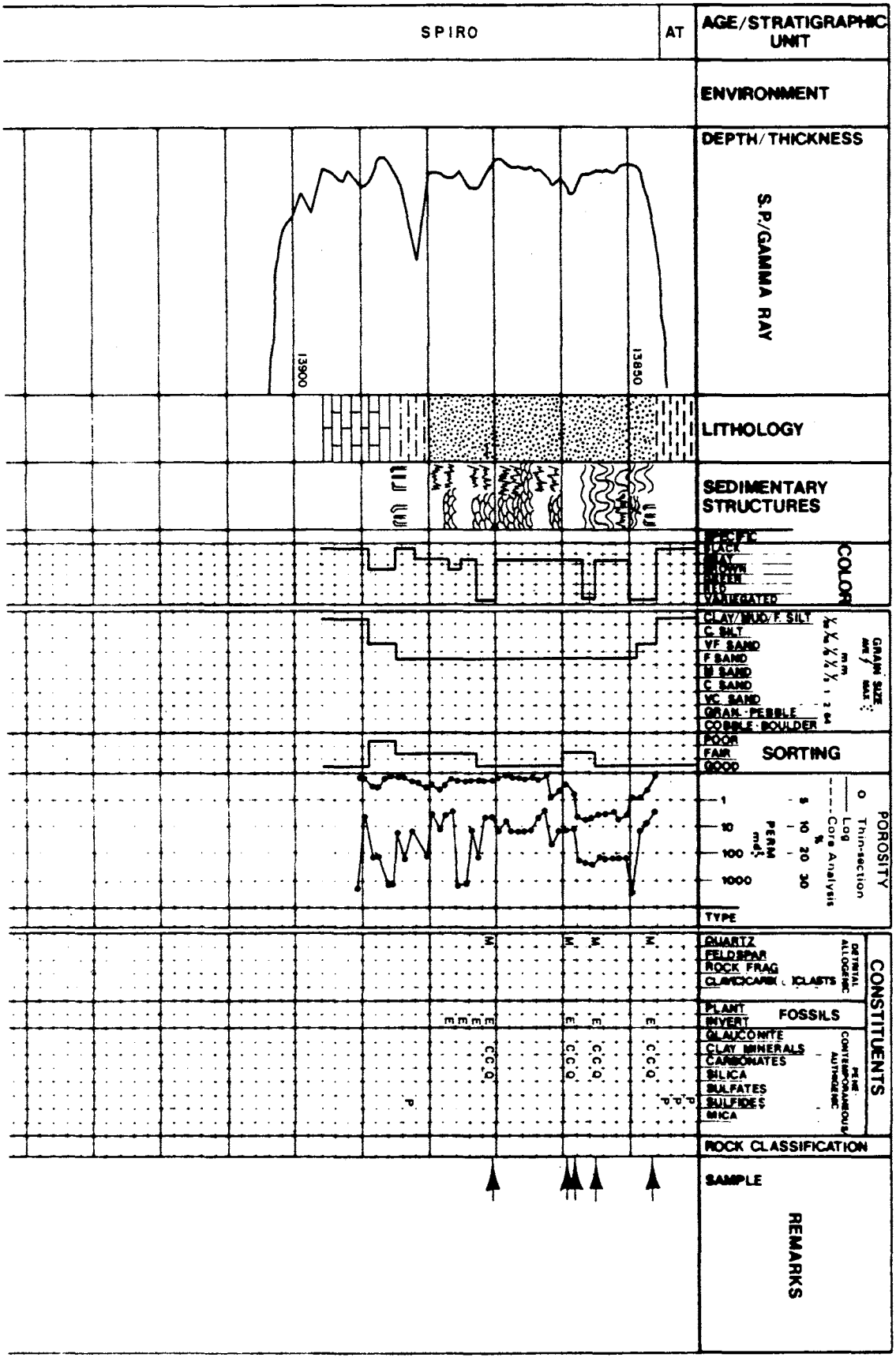

SPIRO
AT
AGE/STRATIGRAPHIC UNIT
ENVIRONMENT
DEPTH/THICKNESS
S.P/GAMMA RAY
13900
13850
LITHOLOGY
SEDIMENTARY STRUCTURES
COLOR
SPECIFIC
BLACK
GRAY
BROWN
GREEN
RED
VARIEGATED
CLAY/MUD/F. SILT
C. SILT
VF SAND
F SAND
M SAND
C SAND
VC SAND
GRAN.-PEBBLE
COBBLE-BOULDER
GRAIN SIZE
mm
MIN
MAX
SORTING
POOR
FAIR
GOOD
POROSITY
Thin-section
Log
Core Analysis
PERM md.
%
TYPE
CONSTITUENTS
DETRITAL ALLOGENIC
QUARTZ
FELDSPAR
ROCK FRAG
CLAY/CARB. CLASTS
FOSSILS
PLANT
INVERT
CONTEMPORANEOUS AUTHIGENIC
GLAUCONITE
CLAY MINERALS
CARBONATES
SILICA
SULFATES
SULFIDES
MICA
ROCK CLASSIFICATION
SAMPLE
REMARKS

Figure 39 Core description of Shell Jankowsky No.1-21, S 1/2, N 1/2, section 21, T6N, R20E; cored interval from 13,717 to 13,758 feet (right).

SUMMARY

Core is composed of fine- to coarse-grained sandstone and interstratified sandstone-siltstone and shale, in five units, described from bottom to top.

1. From 13,755 to 13,758 feet, interstratified sandstone-siltstone and shale.

2. From 13,743 to 13,755 feet, medium- to coarse-grained, moderately- to well-sorted sandstone. Fossils and intraclasts are present in the upper foot; the unit is generally massive bedded. Porosity averages 10%.

3. From 13,736 to 13,743 feet, interstratified sandstone-siltstone and shale. Lenticular bedding occurs locally.

4. From 13,727 to 13,736 feet, fine-grained sandstone. It is well sorted and has an average porosity of 5%. Fossils are common; it is massively bedded.

5. From 13,717 to 13,727 feet, medium- to coarse-grained sandstone. Coarse-grained sand in thin beds appears to be more porous than the medium-grained sand. It is well-sorted, massively bedded; porosity ranges from 5 to 11%. Fossils are visible locally in hand specimen.

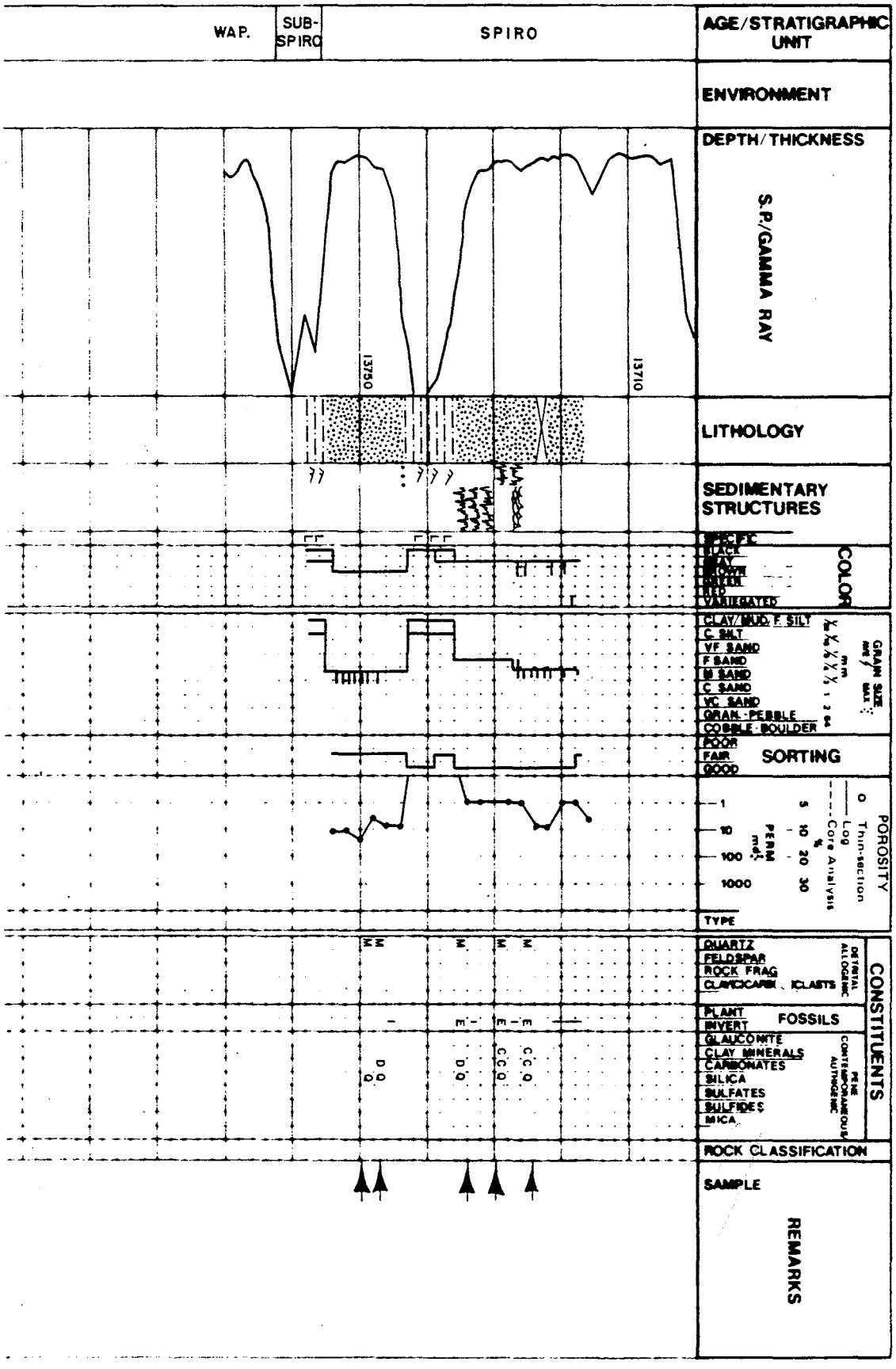

WAP.
SUB-SPIRO
SPIRO
AGE/STRATIGRAPHIC UNIT
ENVIRONMENT
DEPTH/THICKNESS
S.P/GAMMA RAY
13790
13710
LITHOLOGY
SEDIMENTARY STRUCTURES
COLOR
SPECIFIC
BLACK
GRAY
BROWN
GREEN
RED
VARIEGATED
CLAY/MUD, F SILT
C SILT
VF SAND
F SAND
M SAND
C SAND
VC SAND
GRAN - PEBBLE
COBBLE - BOULDER
GRAIN SIZE AVG / MAX
mm
SORTING
POOR
FAIR
GOOD
POROSITY
PERM md
Thin-section
Log
Core Analysis
%
TYPE
CONSTITUENTS
QUARTZ
FELDSPAR
ROCK FRAG
CLAY/COAL
DETRITAL ALLOGENIC
CLASTS
PLANT
INVERT
FOSSILS
GLAUCONITE
CLAY MINERALS
CARBONATES
SILICA
SULFATES
SULFIDES
MICA
CONTEMPORANEOUS AUTHIGENIC
ROCK CLASSIFICATION
SAMPLE
REMARKS

Figure 40 Core description of Mustang Lyons No.1-27, SE 1/4, section 27, T6N, R21E in the Red Oak-Norris gas field; cored interval from 12,213 to 12,244 feet (right).

SUMMARY

The core is composed of medium-grained, unfossiliferous sandstone, in two intervals described from bottom to top.

1. From 12,240 to 12,244 feet, a transition unit of interstratified siltstone-sandstone and shale. Burrows, bioturbation and flowage are common sedimentary structures.

2. From 12,213 to 12,240, medium-grained, well sorted sandstone. Clay intraclasts are common locally. Unimodal and bimodal crossbedding are also present. Porosity averages 17%.

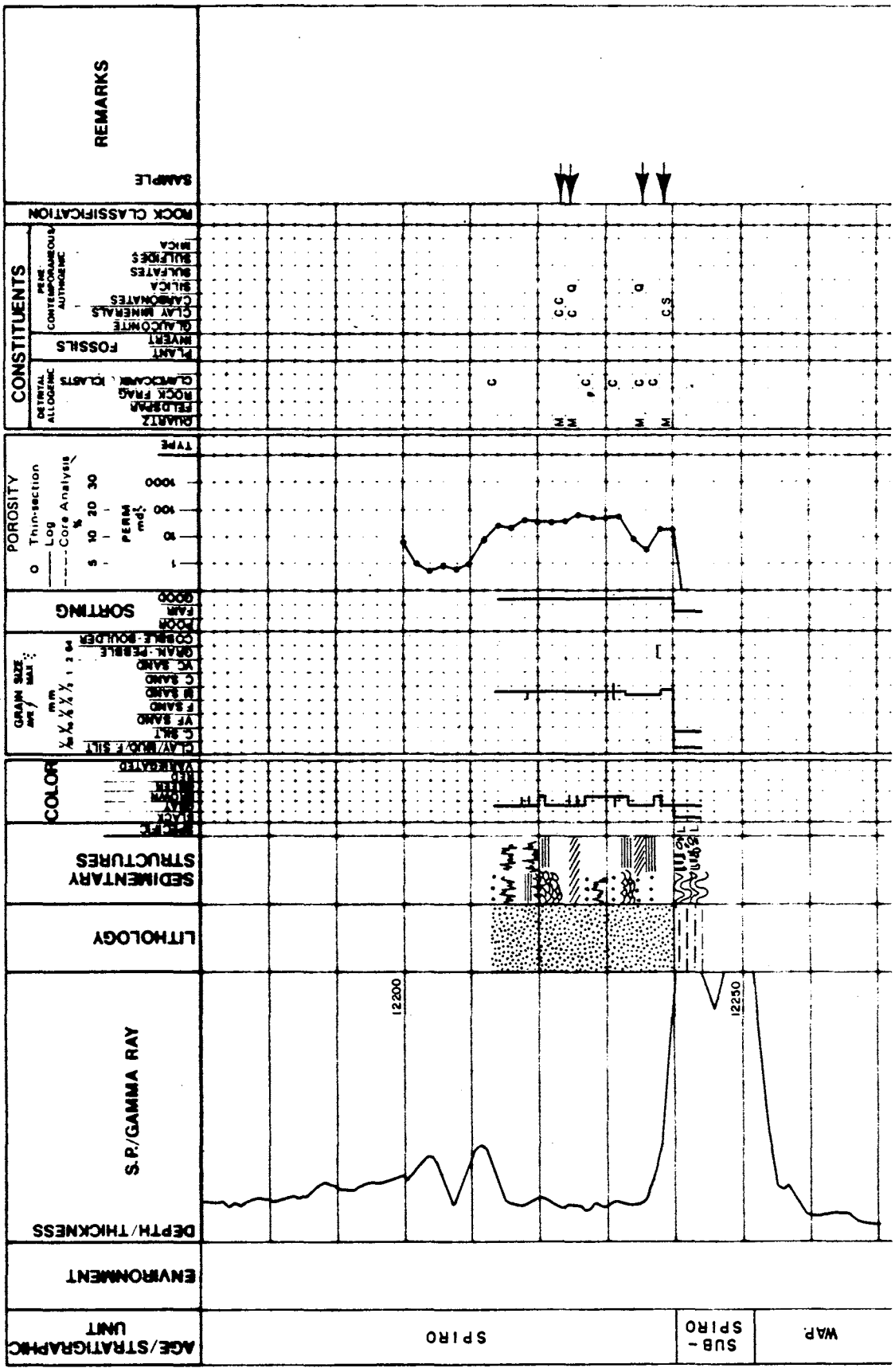

REMARKS
SAMPLE
ROCK CLASSIFICATION
CONSTITUENTS
DETRITAL ALLOGENIC
QUARTZ
FELDSPAR
ROCK FRAG
GLAUCONITE
FOSSILS
PLANT
INVERT
PERIPHERAL CONTEMPORANEOUS AUTHIGENIC
GLAUCONITE
CLAY MINERALS
CARBONATES
SILICA
SULFATES
SULFIDES
MICA
POROSITY
Thin-section
Log
Core Analysis
PERM md.
TYPE
SORTING
GRAIN SIZE mm
COLOR
SEDIMENTARY STRUCTURES
LITHOLOGY
S.P./GAMMA RAY
12200
12250
DEPTH/THICKNESS
ENVIRONMENT
AGE/STRATIGRAPHIC UNIT
SPIRO
SUB-SPIRO
WAP

Figure 41 Core description of Midwest Free No.1, SE 1/4, section 11, T6N, R21E, in the Red Oak Field; cored interval from 11,818 to 11,890 feet (right).

SUMMARY

The core is composed is of sandstone and sandy limestone, in six units, described from bottom to top.

1. From 11,884 to 11,890 feet, black fissile shale.

2. From 11,877 to 11,884 feet, fine-grained sandstone with an average porosity of 10%. Burrows are the dominant sedimentary structure.

3. From 11,874 to 11,877 feet, limestone which is fossiliferous and contains a high percentage of quartz grains. A thin shale bed and some intraclasts are also present.

4. From 11,862 to 11,874 feet, a medium-grained quartzarenite. Crossbedding is the dominant sedimentary structure and stylolites are common locally. Porosity ranges from 12 to 28%.

5. From 11,827 to 11,862 feet, is a fine-grained quartzarenite. Burrows, flowage, and crossbedding are common sedimentary structures. Fossils are visible macroscopically and in thin section. Porosity ranges from 8 to 28%. Shale laminae and deformed shale clasts are present and stylolites are common.

6. From 11,818 to 11,827 feet, an interbedded fine-grained sandstone and shale. Fossils are present in hand specimen.

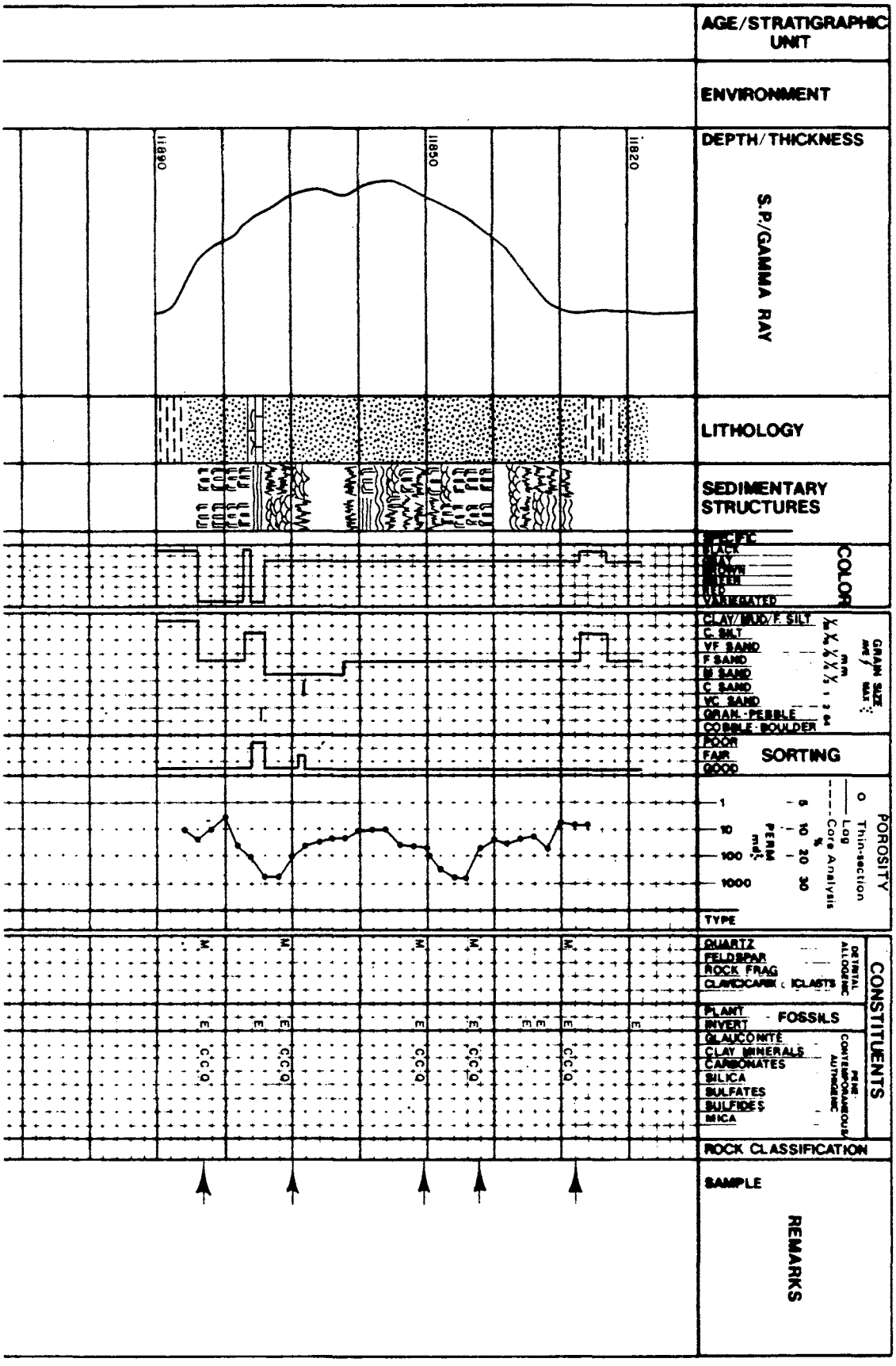

AGE/STRATIGRAPHIC UNIT
ENVIRONMENT
DEPTH/THICKNESS
11890
11850
11820
S.P./GAMMA RAY
LITHOLOGY
SEDIMENTARY STRUCTURES
COLOR
SPECIFIC
BLACK
GRAY
BROWN
GREEN
RED
VARIEGATED
GRAIN SIZE
CLAY/MUD/F. SILT
C. SILT
VF SAND
F SAND
M SAND
C SAND
VC SAND
GRAN.-PEBBLE
COBBLE-BOULDER
SORTING
POOR
FAIR
GOOD
POROSITY
Thin-section
Log
Core Analysis
PERM md.
%
TYPE
CONSTITUENTS
DETRITAL ALLOGENIC
QUARTZ
FELDSPAR
ROCK FRAG
CLAY/CARB. CLASTS
FOSSILS
PLANT
INVERT
PENE CONTEMPORANEOUS AUTHIGENIC
GLAUCONITE
CLAY MINERALS
CARBONATES
SILICA
SULFATES
SULFIDES
MICA
ROCK CLASSIFICATION
SAMPLE
REMARKS

Figure 42 Core description of Shell Jankowsky No.1-32, NW 1/4, section 32, T7N, R20E in the Kinta gas field; cored interval from 9,799 to 9,839 feet (right).

SUMMARY

The core is composed of unfossiliferous medium- to coarse-grained sandstone, in three units, described from bottom to top.

1. From 9,830 to 9,839 feet, coarse-grained, moderately-sorted sandstone. Flowage is the only sedimentary feature. Porosity is high, ranging from 17 to 25%.

2. From 9,809 to 9,830 feet, is a quartzarenite that ranges from fine- to coarse-grained. Shale intraclasts are present as well as some unimodal crossbedding. Sorting varies from good to poor; porosity averages 15%.

3. From 9,799 to 9,809 feet, medium-grained, well-sorted sandstone. Flowage is the only sedimentary structure; porosity ranges from 12 to greater than 30%.

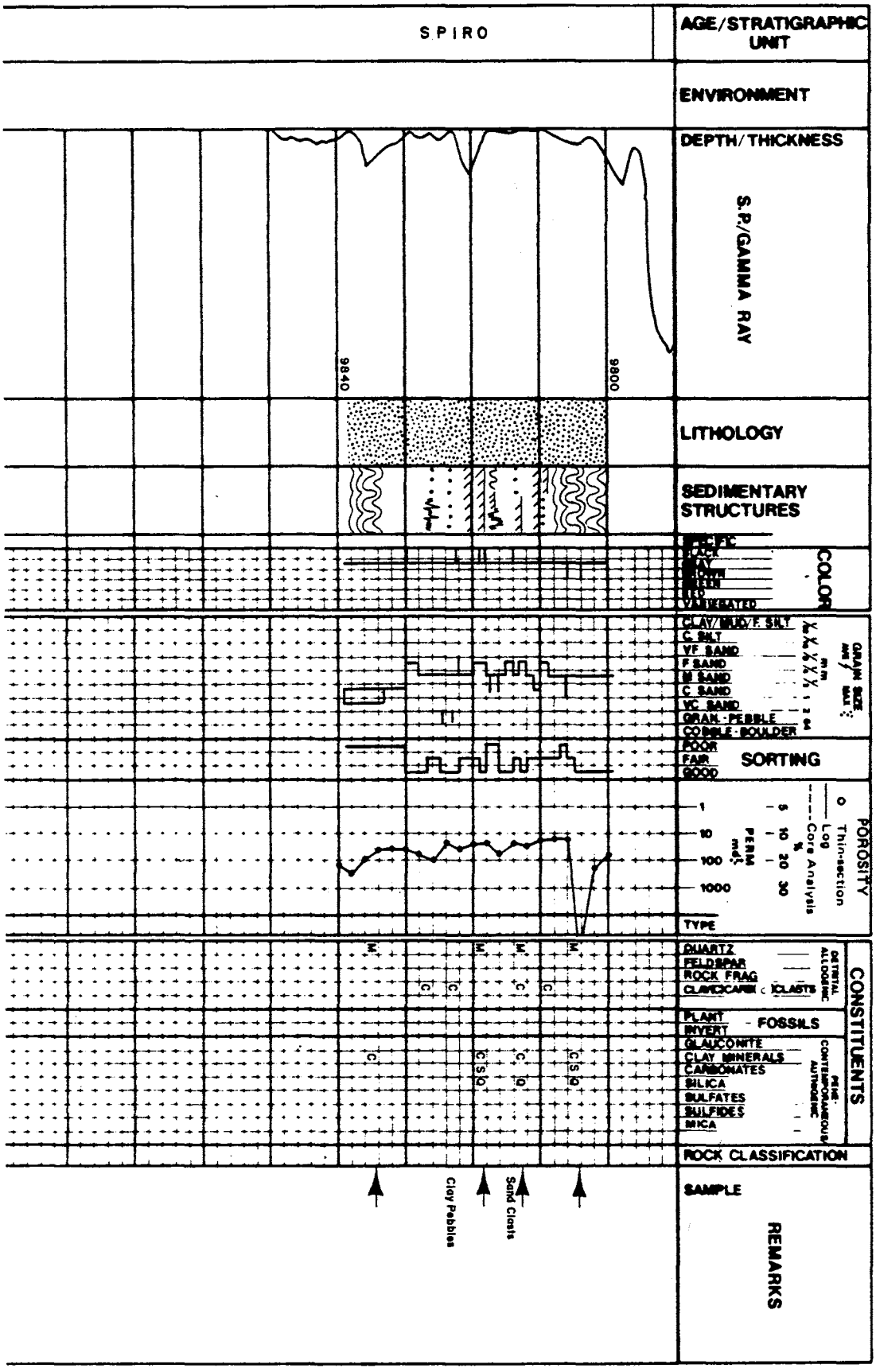

SPIRO
AGE/STRATIGRAPHIC UNIT
ENVIRONMENT
DEPTH/THICKNESS
S.P/GAMMA RAY
9840
9800
LITHOLOGY
SEDIMENTARY STRUCTURES
COLOR
SPECIFIC
BLACK
GRAY
BROWN
GREEN
RED
VARIEGATED
GRAIN SIZE mm
CLAY/MUD/F. SILT
C. SILT
VF SAND
F SAND
M SAND
C SAND
VC SAND
GRAN - PEBBLE
COBBLE - BOULDER
SORTING
POOR
FAIR
GOOD
POROSITY
Thin-section
Log
Core Analysis
PERM md
TYPE
CONSTITUENTS
QUARTZ
FELDSPAR
ROCK FRAG
CLAY/CARB CLASTS
DETRITAL ALLOGENIC
PLANT
INVERT
FOSSILS
GLAUCONITE
CLAY MINERALS
CARBONATES
SILICA
SULFATES
SULFIDES
MICA
PENE-CONTEMPORANEOUS AUTHIGENIC
ROCK CLASSIFICATION
SAMPLE
REMARKS
Clay Pebbles
Sand Clasts

Figure 43 Core description of Humble Burge No.1, NE 1/4, section 31, T8N, R21E; cored interval from 6,623 to 6,677 feet in the Kinta gas field (right).

SUMMARY

This core is composed of very fine-to medium-grained sandstone, in five units, described from bottom to top.

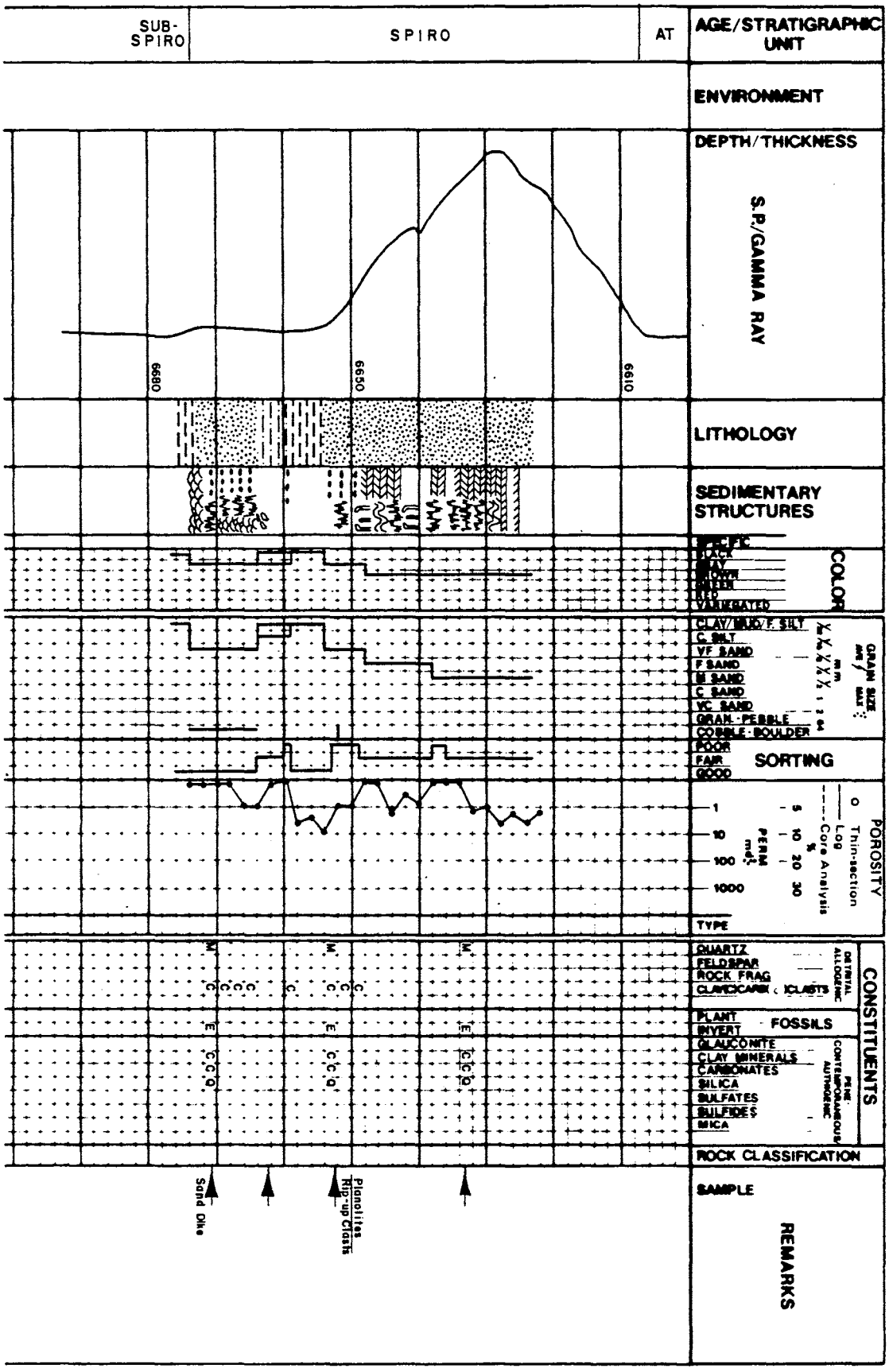
1. From 6,664 to 6,674 feet, is a fine-grained, tightly cemented sandstone. Shale intraclasts are common throughout the unit, and small- and medium-scale crossbedding is present. Fossils are visible in thin section.

2. From 6,659 to 6,664 feet, interlaminated siltstone and shale. Some intraclasts are present as well as burrows and flowage. A thin conglomerate with siderite clasts is present at the top.

3. Dark fissile shale from 6,654 to 6,659 feet.

4. From 6,648 to 6,654 feet, conglomerate that contains fine-grained sand together with siderite and shale clasts. Thin shale laminae and burrows are also present.

5. From 6,623 to 6,648 feet, fine- to medium-grained sandstone. Sedimentary structures include medium-scale crossbedding, flowage, and burrows. Fossils are visible in hand specimen. Porosity ranges from 0 to 8%.


SUB-SPIRO
SPIRO
AT
AGE/STRATIGRAPHIC UNIT
ENVIRONMENT
DEPTH/THICKNESS
S.P./GAMMA RAY
6680
6650
6610
LITHOLOGY
SEDIMENTARY STRUCTURES
COLOR
SPECIFIC
BLACK
GRAY
BROWN
GREEN
RED
VARIEGATED
GRAIN SIZE
CLAY/MUD/F. SILT
C. SILT
VF SAND
F SAND
M SAND
C. SAND
VC SAND
GRAN.-PEBBLE
COBBLE-BOULDER
SORTING
POOR
FAIR
GOOD
POROSITY
PERM md
Thin-section
Log
Core Analysis
%
TYPE
CONSTITUENTS
DETRITAL ALLOGENIC
QUARTZ
FELDSPAR
ROCK FRAG
CLAY/CARB. CLASTS
FOSSILS
PLANT
INVERT
AUTHIGENIC CONTEMPORANEOUS
GLAUCONITE
CLAY MINERALS
CARBONATES
SILICA
SULFATES
SULFIDES
MICA
ROCK CLASSIFICATION
SAMPLE
REMARKS
Sand Dike
Pisolites
Rip-up Clasts

VITA

Ellen Marie Ostroff Hooker

Candidate for the Degree of

Master of Science

Thesis: DISTRIBUTION AND DEPOSITIONAL ENVIRONMENT OF THE SPIRO SANDSTONE, ARKOMA BASIN, HASKELL, LATIMER AND PITTSBURG COUNTIES, OKLAHOMA

Major Field: Geology

Biographical:

Personal Data: Born in Dallas, Texas, September 4, 1961, the daughter of Anton G. and Nancy C. Ostroff. Married John David Hooker on December 21, 1985.

Education: Graduated from Tyler Street Christian Academy, Dallas, Texas, in May, 1980; received Bachelor of Science degree in Geology from Baylor University in August, 1985; completed requirements of Master of Science degree at Oklahoma State University in July, 1988.

Professional Experience: Professional Summer Geologist, Mobil Exploration and Production Services, Inc. (Dallas), summers, 1983, 1984, and 1985; Lab Assistant, Baylor University Geology Department, 1984-85; Teaching Assistant, Oklahoma State University Geology Department, 1985-86, 1986-87; Assistant Geologist, Patrick J.F. Gratton, Inc., summer, 1986.

Junior Member of the American Association of Petroleum Geologists; Member of the Dallas Geological Society.

R 16 E | R 17 E | R 18 E | R 19 E | R 20 E | R 21 E

T 8 N | T 7 N | T 6 N | T 5 N | T 4 N

WPCK

HASKELL COUNTY
PITTSBURG COUNTY

CROWDER | QUINTON | KINTA | KINTA

LAKE EUFAULA

KINTA FAULT ZONE

PITTSBURG COUNTY | HASKELL COUNTY

HASKELL COUNTY | LATIMER COUNTY

PITTSBURG COUNTY | LATIMER COUNTY

SANS BOIS FAULT ZONE

CARBON FAULT

WILBURTON | WILBURTON

RED OAK ANTICLINE | BRAZIL | RED OAK

HAILEYVILLE | HARTSHORNE

PITTSBURG COUNTY | LATIMER COUNTY | LE FLORE COUNTY

LEGEND

- GAS WELL
- DRY HOLE
- STATUS UNKNOWN
- NDE NOT DEEP ENOUGH
- F/O FAULTED OUT
- NORMAL FAULT
- THRUST FAULT
- MAJOR GAS FIELD

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STRUCTURAL CONTOUR MAP
TOP OF WAPANUCKA LIMESTONE

CI = 250'

Thesis
1988
H783d
cop. 2

0 5
SCALE IN MILES

SPIRO – ARKOMA BASIN | PLATE I

E. O. HOOKER | 1988

R 16 E | R 17 E | R 18 E | bSPR TO WPCK | R 19 E | R 20 E | R 21 E

T 8 N | T 7 N | T 6 N | T 5 N | T 4 N

CROWDER | THICK | THIN | PITTSBURG COUNTY | HASKELL COUNTY | QUINTON | KINTA | LAKE EUFAULA | PITTSBURG COUNTY | LATIMER COUNTY | HASKELL COUNTY | LATIMER COUNTY | RED OAK | WILBURTON | HAILEYVILLE | HARTSHORNE | LE FLORE COUNTY

LEGEND

- GAS WELL
- DRY HOLE
- STATUS UNKNOWN
- NDE NOT DEEP ENOUGH

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THICKNESS MAP
BASE SPIRO TO TOP WAPANUCKA

CI = 10'

0 5
SCALE IN MILES

SPIRO – ARKOMA BASIN — PLATE II

E. O. HOOKER 1988

R 16 E R 17 E R 18 E R 19 E R 20 E R 21 E

T 8 N T 7 N T 6 N T 5 N T 4 N

Net SP-Y

HASKELL COUNTY
PITTSBURG COUNTY

PITTSBURG COUNTY
HASKELL COUNTY

HASKELL COUNTY
LATIMER COUNTY

PITTSBURG COUNTY
LATIMER COUNTY

PITTSBURG COUNTY
LATIMER COUNTY

LATIMER COUNTY
LE FLORE COUNTY

CROWDER
QUINTON
KINTA
WILBURTON
HAILEYVILLE
HARTSHORNE
RED OAK
LAKE EUFAULA

LEGEND

- GAS WELL
- DRY HOLE
- STATUS UNKNOWN
- NDE NOT DEEP ENOUGH
- NA DATA NOT AVAILABLE

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POROSITY MAP OF SPIRO SANDSTONE

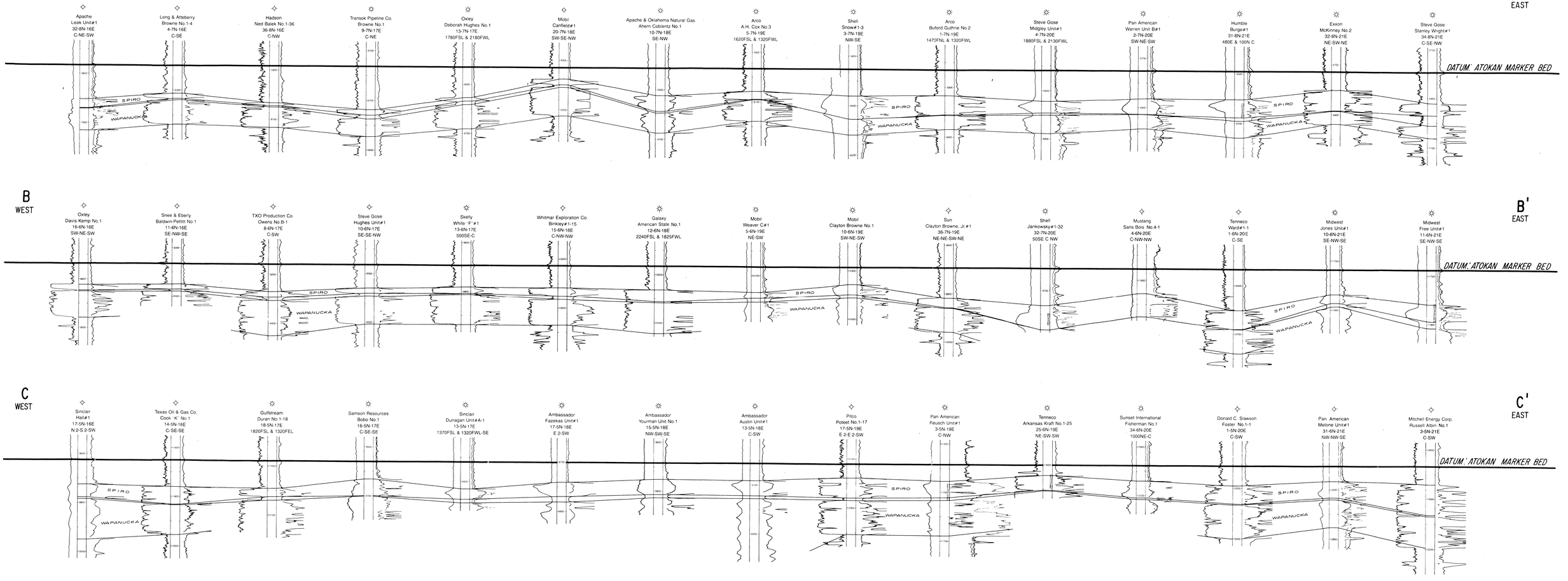
(Feet of Ø > 7%)

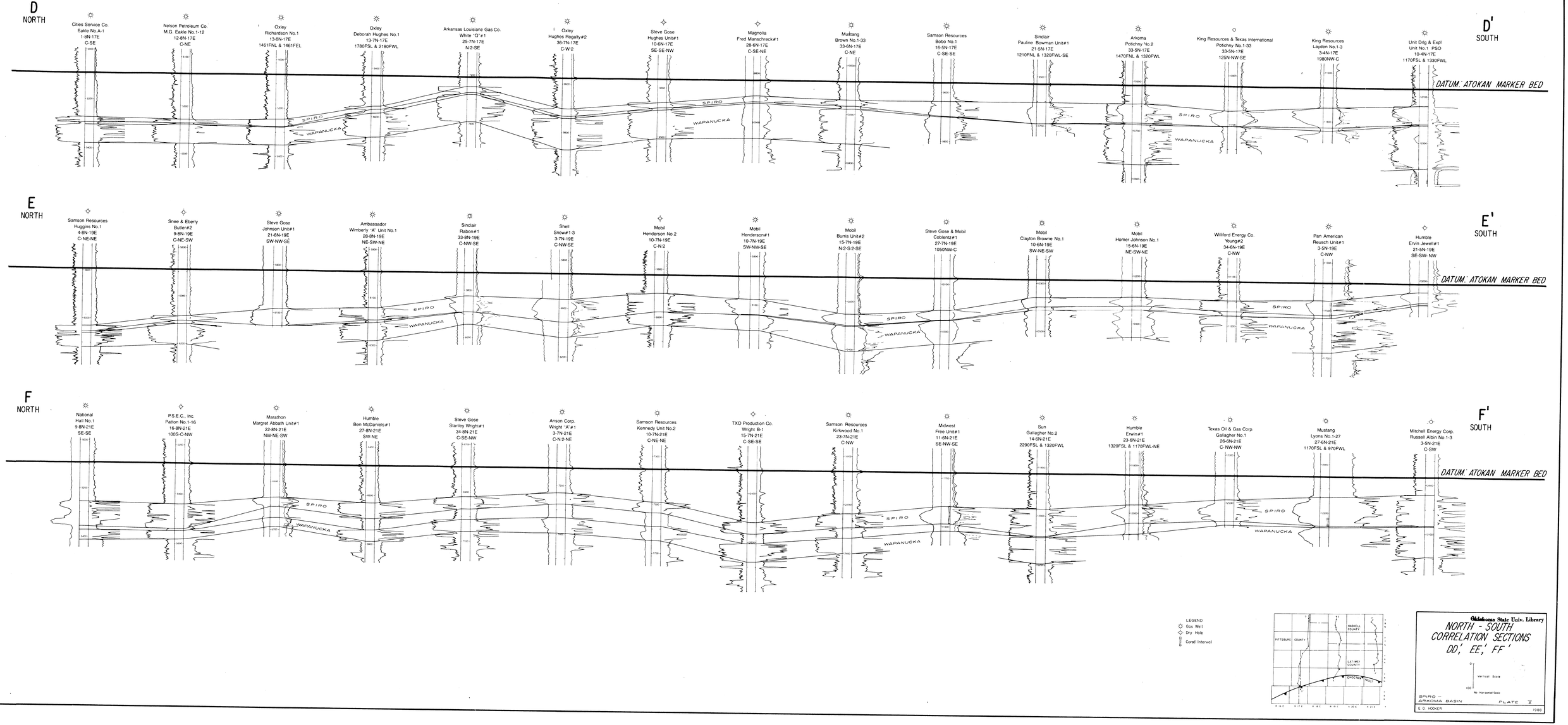
CI = 10'

0 5
SCALE IN MILES

SPIRO – ARKOMA BASIN PLATE III

E. O. HOOKER 1988


A
WEST
A'
EAST
Apache
Leak Unit#1
32-8N-16E
C-NE-SW
Long & Atteberry
Browne No.1-4
4-7N-16E
C-SE
Hadson
Ned Balek No.1-36
36-8N-16E
C-NW
Transok Pipeline Co.
Browne No.1
9-7N-17E
C-NE
Oxley
Deborah Hughes No.1
13-7N-17E
1780FSL & 2180FWL
Mobil
Canfield#1
20-7N-18E
SW-SE-NW
Apache & Oklahoma Natural Gas
Ahern Coblentz No.1
10-7N-18E
SE-NW
Arco
A.H. Cox No.3
5-7N-19E
1620FSL & 1320FWL
Shell
Snow#1-3
3-7N-19E
NW-SE
Arco
Buford Guthrie No.2
1-7N-19E
1470FNL & 1320FWL
Steve Gose
Midgley Unit#1
4-7N-20E
1880FSL & 2130FWL
Pan American
Warren Unit B#1
2-7N-20E
SW-NE-SW
Humble
Burge#1
31-8N-21E
480E & 100N C
Exxon
McKinney No.2
32-8N-21E
NE-SW-NE
Steve Gose
Stanley Wright#1
34-8N-21E
C-SE-NW
DATUM: ATOKAN MARKER BED
SPIRO
WAPANUCKA
B
WEST
B'
EAST
Oxley
Davis Kemp No.1
16-6N-16E
SW-NE-SW
Snee & Eberly
Baldwin-Pettitt No.1
11-6N-16E
SE-NW-SE
TXO Production Co.
Owens No.B-1
8-6N-17E
C-SW
Steve Gose
Hughes Unit#1
10-6N-17E
SE-SE-NW
Skelly
White "F" #1
13-6N-17E
500SE-C
Whitmar Exploration Co.
Birkley#1-15
15-6N-18E
C-NW-NW
Galaxy
American State No.1
12-6N-18E
2240FSL & 1825FWL
Mobil
Weaver C#1
5-6N-19E
NE-SW
Mobil
Clayton Browne No.1
10-6N-19E
SW-NE-SW
Sun
Clayton Browne, Jr.#1
36-7N-19E
NE-NE-SW-NE
Shell
Jankowsky#1-32
32-7N-20E
50SE C NW
Mustang
Sans Bois No.4-1
4-6N-20E
C-NW-NW
Tenneco
Ward#1-1
1-6N-20E
C-SE
Midwest
Jones Unit#1
10-6N-21E
SE-NW-SE
Midwest
Free Unit#1
11-6N-21E
SE-NW-SE
DATUM: ATOKAN MARKER BED
SPIRO
WAPANUCKA
C
WEST
C'
EAST
Sinclair
Hall#1
17-5N-16E
N 2-S 2-SW
Texas Oil & Gas Co.
Cook "K" No.1
14-5N-16E
C-SE-SE
Gulfstream
Duran No.1-18
18-5N-17E
1820FSL & 1320FEL
Samson Resources
Bobo No.1
16-5N-17E
C-SE-SE
Sinclair
Dunagan Unit#A-1
13-5N-17E
1370FSL & 1320FWL-SE
Ambassador
Fazekas Unit#1
17-5N-18E
E 2-SW
Ambassador
Yourman Unit No.1
15-5N-18E
NW-SW-SE
Ambassador
Austin Unit#1
13-5N-18E
C-SW
Pitco
Poteet No.1-17
17-5N-19E
E 2-E 2-SW
Pan American
Fleusch Unit#1
3-5N-19E
C-NW
Tenneco
Arkansas Kraft No.1-25
25-6N-19E
NE-SW-SW
Sunset International
Fisherman No.1
34-6N-20E
1000NE-C
Donald C. Slawson
Foster No.1-1
1-5N-20E
C-SW
Pan American
Melone Unit#1
31-6N-21E
NW-NW-SE
Mitchell Energy Corp.
Russell Albin No.1
3-5N-21E
C-SW
DATUM: ATOKAN MARKER BED
SPIRO
WAPANUCKA
LEGEND
Gas Well
Dry Hole
Cored Interval
PITTSBURG COUNTY
HASKELL COUNTY
LATIMER COUNTY
LEFLORE COUNTY
Oklahoma State Univ. Library
WEST - EAST
CORRELATION SECTIONS
AA,' BB,' CC'
Vertical Scale
No Horizontal Scale
SPIRO - ARKOMA BASIN
PLATE IV
E. O. HOOKER
1988


D
NORTH
Cities Service Co.
Eakle No.A-1
1-6N-17E
C-SE
Nelson Petroleum Co.
M.G. Eakle No.1-12
12-6N-17E
C-NE
Oxley
Richardson No.1
13-8N-17E
1461FNL & 1461FEL
Oxley
Deborah Hughes No.1
13-7N-17E
1780FSL & 2180FWL
Arkansas Louisiana Gas Co.
White "O" #1
25-7N-17E
N-2-SE
Oxley
Hughes Rogalty#2
36-7N-17E
C-W-2
Steve Gose
Hughes Unit#1
10-6N-17E
SE-SE-NW
Magnolia
Fred Manschreck#1
28-6N-17E
C-SE-NE
Mustang
Brown No.1-33
33-6N-17E
C-NE
Samson Resources
Bobo No.1
16-5N-17E
C-SE-SE
Sinclair
Pauline Bowman Unit#1
21-5N-17E
1210FNL & 1320FWL-SE
Arkoma
Polichny No.2
33-5N-17E
1470FNL & 1320FWL
King Resources & Texas International
Polichny No.1-33
33-5N-17E
125N-NW-SE
King Resources
Layden No.1-3
3-4N-17E
1980NW-C
Unit Drlg & Expl
Unit No.1 PSO
10-4N-17E
1170FSL & 1330FWL
D'
SOUTH
DATUM: ATOKAN MARKER BED
SPIRO
WAPANUCKA
E
NORTH
Samson Resources
Huggins No.1
4-8N-19E
C-NE-NE
Snee & Eberly
Butler#2
9-8N-19E
C-NE-SW
Steve Gose
Johnson Unit#1
21-8N-19E
SW-NW-SE
Ambassador
Wimberly "A" Unit No.1
28-8N-19E
NE-SW-NE
Sinclair
Rabon#1
33-8N-19E
C-NW-SE
Shell
Snow#1-3
3-7N-19E
C-NW-SE
Mobil
Henderson No.2
10-7N-19E
C-N-2
Mobil
Henderson#1
10-7N-19E
SW-NW-SE
Mobil
Burris Unit#2
15-7N-19E
N-2-S-2-SE
Steve Gose & Mobil
Cobleritz#1
27-7N-19E
1050NW-C
Mobil
Clayton Browne No.1
10-6N-19E
SW-NE-SW
Mobil
Homer Johnson No.1
15-6N-19E
NE-SW-NE
Williford Energy Co.
Young#2
34-6N-19E
C-NW
Pan American
Reusch Unit#1
3-5N-19E
C-NW
Humble
Ervin Jewell#1
21-5N-19E
SE-SW-NW
E'
SOUTH
DATUM: ATOKAN MARKER BED
SPIRO
WAPANUCKA
F
NORTH
National
Hall No.1
9-8N-21E
SE-SE
P.S.E.C., Inc.
Patton No.1-16
16-8N-21E
100S-C-NW
Marathon
Margret Abbath Unit#1
22-8N-21E
NW-NE-SW
Humble
Ben McDaniels#1
27-8N-21E
SW-NE
Steve Gose
Stanley Wright#1
34-8N-21E
C-SE-NW
Anson Corp.
Wright "A"#1
3-7N-21E
C-N-2-NE
Samson Resources
Kennedy Unit No.2
10-7N-21E
C-NE-NE
TXO Production Co.
Wright B-1
15-7N-21E
C-SE-SE
Samson Resources
Kirkwood No.1
23-7N-21E
C-NW
Midwest
Free Unit#1
11-6N-21E
SE-NW-SE
Sun
Gallagher No.2
14-6N-21E
2290FSL & 1320FWL
Humble
Erwin#1
23-6N-21E
1320FSL & 1170FWL-NE
Texas Oil & Gas Corp.
Gallagher No.1
26-6N-21E
C-NW-NW
Mustang
Lyons No.1-27
27-6N-21E
1170FSL & 970FWL
Mitchell Energy Corp.
Russell Albin No.1-3
3-5N-21E
C-SW
F'
SOUTH
DATUM: ATOKAN MARKER BED
SPIRO
WAPANUCKA
LEGEND
Gas Well
Dry Hole
Cored Interval
PITTSBURG COUNTY
HASKELL COUNTY
LATIMER COUNTY
LEFLORE COUNTY
R 16 E
R 17 E
R 18 E
R 19 E
R 20 E
R 21 E
T 8 N
T 7 N
T 6 N
T 5 N
T 4 N
T 3 N
Oklahoma State Univ. Library
NORTH - SOUTH
CORRELATION SECTIONS
DD', EE', FF'
0
Vertical Scale
100
No Horizontal Scale
SPIRO – ARKOMA BASIN
PLATE V
E.D. HOOKER
1988

R 16 E | R 17 E | R 18 E | R 19 E | R 20 E | R 21 E

T 8 N | T 7 N | T 6 N | T 5 N | T 4 N

ATKI TO BMPC

HASKELL COUNTY
PITTSBURG COUNTY

CROWDER | QUINTON | KINTA | LAKE EUFAULA

THIN | THICK | FAULT ZONE | SANS BOIS FAULT ZONE

PITTSBURG COUNTY
LATIMER COUNTY

HASKELL COUNTY
LATIMER COUNTY

WILBURTON | PANAMA PEAK

HAILEYVILLE | HARTSHORNE

LATIMER COUNTY
LE FLORE COUNTY

LEGEND

- GAS WELL
- DRY HOLE
- STATUS UNKNOWN
- NDE NOT DEEP ENOUGH
- NA DATA NOT AVAILABLE

Oklahoma State Univ. Library

THICKNESS MAP
ATOKAN MARKER BED
TO BASE WAPANUCKA

CI = 20'

SCALE IN MILES

SFIRO – ARKOMA BASIN | PLATE VI

E. O. HOOKER | 1988

R 16 E | R 17 E | R 18 E | R 19 E | R 20 E | R 21 E

T 5 N | T 4 N

ATK1 TO SPRO

HASKELL COUNTY
PITTSBURG COUNTY

CROWDER | QUINTON | KINTA | LAKE EUFAULA

KINTA FAULT ZONE

HASKELL COUNTY
LATIMER COUNTY

PITTSBURG COUNTY
LATIMER COUNTY

SANS BOIS FAULT ZONE

PITTSBURG COUNTY
LATIMER COUNTY

WILBURTON | RED OAK | HAILEYVILLE | HARTSHORNE

LATIMER COUNTY
LE FLORE COUNTY

LEGEND

- GAS WELL
- DRY HOLE
- STATUS UNKNOWN
- NDE NOT DEEP ENOUGH
- NA DATA NOT AVAILABLE
- NORMAL FAULT

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THICKNESS MAP ATOKAN MARKER BED TO TOP SPIRO

CI = 20'

0 5
SCALE IN MILES

SPIRO – ARKOMA BASIN

PLATE VII

E. O. HOOKER

1988

R 16 E | R 17 E | R 18 E | R 19 E | R 20 E | R 21 E

T 8 N | T 7 N | T 6 N | T 5 N | T 4 N

SPRO TO WPCK

THICK

THIN

HASKELL COUNTY
PITTSBURG COUNTY

HASKELL COUNTY
LATIMER COUNTY

PITTSBURG COUNTY
LATIMER COUNTY

LATIMER COUNTY
LE FLORE COUNTY

CROWDER

QUINTON

KINTA

RED OAK

WILBURTON

HAILEYVILLE

HARTSHORNE

LAKE EUFAULA

LEGEND

- GAS WELL
- DRY HOLE
- STATUS UNKNOWN
- NDE NOT DEEP ENOUGH

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THICKNESS MAP
TOP SPIRO TO TOP WAPANUCKA

CI = 10'

0 5
SCALE IN MILES

SPIRO – ARKOMA BASIN

PLATE VIII

E. O. HOOKER

1988

R 16 E | R 17 E | R 18 E | R 19 E | R 20 E | R 21 E

T 8 N
T 7 N
T 6 N
T 5 N
T 4 N

Net SP-X

HASKELL COUNTY
PITTSBURG COUNTY
LATIMER COUNTY
LE FLORE COUNTY

CROWDER
QUINTON
KINTA
RED OAK
WILBURTON
HAILEYVILLE
HARTSHORNE
LAKE EUFAULA

THIN
THICK

LEGEND

- GAS WELL
- DRY HOLE
- STATUS UNKNOWN
- NDE NOT DEEP ENOUGH

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NET SAND ISOPACH MAP OF THE SPIRO SANDSTONE

CI = 10'

SCALE IN MILES

SPIRO - ARKOMA BASIN — PLATE IX

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