DEPOSITIONAL FACIES ANALYSIS AND POROSITY DEVELOPMENT OF THE (PENNSYLVANIAN) UPPER MORROW CHERT CONGLOMERATE "PURYEAR" MEMBER, ROGER MILLS AND BECKHAM COUNTIES, OKLAHOMA

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CHAPTER I

INTRODUCTION

Location

This subsurface investigation involves examination of "Puryear" member of the Upper Morrow (Pennsylvanian) Chert Conglomerates present within a limited area of the deep Anadarko basin. This includes thirteen Townships within Roger Mills and northern Beckham Counties, Oklahoma. Specifically, this area is defined by Townships 11 North through 14 North, Ranges 24 through 26 West; and, Township 12 North, Range 21 West (Figure 1). The latter Township is included because of the availability of core. Upper Morrow Chert Conglomerates were analyzed in detail from the G.H.K.-Apache Gregory No. 1-29 well located at Sec. 29, T. 12 N., R. 21 W.; and the Exxon-Sayre Ranch No. 2-35 well located at Sec. 35, T. 13 N., R. 26 W. Various fields within this area include: Reydon, Cheyenne, Rankin, Dempsey, NW Berlin, Sweetwater, NE Mayfield, N New Liberty, and W Carpenter.

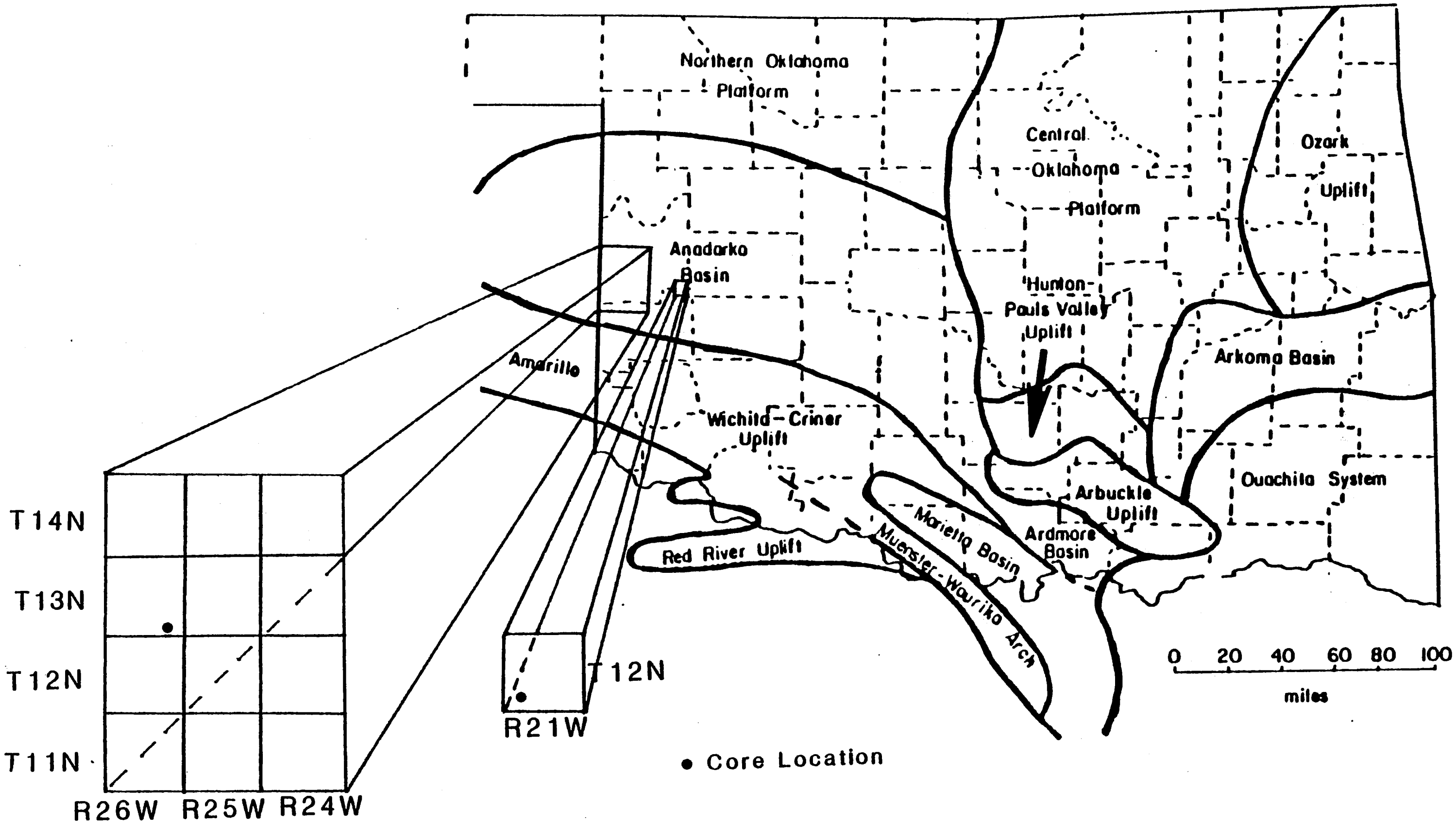

Figure 1. Major Geologic Provinces and Location of Study Area (Al-Shaieb, Shelton, and Others, 1981).

Objectives

The objectives of this study include:

1. Discussion of fan delta depositional processes and facies as reported in the literature.

2. Constructing subsurface maps to illustrate structure, sand geometry, trends, and source directions of the Upper Morrow "Puryear" Chert Conglomerate.

3. Recognizing various "Puryear" facies utilizing well-log signatures and constructing a facies map of "Puryear" time.

4. Analyzing the porosity of the various "Puryear" facies utilizing neutron-density porosity logs and constructing a characteristic log signature that represents the facies with well-developed porosity.

5. Evaluating petrographic and diagenetic characteristics of the Upper Morrow "Puryear" Chert Conglomerate.

6. Describing petrologic features, the specific depositional facies, and the relationship between well-log signatures and rock composition of an Upper Morrow "Puryear" Chert Conglomerate core.

Methods of Investigation

In order to accomplish the objectives of this study, various methods of data collection were utilized. One of these included an extensive literature search of alluvial fan and fan delta depositional environments, processes, lithologies, and facies.

Two Upper Morrow Chert Conglomerate cores were analyzed in order to evaluate their petrographic and diagenetic character, their facies within a certain depositional environment, and their correlation of lithology to log response. One set of well cuttings was examined for the purpose of understanding lithology and log response of Upper Morrow Chert Conglomerates.

Petrographic analysis was conducted on twenty-five samples from the G.H.K.-Apache Gregory No. 1-29 well, seven samples from the Exxon-Sayre Ranch No. 2-35 well, and 10 samples from the Exxon-Boyd Hartman well cuttings. Thin sections were impregnated with blue epoxy to assist in identification of porosity. Boyd-Hartman well cuttings were only analyzed for qualitative purposes; however, detrital constituents, diagenetic constituents, and porosity of the other two cores were point-counted. Extracted clay minerals were analyzed by X-ray diffraction and included a natural, heated, and glycolated analysis which aided in identification of detrital and diagenetic clays.

Selected samples of the G.H.K.-Apache Gregory core were analyzed by a scanning electron microscope (SEM) coupled with the Energy Dispersive X-ray Analysis (EDXA) for additional composition and morphological data of the diagenetic constituents of the chert conglomerate. Cathodoluminescence was used to evaluate and detect pressure solution features.

Vitrinite reflectance measurements were made from several shale samples of the cores for thermal history evaluation. Isotopic analyses of several core samples were obtained in order to determine carbonate mineralogy and approximate carbonate content.

Subsurface data was collected from gamma-ray and resistivity logs, and neutron-density porosity logs. The combination of the gamma-ray and resistivity logs was used for preparing a structure contour map on top of the "Thirteen Finger" Limestone, a sandstone isolith map of the "Puryear", and for analyzing the various "Puryear" facies. Porosity of each "Puryear" facies was analyzed by evaluating neutron-density porosity logs.

Previous Works

Numerous studies have been focused on Upper Morrow shallow marine and deltaic complexes of the Anadarko basin, but little research has been devoted to Upper Morrow Chert Conglomerates. One of the first reports of Upper Morrow Chert Conglomerates was by Tutten (1972) who discussed the geology and development of Washita Creek Gas Field which is located in Hemphill County, Texas, and lies in the deep Anadarko basin. Although initial exploration was for Hunton Group, a Morrow gas sand was penetrated in 1960 and placed on production in 1969. Four wells in this field have produced four billion cubic feet of gas from the Upper Morrow around -13,600 feet. In this area, the Upper Morrow pay zone, the "Puryear", occurs 150 to 300 feet below the Atoka-Morrow surface with producing sand thicknesses of 5 to 8 feet. Tutten (1972) described the Morrow sands as "tan to gray in color, fine, medium to coarse grained, sub-rounded and sub-angular, friable in part, consolidated with a calcareous matrix," with some sands having kaolinite and silica matrix, as well as intergranular porosity. The reservoir data of the Washita Creek Field revealed that the Upper Morrow is associated with abnormally high pressure gradients which result in high drilling costs. Also, the various electric log types used in Morrow evaluation included: 1) a density log, 2) dip-meter logs, and 3) hydrocarbon mud logs. (Upper Morrow gas contained 1.3 grains of hydrogen sulfide, a maximum BTU of 977, and less nitrogen and carbon dioxide than Lower Morrow sands).

A field study prepared by Huber (1974) was conducted on the Upper Morrow Chert Conglomerates within the Reydon Field. This field occurs in the western Anadarko basin, Townships 13 and 14 North - Ranges 26 West, Roger Mills County, Oklahoma. Huber (1974) described the reservoir rock as chert conglomerates that grade up to coarse quartz wash to fine-grained sandstones. He made a structure map on top of the Upper Morrow 'A' zone and an isopachous map of the gross Upper Morrow sandstone. A cross section from the northwest to the west Reydon field was also constructed. From this data, Huber (1974) interpreted that three separate lenticular sands contributed to production. These sands trended northwest-southeast, with the source being from the southwest (the Amarillo-Wichita uplift). The trapping mechanism is believed to be a combination of local stratigraphic traps with early, subtle structures. Huber (1974) interpreted that these reservoirs were deposits from a subsea fan complex.

Borger (1977) also conducted a study of Upper Morrow reservoirs at Reydon field in Roger Mills County, Oklahoma. The Reydon field was first discovered in 1961, but Upper Morrow completion did not occur until 1970. By 1977, 15 of 25 wells were completed in Upper Morrow reservoirs. The Reydon field occurs on the northwestern flank of the deep Anadarko basin with sediments indicating a relatively stable marine environment. Although the Amarillo-Wichita Mountains were a source from the south, Borger (1977) believed that a northern source was dominant at Reydon field during the Upper Morrow. Stratigraphically, the Morrow consists of three members at Reydon field: 1) Lower Morrow, with 1550 feet of shale and several interbedded sandstones, 2) Middle Morrow, the "Squaw Belly" shaley limestone, and 3) Upper Morrow, 1500 feet of marine shales and several thin sandstone lenses. A coal bed at the base of the Thirteen Finger Limestone marks the unconformable top of the Morrow. Borger (1977) divided the Upper Morrow sandstone lenses into five units with the letters 'A' through 'E'; the 'A' sand is the most widespread. These sandstones are described as "white to buff, well sorted, subrounded, fine grained, tight sands, predominately cemented by silica but with occasional calcite and/or dolomite as an additional cementing agent." These sands also contain abundant chert that ranges in size from fine sand to cobbles. The chert grains are well-rounded and indicate reworking. An absence of feldspars and abundant clay minerals was the basis for Borger's (1977) idea that the granitic Amarillo-Wichita uplift was not a source. Borger (1977) also proposed that exposed pre-Pennsylvanian and reworked Lower Morrow and Springer deposits were principal sources north of the field. These sandstones trend west-northwest--east-southeast, exhibit a discontinuous distribution pattern, and interfinger with dark marine shales. Borger (1977) stated that this suggests a complex pro-delta depositional environment.

Two structure maps, one at the top of the Squaw Belly and one at the top of the Morrow, showed a low relief, west-northwest--east-southeast trending anticline with regional dip into the basin. An isopach map of the Upper Morrow revealed that structure influenced sandstone deposition. However, isopach maps of individual sand lenses ('A'-'C') showed no structural influence. Borger (1977) postulated that stratigraphic and sedimentologic controls governed sand distribution.

Reservoir data showed that the average porosity for the 'A' sands is 12.4%; the 'B'-'E' sands showed an average porosity between 7-10%. A net sand isopach of unit 'A' with porosity greater than or equal to 7% revealed that the reservoir followed the overall sand body configuration. Reservoir data also showed that Upper Morrow sands exhibit high pressures and temperatures. Initial pressure of unit 'A' was 12,550 psia and reservoir temperature was 280° F.

Reserves of individual wells at Reydon field ranged from four to thirty-five Bcf. Although these estimates could vary because of their young productive life, the average well would recover 15 to 16 Bcf. This estimate showed total Upper Morrow reserves for Reydon field to range from 225 to 240 Bcf. Drilling and production problems existed, but could be treated with modern operational techniques. For example, especially porous and productive zones show higher pressures but are controlled by heavier mud weight. Also, iron-carbonate scale deposits developed down hole and were treated periodically with acid. Borger (1977) concluded that these Upper Morrow sands include an economic risk, but they are overall profitable ventures.

Several field studies were conducted for the Texas Panhandle Geological Society which concerned Upper Morrow Chert Conglomerates. Shelby (1977) prepared a report on the Buffalo Wallow Field in Block M-1, H&GNRR Survey, Hemphill County, Texas. A structural contour map was constructed on top of the Morrow, and a net porosity isopach map (greater than 8% porosity) of the "Puryear" sand was also included. From this data, Shelby concluded that three Upper Morrow sandstones were productive, with the "Puryear" as the greatest producer. The "Puryear" reservoir rock was described as "white to buff, subangular, kaolinitic, with traces of white to buff, vitreous cherts." Shelby (1977) added that it consists mostly of quartz in the Buffalo Wallow Field and is termed "quartz wash". The "Puryear" sand in this area was deposited as a stream channel trending northwest-southeast with sand discontinuity responsible for the stratigraphic trap. Acid treatments were necessary for better flow.

Buckthal (1977) also prepared a report for the Texas Panhandle Geological Society concerning the Upper Morrow in the Shriekey Field. This field is located in Block M-2, H&GN Survey, Roberts County, Texas, and trends parallel to the Amarillo-Wichita Mountains. Buckthal (1977) identified that the producing zone in the field was from a Morrow chert conglomerate bed. This zone was 60-70 feet below the top of the Morrow and termed the "Shriekey Zone." Buckthal (1977) made a stratigraphic section of the Morrow, a structure contour map on top of the Morrow, and a gross Shriekey zone isopach map. He interpreted the Shriekey zone to be deposited in a nearshore environment. Buckthal also proposed that its traps were stratigraphic, and its location and shape may have been influenced by the Morrowan Red Deer-Locke Anticlinal trend. The Shriekey zone contains a high percentage of chert that was reworked from Mississippian cherty limestones. The rocks within this field were described as "white, buff, brown and gray, vitreous to dull, weathered, opaque, fractured chert conglomerate with variable amounts of white to gray, fine to coarse grained sub-angular to sub-rounded sandstone, plus occasional limestone pebbles." Buckthal (1977) observed that leaching of chert pebbles created cavities which commonly filled with secondary quartz and calcite; pyrite and glauconite were also common. The chert conglomerate was treated with 15% HCl in the Upper Morrow Shriekey Field.

Lacer (1977) prepared the last field study, to date, over the Upper Morrow "Puryear" Sand in Washita Creek Field for the Texas Panhandle Geological Society. This study was located in Block A-1, H&GN Survey; and Block C, G&MMB&A Survey, Hemphill County, Texas. Lacer constructed a gross Upper Morrow isopach sand map and a structure contour map on estimated tops of the Morrow. From this data, he determined that the "Puryear" Sand was deposited as a stream channel trending west-northwest to east-southeast. Lacer (1977) also determined that sand discontinuity was responsible for the stratigraphic traps. The Upper Morrow "Puryear" Sand in the Washita Creek Field was described as "white to gray, fine to coarse grained, tight to slightly porous, slightly calcareous, very slightly glauconitic, micaceous sand and quartz wash."

Simon et al. (1979) conducted a study on individual lithologies of Morrow-Springer age to determine the correct stimulation treatment fluid necessary during completion. Although lower Morrow and Springer sandstones in the Anadarko basin were the major concern, Upper Morrow Chert Conglomerates were included. The rock type was described as having vitreous to opaque, weathered chert pebbles in a medium grained quartz, chert, and feldspar matrix. Cementing features which reduced porosity and permeability included iron-rich dolomite, siderite, and authigenic chlorite. Three fluids were tested on the Upper Morrow Chert Conglomerate. Simon et al. (1979) reported that the results were inconclusive, but gelled 3% HCl tested the best. This was probably because the acid removed iron-rich dolomite and siderite, and increased porosity and permeability.

Major structural and stratigraphic features of the Anadarko basin were reported by Evans (1979). Within the stratigraphic section, Evans only discussed the major producing formations, and therefore, included the Upper Morrow. Evans (1979) stated that erosion of Mississippian cherty limestones caused large quantities of chert to be deposited within the southern Anadarko basin. He also proposed that the chert clastics were derived from mountain uplifting and were deposited in fan deltas. Evans (1979) defined the limits of the chert to be along the northern edge of the Lips Fault Trend. The Lips Fault runs through Roberts, Hemphill, and Wheeler Counties, Texas, as well as Roger Mills, Beckham, and Washita Counties, Oklahoma. This fault runs northwest-southeast and parallel to the Wichita uplift. Typical chert facies here include chert conglomerate grading upward into a medium- to fine-grained sandstone.

Voris (1980) conducted a field study in West Cheyenne Field located at T 13-14 N, R 24-25 W, Roger Mills County, Oklahoma. The reservoir rock was Upper Morrow "Puryear" and was described as "quartz and chert, fine to coarse grained, subangular to angular, poorly sorted, fractured, non-calcareous (some silica cement)," with "occasional black asphalt stain, quartz grains clean, chert grains gray to offwhite, opaque to subtranslucent." Voris (1980) constructed a structure map on top of the "Puryear", an isopach map of the gross "Puryear", and a northeast-southwest cross section through the field. From this data, Voris (1980) interpreted the field as a northwest-southeast trending lens of cherty sandstones. The combination structural-stratigraphic trap was due to a south plunging structural nose. The environment of deposition was determined inconclusive because of only one core available.

Shelby (1980) discussed various features of the chert conglomerate on a regional basis. He proposed that Upper Morrow northern sources graded into chert conglomerate distributary channels. These distributary channels are elongate and extend for miles, but the individual channel width hardly ever exceeds one mile. Petrology of the chert conglomerates revealed "white, bluish white to bluish gray, buff to brown, vitreous to dull, opaque to translucent chert in a fine to coarse, poorly sorted quartz sand, chert, and feldspar matrix." The chert was commonly corroded and fossiliferous. Authigenic constituents included chlorite, kaolinite, siderite, and iron-rich dolomite. The average porosity was 14.5%. Shelby (1980) proposed that the chert conglomerates were deposited in fan delta complexes prograding eastward. Proximal facies contained thick prodelta deposits. Shelby (1980) stated that these are typical progradational facies composed of prodelta muds, delta front silts and sands, and distributary channel chert conglomerates.

Hawthorne (1984) researched the Upper Morrow Chert Conglomerates and Sandstones of the Reydon and Cheyenne Fields in Roger Mills County, Oklahoma. The thrust of his research included the construction of eight regional cross sections, five regional isopach maps, and a discussion of the depositional synthesis of the study area. From this data, Hawthorne (1984) described log characteristics of each of the five Chert Conglomerate members, thins and thicks of each member, and the various trends. After combining these details, the depositional synthesis of each Chert Conglomerate member through time was proposed for the study area. Generally, the Reydon and Cheyenne Fields represented the maximum extent of fan delta progradation. Each Chert Conglomerate member ("Bradstreet," "Pierce," "Hollis," "Puryear," "Purvis") represented a pulse of tectonic activity as each member became better developed and extended farther into the area. The "Puryear" was the best developed and most widespread member over the area, and indicated a time of greatest tectonic uplift as well as fan delta progradation. During "Purvis" deposition, tectonic activity and progradation subsided causing the "Purvis" to be less extensive and less developed. Overall, Hawthorne (1984) proposed that the "Puryear" was the best reservoir and that more exploratory targets existed within the Reydon and Cheyenne Fields.

Sturm et al. (1985) recognized prolific Upper Morrowan-age washes in Roger Mills and Beckham Counties, Oklahoma. The unpredictable nature of these wash trends is porportional to the complex depositional history of these sediments. Sturm et al. (1985) stated that the Upper Morrowan washes reflect the tectonic uplifting of the Wichita Mountains, and that they were deposited in prograding fan delta complexes. Sturm et al. (1985) summarized that in order to explore these washes successfully, integration of all information into a model is necessary; this includes correlating lithology, facies, log response, distribution, structure, and seismic control.

Willingham (1985) discussed the geology of the Upper Morrow "Puryear" member at Cheyenne Field, Roger Mills County, Oklahoma. The "Puryear" in this field is a quartz sandstone and a chert conglomerate that was deposited in an overall regressive cycle. A typical core example showed that it was a "coarsening-upward, poorly sorted, matrix-supported conglomerate consisting of fine to coarse-grained quartz sandstone with pebble to cobble-sized, angular and subrounded chert clasts." The "Puryear" in the Cheyenne

Field trended northwest-southeast and was proposed as a delta-front deposit associated with a fan delta system.

The Atokan Berlin Field in Beckham County, Oklahoma, was studied by Lyday (1985). Although the thrust of his report covered the Atoka dolomite wash, the Upper Morrow Chert Conglomerate was mentioned. Lyday (1985) reported that the Atoka dolomite wash overlies Morrowan Chert Conglomerates in this area. The main point was to show that these cherty clastics extend into or very close to the Elk City Field.

Carroll (1986) discussed Pennsylvanian fan delta deposition that resulted from tectonic uplift in southwestern Anadarko basin. Lower Pennsylvanian sedimentation was dominated by chert and dolomite washes, while Mid- to Late Pennsylvanian deposition was dominated by arkosic washes. Detailed stratigraphy showed seven major pulses from Morrow-Missourian that ended unconformably. Nine more conformable subsequences were subdivided from these and were proposed as individual drainage-basin erosional cycles. These subsequences coarsen-upward and are capped with a fining-upward sequence. Distal marine shales were found interfingering with the washes and were responsible for stratigraphic traps. Carroll (1986) stated that the best reservoirs occurred in braided channels and fan delta front deposits.

CHAPTER II

GEOLOGIC SETTING

Stratigraphy

A wide variety of lithologies that compose the sedimentary sequence in the Anadarko basin range in age from Cambro-Ordovician through the Permian. Figure 2 shows the asymmetric nature of the Anadarko basin with thick accumulations near the Wichita uplift and progressive thinning onto the shelf. The lower Paleozoic represents a time of marine inundation and dominance of carbonate sedimentation, while the upper Paleozoic rocks are dominated by clastic sedimentation.

The Anadarko basin began to subside during the late Cambrian and caused a marine transgression which produced the Reagan Sandstone. Continued submergence and transgression flooded the continental margin and allowed deposition of a thick carbonate sequence. This accumulation can be up to 5000 feet in the deep basin and is known as the Cambro-Ordovician Arbuckle Group (Wickham, 1978).

A change in depositional environment occurred during deposition of the overlying mid-upper Ordovician Simpson Group. These rocks are composed of green shales, clean

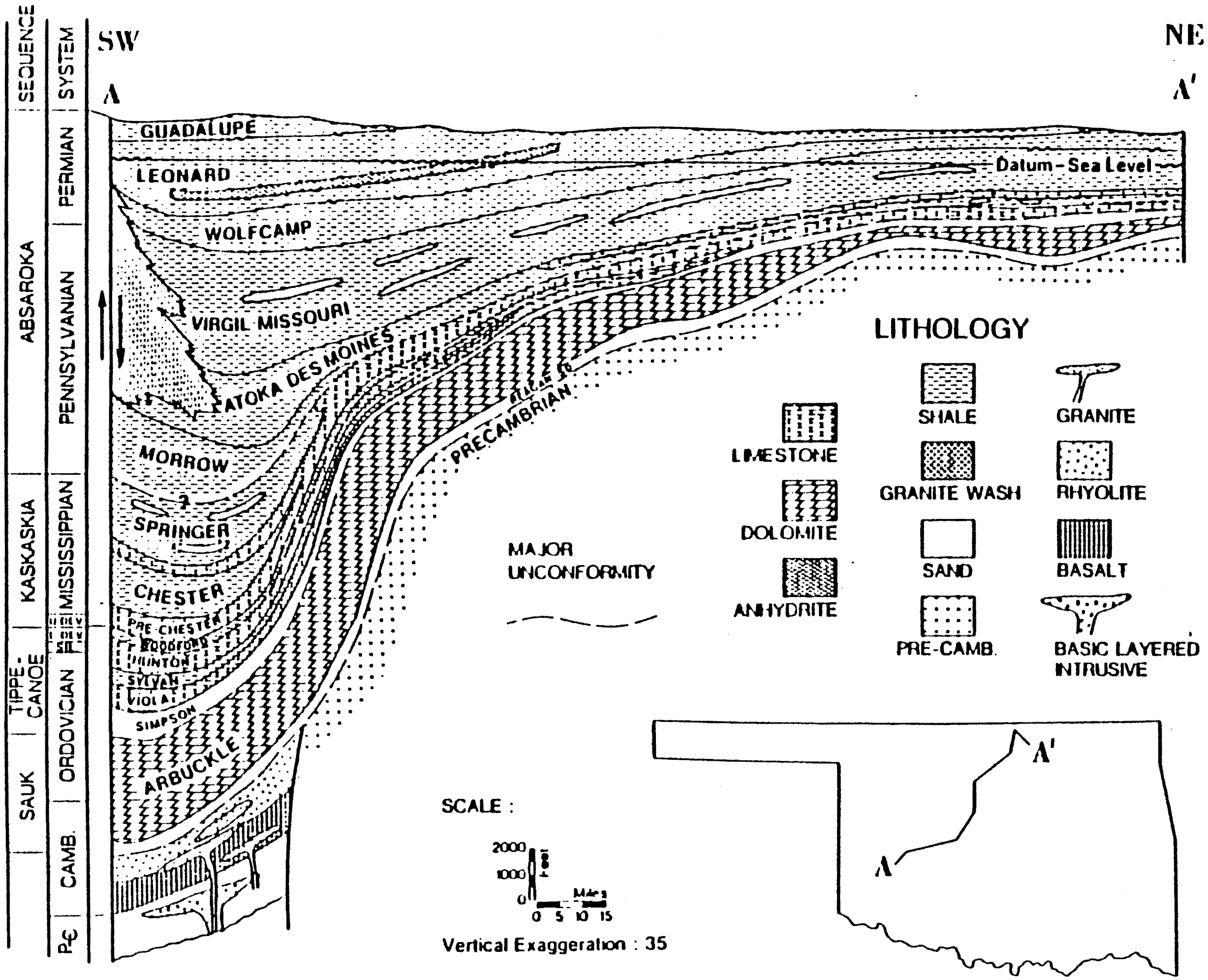

Figure 2. Idealized Stratigraphic Section Showing Variations in Thickness and Facies from the Shelf (Right Side) into the Anadarko basin (Left Side) (Modified from Wickham, 1978).

sandstones, and limestones which are the only clastics of lower Paleozoic age in the Anadarko basin (Webster, 1980). Sources for these clastics were from the north and east (Rascoe and Adler, 1983).

The upper Ordovician Viola Limestone, the Sylvan Shale, and the Siluro-Devonian Hunton Group cap the Simpson Group. The Hunton Group of carbonates and marly shales as well as the overlying Woodford Shale bear a significance in the Anadarko basin. These formations share close thicknesses with those on the craton; this signifies that the basin and craton were subsiding at about the same rate during the Devonian.

The Devonian Woodford Shale and Mississippian Sycamore and Caney Formations indicate a change of environment. These darker shales reveal that shallow-water marine conditions changed to restricted, deeper waters. Webster (1980) notes that, at this time, the deep basin began subsiding faster than the craton; this is based on 5,500 feet of Mississippian shale found in the deep basin compared to 500 feet on the northern shelf.

Pre-Chester rocks within the Anadarko basin consist mainly of cherty limestones and dolomites. The cherty zones in the Mississippi Limestones are considered to be the source for the Upper Morrow Chert Conglomerates.

Chester rocks record a time in which the seas began to withdraw from the Mid-Continent. This regression produced the Springer Formation in the Anadarko basin as shale with several thick interbedded sandstones. At the end of the Chester Series, the Mid-Continent emerged and left upper Mississippian carbonates exposed in the Anadarko basin (Rascoe and Adler, 1983).

The Pennsylvanian rocks represent a period when clastic sedimentation dominated the Anadarko basin. The cyclic nature of deposition at this time produced a complex system of depositional environments. Deltaic and shallow-marine deposits comprise the majority of upper Paleozoic rocks in the Anadarko basin.

The Morrowan Series represents a time of marine transgression into the Mid-Continent with intermittent regressions. Morrowan sediments are dominantly shales with discontinuous sandstones, conglomerates, and limestones that form a wedge of thick accumulations against the Wichita uplift and thin onto the shelf (Figure 2). The Morrow is defined as the unit between the base of the Atokan "Thirteen Finger" Limestone and the top of the truncated Mississippian surface (Shelby, 1980). A paleogeographic map of the Morrow reveals a sand source west-northwest of the Texas and Oklahoma Panhandles as well as to the north-northeast (Figure 3). The Amarillo-Wichita uplift was the major source from the southwest by the end of Morrow time.

The Morrowan Series is normally divided into upper and lower units. Most authors agree that the lower Morrow is characterized by shallow marine sandstones, while the upper Morrow is characterized by deltaic sandstones (Swanson,

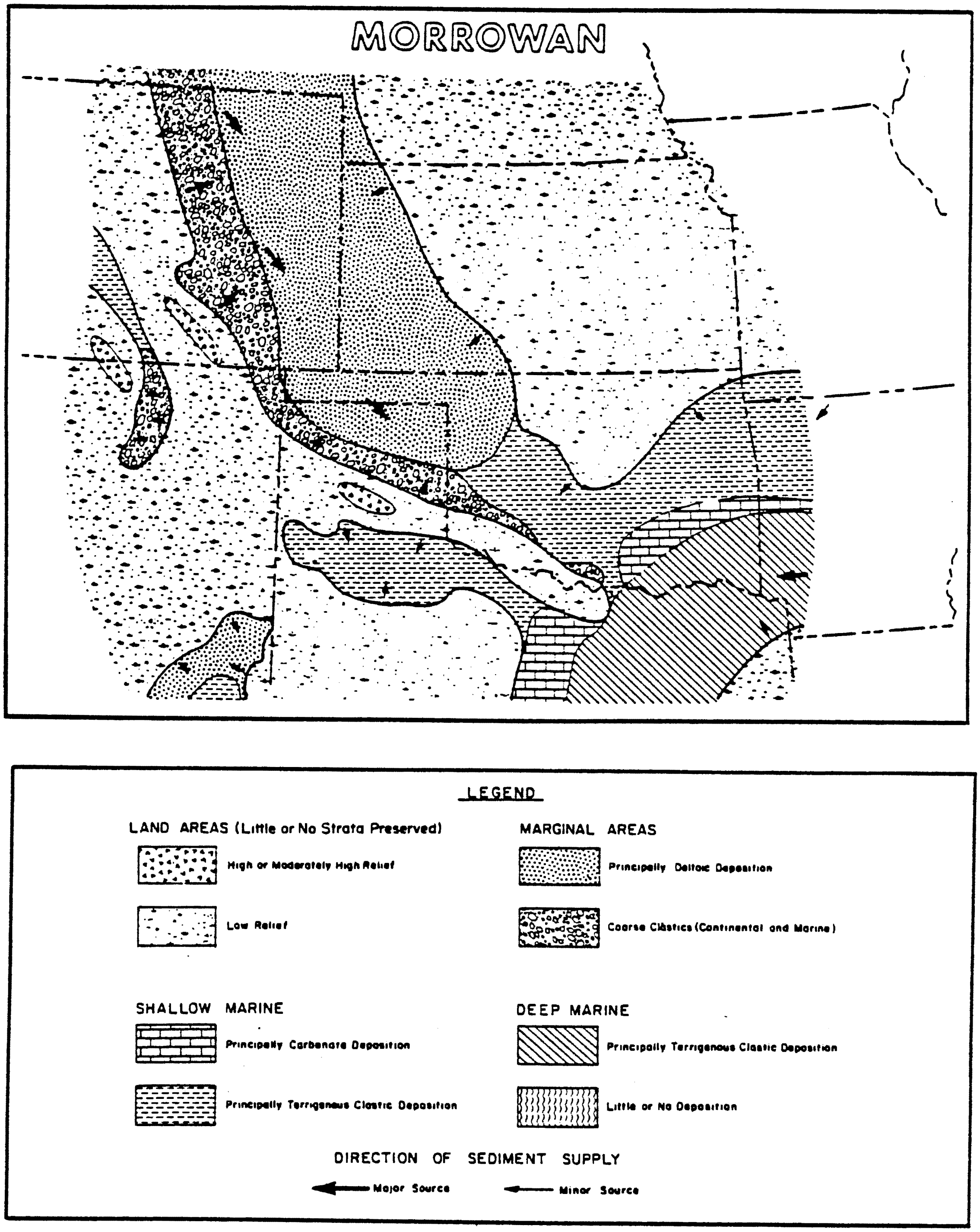

Figure 3. Paleogeographic Map of Morrow (Moore, 1979).

1979; Shelby, 1980; Rascoe and Adler, 1983; Walker, 1986). Lower Morrow deposits are described as "normal" shallow-marine claystones, sandstones, limestones, and sandy limestones. These deposits can be classified as tidal ridge/shoal complexes, offshore bars, tidal flats, and transgressive deposits (Walker, 1986). Figure 4 shows the known distribution of shallow-marine sandstones in the Anadarko basin. Upper Morrow deposits consist mainly of widespread marine shales with many discontinuous coarse-grained clastics. These clastics are related to fluvial/deltaic processes and can be classified as distributary channels, delta fringe, interdistributary bays, levee/splay deposits, point bars, and stream mouth bar deposits. Figure 5 shows the known distribution of the deltaic complexes in the Anadarko basin. Note that the Upper Morrow Chert Conglomerate is confined to a relatively small area in southwestern Anadarko basin. These deposits were shed from the initial uplift of the Amarillo-Wichita Mountains and indicate erosion of cherty Mississippian limestones (Evans, 1979).

The Atokan time was dominated by the formation of the major Pennsylvanian tectonic features which began during the Morrow. Although a northwest source was still supplying sediment, the Amarillo-Wichita uplift was the major source for the Anadarko basin at this time. Erosion of the Cambro-Ordovician Arbuckle Group from the Wichitas produced a thick wedge of dolomite wash. The Precambrian granite was limited

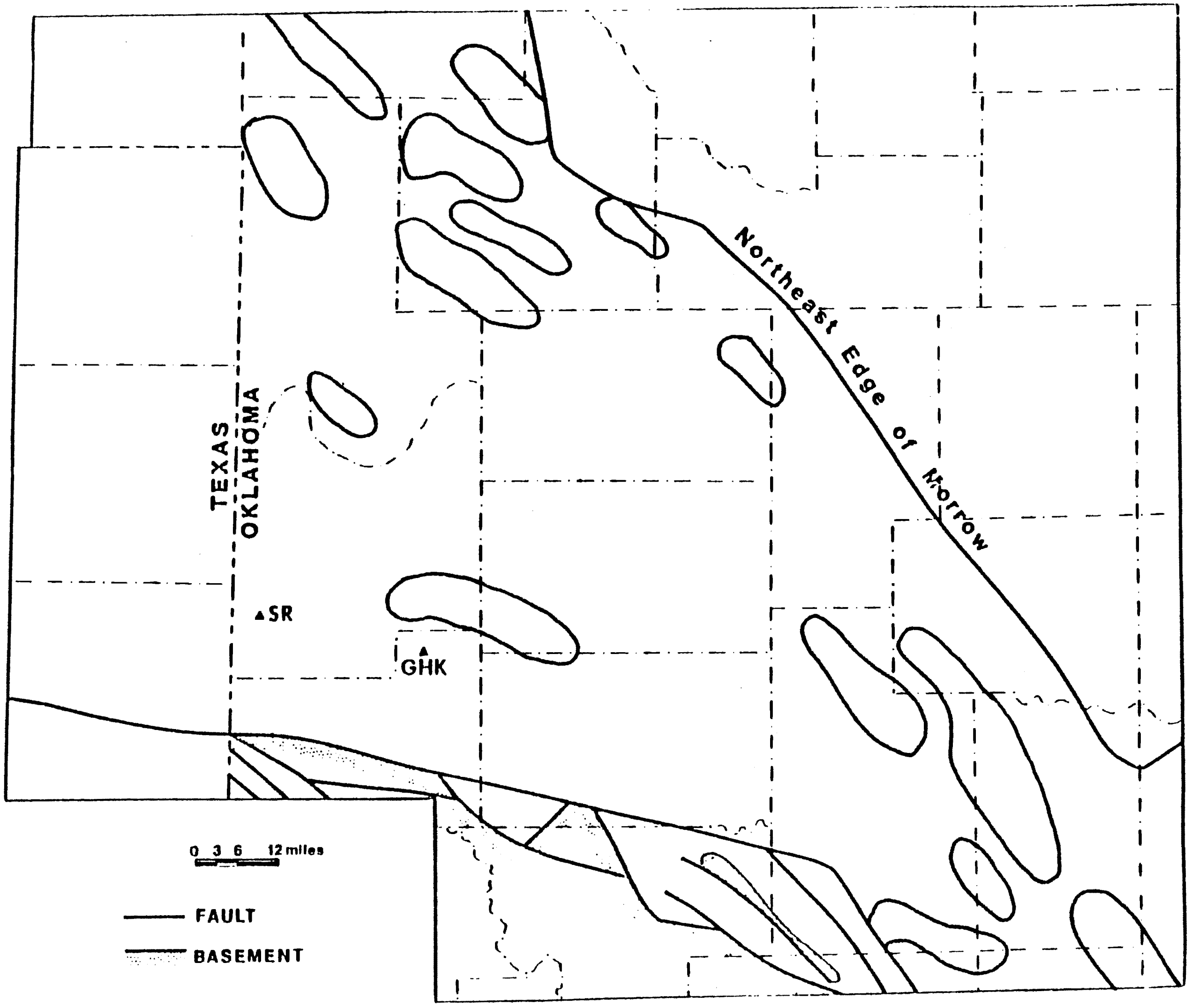

Figure 4. Known Distribution of Shallow Marine Sandstones (Modified from Busch, 1959; after Walker, 1986).

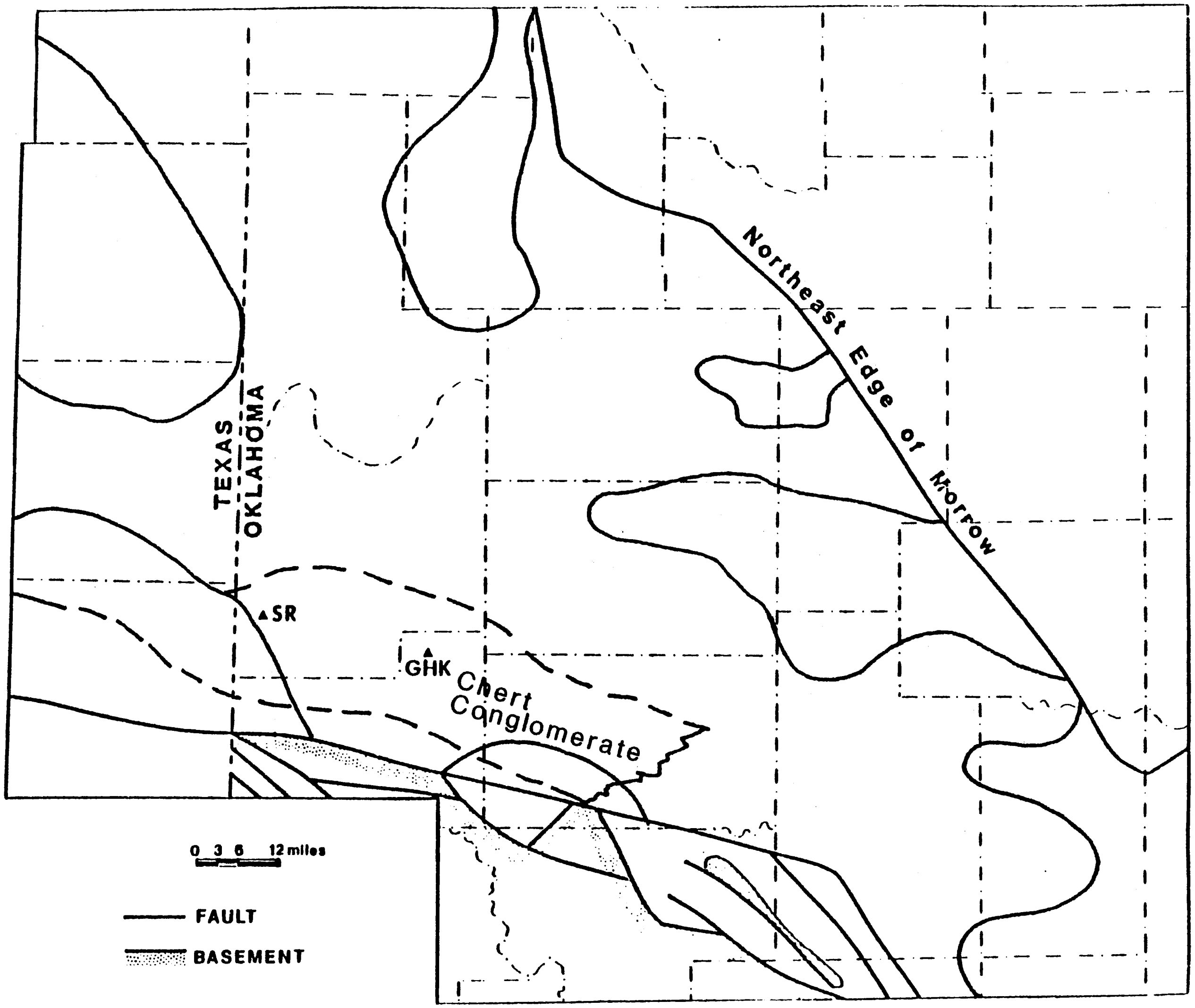

Figure 5. Known Distribution of Deltaic Sandstones (Modified from Walker, 1986; after Evans, 1979; Forgotson, 1979.

in exposure and contributed only minor amounts of clastic detritus to the deep basin (Lyday, 1985). The widespread "Thirteen Finger" Limestone was also deposited over most of the deep basin during the Atokan and indicates the discontinuous supply of clastic input through Atokan time.

Desmoinesian sediments reflect a major marine transgression occurred with periodic regressions of deltaic deposition. A northerly deltaic source was still contributing during the early Desmoinesian, but it decreased in importance by the end of the Desmoinesian. The Precambrian granite was eroded from the Wichitas throughout this time. By the end of the Desmoinesian, marine carbonate deposition covered most of the Mid-Continent (Moore, 1979).

The Virgilian rocks consist of deltaic clastic wedges which alternate with shallow-marine shelf-carbonates. Although Precambrian granite was still eroding from the Wichita uplift, the tectonic activity had subdued and caused deposition to slow down (Rascoe and Adler, 1983).

The Permian represents the final filling of the Anadarko basin. The Wolfcampian consists of a lower transgressive unit of limestones and shales with an upper regressive unit of red shales. Leonardian and Guadalupian sediments contain cyclic red beds and evaporites. By the end of the Permian, the Wichita uplift had ceased along with the final withdrawal of Paleozoic seas from the southern Mid-Continent (Moore, 1979).

Structural Setting and Tectonics

The Anadarko basin is one of the major structural features found within the north-northwest trending basins and uplifts of the Mid-Continent. Figure 1 illustrates the major geologic provinces of Oklahoma and the Texas Panhandle. The two major provinces are the Wichita uplift to the northwest and the Arbuckle uplift to the southeast (Webster, 1980). Other structurally positive features include the Criner, Muenster-Waurika, and Tishomingo uplifts as well as the Hunton-Pauls Valley uplift. Other basins which fall within this trend are the Marietta and Ardmore.

The Anadarko basin is highly asymmetric in nature with its axis lying near the deep basin and trending northwest-southeast (Figure 2). The development of this basin was first proposed by Ham et al. (1964) as the southern Oklahoma geosyncline. Although the southern Oklahoma geosyncline theory was accepted for many years, the recent work by various authors proposes that this region is an aulacogen.

Burke and Dewey (1973) and Wickham (1978) explained that aulacogens develop from hot spots and triple junctions. Wickham (1978) states that aulacogen formation occurs in three stages: 1) the rifting stage, which is associated with intrusive and extrusive igneous activity, 2) the subsiding stage, and 3) the deformation stage, in which local basins and uplifts form.

The geologic history of the Anadarko basin closely relates to aulacogen formation. The rifting stage is represented by Precambrian-early Cambrian igneous basement rocks. The subsiding stage is represented by the thick sedimentary sequence produced in the Anadarko basin from late Cambrian-early Mississippian. The deformation stage is represented by the occurrence of orogenic conglomerates in the basins from late Mississippian-early Pennsylvanian through the end of the Pennsylvanian.

The deformation stage of the southern Oklahoma aulacogen was responsible for the full development of the Anadarko basin. Deformation began in the late Mississippian as the North American plate collided with the Afro-South American plate. This caused compressive stresses to transmit far into the Mid-Continent and reactivate old basement faults in the aulacogen (Walper, 1977).

The deformation stage in the southern Oklahoma aulacogen consists of two, deformational pulses which altered the aulacogen into its present configuration (as in Figure 1). The first phase is represented by the Wichita orogeny which occurred in late Mississippian through Desmoinesian time and marks the rise of the Amarillo-Wichita Mountain horst block out of the center of the aulacogen. This caused the depocenter to move northward and produce the Anadarko and Ardmore basins. 30,000 feet of vertical displacement is noted to occur along the Wichita fault zone along with anticlines and faults within the Anadarko basin (Webster, 1980).

The second phase of deformation is represented by the Arbuckle orogeny during the Virgilian time. This phase includes uplift of the Arbuckle Mountains, and folding and subsidence of the Ardmore basin (Webster, 1980).

The Amarillo-Wichita uplift produced a thick wedge of orogenic conglomerates consisting of chert wash, dolomite wash, and granite wash in the Anadarko basin. Subsidence occurred at a fast rate during the uplift and filled the basin with 10,000 feet of Morrow and Atokan sediments. Alternating sands, conglomerates, and shales were deposited in the deep basin while thin sands, shales, and limestones were produced on the northern shelf (Walker, 1986).

Pennsylvanian deformation within the aulacogen was dominated by vertical and horizontal displacements along major fault zones that were reactivated during the plate collision (Wickham, 1978). Most authors favor the wrench fault theory for explaining the structural style of the southern Oklahoma aulacogen. Wrench faulting in the Mid-Continent, according to Walper (1970), can be explained by the Wichita Megashear. This megashear constitutes fairly wide and complex zones of left-lateral strike-slip (wrench faults) faulting and are usually arranged "en-echelon". Walper (1970) also states that this megashear produces a vertical component of movement as high-angle normal and reverse faults. In order for the Wichita megashear to have occurred, then compressional stresses needed to come from the northeast-southwest. Various work has shown structural and stratigraphic evidence to support that the direction of stress was coming from the collision of the Afro-South American continent and North American continent (Wickham, 1978; and Webster, 1980).

By the end of the Pennsylvanian, the Anadarko basin was fully developed and the orogenic, destructional phase had ended. Permian red beds deposited over the orogenic sediments marked the end of deposition and active tectonism of the area (Webster, 1980).

Local Stratigraphy and Structure

The stratigraphic section and type log of the Morrow in the study area are shown in Figure 6. The upper Morrow, as seen in the subsurface from well logs, is bounded above by the widespread subsurface marker, the Atokan "Thirteen Finger" Limestone. The "Thirteen Finger" Limestone is composed of thin, alternating limestones and shales and is distinguished by its characteristic conductivity curve. The upper Morrow is bounded below by the "Squaw Belly" Limestone, so named because of its characteristic log signature (Shelby, 1980).

The Upper Morrow Chert Conglomerates in the study area include five separate sand bodies that occur between thick sequences of marine shales (Figure 7). The "Puryear" member

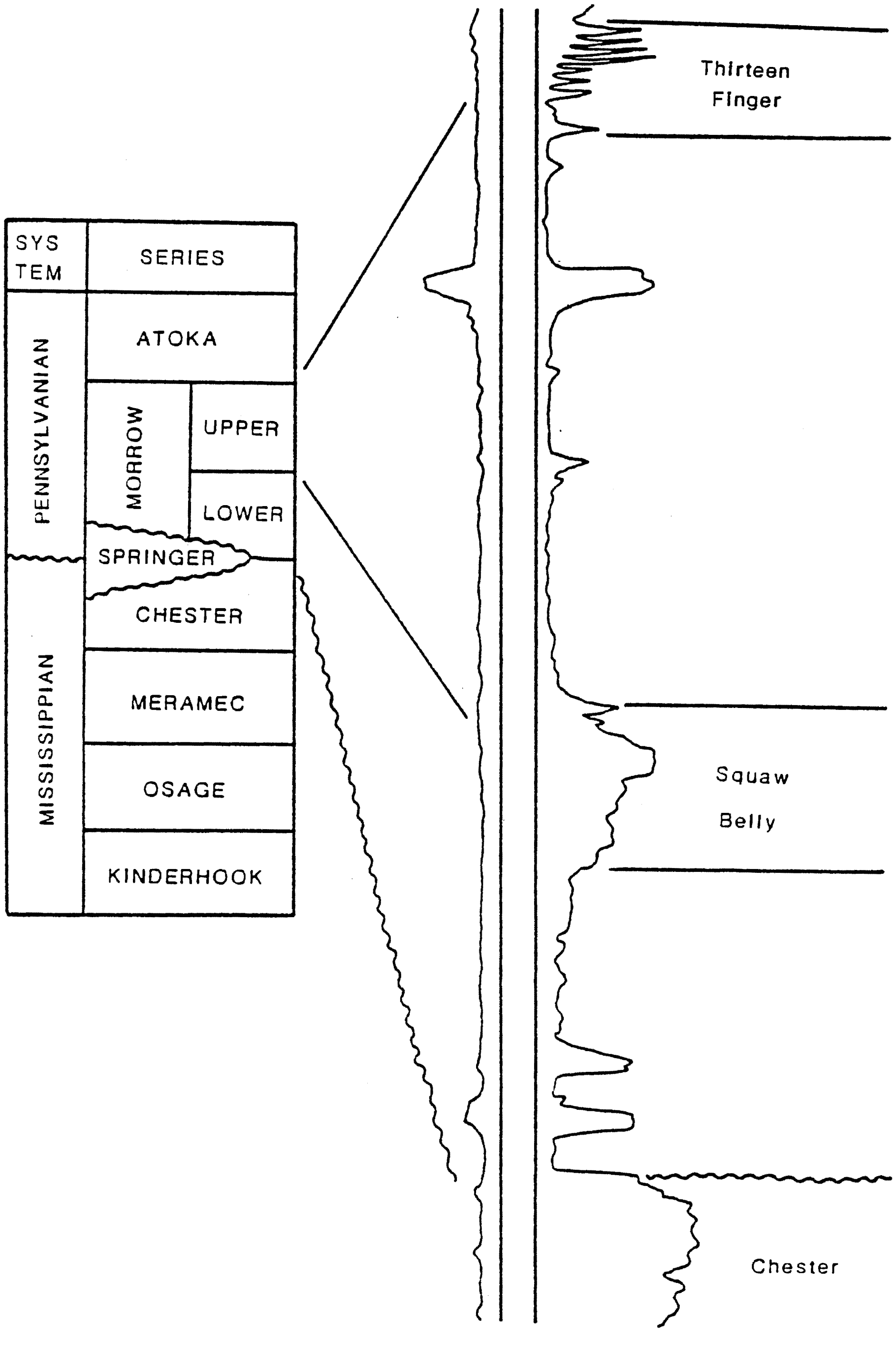

Figure 6. Stratigraphic Section of Morrow Type Log (Shelby, 1980).

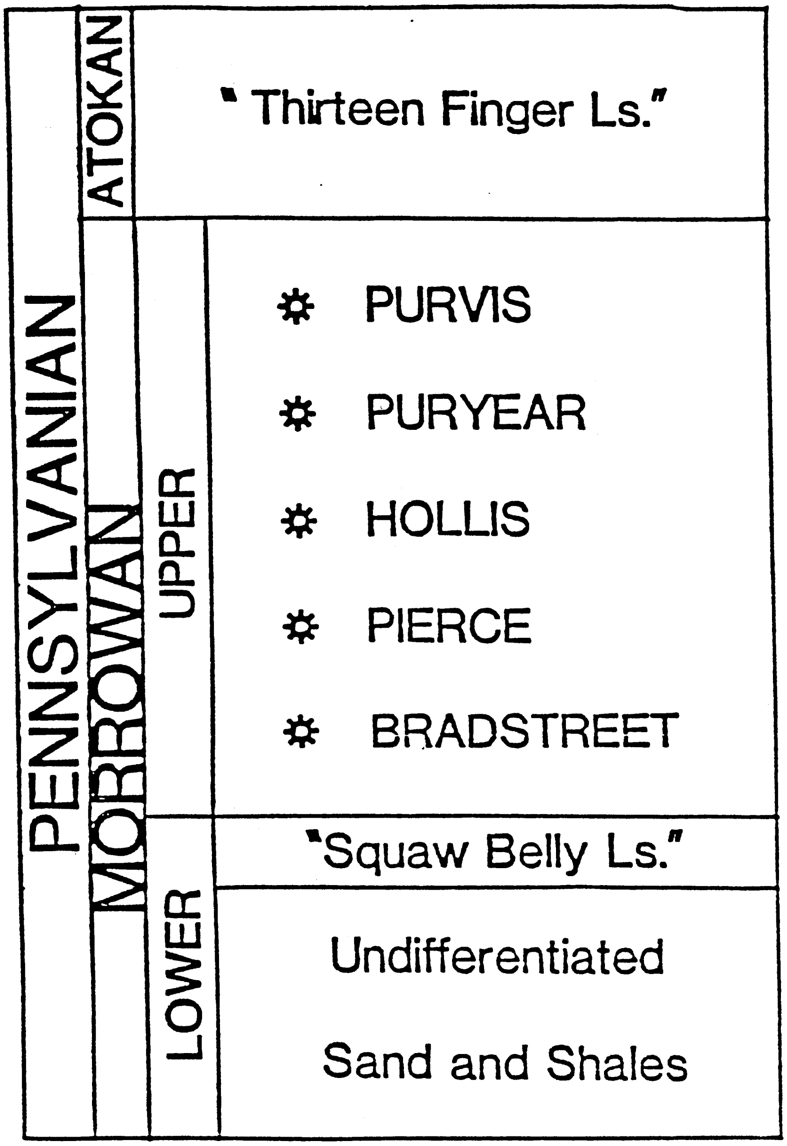

Figure 7. Local Stratigraphic Section of Upper Morrow (Hawthorne, 1984).

represents the second-to-last pulse of chert wash from the Wichita uplift and is the main sand unit of this study.

The Upper Morrow Chert Sands and Conglomerates occur in the subsurface around -13,600 feet. Sources are from the Amarillo-Wichita Mountains to the south and southwest.

The study area lies north of the Anadarko basin's structural axis. The structure contour maps (Figures 8 and 9) show that regional dip is from north to south with an average of 100 feet per mile (approximately 1^{o} dip). Several high and low features occur in each corner of the area of Figure 8, but no closure is observed. A few horst and graben-type faults are located in the southern portion of the area and reveal a maximum throw of about 2000 feet. These faults are trending W/NW, approximately 0^{o}-30^{o} away from the Amarillo-Wichita uplift. The faults appear to be an extension of the Lips Fault Trend that is reported by Evans (1979), see Figure 10. The structure contour map was constructed on top of the "Thirteen Finger" Limestone because of its regional extent and its proximity to the top of the Morrow.

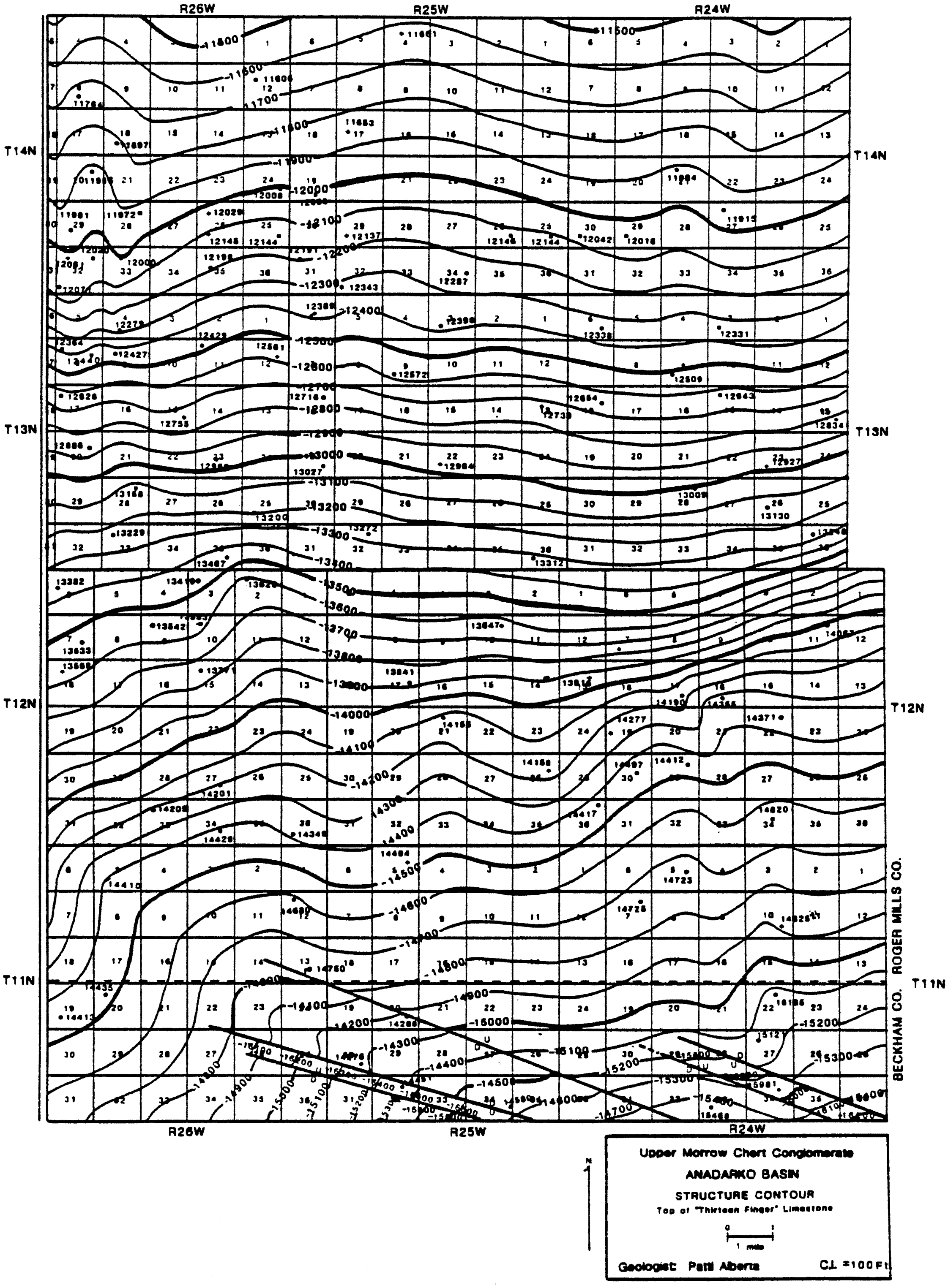

Figure 8. Structure Contour Map, T11N-T14N, R24W-R26W.

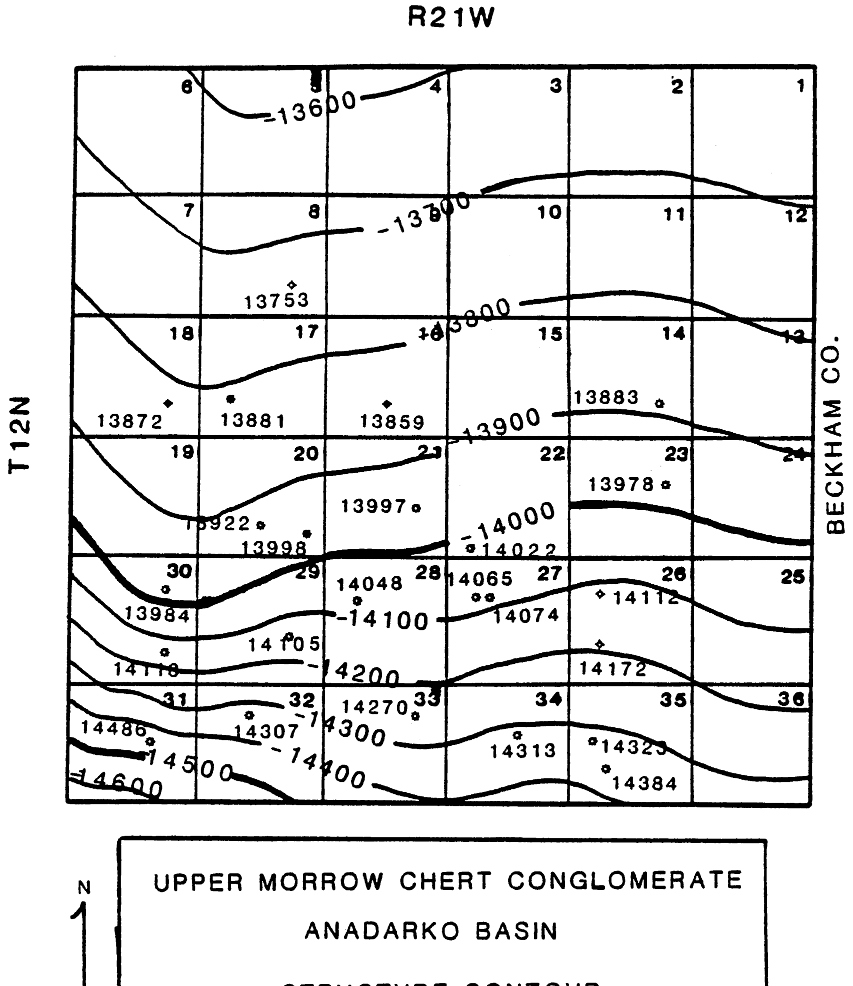

Figure 9. Structure Contour Map, T12N, R21W.

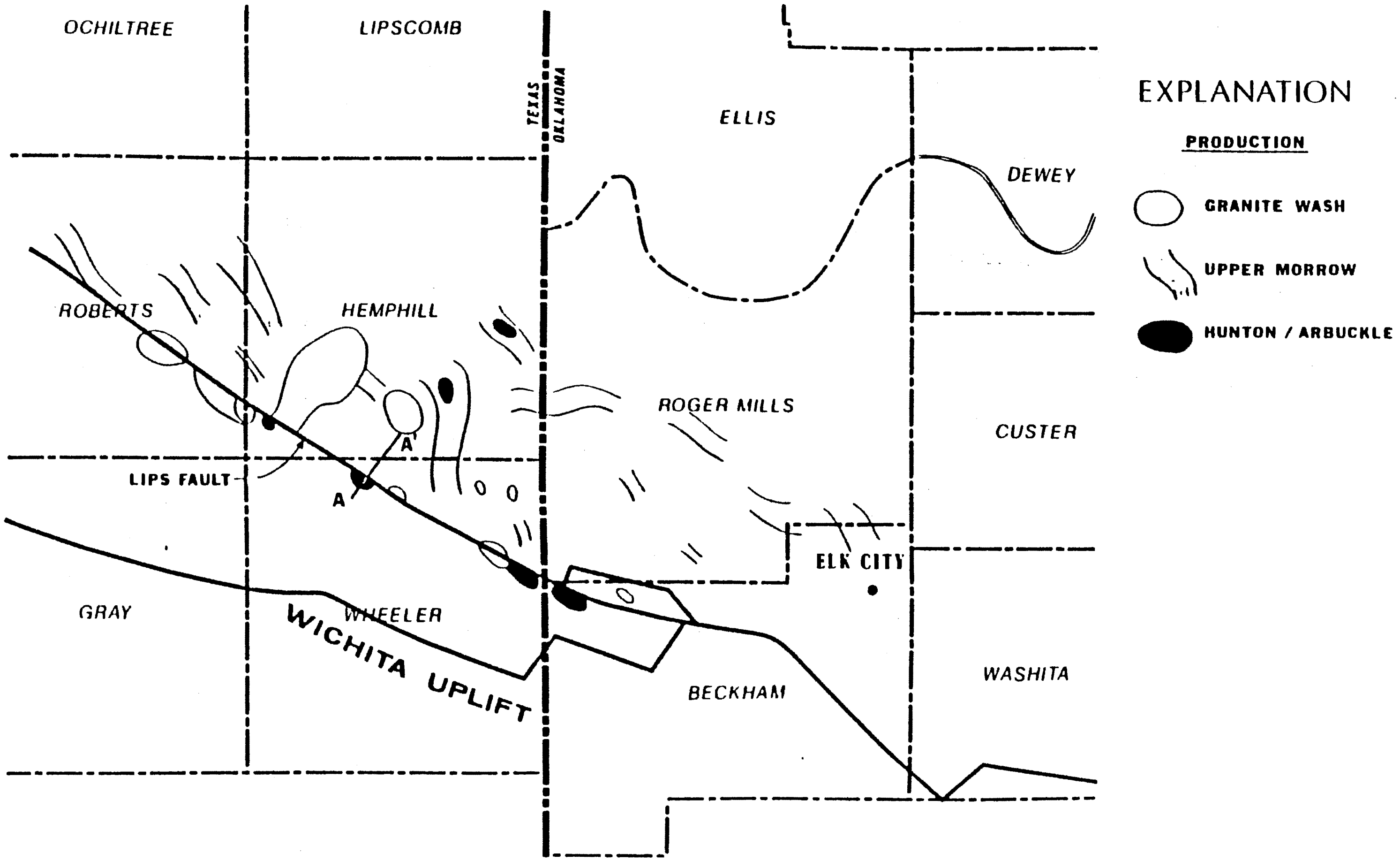

Figure 10. Location of Lips Fault Trend (Evans, 1979).

CHAPTER III

DEPOSITIONAL ENVIRONMENT

Introduction

The "Puryear" is the best-developed and most productive member of the Upper Morrow Chert Conglomerates. Although previous investigaters have mapped the "Puryear" in various fields and have determined the depositional environment as fan delta complexes, no detailed discussion of these depositional environments has been included. An understanding of the overall depositional environment is important for successful interpretations. Because the "Puryear" is best-developed, it probably best represents the chert conglomerate fan delta environment as a whole. That is why the "Puryear" has been selected for this study.

The purpose here is:

1. To discuss and evaluate literature dealing with processes controlling fan delta development and the facies which result from those processes.

2. To interpret the Upper Morrow Chert Conglomerate facies from available cores.

3. To construct a sandstone isolith map of the "Puryear" to illustrate geometry, trends, and source directions.

Fan Delta Definition

The recognition of fan delta deposits in the rock record has increased during recent years. Generally, fan deltas are alluvial fans that prograde into a body of water (McGowen, 1971; Wescott and Ethridge, 1980; Dutton, 1982; Ethridge, 1985; and Galloway, 1985). Specifically, fan deltas are a system composed of bed-load streams that braid to a coastline, form a cone on the surface in map view, and are usually confined to tectonically active areas (Bull, 1972; and Ethridge, 1985) (See Figure 11). Because alluvial fans are an inherent part of the fan delta system, their study should be incorporated for a complete understanding of fan delta deposition.

Fan Delta Depositional Processes

Fan construction relies on a limited suite of depositional processes. The two main categories are those related to water-laid sediments and debris flow deposits. Water-laid sediments are those which are deposited from any fluvial system, and have a wide variety of sedimentary structures. Debris flows and related deposits are those that are transported by mass gravity flows and have few sedimentary structures (McGowen, 1971; Bull, 1972; and Nilsen, 1982).

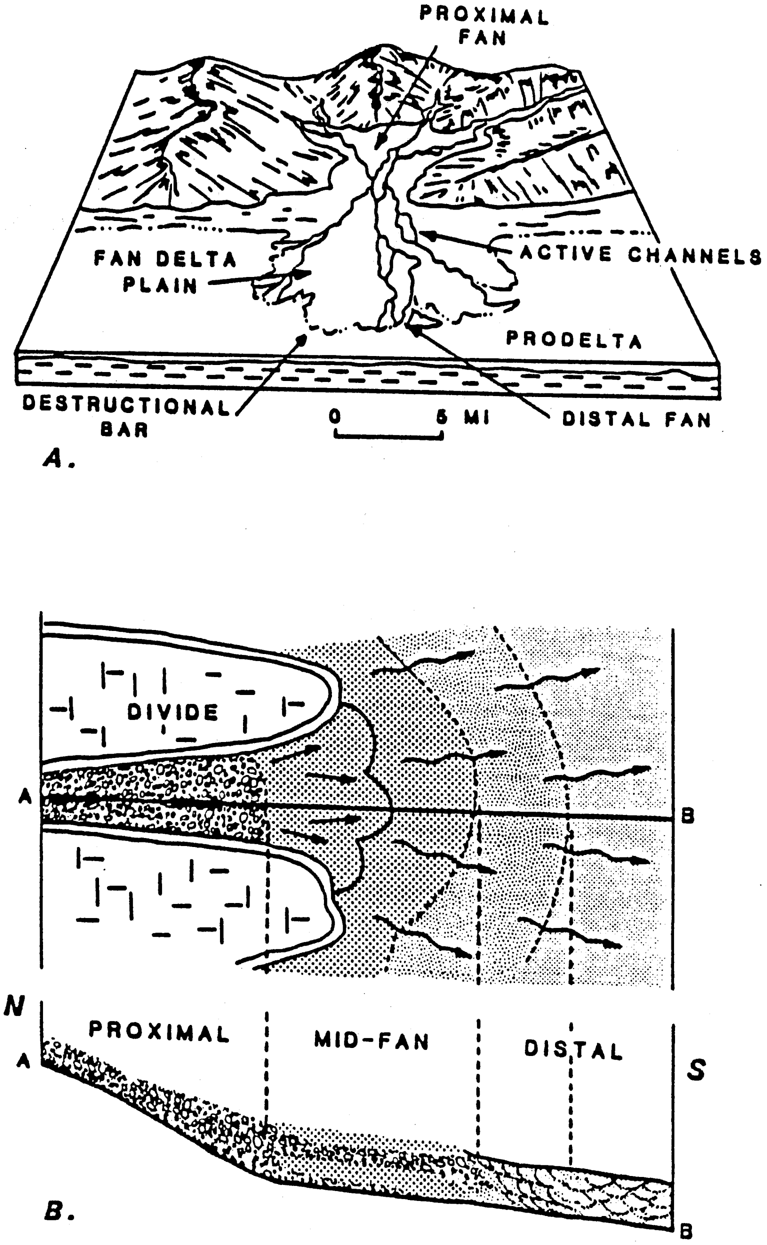

Figure 11. (A) Schematic Diagram of a Fan Delta System (Modified from Dutton, 1982).
(B) Plan View and Cross Section of the Fan Delta System (Modified from Nilsen, 1982; After McGowen and Groat, 1971).

The water-laid sediments can be divided into five subgroups. One of the most common types are streamflow deposits. These are described as stream-channel sediments in which there is a steady supply, or confined flow, of water and detritus. Streamflow deposits are channel cut-and-fill deposits that result after flood subsidence (McGowen, 1971; Bull, 1972; and Nilsen, 1982). These fill long and narrow channels that fine and shallow downfan; inner fan channels fill straight and entrenched, while mid- and outer fan channels fill in braided streams. The channels have concave up bases and erosional contacts (Nilsen, 1982). Streamflow deposits occur where suspension load is high; where there is a lack of bed load, sediment transport is low and fall velocity decreases. Longitudinal bars result in cuspate and linguoid ripples from falling flood stage (McGowen, 1971). Streamflow deposits are more coarse-grained and more poorly sorted than sheetflow deposits (discussed below) (McGowen, 1971; and Bull, 1972).

Another type of water-laid sediment is streamflood deposits. These are similar to streamflow deposits in that they are from confined flow within channels. McGowen (1971) states that the difference is streamflood deposits originate where a large amount of water and detritus emerge at the canyon head and form linear shapes.

Sieve deposits are also classified as water-laid sediments. These are a type of streamflow deposit that form permeable lobes of gravel. Sieve deposits have little or no sand, silt, or clay, and mainly consist of gravel. They have excellent sorting and result in massive, well-imbricated beds. Sieve deposits are not common, but are typical of proximal parts of arid fans (Hooke, 1967; McGowen, 1971; and Bull, 1972).

The bulk of fan deposits occur as sheets, and the most common water-laid sediment is sheetflow deposits. Sheetflow deposits result from less channelized, unconfined, lateral flow, and are described as a network of braided streams that contain longitudinal bars (McGowen, 1971; Bull, 1972; and Nilsen, 1982). McGowen (1971) borrows Bull's (1963) explanation that these deposits are "caused by the decrease in depth and flow velocity that results from the increase in width as the flow spreads out on the fan."

The fan shape is a product of these sheetflow processes; continual shifting creates a uniform distribution of sediments. Channels lengthen as the fan area increases. A change in the fan form is due to a change in the stream gradient; thus, sheetflow deposits result in the development of levees where beds thin and sediments fine away from the channels (McGowen, 1971; and Nilsen, 1982). Bull (1972) believes that the extensive sheet-like aspect, in which sheets are 10-100 times wider than the channel transversing, is one of the best keys in identifying fan environments. Sheetflood deposits are another type of water-laid sediment, and are similar to sheetflow deposits in that they are less channelized, unconfined flow deposits.

These are viscous sediments deposited from surges of floodwater from channels and spread as sheets over fan parts. Sheetflood deposits are caused by flow widening into shallow bands, along with a decrease in depth and flow velocity. These usually occur near the distal fan, and therefore, form a blanket-shaped deposit of sand or gravel bars due to a short distance and flow time. Sheetflood deposits are fairly well-sorted, have parallel laminations from upper flow regime, and are usually sandy with some clay. Sheetflood deposits are described as crevasse splay deposits (McGowen, 1971; Bull, 1972; and Nilsen, 1982).

In addition to water-laid sediments, debris flows offer another type of fan deposition. Generally, debris flows have a higher density and viscosity than water-laid sediments. Abrupt margins of debris flows indicate a highly viscous flow. The plastic behavior can be such to allow transport of boulders weighing several tons (Bull, 1972). Debris flows are poorly sorted, can have reverse and normal grading, contain few sedimentary structures, usually form disorganized beds, and contain an abundance of muddy matrix (Bull, 1972; and Nilsen, 1982).

Heward (1978) explains that debris flows are a highly irregular process that is rain dependent. Other factors which promote debris flowage include: 1) source areas which provide a mud matrix, 2) steep slopes, and 3) scarce vegetation (Bull, 1972; and Nilsen, 1982).

Debris flows are not only confined within channels, but can occur as lobate sheets on interfan areas. However, debris flows are most common near the fan apex (Bull, 1972; and Nilsen, 1982).

Bull (1972) lists several features which aid in debris flow recognition: 1) old debris flows have surficial lobes of cobbles due to rain flushing the matrix, 2) uniform thickness of beds, 3) a fluid debris flow has graded bedding and imbrication, 4) a viscous debris flow has uniform distribution of large clasts, and 5) water-laid sediments interbedded with beds that appear undefined.

Mudflow deposits are a type of debris flow that consist mainly of fine-grained material (sand-size and finer). The viscosities can vary and create a range from thin, widespread sheets where centers thicken, to thick, lobate deposits. One characteristic feature of mudflow deposits is polygonal dessication cracks (Bull, 1972; and Nilsen, 1982).

Nilsen (1982) notes that deposition does not always occur down channel systems along the fan, for landslides can also be a source of sediment transport. The material transported can be of any size and of any origin. Landslide deposits can extend for short distances or to distal fan ends, and therefore, can be easily confused with debris and mudflow deposits in the ancient record.

Fan Delta Facies

Fan deltas can be divided into four facies: proximal fan, mid fan, distal fan, and prodelta (see Figure 11). The type of facies formed depends on whether the fan is formed in humid or arid climates; although, most fan deltas are formed in humid environments.

Proximal facies occur in the upper fan, at the apex, where an entrenched canyon head feeds the outer fan areas. Proximal fan deltas behave mostly as alluvial fans in that they are highly channelized and form thick, lenticular bodies. This channelized area consists of one, or possibly several, major deep and broad channels.

A limited suite of deposits characterizes the proximal fan facies. These deposits make up the fan's coarsest material which includes boulders, gravels, and very coarse-grained sands. Anadon et al. (1985) describes proximal sediments from Montserrat, Spain, as poorly sorted, unstratified, clast-supported conglomerates that interbed with sandstones; he interprets these as highly concentrated stream or sheetfloods. Sequences in the Copper River delta of pebbly, coarse sand to medium- to fine-grained sand with medium- to large-scale cross bedding and contorted zones are interpreted by Galloway (1976) as proximal distributary channels. Ethridge (1985) discusses Boothroyd's (1972) proximal bars as gravel-sized sheet bars that contain horizontal bedding, and imbricated pebbles. The most common proximal deposits are debris flow deposits. These are discussed in the previous section, but are basically matrix supported conglomerates that generally show no well-developed structures. Sieve deposits are also characteristic of proximal facies, and are described as permeable lobes of gravel.

The next major facies is the mid fan which represents the facies with the widest depositional extent. Generally, the mid fan is composed of a network of braided streams on the subaerial fan delta plain.

The non-channelized areas of the mid fan are described as the flood plain. Wescott and Ethridge (1980) describe flood plain deposits as silty, very fine-grained sand with ripple laminae, ripple drift laminae, and small scour troughs. These deposits also contain abundant burrows, dessication cracks, and plant debris, such as roots.

The dominant facies of the mid fan is the channel facies. Broad, shallow braided stream channels comprise the major portion of the channel facies. Braided streams are named such because they divide into several channels, meet, and redivide. Braided streams have a high width to depth ratio, and have a large bedload to discharge ratio (Galloway, 1985; and McGowen, 1971).

The channelized areas are filled with a complex arrangement of conglomeratic bars and interbedded sands in ribbon- to sheetlike geometries. Transverse and longitudinal bars are the major features of braided streams.

Bars develop when a local change within the stream causes it to deposit some coarser bedload material. A particular area within the channel became incompetent to transport certain grain sizes and allowed for sediment accumulation downcurrent forming longitudinal bars. After the development of longitudinal bars, flow develops transverse to the direction of the underlying bar. Transverse bars are not as common, but develop in channels that cross longitudinal bars, in channels that are lateral to longitudinal bars, or during long periods of discharge. Transverse bars have a wedge-shaped profile and thicken downcurrent. Bar development is related to flooding, for when water and sediment are confined to the channel, conditions are inadequate (McGowen, 1971; and Kingsley, 1984).

Longitudinal bars contain cross trough sets that migrate downfan; these can be due to transverse bars migrating over longitudinal bars. Parallel laminae are common, and the angle of laminae inclination indicates the fluctuating flow conditions. Crescent shape or straight scour troughs bound bars as erosional surfaces. Transverse bars contain parallel laminae, wavy laminae, and foreset cross strata (McGowen, 1971).

Braided stream deposits are recognized not only by bar development, but also by their texture and stratification. Braided streams can have a variable textural maturity due to the amount of matrix, degree of sorting, and roundness.

Most deposits are poorly sorted due to flashy discharge, and are clast supported. Stratification can also vary from crudely to well-developed, and planar horizontal to inclined. Most deposits are well imbricated and thin; thin sequences result from the rapidly shifting, shallow channels. A frequent feature is curved erosion surfaces which reflect the rapid lateral shifting of channels (Nemec and Steel, 1984). Kingsley (1984), however, states that the absence of major erosional surfaces between braided deposits indicates a continuous stacking. The typical sequence includes multiple stacks of thin, crude- to well-developed stratification of imbricated conglomerates that fine-upward into sandstones (Dutton, 1982; Nemec and Steel, 1984; and Anadon et al., 1985). See Figure 12.

The sandstones which cap the fining-upward braided sequence are sometimes referred to as channel fill deposits. These are usually clean, fine sands that are less well sorted. The channel fill sands can be well stratified with parallel laminae, and can contain interbedded muddy, ripple laminae (Figure 12). The channel fill deposits indicate waning flow or declining discharge (McGowen, 1971; Galloway, 1976; Nemec and Steel, 1984; and Anadon et al., 1985).

If waning flow decreases and the braided stream undergoes avulsion, then abandoned channel deposits are accumulated. Channels capped with alternating sand and mud indicate abandonment. Wavy ripples or laminae and small trough sets can occur. When homogenous muds or muddy sands

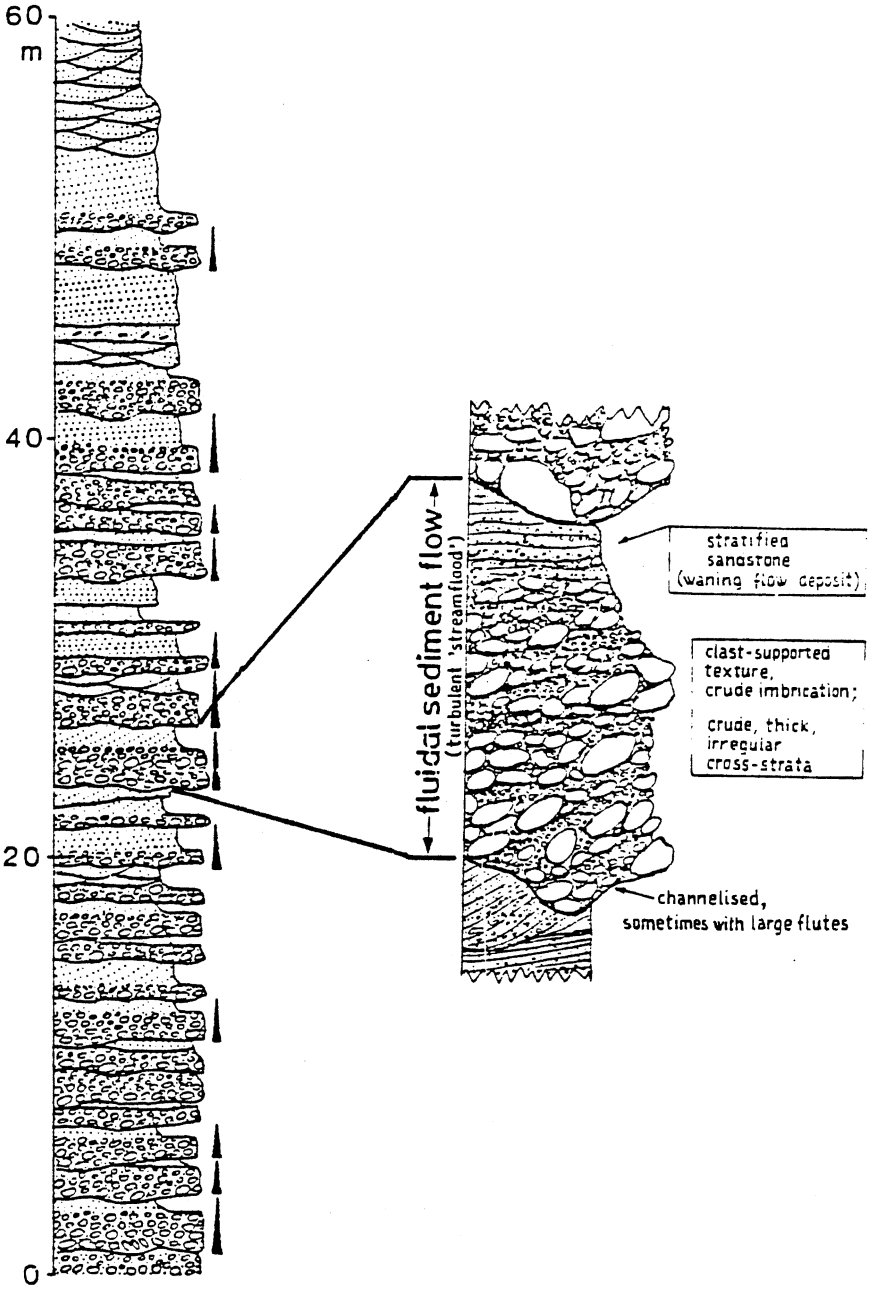

Figure 12. Typical Sequences of Braided Stream Deposits (Nemec and Steel, 1984).

cap the alternating sequence, final abandonment has been reached (McGowen, 1971).

Abandoned channels can lead to ponding if water partly fills the channel most of the year. Anadon et al. (1985) found non-marine algal deposits in conglomeratic channel fills, and described them as ponded sediments. Plant debris, roots, and injection features within muds are also indicative of ponded sediments. Ponding facies can be found not only in the lower mid fan, but also in the distal fan.

Crevasse channel deposits are also located in the mid and distal fan. Crevassing occurs when floodwaters break through a channel and form a splay out onto the floodplain. Deposition of symmetrical fine, silty sands with parallel laminae occurs when the floodwater decelerates; the crevasse splay fines from the channel margin. The crevasse channel will deepen if repetitive floodwaters continue to discharge from the channel (McGowen, 1971; and Leeder, 1982).

Overbank facies occur in the mid and distal fan, and are similar to crevasse splays in that they are related to flooding. Overbank deposits form when floodwaters break over the channel margin; however, they are not as destructive as crevasse splays because they do not form minor channels. Overbank deposits form on active portions of the fan plain, and thus, it is common to find conglomeratic channel deposits between them. Anadon et al.

(1985) describes overbank deposits of the Eocene fan delta of Montserrat, Spain, as thin and laterally discontinuous layers of sandstone, siltstone, and mudstone.

The third major facies of fan deltas is the distal or lower fan. McGowen (1971) states that the distal fan is the area between normal sea level and that associated with the most seaward longitudinal bars. Several facies of the lower fan delta plain (lower mid fan) overlap with the distal fan: crevasse channels, overbank deposits, and ponds. The main facies of the distal fan delta include more shallow and narrow braided streams as well as marsh/swamp deposits. The braided streams are less channelized in which flow spreads out and deposits laterally extensive sheets; a combination of longitudinal and linguoid bars is found. These distal segments are usually fine- to very fine-grained muddy sands with abundant mud drapes. Wavy, ripple, and flaser laminae are common. Bioturbation and organic matter can also be found (Wescott and Ethridge, 1980; Nilsen, 1982; and Anadon et al., 1985).

Marsh deposits form in low gradient areas of inactivity where channels have been abandoned; they form in areas where sediment lies just above or below the water table. These deposits contain muddy sand, laminations of mud and organics, and isolated pebble layers.

A transition zone exists between the subaerial, distal fan and subaqueous, outer fan. Depending upon whether the fan delta is wave, fluvial, or tidal dominated, certain deposits will form. These include: intertidal, depositional or erosional beaches, destructional phase bars, and algal mounds (carbonates).

The fan delta front is another facies to be considered. Swanson (1979) describes delta front deposits as material that is formed "in shallow interdistributary areas away from actively building stream-mouth" channels. Delta front deposits usually consist of alternating layers of fine sandstone and claystone.

The fourth major facies of fan delta environments is the prodelta facies (see Figure 11). The prodelta is of marine influence, and is the furthest facies seaward. This facies is purely subaqueous sedimentation. Deposits can be highly fossiliferous, carbonate-rich muds with or without ripple laminae and burrows. The prodelta facies commonly intercalates with fan delta front sands (Kingsley, 1984; and Anadon et al., 1985).

Study of Cores

G.H.K.-Apache Gregory No. 1-29

This well is located at NE NW SE, Sec. 29, T. 12 N., R. 21 W., in Beckham County, OK. The well represents the "Puryear" member of the Upper Morrow Chert Conglomerates and includes the cored interval from 17,120-17,189 feet. Sixteen feet of core are missing between 17,149-17,165 feet. The construction of a petrolog (Appendix A) shows detailed lithology, sedimentary structures, grain size, porosity, detrital and diagenetic constituents of the core. The gamma-ray log on the left-hand side of the petrolog is correlated with the core data. Appendix B contains photos of the G.H.K.-Apache Gregory No. 1-29 core.

The base of the core from 17,187-17,189 feet includes a dark gray to black, crinoidal shale. This shale contains fine, parallel laminations with occasional soft sediment deformation. The interval lying above from 17,134-17,187 feet shares a sharp contact with the lower shale. This interval consists of numerous stacked fining-upward sequences. The thickness of these sequences varies from a few inches to three feet. The contacts between each sequence range from gradational to erosive, but sharp contacts are the most common while erosive contacts occur the least.

Very few completely developed sequences from conglomerate to fine sandstone occur. In fact, the individual fining-upward sequences become progressively finer up through the core. This is noted by the logged grain size as well as by the gamma-ray log. From 17,168.5-17,187 feet, the sequences consist of gray, poor-moderately sorted, cherty conglomerates which grade up to coarse-grained, subangular-subrounded, poor-moderately sorted sandstones. Porosity in this zone is visible to the eye and appears to be from dissolved chert grains. From 17,134-17,168.5 feet, repetitive sequences of light gray, very coarse-grained, cherty sandstones grade up to fine-grained, poor-well-sorted, subangular-subrounded, sandstones. Sporadic stylolites occur in this zone along with abundant shale stringers that emphasize cross-bedding. Throughout this interval (17,134-17,187 feet), crude- to well-developed stratification occurs, along with graded bedding and crudely-developed imbrication.

The interval lying above from 17,122-17,134 feet contains interbedded black shales and light gray, medium-grained sandstones. The shales range in thickness from one-fourth of an inch to one foot and display soft-sedimentary contortions. The sandstones are composed of repetitive sequences of poorly-sorted, subangular-subrounded, medium-grained rocks that grade up to fine-grained, moderately-sorted, subangular sandstones. These sandstone sequences display crude- to well-developed stratification, crudely-developed imbrication, and graded bedding.

The remaining two feet cap the sequence with finely-laminated, undisturbed, black shale.

This core appears to represent a main distributary channel with gradual abandonment. The bottom two feet are interpreted as a marine prodelta mud. A distributary channel prograded over this and developed stacked sequences of braided stream deposits. The texture and stratification suggest that this channel was not rapidly shifting laterally, but remained for a long period of continuous stacking under sheetflow processes. Figure 13 is a core

Figure 13. One Fining-Upward Sequence of a Braided Stream Deposit Within the Apache Gregory Core at 17,180 Feet.

photo of a representative braided stream deposit. Figure 14 shows the characteristic variations of the braided stream deposits within the core. Note the low gamma-ray log response with slight deflections representing fining-up sequences. From 17,122-17,134 feet, gradual abandonment of the distributary channel occurred. This is represented by the alternating sands and muds (Figure 15) as well as by the gradual decrease in sandstone grain size. The deflection on the gamma-ray log at 17,134 feet corresponds with this, as well as decreased logged porosity. The top two feet of undisturbed shale represent final abandonment of the distributary channel. The high gamma-ray log response emphasizes this abandonment.

Exxon-Sayre Ranch No. 2-35

This core represents a non-producing "Purvis" member of the Upper Morrow Chert Conglomerates. The well lies at S/2 SE, Sec. 35, T. 13 N., R. 26 W., Roger Mills County, OK. The cored section from this well came from depths 16,357-16,385 feet. A petrolog (Appendix C) shows the various sedimentological features of this core, along with the correlated gamma-ray log. Appendix D contains photos of the Exxon-Sayre Ranch No. 2-35 core. The "Purvis" is discussed here to show the variances between the different Chert Conglomerate members.

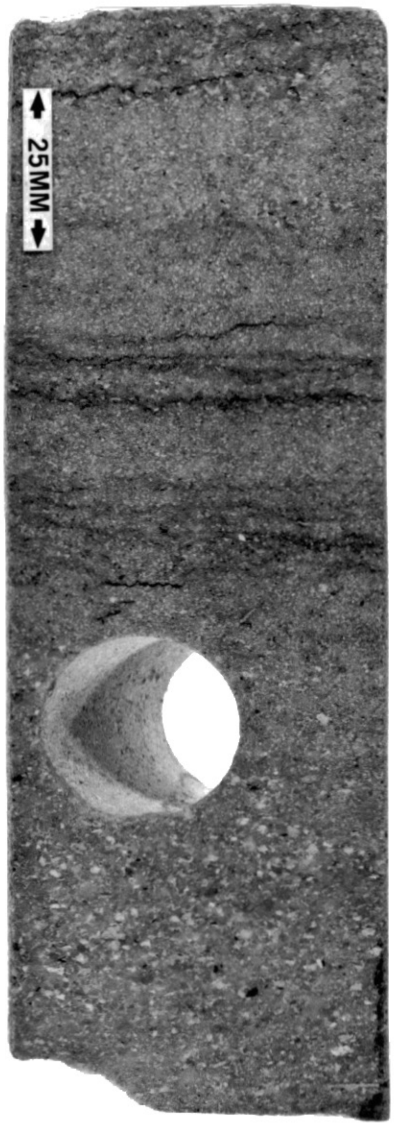

Figure 14. A Braided Stream Deposit Within The Apache Gregory Core at 17,143 Feet.

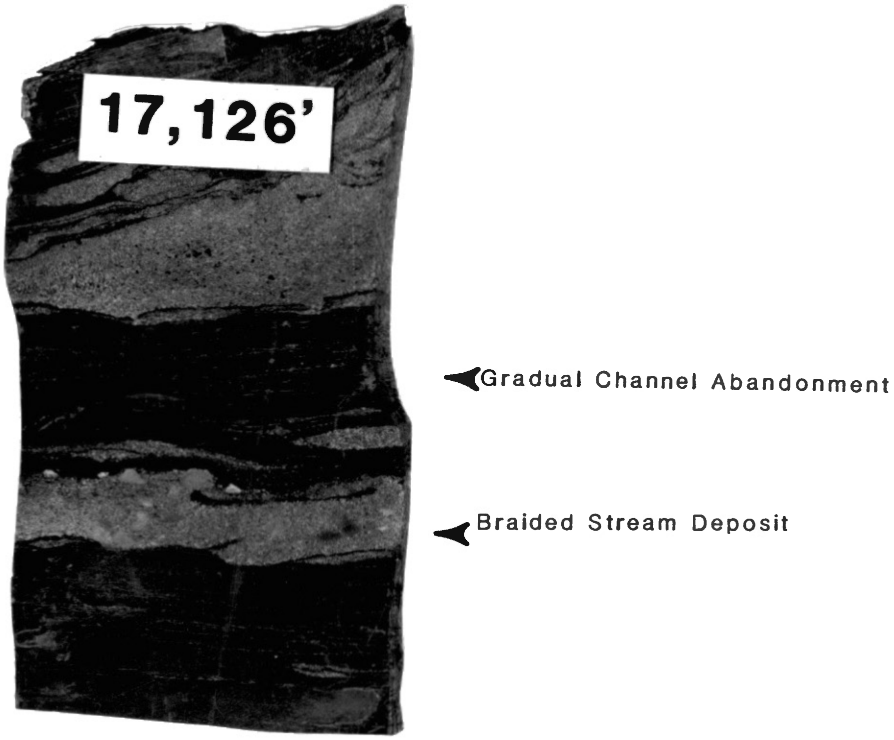

Figure 15. A Representative Core Piece of Gradual Channel Abandonment Within the Apache Gregory Core.

The bottom of the core from 16,376.5-16,385 feet contains a greenish-black, parallel laminated shale with thin pyrite layers and small (less than 1/16 inch) pyrite nodules which appear to be pyritized worm burrows. Brachiopod shell fragments occur sporadically throughout the shale with an abundance occurring between 16,381-16,383 feet. Between 16,375-16,376.5 feet, interbedded fine sandstone and shale appear with the sand layers becoming thicker at the top; in other words, this zone changes from flaser to lenticular bedding. Soft-sediment deformation occurs at 16,376.5 feet with the introduction of the first sand layer.

The next interval between 16,368-16,375 feet includes very poorly sorted, angular-subangular, dark gray chert conglomerates. The chert clasts within this interval are white, blue, buff, and yellow in color. This interval contains a dominance of poorly-sorted chert conglomerates with sharp- to erosional contacts separating them. However, these conglomerates appear to have poorly developed fining-up sequences as well. The sequence grades from conglomerate to medium- or fine-grained, poorly-sorted, angular-subangular, cherty sandstones. The thickness of these sequences ranges from 1/4 inch to half a foot with either sharp or erosional contacts separating them. The sequences contain crude imbrication, crude stratification, and crude- to well-developed graded bedding. Occasional stylolites and shale stringers appear throughout this section.

The overlying foot contains interlaminated dark gray, fine- to very fine-grained sandstones with black shales. This zone grades from lenticular bedding to flaser bedding with occasional soft-sediment deformation.

From 16,362-16,367 feet, a highly burrowed, grayish-black shale occurs with some burrows sideritized. Thin coal laminae mark the end of burrowing around 16,362 feet.

The remainder of the core, 16,357-16,362 feet, includes a parallel laminated, black shale. The bottom two feet of this shale contains occasional siderite layers and nodules. The top three feet contain thin pyrite layers and small nodules.

The lithologies and gamma-ray log indicate that this core most likely represents a minor distributary channel. The basal shale indicates that a shallow marine-prodeltaic environment existed previous to the "Purvis" deposition. The flaser-lenticular bedding above this prodelta environment possibly records the gradual movement of the distributary channel into the area. The introduction of the poorly-sorted conglomerate sequence represents the progradation of the distributary channel. The lithologies, sedimentary structures, and fining-up sequences of the conglomerates indicate that this interval records the deposition of stacked braided stream deposits from sheetflow processes. Figure 16 reveals representative braided stream deposits within the core. Gradual abandonment of the distributary channel is represented by the lenticular to

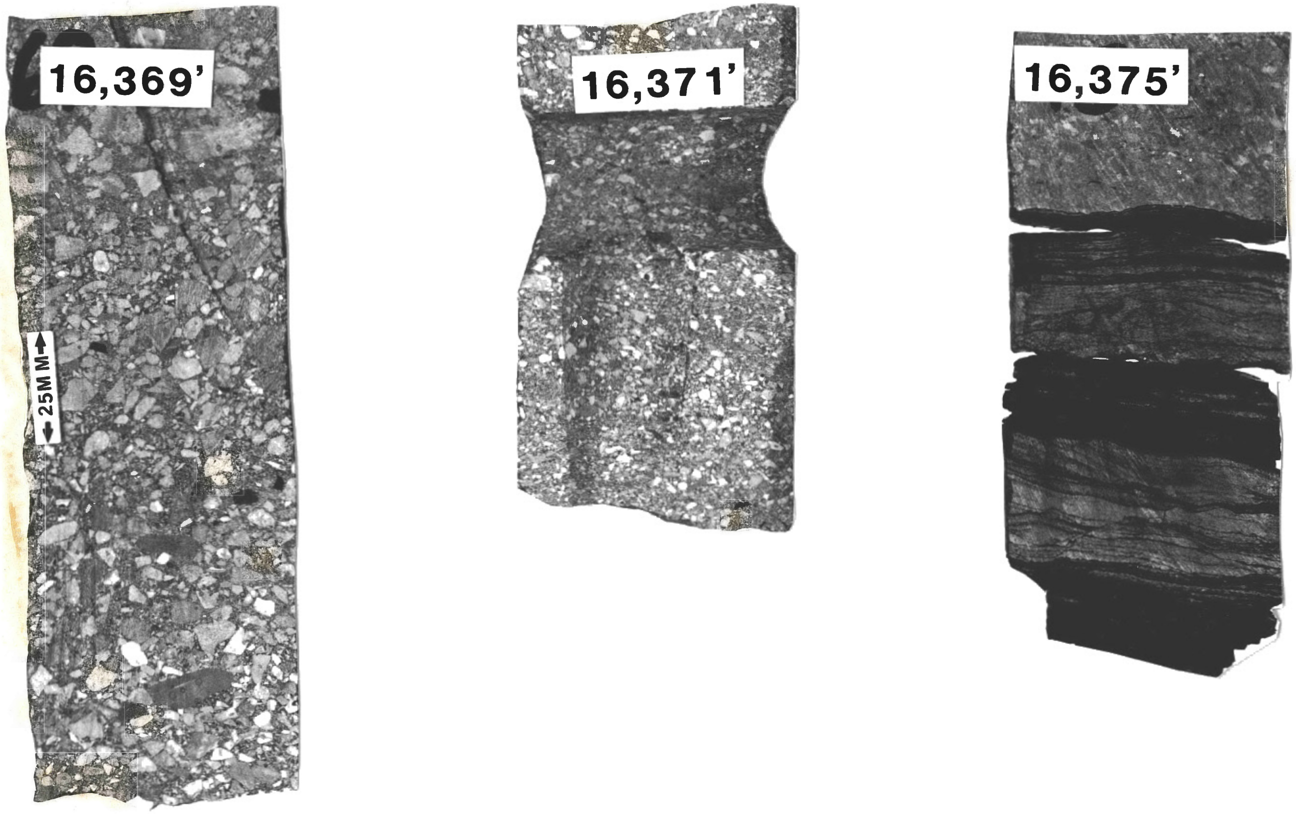

Figure 16. Braided Stream Deposits Within the Sayre Ranch Core.

flaser bedding above the conglomerates. The remainder of the core indicates final abandonment of the channel sequence and movement into a swamp/marsh environment.

Note that the low gamma-ray log response shows the channel progradation. The lowest gamma-ray reading corresponds with the highest logged porosity. Channel abandonment is recorded by the highest gamma-ray response.

"Puryear" Distribution

A net sandstone isolith map of the "Puryear" member was constructed for the study area and is shown in Figure 17. This unit was also mapped in T. 12 N., R. 21 W., and is illustrated in Figure 18. The net thickness was defined by more than 15 API units from the shale base line on the gamma-ray log response. Source directions appeared to be from the west-southwest in the western study area and from the south in the eastern study area of Figure 17. A southwesterly source seemed to prevail for the "Puryear" in Figure 18. The lobate geometry of the sand bodies suggests deposition occurred under deltaic influence, and this could support the chert conglomerate fan delta theory.

The "Puryear" appears to be best developed in the western part of the study area in Figure 17. The northern half (T 14 N and T 13 N) shows the most fan delta influence with the lobes trending in a northerly direction. The mid section (T 13 N and T 12 N) reveals lobes trending east-northeast in the western study area as the lobe still trends

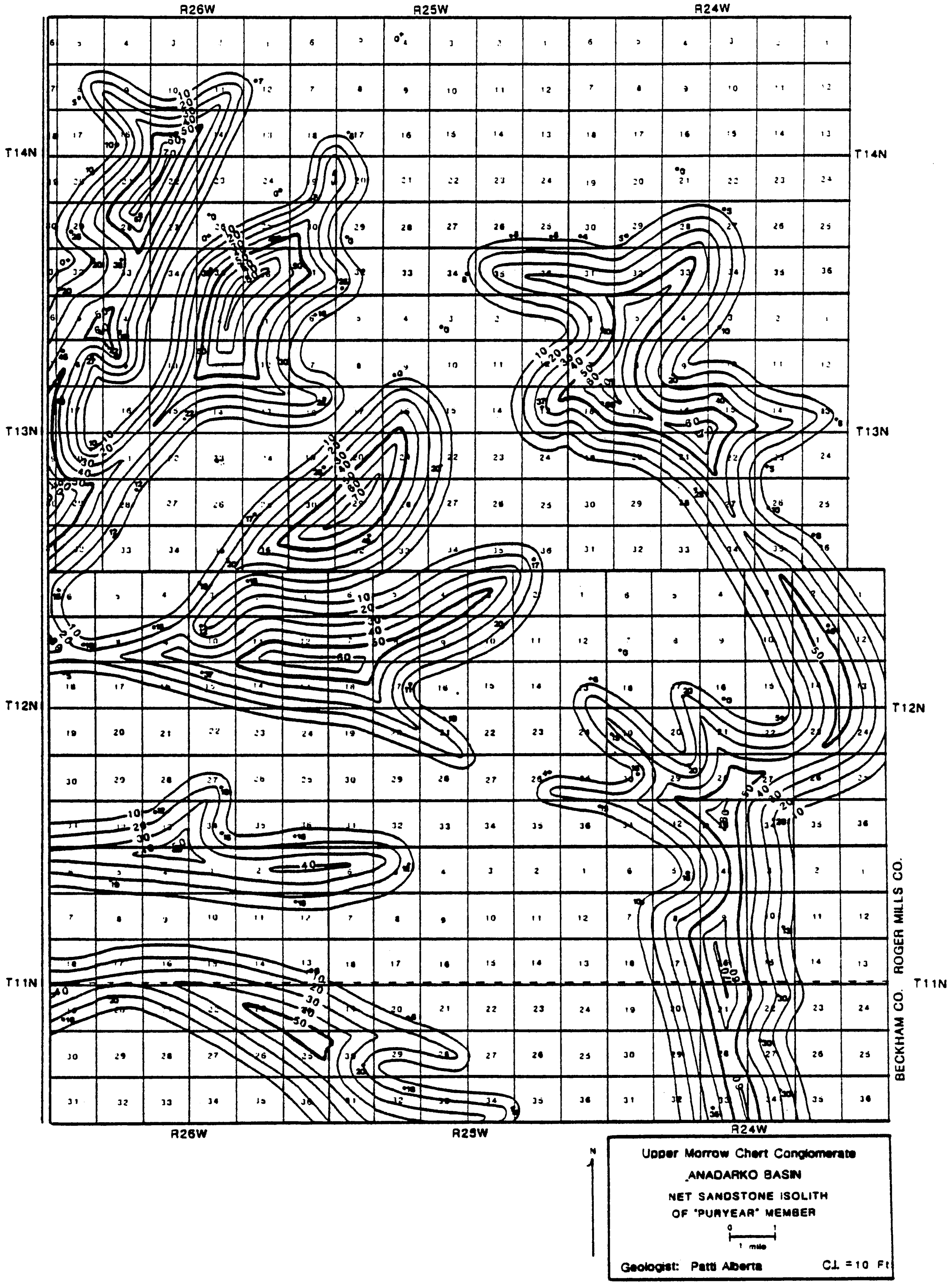

Figure 17. "Puryear" Sandstone Isolith Map, T11N-14N, R24W-26W.

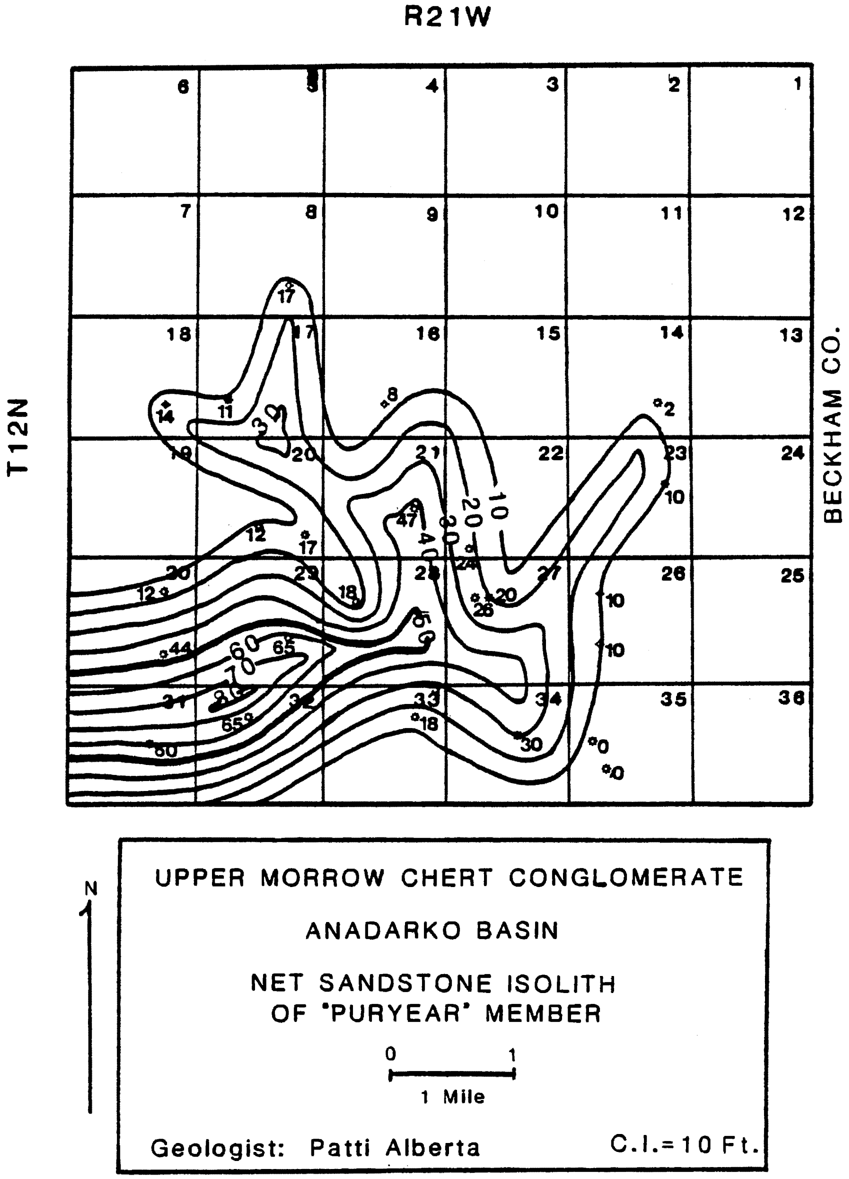

Figure 18. "Puryear" Sandstone Isolith Map, T12N, R21W.

northward in the eastern area. The southern half (T 12 N and T 11 N) contains several lobes which are trending east in the west area while the eastern area is still dominated by the north-trending lobe. The southwestern lobe begins to trend southeast at its distal end; this could possibly be from two lobes merging. The fan delta lobe shown in Figure 18 has an overall northeasterly trend. The distal end divides into three lobes which trend in different directions; the westernmost lobe is trending north-northwest, the middle lobe is trending north, and the eastern lobe is trending directly northeast.

Because dip is to the south in the study area, and these sands were deposited in northerly directions, stratigraphic traps are the most probable hydrocarbon trapping mechanisms for this area.

"Puryear" sand thickness reaches a maximum of 65 feet on the logs in both Figures; however, after constructing the net sandstone isolith map, a maximum thickness of 80 feet occurred. These thicker sand areas suggest channelizing within the fan delta complex.

CHAPTER IV

PETROGRAPHY AND DIAGENESIS

Composition

Detrital Constituents

The composition of the Upper Morrow Chert Conglomerates in the G.H.K.-Apache Gregory No. 1-29 core is summarized in Table I, and the Exxon-Sayre Ranch No. 2-35 petrographic data is summarized in Table II.

Monocrystalline quartz is the most abundant constituent within the Apache Gregory core and ranges from 24-62 percent; the average is 49 percent. Monocrystalline quartz is a minor constituent within the Sayre Ranch core, ranging between 1-2 percent with the average as 2 percent. Polycrystalline quartz ranges between 1-10 percent and averages at 4 percent in the Apache Gregory core; traces to 4 percent occur in the Sayre Ranch well with the average being 2 percent. Both quartz types appear angular-subangular due to overgrowths, but are actually subround. Also, both quartz types exhibit fracturing probably due to compaction, but it appears to be more common in the polycrystalline quartz.

TABLE I

THIN SECTION DATA FOR THE G.H.K.-APACHE GREGORY No. 1-29 WELL

Depth	Quartz Mono	Quartz Poly	Feldspar	Chert	Plutonic	Detrital Matrix	Other Detrital	Quartz Overgrowths	Dolomite	Chlorite	Illite	Porosity
17124.5	41	3	7	27	2	3	tr	1		9	3	4
17127.0	48	2	12	20	tr	1	2	2	2	1	10	tr
17129.0	46	3	13	14	2	3	1	3	tr	4	8	2
17130.0	52	1	15	11	tr	tr	1	3	tr	3	7	6
17132.5	40	2	12	14	2	1	1	2	tr	5	5	15
17135.0	51	3	11	9	2	1	tr	3		2	9	9
17137.0	47	2	14	9	2	tr	1	2	1	5	4	13
17138.5	61	1	9	4	tr	tr	tr	6	1	2	7	9
17141.0	62	2	12	9	tr	tr	2	3	tr	2	3	5
17141.0	56	3	14	3	3	tr	tr	4	1	5	2	9
17143.5	57	4	13	7	2	tr	tr	3	1	2	2	9
17146.0	60	5	9	15	tr		3	4	3	tr	1	tr
17148.0	53	6	11	7	tr	tr	1	2	tr	1	4	13
17166.0	60	4	12	3	tr	tr	3	3	tr	4	2	9
17167.5	56	6	7	9	1	tr		4	3	7		7
17171.0	50	5	15	14	tr		1	4	tr	3	2	6
17173.0	54	7	9	6	10	1	tr	4		3		6
17174.0	28	7	7	20	3	tr	1	2	2	14	6	10
17176.0	41	4	11	8	8	tr	tr	3	tr	13	5	7
17177.0	52	5	13	12			1	3	tr	tr	6	8
17180.0	41	10	8	16	4	1	2	3	2	6		7
17182.0	52	5	12	15	tr	1	tr	3	tr	1	5	6
17184.0	42	5	11	5	5	tr	tr	3	16	6	tr	7
17185.0	50	4	6	18	tr	tr	tr	7	7	7		1
17186.5	24	3	tr	60	tr	1	tr	2	6	3	tr	1

TABLE II

THIN SECTION DATA FOR THE SAYRE RANCH No. 2-35 WELL

Depth	Quartz Mono	Quartz Poly	Feldspar	Chert	Organics	Quartz Overgrowths	Chalcedony	Dolomite	Pyrite	Collophane	Porosity
16368	2	1	0	68	3	1	1	20	tr	1	3
16370	2	1	tr	71	2	1	1	15	tr	0	7
16371	2	3	0	82	2	1	1	3	tr	1	5
16373	1	tr	0	67	2	tr	1	25	tr	tr	4
16374	2	4	1	75	1	1	1	10	tr	0	5

Feldspars occur in greater percentages in the Apache Gregory core than in the Sayre Ranch core. Plagioclase feldspars are the dominant type occurring and frequently display fracturing or offset twinning. Traces of perthite are also noted. Feldspars range from traces to 15 percent and average at 10 percent in the Apache Gregory core; feldspars in the Sayre Ranch core range from 0-1 percent and average as traces.

The main rock fragments observed within these rocks are chert and plutonic grains. Chert within the Apache Gregory core ranges between 3-60 percent, while the average falls at 13 percent. The chert percentages vary throughout the core and most likely represent the multiple stacks of fining-upward sequences. Plutonic rock fragments are not abundant, for they compose only 2 percent on the average; however, plutonic grains are found occurring between 0-10 percent. Chert is the only rock fragment of the Sayre Ranch core. It is the dominant constituent ranging from 67-82 percent and averaging at 72 percent. The chert within these rocks occurs in various sizes ranging from pebbles to fine sandstone. Roundness of the chert also varies from angular to rounded, but mainly occurs as subangular-subrounded grains. Several chert varieties are noted and most likely represent the variety of chert eroded from the Mississippian limestones. Most chert grains are composed of microcrystalline quartz, but others contain siliceous sponge spicules and fossils.

Figure 19 is a thin section photomicrograph of the various detrital constituents.

Other minor detrital constituents of the Apache Gregory core include muscovite, biotite, chlorite, zircon, tourmaline, organic matter, and pyrite. These grains comprise a trace percentage of the sands and conglomerates, although they occasionally make up 2 percent of the rocks. Minor detrital constituents of the Sayre Ranch core include traces of pyrite and a few percent of organic matter.

Minor amounts of illitic detrital matrix occur in the Apache Gregory core. Detrital matrix comprises up to 3 percent of these sands, but averages as trace amounts. No detrital matrix is observed in the Sayre Ranch core.

According to Folk's classification, the Upper Morrow Chert Conglomerates and Sandstones range in composition (see Figure 20). Most samples of the Apache Gregory core are moderately- to well-sorted, subangular to subrounded, and are plotted as feldspathic litharenites and lithic arkoses; other samples are plotted as subarkoses, sublitharenites, and litharenites. The range in composition is due to the varying amounts of feldspar and chert throughout the core. Note that the Sayre Ranch core samples are all litharenites due to the dominance of chert.

Because of the varying composition of these chert conglomerates and sandstones, another compositional plot was constructed for better lithologic delineation. The ternary diagram was constructed using the main detrital

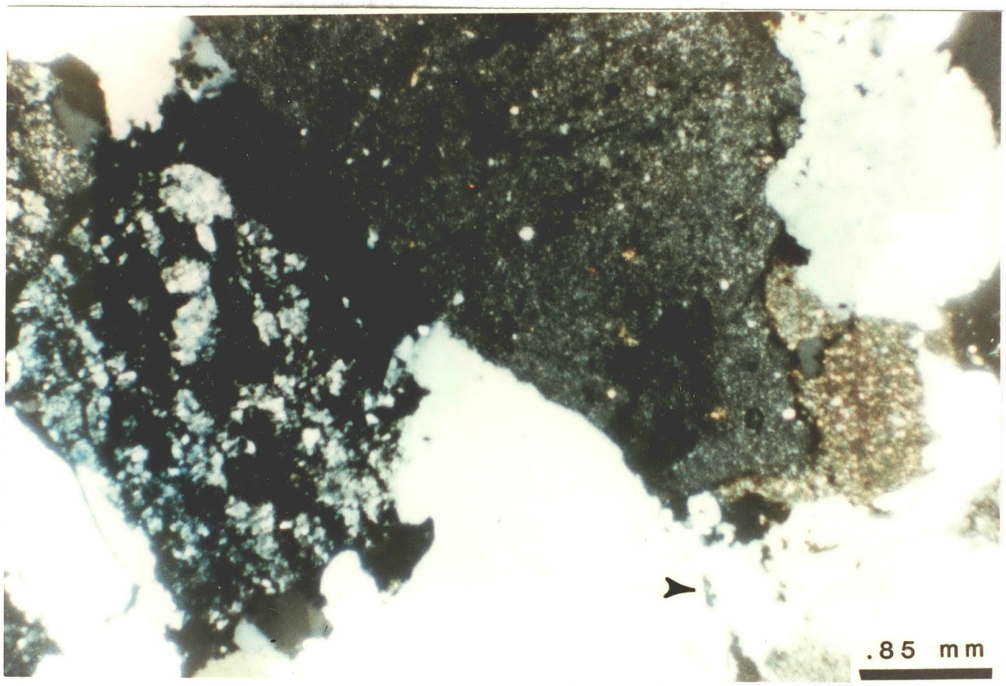

Figure 19. Thin Section Photomicrograph Revealing the Various Detrital Constituents (Quartz, Feldspar, and Chert). Note the Syntaxial Quartz Overgrowth (➤).

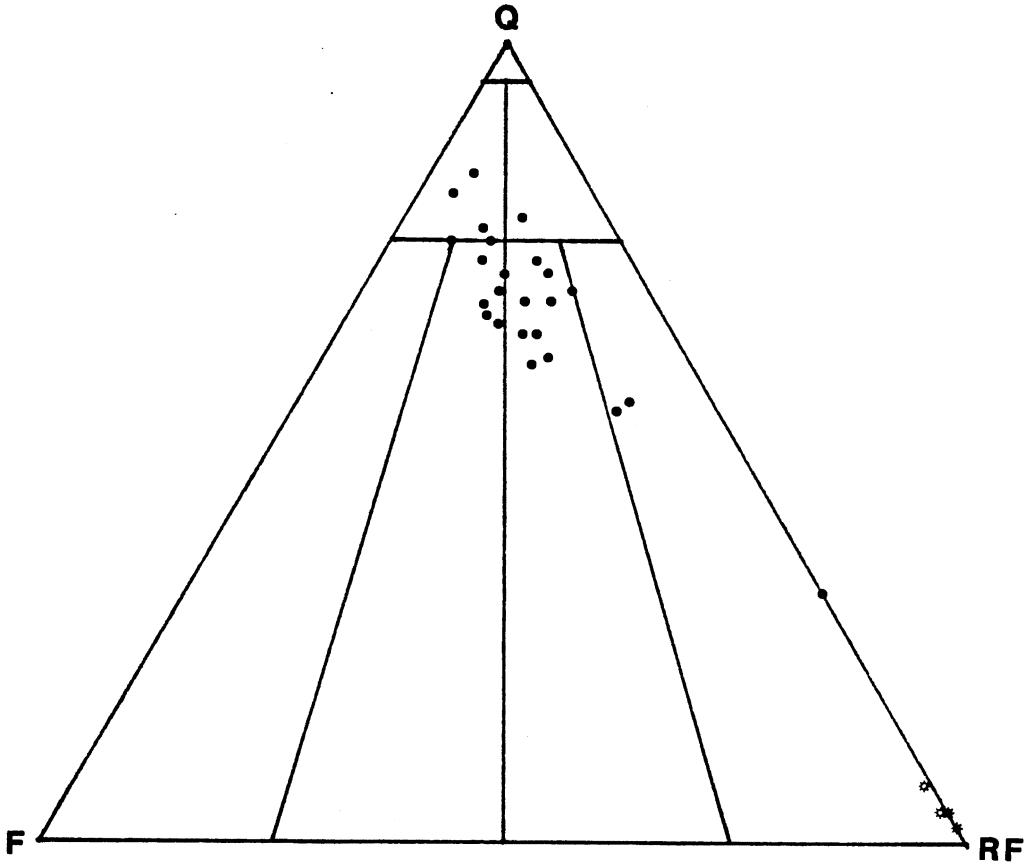

Figure 20. Classification of Upper Morrow Chert Conglomerates. Note: G.H.K. samples are dots, Sayre Ranch samples are stars.

constituents: quartz, feldspar, and chert. Figure 21 illustrates that from this plot, the chert conglomerates and sandstones can be divided into three petrofacies. These include: 1) a dominance of chert, 2) a dominance of quartz and feldspar, and 3) mixtures of 1 and 2. Note that the majority of the Apache Gregory core samples fall into the mixed petrofacies, with one sample showing a dominance of chert; all samples of the Sayre Ranch core represent the chert dominated petrofacies. Petrographically, the chert dominated petrofacies are generally coarser-grained compared to the quartz-feldspar petrofacies.

Authigenic Constituents

Quartz overgrowths are a common diagenetic constituent of the chert conglomerates. The Apache Gregory core samples have a range from 1-7 percent, while the average is at 3 percent. Quartz overgrowths in the Sayre Ranch core reach and average at 1 percent. Traces to 1 percent of chalcedony cement occur in both cores and is usually found as sparse, isolated patches.

Traces of albite overgrowths are noted in the Apache Gregory samples. They are small, well-developed, and take on the same twinning or crystallographic orientation of the detrital feldspar grain.

Dolomite is a common diagenetic feature of both cores. It ranges between 0-16 percent in the Apache Gregory samples, but only averages at 2 percent. Dolomite is more

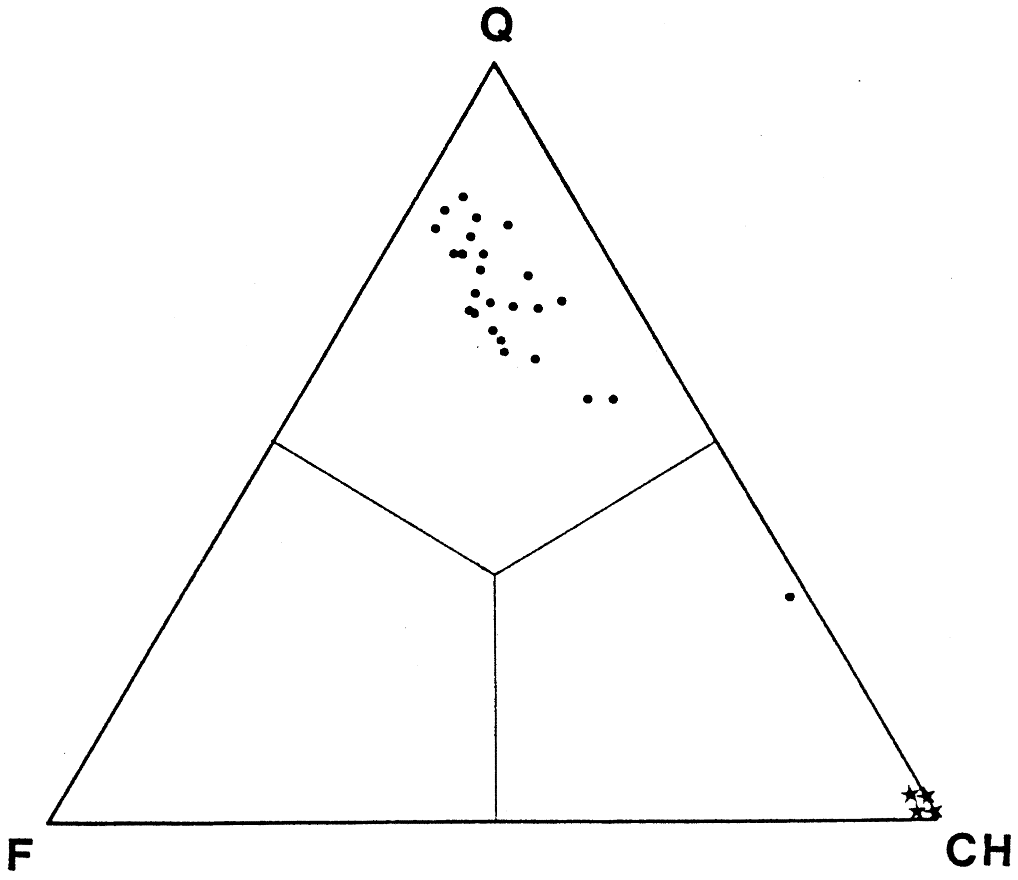

Figure 21. Ternary Diagram Representing the Various Chert Conglomerate Petrofacies. Note: G.H.K. samples are dots, Sayre Ranch samples are stars.

dominant in the Sayre Ranch core, for it ranges between 3-25 percent and averages at 15 percent. Calcite is found as traces in sparse patches.

Chlorite and illite are the authigenic clays observed only in the Apache Gregory core samples. Chlorite is found rimming grains, but it mostly occurs as pore-fill. Chlorite ranges between 0-14 percent with the average at 4 percent. Illite is found mostly as pore-fill, but also occurs as an alteration product of feldspars. Illite occurs between 0-10 percent and averages at 4 percent in the Apache Gregory samples.

Collophane is noted only within the Sayre Ranch core samples. It reaches up to 1 percent, but averages in traces. Collophane is found replacing fossil-type chert grains.

Porosity occurs in both cores and is identified petrographically from the blue epoxy. Traces to 15 percent porosity are found in the Apache Gregory core, but averages at 7 percent. Porosity is not as well-developed within the Sayre Ranch core, but ranges between 3-7 percent and averages at 5 percent.

Diagenesis

Introduction

Physical and chemical processes during diagenesis have altered the chert conglomerates and sandstones into their present state. Compaction is the physical process responsible for fractured grains, as well as for pressure solution features. Fracturing is noted by offset twinning of feldspars and crushed detrital, monocrystalline and polycrystalline quartz grains in the chert conglomerates. Pressure solution is noted by sutured quartz grains and is distinguished from quartz overgrowths through the aid of cathodoluminescence.

Chemical processes are mostly responsible for the diagenetic changes that occurred in the chert conglomerate. These processes include precipitation, alteration, replacement, and dissolution.

Cementing Features

Chemically precipitated minerals commonly occur as cements. Four types of cement are observed within the chert conglomerate. These include silica cement, carbonate cement, authigenic clays, and authigenic albite.

Silica cement occurs as syntaxial quartz overgrowths and is separated from detrital quartz grains by dust rims. Figure 19 displays characteristic quartz overgrowths of the chert conglomerate. Cathodoluminescence further aids in detecting quartz overgrowths in absence of the dust rim. Since the impurities of the detrital quartz grains differ from quartz overgrowths, consequently, the luminescent properties are different. In general, the quartz overgrowth exhibits dull to non-luminescent properties, while the detrital quartz grain exhibits brighter blue or red properties. Chalcedony is another type of silica cement found within the chert conglomerates. It is a minor cement and occurs as isolated, fibrous patches.

Carbonate cement occurs in the chert conglomerates as calcite and dolomite. The dolomite is normally found within the pore space cementing detrital grains. It is also found replacing chert, feldspars, and detrital matrix, as well as corroding quartz grains. Dolomite replacement is shown in Figure 22-A. The dolomite is usually identified by its rhombic morphology, but where the rhombs are not well-developed or have been corroded, isotopic analyses confirm dolomite composition. Table III displays the isotopic data reported from several chert conglomerate samples. The d^{13}C values show a slight depletion and suggests organic contribution during burial (Walker, 1986). The d^{18}O values are heavy and suggest a possible deep brine water origin.

Authigenic chlorite and illite are the diagenetic clays which occur as cements. Chlorite occurs as grain coatings and as pore-filling. Illite is found mostly as pore-fill, but is also noted as an alteration product from feldspars. The characteristic green color of chlorite in plane

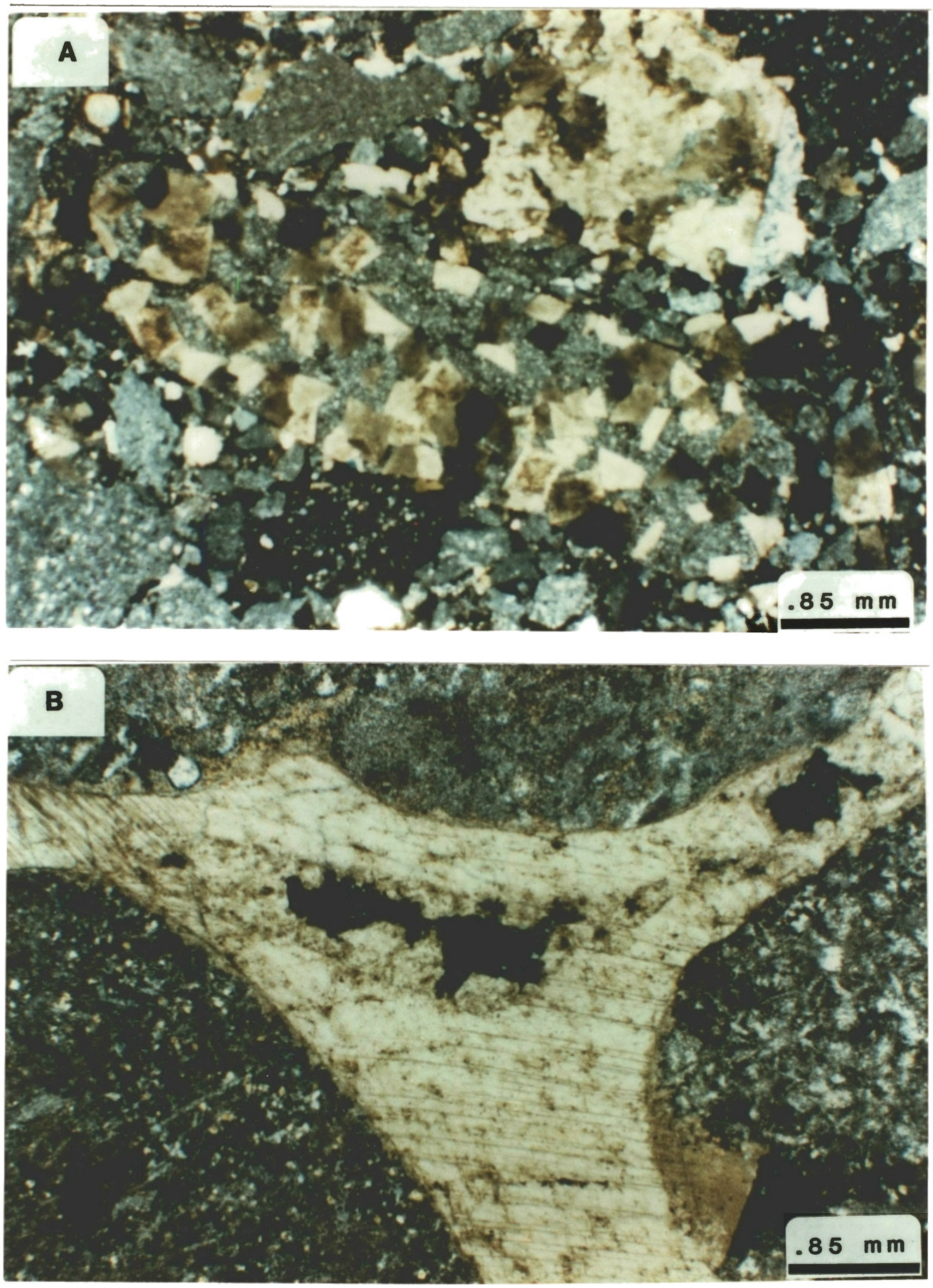

Figure 22. (A) Photomicrograph of Dolomite Replacing Chert; Cross Polarized.
(B) Photomicrograph of Dolomite Dissolution; Cross Polarized.

TABLE III

CHERT CONGLOMERATE ISOTOPIC DATA

Sample	Composition	dC13	dO18
GHK-17174	Dolomite	-2.4	20.8
GHK-17176	Dolomite	-6.1	22.0
GHK-17184	Dolomite	-6.2	22.3
GHK-17185	Dolomite	-2.6	21.1
SR-16373	Dolomite	-2.1	22.4

polarized light as well as the bright yellow color of illite under cross nicols are observed through petrographic analysis. However, their characteristic morphologies are distinguished by the scanning electron microscope (SEM). Note the plate-like structure of chlorite versus the lath-like structure of illite (see Figures 23 and 24).

X-ray diffraction analysis is an important tool in identification of authigenic clays within the chert conglomerate. Figure 25 represents x-ray diffraction at 17,143.5 feet in the GHK-Apache Gregory core. The natural, glycolated, and heated samples indicate clay mineral assemblage to be chlorite and illite.

Authigenic albite occurs as feldspar overgrowths and is only found within the chert conglomerates and sandstones of the Apache Gregory core. The albite overgrowths are noted in petrographic analysis as taking on the same twinning or crystallographic orientation as the detrital feldspar; but, further identification of authigenic albite is distinguished in SEM photomicrographs by its characteristic morphology (Figure 26). Because of the undisturbed nature of the albite overgrowths, they appear to have formed late diagenetically.

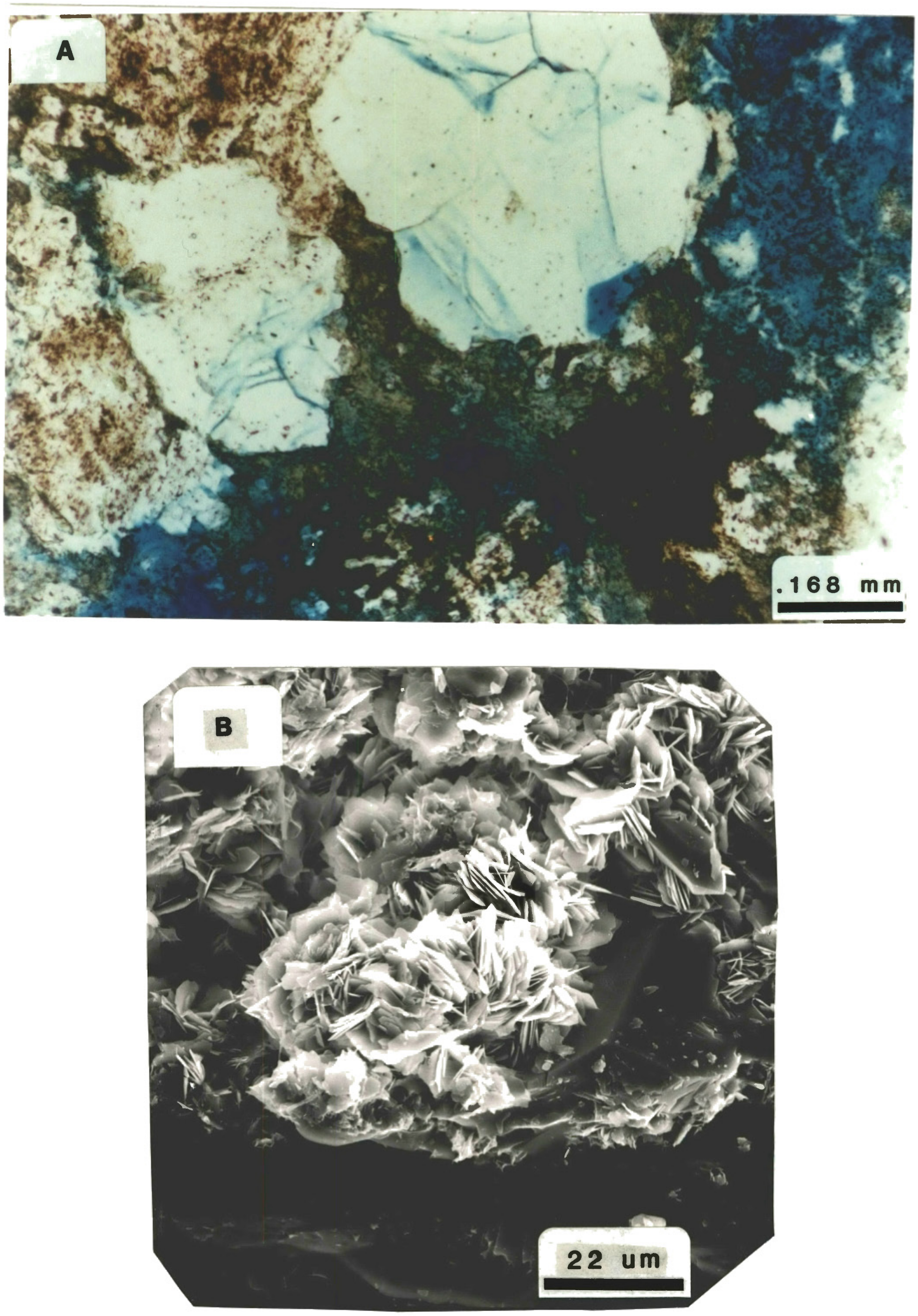

Figure 23. (A) Photomicrograph of Authigenic Chlorite; Plane Polarized.
(B) SEM Photomicrograph of Authigenic Chlorite.

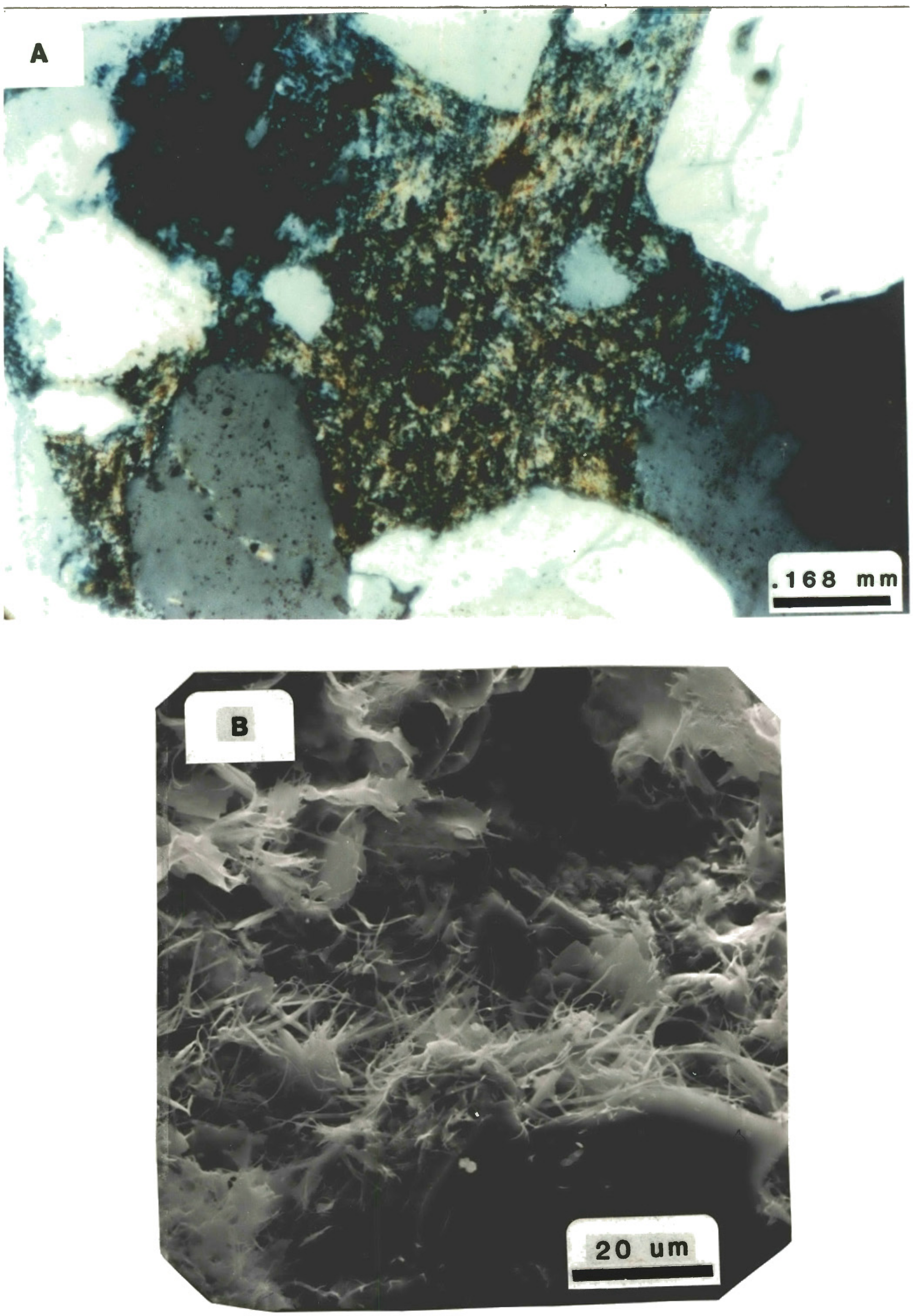

Figure 24. (A) Photomicrograph of Authigenic Illite; Cross Polarized.
(B) SEM Photomicrograph of Authigenic Illite.

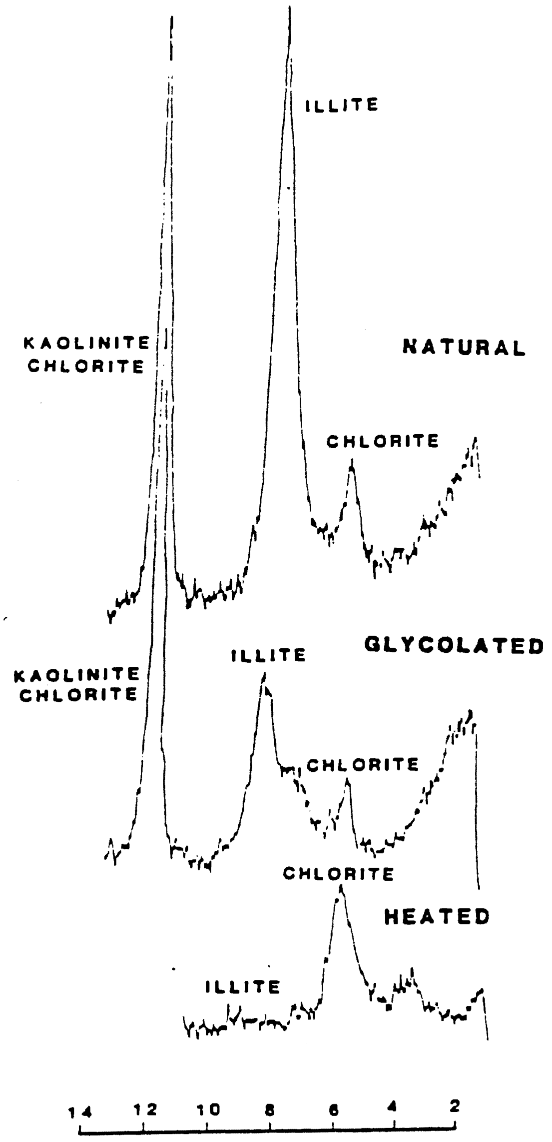

Figure 25. X-Ray Diffraction Peaks Revealing the Various Clays Found Within the G.H.K.-Apache Gregory No. 1-29 Core.

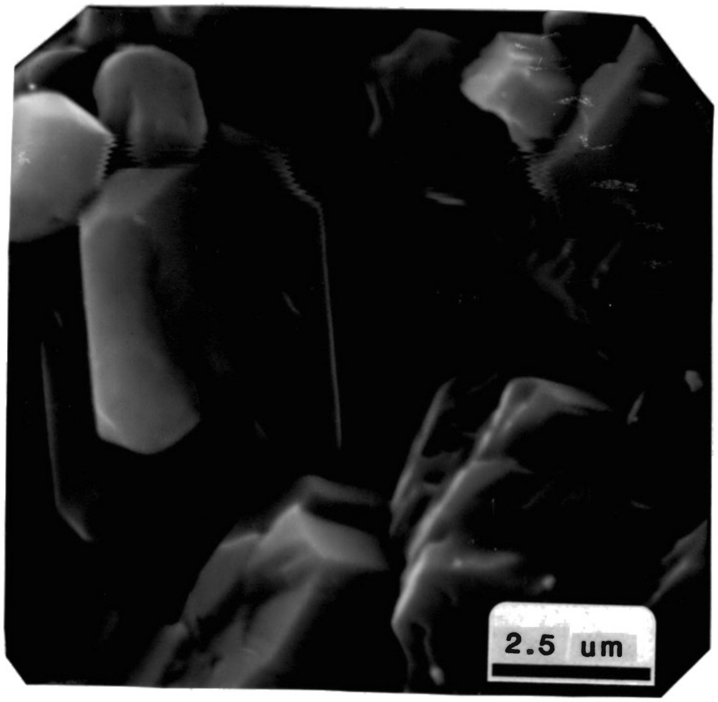

Figure 26. SEM Photomicrograph of Authigenic Albite Cement.

Dissolution Features

Four different dissolution features are found in the chert conglomerates. These include the dissolution of detrital feldspars, detrital chert grains, detrital matrix, and carbonate cements.

Figure 27 shows an example of the extensive dissolution of detrital feldspars as seen in thin section. Note the oversize pore in the upper photomicrograph as well as the honeycomb texture of the dissolved feldspar in the lower photomicrograph.

Figure 28 illustrates the dissolution of detrital chert grains. The bottom photo displays selective dissolution of certain chert. The chert grains which are composed of siliceous sponge spicules and fossils have undergone selective dissolution. The chert matrix between the siliceous spicules and fossils appears to be less stable than the spicules and fossils themselves. Therefore, the chert matrix dissolved faster, generating microporosity.

The detrital matrix of the chert conglomerates is composed mainly of illite and other metastable constituents, and therefore, dissolved at a higher rate relative to detrital grains. This dissolution of detrital matrix is shown in Figure 29.

Figure 22-B shows the dissolution of dolomite cement. Dolomite dissolution is a common feature within the chert conglomerates and normally occurs between detrital grains.

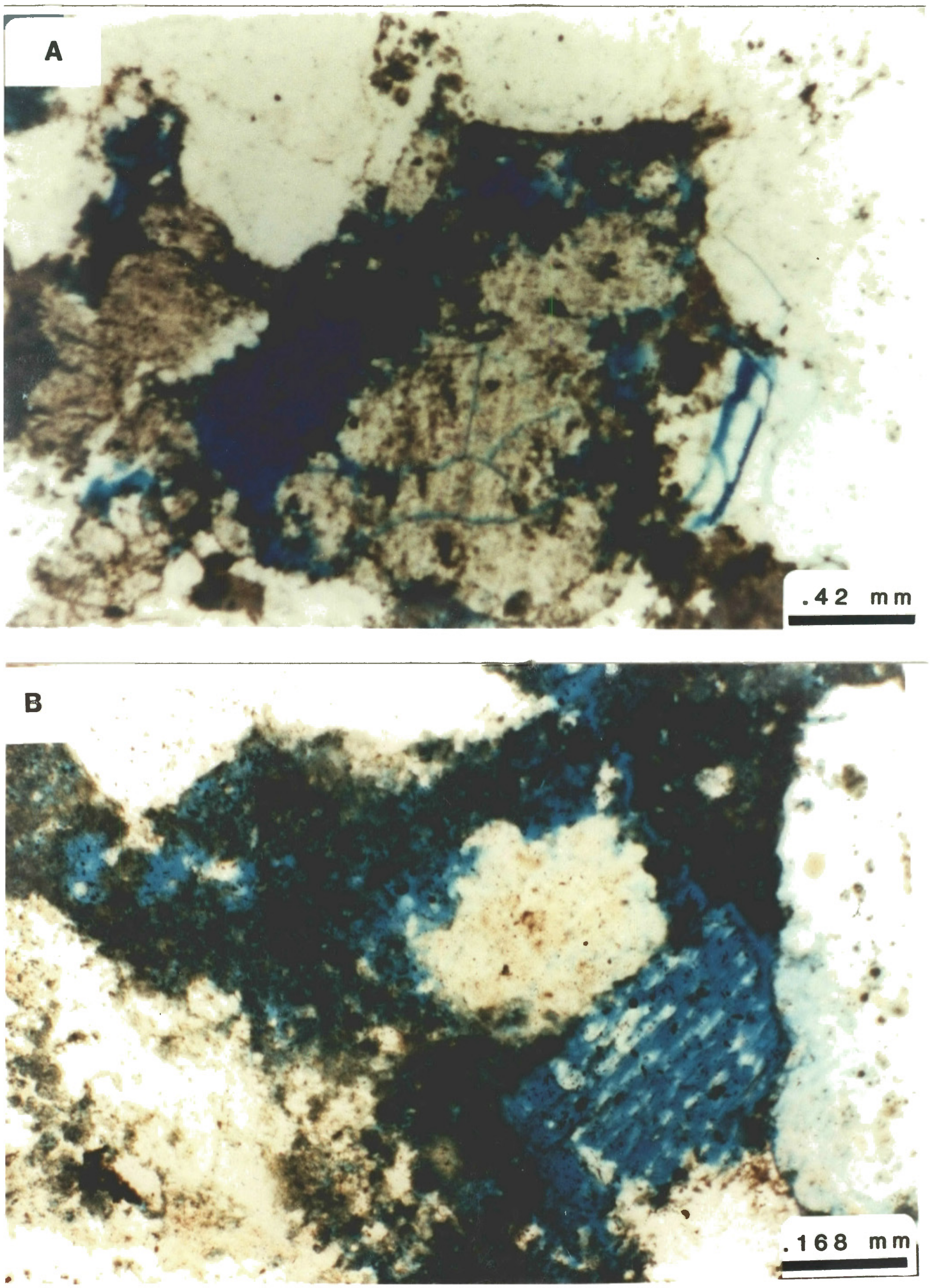

Figure 27. (A) Photomicrograph of Dissolved Feldspar Owing To Oversize Pore Space and Enlarged Intergranular Porosity; Plane Polarized.
(B) Partial Dissolution of Feldspar Owing To Moldic Porosity and Oversize Porespace; Plane Polarized.

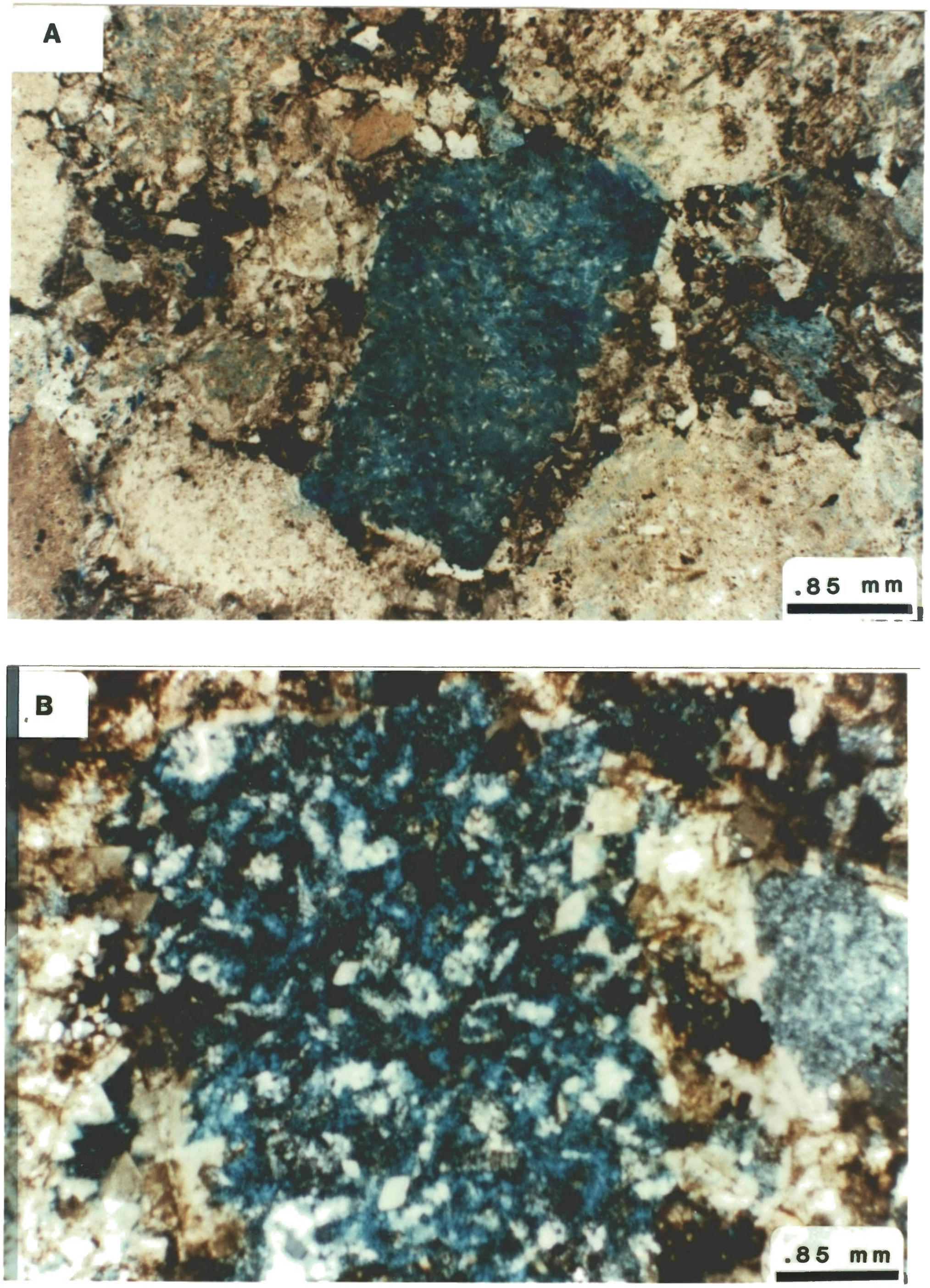

Figure 28. (A) Photomicrograph of Dissolution of Detrital Chert; Plane Polarized. (B) Photomicrograph Showing Selective Dissolution of Detrital Chert Creating Microporosity; Cross Polarized.

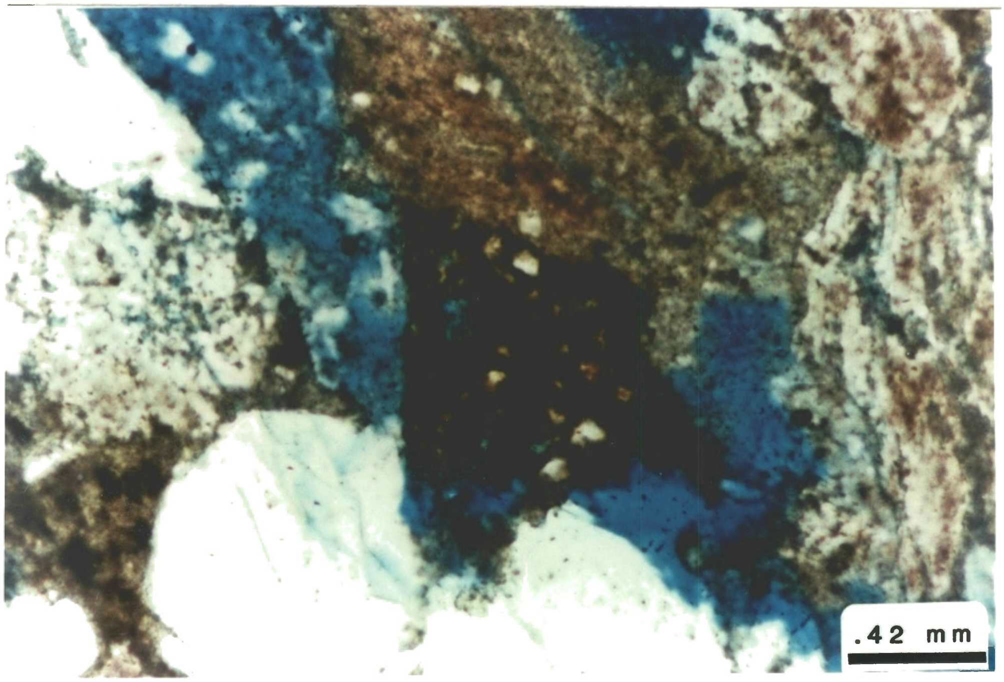

Figure 29. Photomicrograph Showing Dissolution of Detrital Matrix Owing to Oversize Porespace; Plane Polarized.

Porosity Types

Several porosity types occur within the chert conglomerate. These include: 1) enlarged intergranular porosity (EIP), 2) oversize pores, and 3) microporosity.

According to Schmidt and McDonald (1979), enlarged intergranular porosity is primary porosity that has been modified by dissolution of the surrounding grains. This porosity type is illustrated by extensive feldspar dissolution in Figure 27. Oversize pores are due to moldic porosity, partial dissolution of grains, and matrix dissolution. The lower photomicrograph in Figure 27 shows moldic porosity of a feldspar grain; partial dissolution of a feldspar grain is illustrated in the upper photomicrograph. Figure 29 displays the dissolution of detrital matrix, as seen in thin section, that is responsible for the oversize pore space.

Microporosity is the porosity present within authigenic clays and porosity existing within selectively dissolved chert. Because the siliceous sponge spicules and fossils of the chert are being supported by a microcrystalline matrix that is less stable, the microcrystalline matrix dissolves faster and creates micropores. This type of microporosity is common in the chert conglomerate and is shown in Figure 28-B.

Paragenesis

The diagenetic history of the chert conglomerate samples of the GHK-Apache Gregory core is summarized in Figure 30. The initial diagenetic product, as acidic solutions prevailed, was the formation of syntaxial quartz overgrowths. This was followed by compaction and precipitation of calcite cement under basic conditions. As the pH of the solution decreased, a short stage of chalcedony precipitated next. This was followed by the dissolution of detrital matrix, and feldspars. The fluids within the chert conglomerate became basic again with chert dissolution occurring as deep burial or saddle dolomite precipitated in the available pore space and also replaced various constituents. Slightly acidic solutions prevailed next and allowed the precipitation of authigenic chlorite, with minor illite. The last stage of paragenesis included the increase of pH and allowed for minor precipitation of authigenic albite.

The diagenetic history of the Sayre Ranch core samples generally follows that of the Apache Gregory core samples and is summarized in Figure 31. The precipitation of syntaxial quartz overgrowths initiated the paragenesis of the Sayre Ranch samples. As the pH of the fluid changed from acidic to basic, an extensive period of dolomite

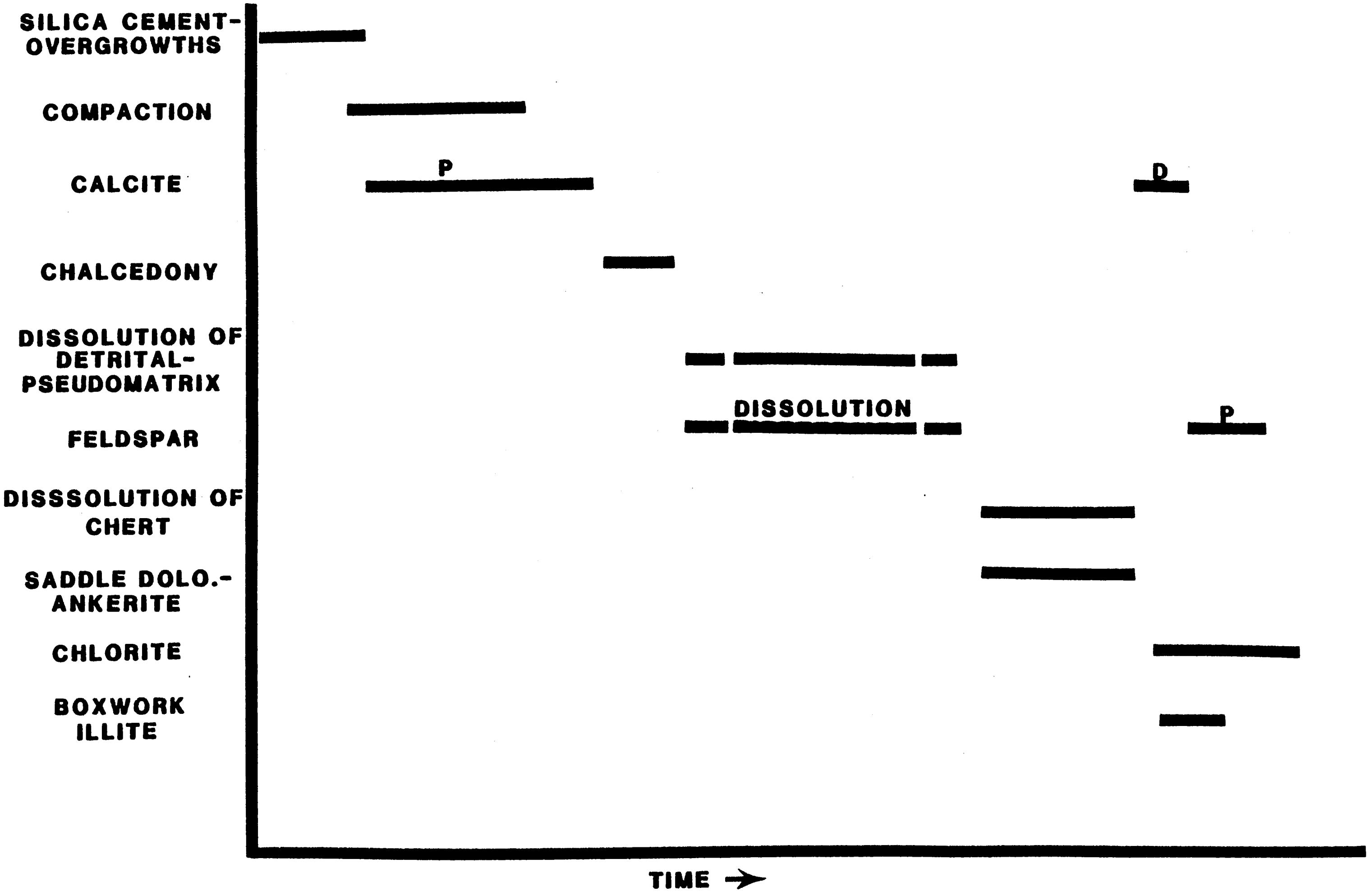

Figure 30. Paragenetic Sequence of "Puryear" Chert Conglomerates in the G.H.K.-Apache Gregory Core.

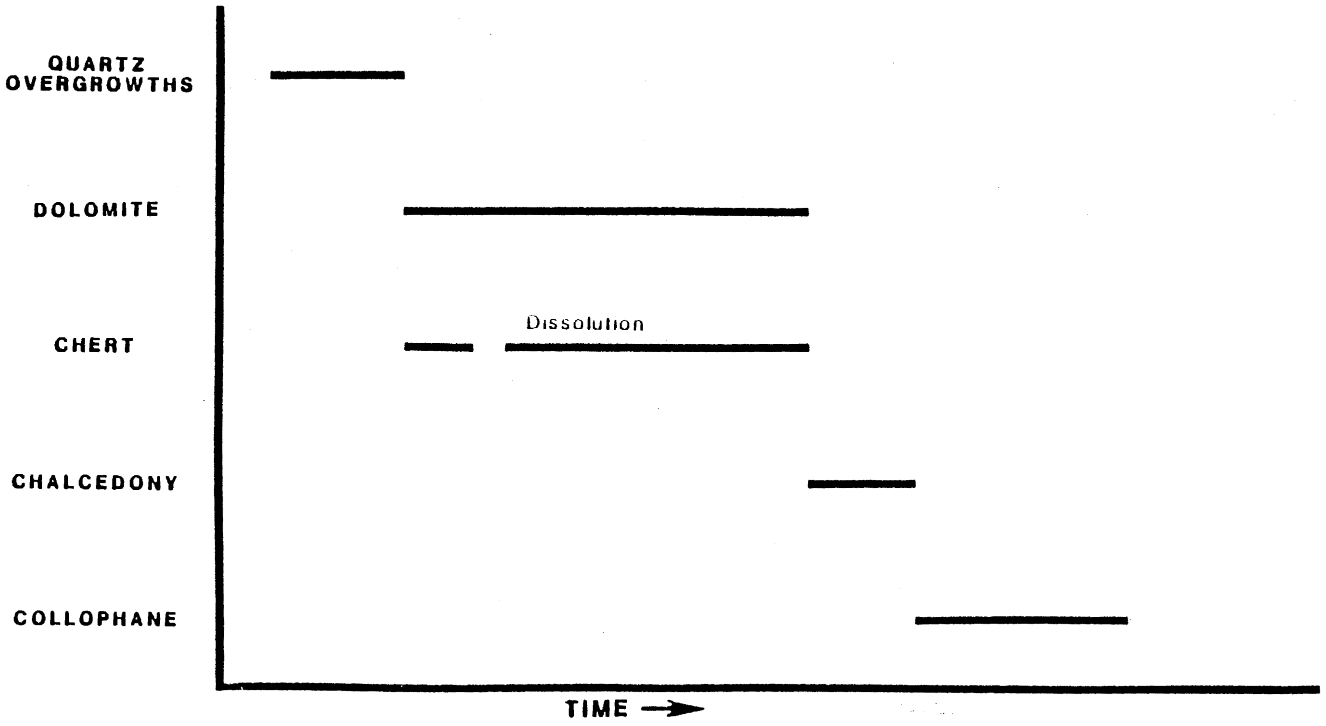

Figure 31. Paragenetic Sequence of "Purvis" Chert Conglomerates in the Exxon-Sayre Ranch Core.

precipitation occurred as chert grains underwent replacement and dissolution. A slight fluctuation in pH caused minor precipitation of chalcedony to occur next. In the last stage of paragenesis, solutions became basic again and allowed collophane to replace detrital chert grains.

CHAPTER V

DEPOSITIONAL FACIES ANALYSIS

"Puryear" Facies of Study Area

Introduction

Various fan delta facies were discussed in the depositional environment chapter. After analyzing well-log signatures throughout the study area, the facies of the "Puryear" correspond well with the previously described fan delta facies. Combining the gamma-ray log response with resistivity and conductivity curves, each "Puryear" facies was devised.

The work of Sneider et al. (1977) and Shelby (1980) were also useful in interpreting the various facies. Shelby (1980) described prograding fan delta sequences as prodelta muds, delta front silts and sands, and distributary channel chert conglomerates. Figure 32 shows a typical log pattern of this progradational sequence, as well as the facies which make up the sequence. This vertical sequence was common in the study area and was useful in delineating several facies. Sneider et al. (1977) described typical log responses of various facies; where this work applies, it will be mentioned.

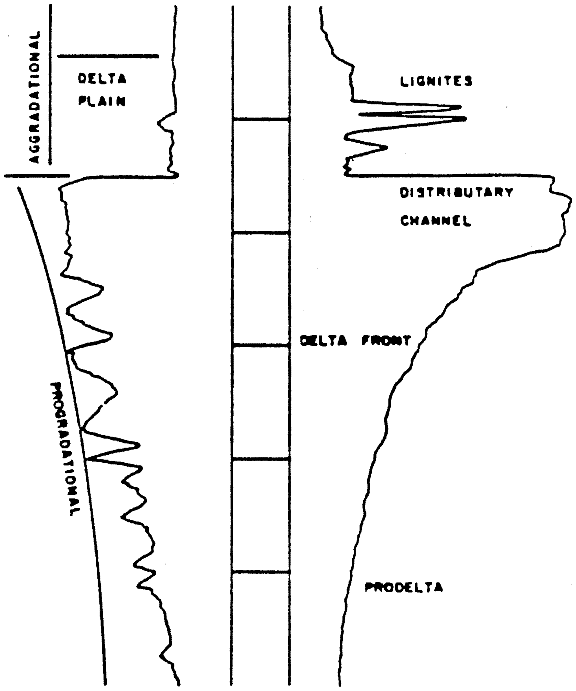

Figure 32. Typical Log Pattern of Progradational Sequence Found Within the Study Area (Shelby, 1980).

Log Characteristics of Facies

The various chert conglomerate facies occurring in the study area include: main distributary channels, minor distributary channels, crevasse splays, overbank deposits, delta front deposits, delta plain, lignites, swamp, and prodelta. The log characteristics of each of these facies are summarized in Figure 33.

Main distributary channels are greater than 20 feet thick, and have a low, blocky, well-developed gamma-ray response. This corresponds well with Sneider et al. (1977) SP curve response of alluvial channel deposits. The gamma-ray can have any combination of the following boundaries: sharp or slightly gradational bases, sharp or gradational tops, and either well-developed, minor development, or no delta front development underneath. The resistivity can be variable, but overall is high; this corresponds well with Sneider et al. (1977). The conductivity curve is usually the inverse of the gamma-ray response.

Minor distributary channels have similar log characteristics as main distributary channels, but they are less than 20 feet thick. This agrees well with Sneider et al. (1977) interpretation.

Crevasse splays are relatively thin to medium in thickness (usually no greater than 10 feet). The gamma-ray log response is low and more rounded to sharp; it is not as blocky as a minor distributary channel. The gamma-ray

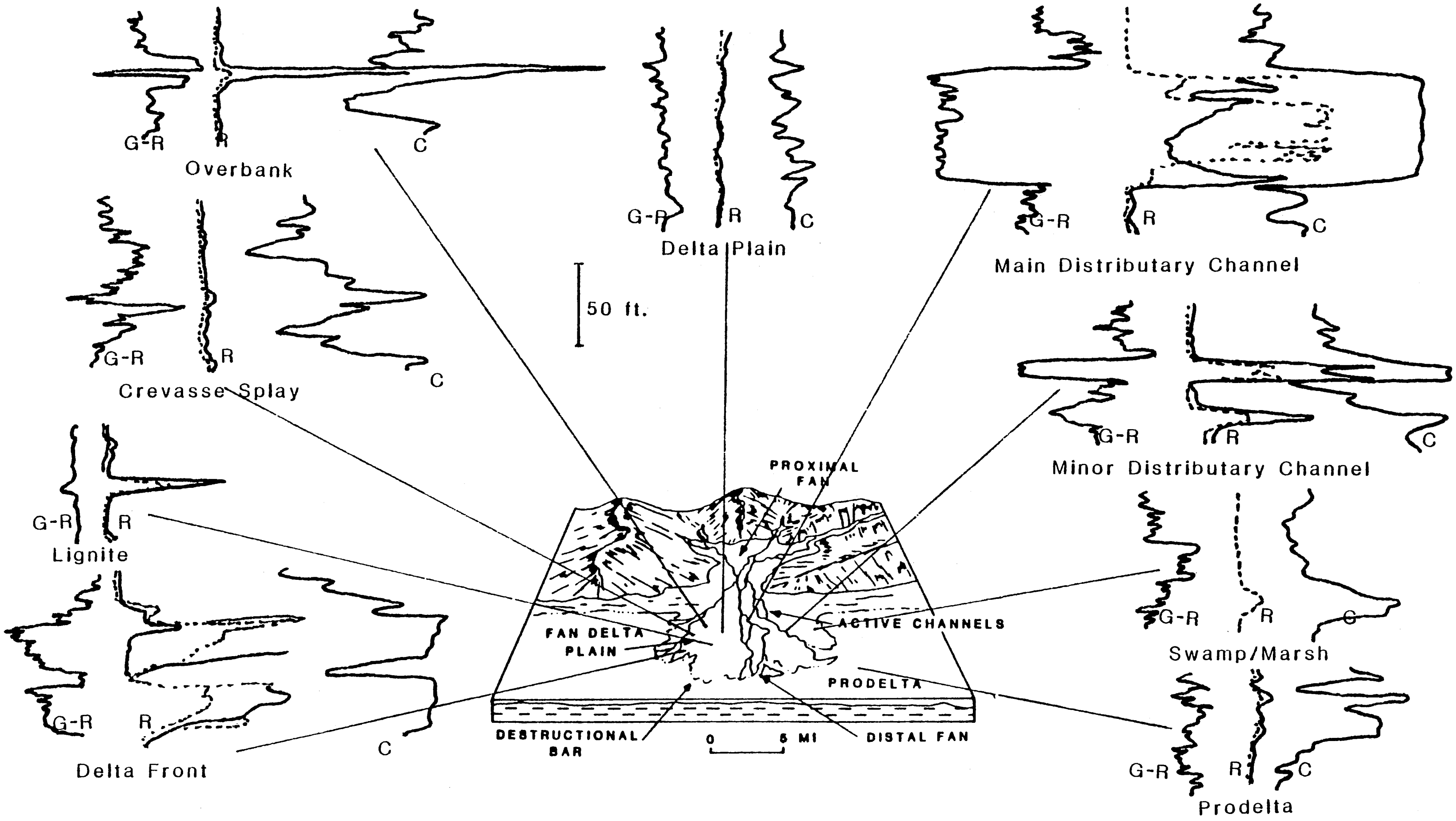

Figure 33. Characteristic Log Signatures of Various Depositional Facies Within the Study Area.

usually has a gradational, fining-upward top and can have a gradational base. The resistivity curve can vary, but it is normally high and sharp. The conductivity curve is usually the inverse of the gamma-ray response.

Overbank deposits are thin (less than 10 feet) and have a low, sharp, gamma-ray response. The resistivity curve is thin and sharp and usually varies from moderate to high. The conductivity curve is thin and sharp and is normally the inverse of the gamma-ray log.

Delta front deposits have variable thicknesses and decrease in gamma-ray response from the base to the top. The resistivity curve is variable, but has an overall moderate response. The conductivity curve shows an inverse of the gamma-ray. Sneider et al. (1977) discusses that stacked sequences of delta front deposits are common; stacked sequences of delta front deposits occur within the study area, but are not common.

Delta plain deposits are variable in thickness. There is usually no gamma-ray response, but the curve can be "ratty". The resistivity curve is normally low and spikey. The conductivity curve varies from "ratty" to sharp and spikey. Sneider et al. (1977) description is similar to this.

Lignites are a deposit on the delta plain. They are thin (less than 10 feet) and have a slight spike for a gamma-ray response. The resistivity is sharp and high as shown in Figure 28, taken from Shelby (1980).

Prodelta log characteristics are considered the same as delta plain log responses. One must use the surrounding facies as a guide to decide whether or not it is delta plain or prodelta.

Swamp deposits are described by Hawthorne (1984) as "hot shales". These deposits have very high and "ratty" gamma-ray responses. The resistivity is variable, but it is usually low and flat. Conductivity is variable and can range from thin and sharp to blocky. Hawthorne (1984) interprets these "hot shales" in the study area to be carbonaceous, and therefore, a type of muddy swamp deposit.

Setting of Study Area Within Fan Delta System

Figures 34 and 35 are facies maps constructed for the study area. The study area contains braided stream deposits (represented by main channel trends) on the subaerial delta plain in the south that prograde into a prodelta environment to the north. Crevasse splays, delta front, and swamp facies are interspersed throughout the area. Because of this setting, the various facies found, and the distance away from the source, the study area most likely represents a lower mid/upper distal fan delta to prodelta environment.

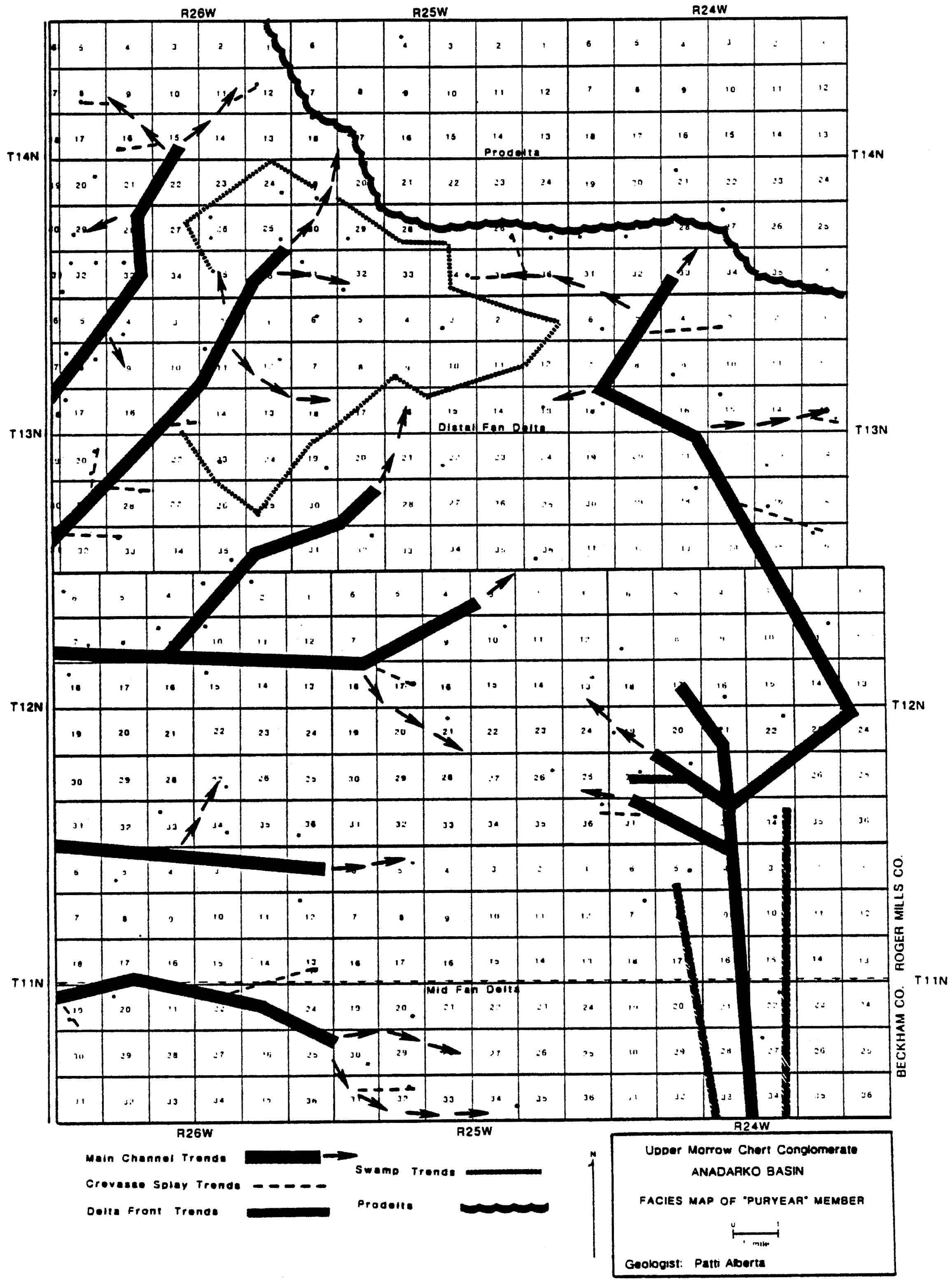

Figure 34. "Puryear" Facies Map, T11N-T14N, R24W-R26W.

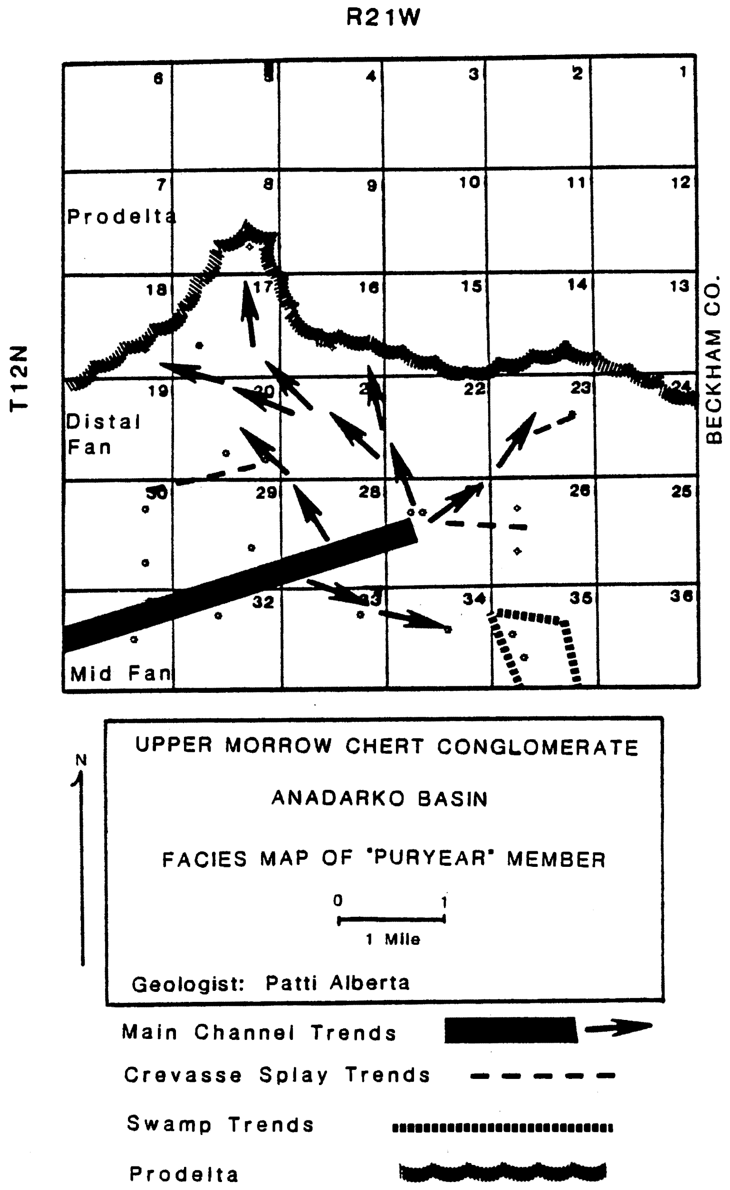

Figure 35. "Puryear" Facies Map, T12N, R21W.

Porosity Analysis of "Puryear" Facies

The porosity of the "Puryear" was analyzed using the neutron-density porosity logs available for the study area. Each facies of the "Puryear" were separated, and the porosity was averaged for each. Average porosities were determined by averaging the neutron response and the density response for every two feet through the facies; the average values for every 2 feet were then averaged together to obtain a composite porosity average for the facies. Figure 36 illustrates a representative log signature and its average porosity for each facies.

The main distributary channel facies have a range of porosity between 5.8-14.2 percent and average at 10.2 percent. All main distributary channels have a neutron-density crossover. Most cross over through the entire channel. Those that only cross over in part of the channel have neutron-density curves that follow close in non-crossover areas.

Minor distributary channel facies show a range in porosity from 3.5-17.8 percent and average at 8.7 percent. Most minor distributary channels have a neutron-density crossover all through the channel. Several logs show no crossover and the neutron-density curves are far apart.

The crevasse splay facies range in porosity from 4.35-16 percent and average at 8.9 percent. Most crevasse splays reveal a neutron-density crossover through part of the

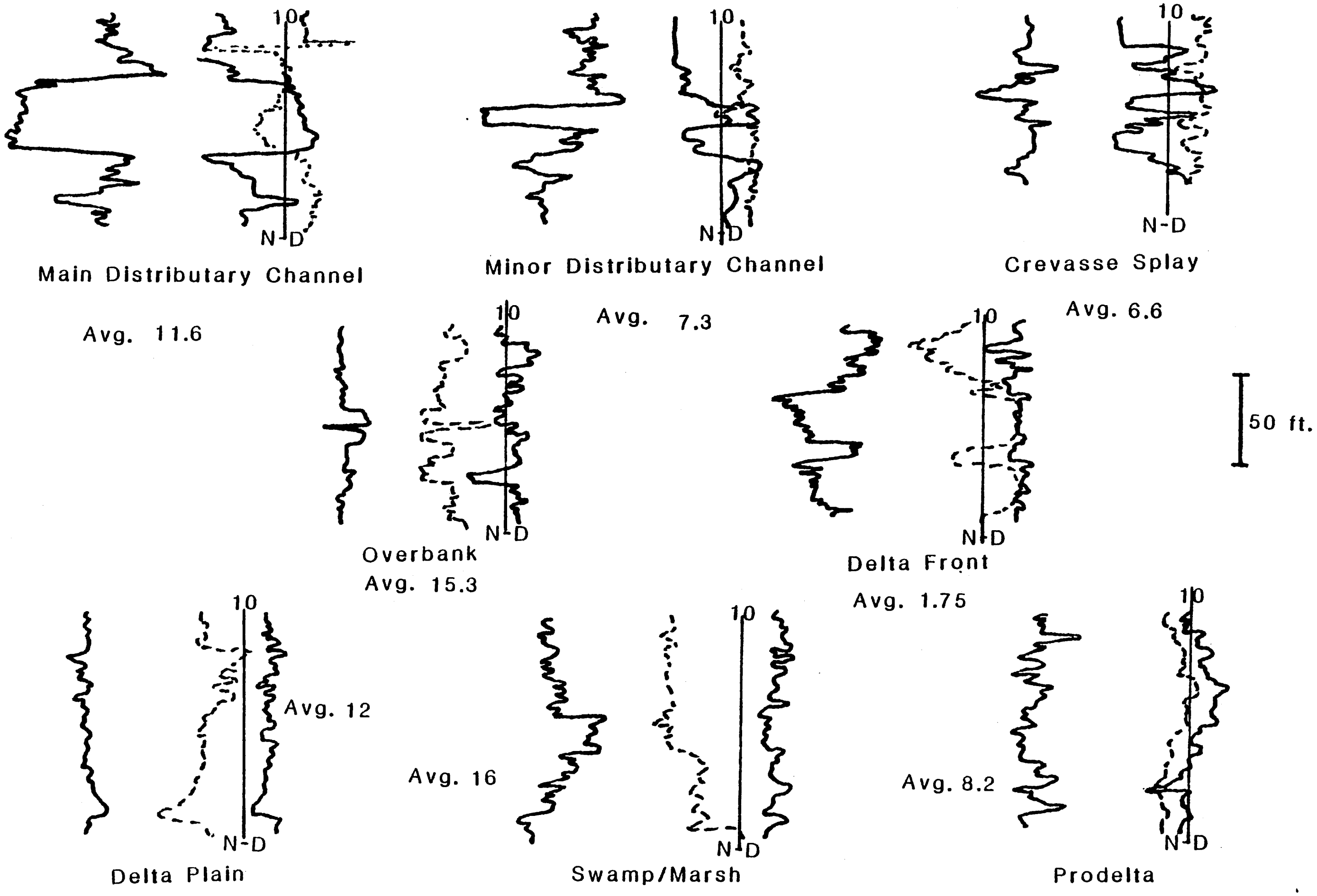

Figure 36. Characteristic Neutron-Density Porosity Responses of the Various Depositional Facies and Their Average Porosities.

facies and track close together in non-crossover areas. Several logs have no crossover and the neutron-density curves track far away.

Overbank facies show a range in porosity from 6.9-15.3 percent and average at 11.1 percent. Neutron-density crossover in the overbank facies was minor, but the neutron-density curves follow close in most.

The delta front facies has a porosity range of 1.75-20 percent with the average at 10.9 percent. Most delta front facies have neutron-density curves that track far apart and most likely indicates shale; crossover was very minor.

The delta plain facies reveal a range in porosity from 7.5-21 percent and average at 13 percent. No crossover occurs in the delta plain facies and all neutron-density curves track far apart, indicating shale.

The prodelta facies have a porosity range of 3.5-18.5 percent and average at 9.9 percent. No neutron-density crossover is observed, and both curves track far away for all prodelta facies; this represents the presence of shale.

The swamp facies range in porosity from 2.5-20 percent and average at 12.8 percent. Neutron-density crossover does not occur in the swamp facies, and the neutron-density curves track far away from each other; the neutron curve is extremely high and the density curve is extremely low. This indicates the presence of shale.

No neutron-density logs were available for the lignite facies.

Facies With The Best Porosity Development

Although each of the "Puryear" facies have relatively good porosity averages, several of these are too optimistic for various reasons. First of all, the average porosities of the delta plain, prodelta, and swamp facies are extremely optimistic. Schlumberger (1972) suggests that for shaly formations this is partly due to the neutron porosity log responding to all of the hydrogen within the shales (even the water), and therefore, causes the neutron porosity to read too high. Also, Schlumberger (1972) reports that the density porosity log in shaly formations reads very small or negative. Thus, between the two, an overly optimistic porosity value will occur.

The average porosities of the overbank facies and the delta front facies are also too optimistic. First of all, delta front and overbank facies rarely occur in the study area. Secondly, because they are rare, not much data is available to account for a more realistic average.

The minor distributary channel facies and the crevasse splay facies both have acceptable porosity averages. However, the range of each is very high. A range of 3.5-17.8 percent for the minor distributary channel facies and a range of 4.35-16 percent for the crevasse splay facies shows that these facies are inconsistent in their porosity development.

The porosity of the main distributary channel facies does not appear to be too optimistic. The absence or minor amount of shale will not affect the neutron and density readings. The range in porosity (5.8-14.2 percent) is relatively small compared to the other facies and reveals a more consistent development of porosity. The main distributary channel facies is present and dominant through the whole study area and allows for a realistic porosity average to be obtained. Therefore, the author believes that the main distributary channel facies represents the facies with the best porosity development. Figure 37 displays a characteristic log signature of the main distributary channel facies.

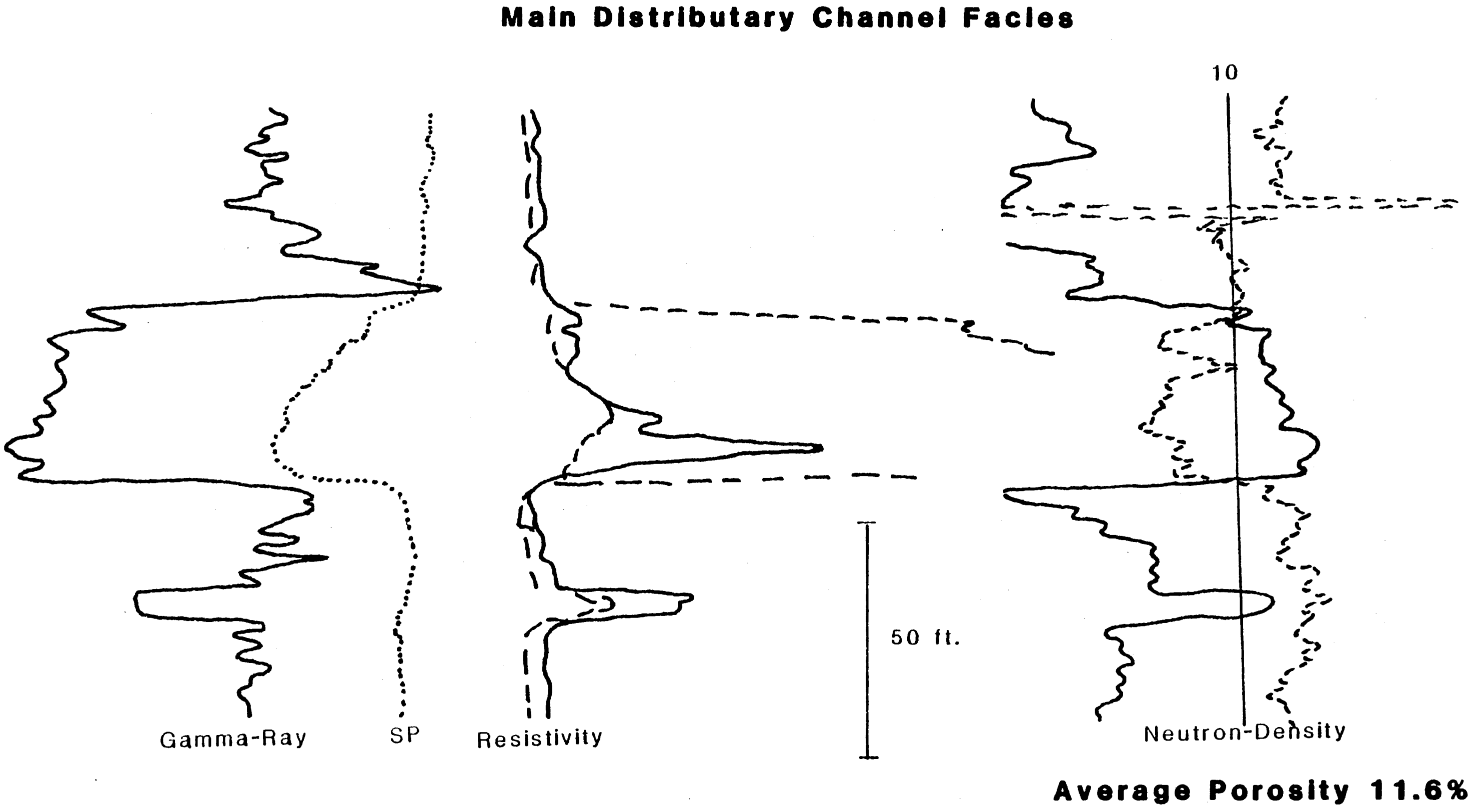

Figure 37. Characteristic Log Signature of the Facies with the Best-Developed Porosity.

CHAPTER VI

THE RELATIONSHIP BETWEEN WELL LOG SIGNATURES AND ROCK COMPOSITION

Figure 38 is an illustration of the G.H.K.-Apache Gregory core lithology related to the resistivity log, the gamma-ray log, and the neutron-density porosity log. Thin section porosity, as well as feldspar and chert percentages, are also correlated with the well log signatures and core. Note: the core and logs are off by 15 feet.

Gamma-Ray Log

The relationship between the gamma-ray log and the core was discussed in the depositional environment section. In general, the gamma-ray log correlated with the fining-upward sequence of the chert conglomerate. Figure 39 illustrates a positive relationship between the gamma-ray log response in A.P.I. units and feldspar content. This shows that as the gamma-ray log response increases, feldspar content increases. This is most likely due to the gamma-ray responding to the K^+ ion in the feldspar. The anomalous point at the top of the graph corresponds to the top of the core where shale stringers are abundant.

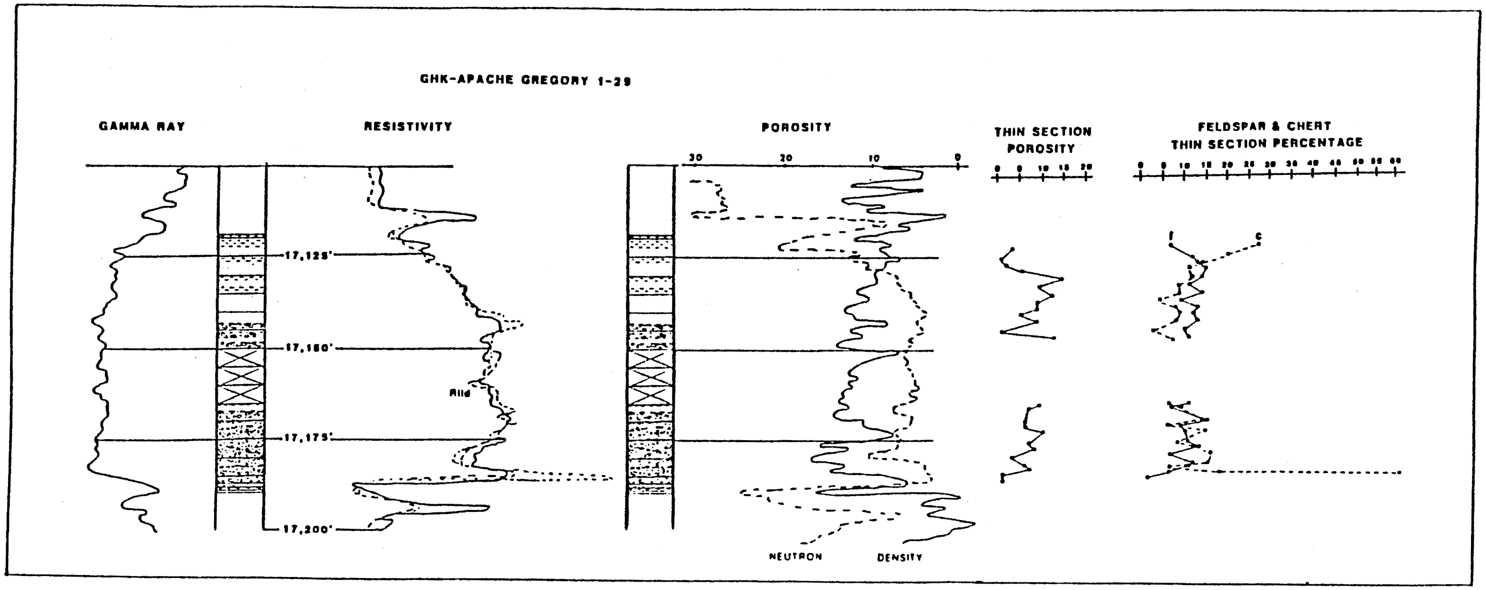

Figure 38. Illustration of G.H.K.-Apache Gregory Core Lithology Related to the Various Log Signatures.

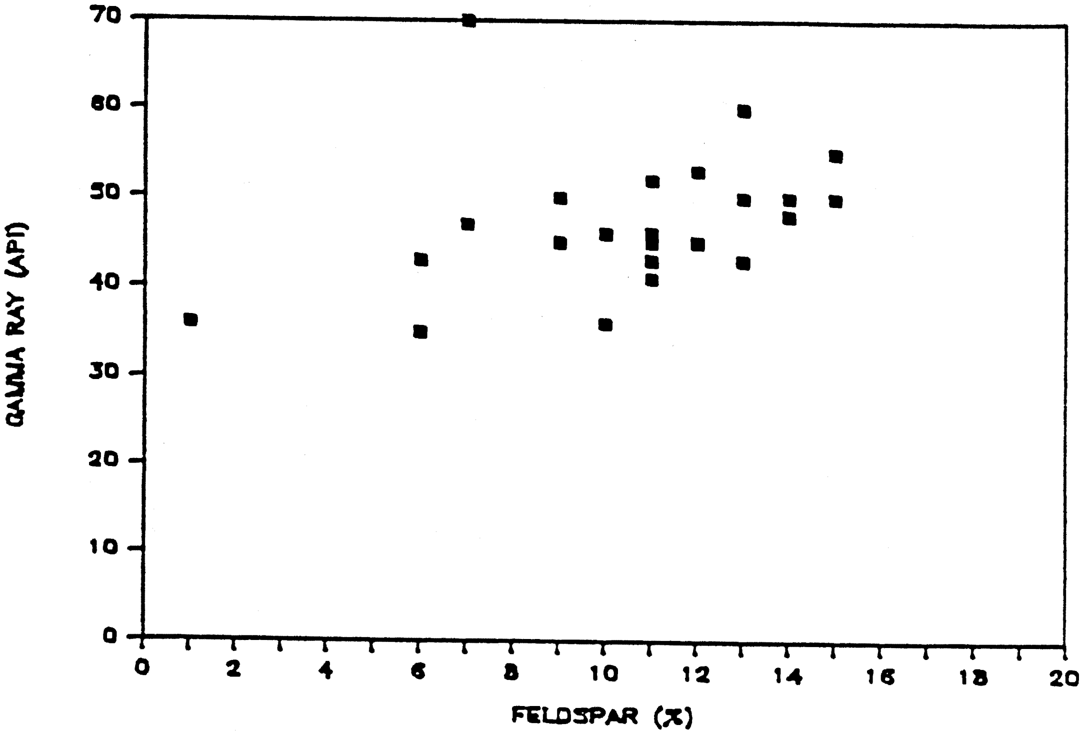

Figure 39. The Relationship Between Feldspar Content (X-axis) and the Gamma-Ray Log Response in API Units (Y-axis).

Resistivity Log

The resistivity log deflects to the right in zones of coarse-grained chert conglomerate and deflects to the left in the zones which contain finer cherty sands. In other words, the resistivity log is deflecting with the multistoried channel deposits. Overall, a decrease in resistivity follows the upward fining sequence of the core.

Neutron-Density Logs

The neutron-density logs show a varying porosity between five and twelve percent; the thin section porosity plot relatively follows the log variances. The cross over between the density and neutron logs indicates a gas productive zone. The lower productive zone is missing from the core, but the upper productive zone correlates with a higher thin section porosity.

The feldspar and chert thin section percentages show an interesting relationship with the neutron-density porosity logs. Zones where the neutron-density porosity have a spread of two to five percent correspond to where the thin section porosity is the greatest; the feldspar and chert percentages at these zones are close in value. However, zones where the neutron-density spread is greater than five percent correspond to where thin section porosity is lowest; the feldspar and chert percentages at these zones do not near each other in value.

This relationship is illustrated in Figure 40. The ratio of (feldspar/feldspar + chert) is plotted on the x-axis, whereas the average neutron-density porosity is plotted on the y-axis. The dots represent the G.H.K.-Apache Gregory core, and the stars represent the Sayre Ranch core. Note that where there is a dominance of feldspar (nearing 100%) or where there is a dominance of chert (nearing 0%), the corresponding porosity is low. On the other hand, where feldspar and chert content are approximately equal (between 35-65%), the porosity is greatest. This suggests that a certain geochemical environment must have existed in which enough feldspar is dissolved to create the basic solution needed to dissolve chert.

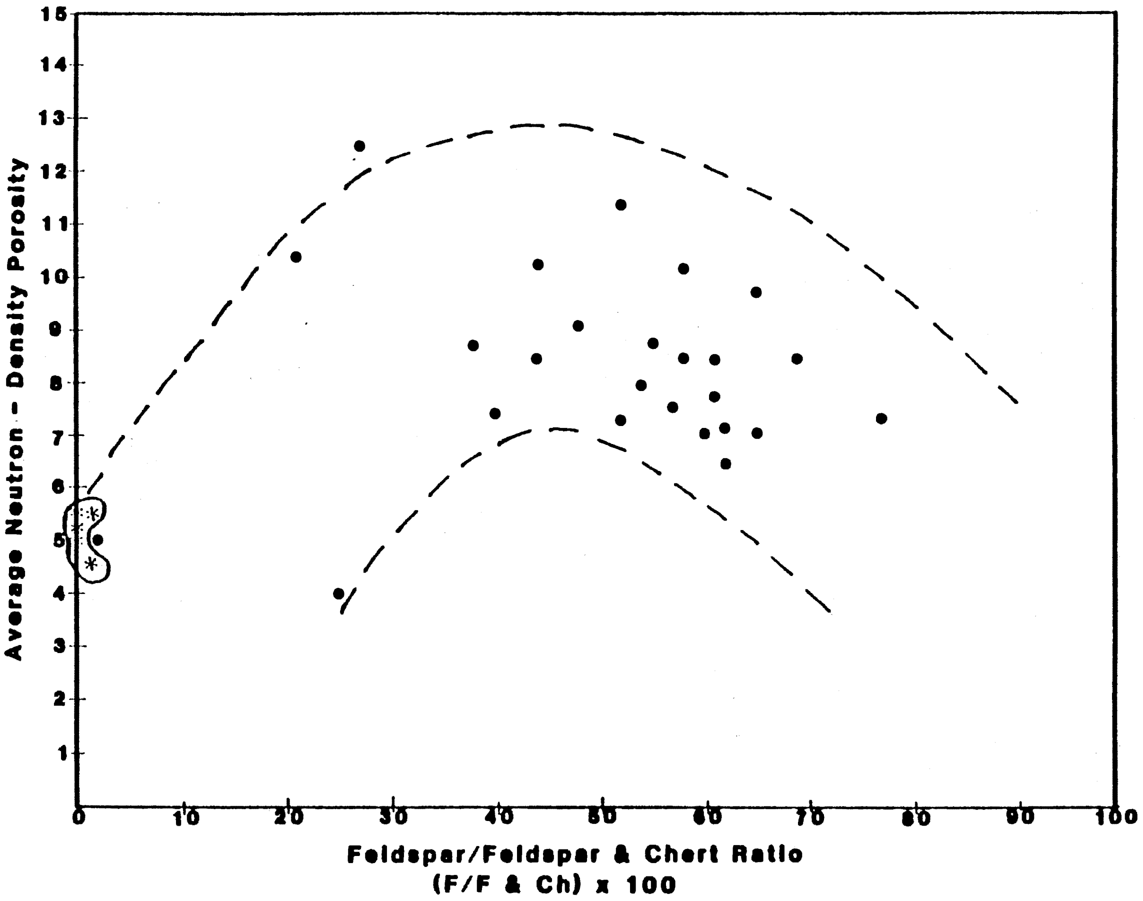

Figure 40. The Average Neutron-Density Porosity (Y-axis) Versus the (Feldspar/Feldspar + Chert) Ratio (X-axis).

CHAPTER VII

CONCLUSIONS

After analyzing various aspects of the Upper Morrow Chert Conglomerates, several conclusions can be made. These include:

1. The Chert Conglomerate was deposited in a fan-delta environment. Proximal, mid, and distal deposits are characterized by various fan delta processes. Water-laid and debris flow processes are the main depositional processes responsible for fan construction.

2. Proximal fan delta facies consist of one or several, major deep and broad channels. Mid fan delta facies include a network of braided streams on the subaerial fan delta plain. Distal fan delta facies comprise more narrow braided stream channels with marsh/swamp deposits. Prodelta facies consist of subaqueous marine muds.

3. The G.H.K.-Apache Gregory No. 1-29 core contains multiple stacks of braided stream deposits and represents a main distributary channel. The Exxon-Sayre Ranch No. 2-35 core also contains multiple stacks of braided stream deposits, but represents a minor distributary channel.

4. Net sandstone isolith maps of the "Puryear" show prograding elongate delta lobes that are sourced from the west-southwest.

5. After analyzing the petrographic and diagenetic characteristics of the Upper Morrow Chert Conglomerates, three petrofacies were recognized. These were: 1) chert conglomerate, 2) quartz and feldspar, and 3) mixtures of 1 and 2.

6. Porosity within the chert conglomerate is mainly secondary. Dissolution of various components is responsible for the different porosity types. These include enlarged intergranular porosity (E.I.P.), oversized pores, and microporosity.

7. Gamma-ray, resistivity, and conductivity logs were utilized to interpret each "Puryear" facies. These facies include: main and minor distributary channels, crevasse splays, overbank, delta front, delta plain, swamp/marsh, lignites, and prodelta.

8. "Puryear" facies maps show interspersed swamp and delta front deposits, with braided stream channels in the south that prograde into a prodeltaic environment to the north. This most likely represents a lower mid/upper distal fan delta to prodelta environment of the study area.

9. The Porosity of each "Puryear" facies was analyzed using neutron-density porosity logs. Delta plain, swamp, and prodelta facies were overly optimistic; overbank and delta front rarely occurred and a realistic average was

unattainable; and crevasse splay and minor distributary channel facies have too wide of a range in porosity to be consistent. The main distributary channel facies did not have a wide porosity average and most likely represents the facies with the best-developed porosity.

10. The gamma-ray log response in A.P.I. units of the G.H.K.-Apache Gregory core increases from the base to the top of the core. This increase corresponds to an increase in feldspar content as well as a decrease in grain size. In addition, the gamma-ray log is responding to an influx of illitic shale as well as feldspar content at the top of the core.

11. In the G.H.K.-Apache Gregory core, zones of highest measured porosity correspond to where chert and feldspar content near each other within five percent. Zones of lowest measured porosity correspond to either areas of a high chert to feldspar ratio or a high feldspar to chert ratio.

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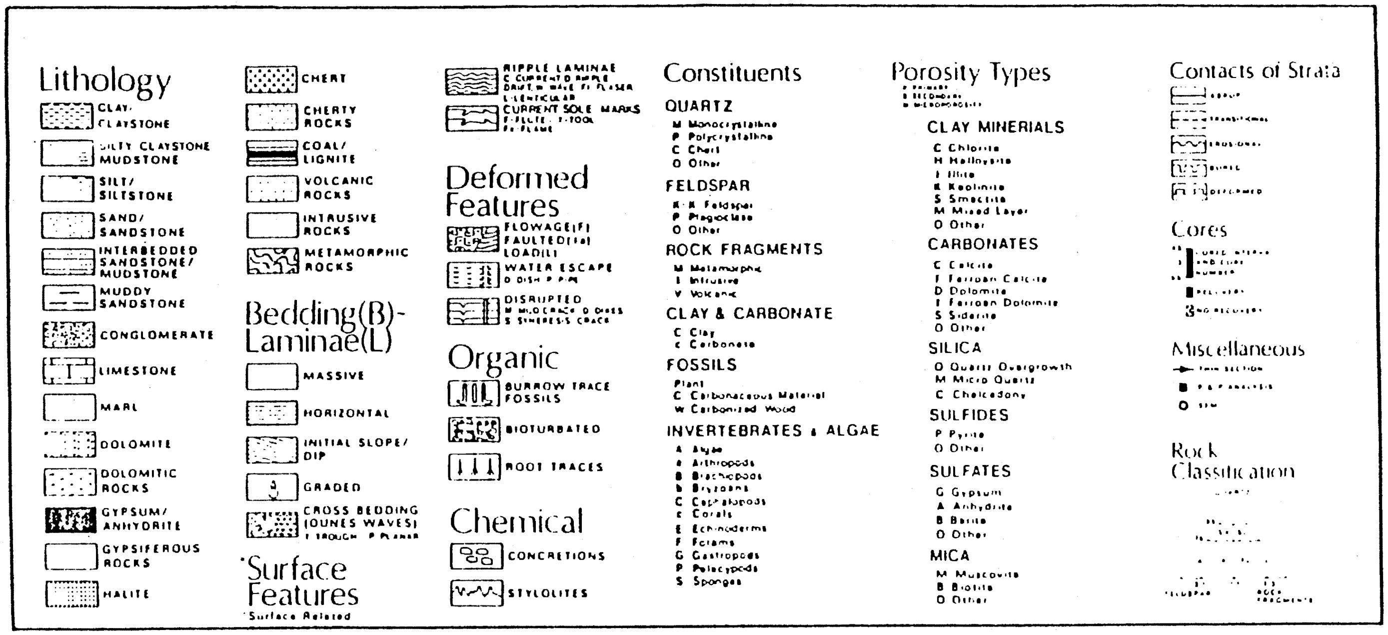
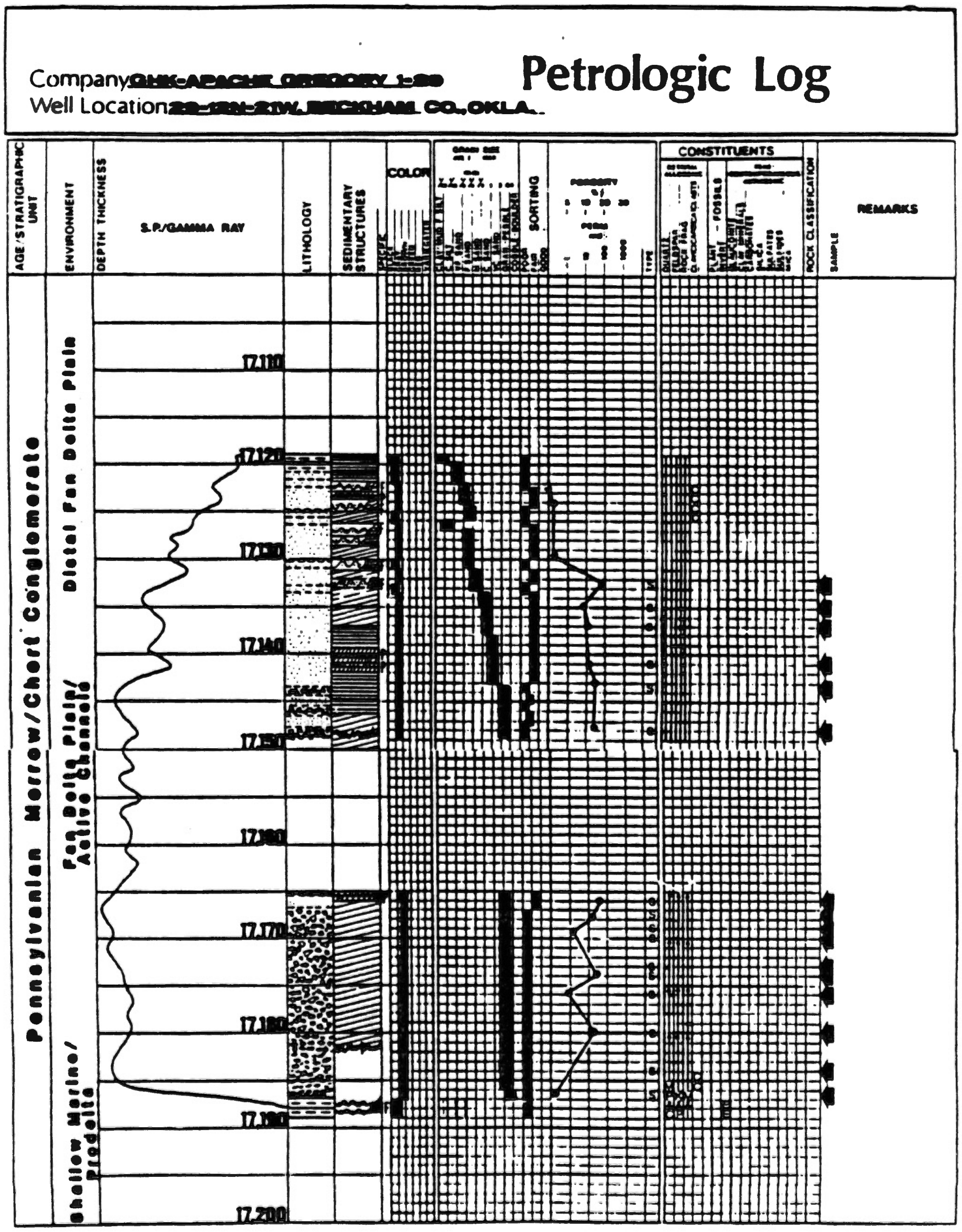
APPENDIXES

APPENDIX A

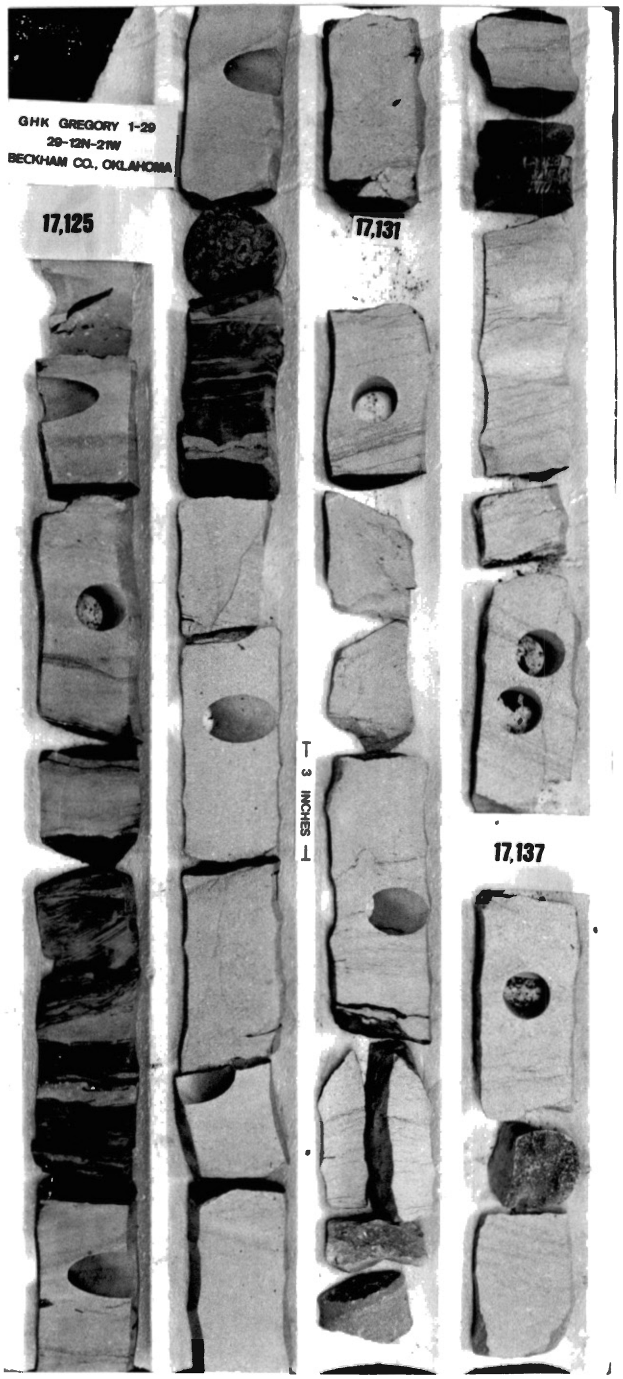
PETROLOG OF G.H.K.-APACHE GREGORY NO. 1-29

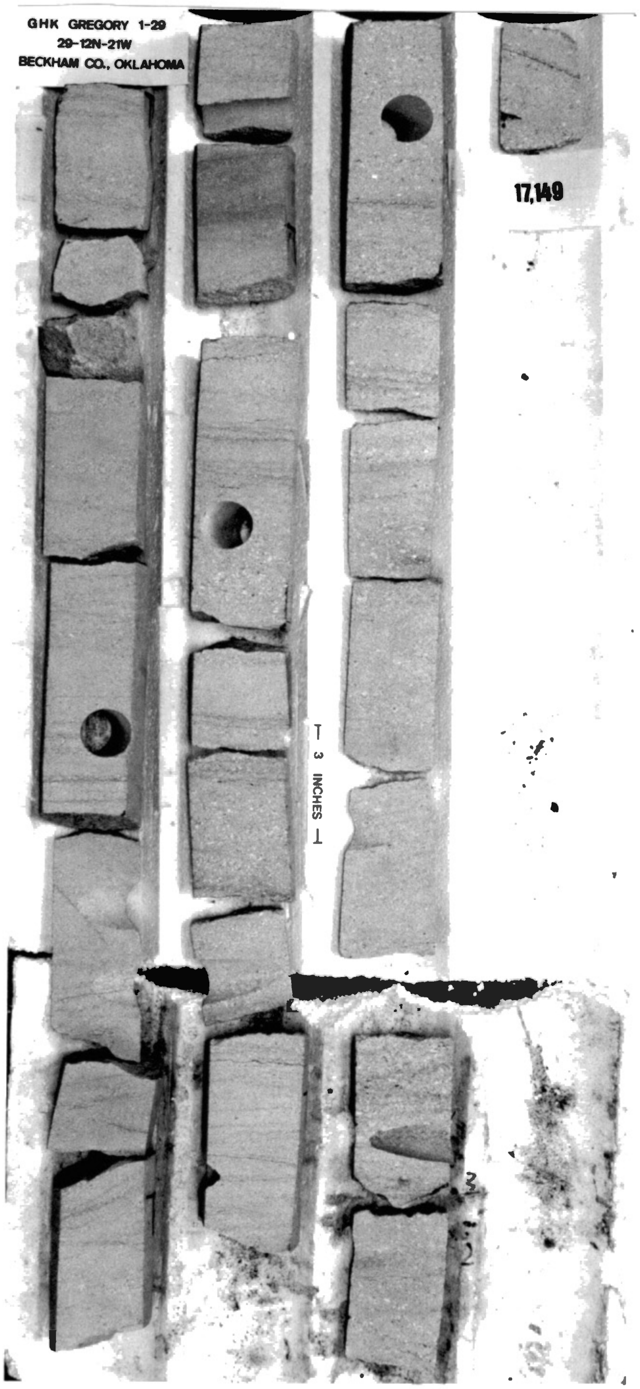

Lithology
CLAY/ CLAYSTONE
SILTY CLAYSTONE MUDSTONE
SILT/ SILTSTONE
SAND/ SANDSTONE
INTERBEDDED SANDSTONE/ MUDSTONE
MUDDY SANDSTONE
CONGLOMERATE
LIMESTONE
MARL
DOLOMITE
DOLOMITIC ROCKS
GYPSUM/ ANHYDRITE
GYPSIFEROUS ROCKS
HALITE
CHERT
CHERTY ROCKS
COAL/ LIGNITE
VOLCANIC ROCKS
INTRUSIVE ROCKS
METAMORPHIC ROCKS
Bedding(B)- Laminae(L)
MASSIVE
HORIZONTAL
INITIAL SLOPE/ DIP
GRADED
CROSS BEDDING (DUNES WAVES)
T TROUGH P PLANAR
*Surface Features
*Surface Related
RIPPLE LAMINAE
C CURRENT D DRIFT W WAVE Fl FLASER
L LENTICULAR
CURRENT SOLE MARKS
F FLUTE T TOOL
Fl FLAME
Deformed Features
FLOWAGE(F)
FAULTED(Fa)
LOAD(L)
WATER ESCAPE
D DISH P PIPE
DISRUPTED
M MUDCRACK 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
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 Bryzoans
C Cephalopods
c Corals
E Echinoderms
F Forams
G Gastropods
P Pelecypods
S Sponges
Porosity Types
P PRIMARY
S SECONDARY
M MICROPOROSITY
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
O Quartz Overgrowth
M Micro Quartz
C Chalcedony
SULFIDES
P Pyrite
O Other
SULFATES
G Gypsum
A Anhydrite
B Barite
O Other
MICA
M Muscovite
B Biotite
O Other
Contacts of Strata
TRANSITIONAL
EROSIONAL
DEFORMED
Cores
RECOVERED
NO RECOVERY
Miscellaneous
THIN SECTION
SEM
Rock Classification
QUARTZ
FELDSPAR
ROCK FRAGMENTS

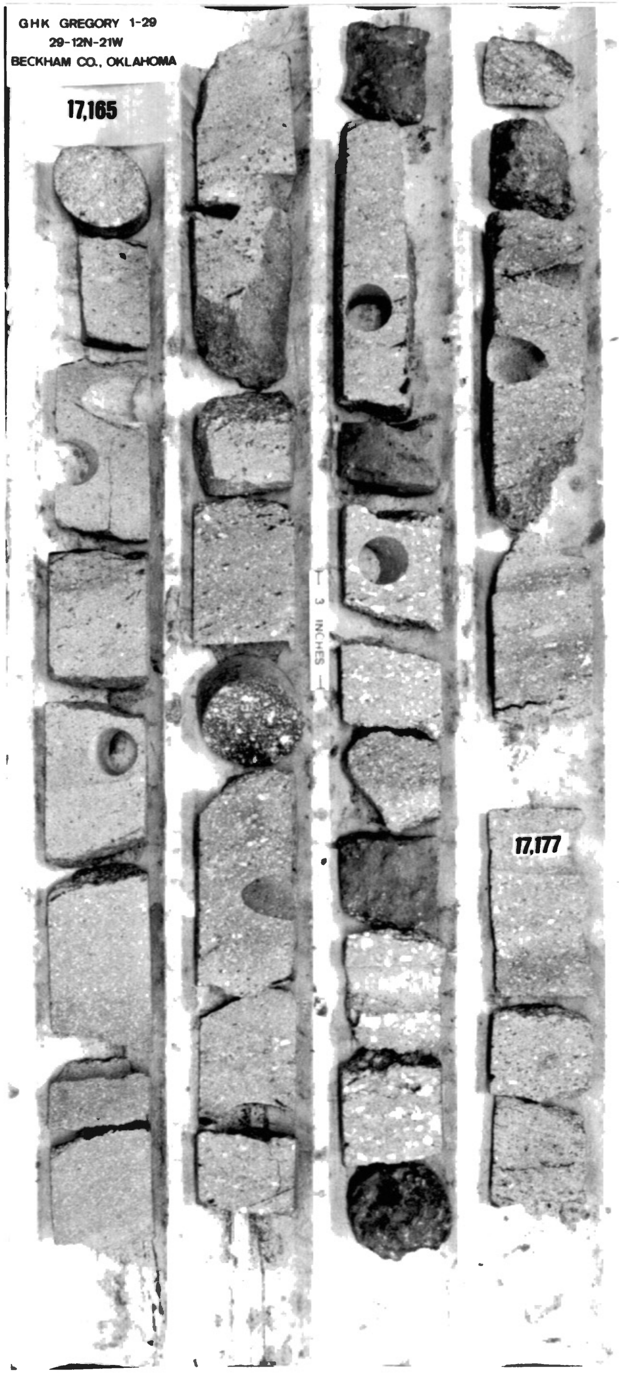

Company GHK-APACHE GREGORY 1-29
Well Location 29-12N-21W, BECKHAM CO., OKLA.
Petrologic Log
AGE/STRATIGRAPHIC UNIT
ENVIRONMENT
DEPTH THICKNESS
S.P./GAMMA RAY
LITHOLOGY
SEDIMENTARY STRUCTURES
COLOR
GRAIN SIZE
SORTING
POROSITY
TYPE
CONSTITUENTS
FOSSILS
ROCK CLASSIFICATION
SAMPLE
REMARKS
Pennsylvanian Morrow/Chert Conglomerate
Distal Fan Delta Plain
Fan Delta Plain/ Active Channels
Shallow Marine/ Prodelta
17,110
17,120
17,130
17,140
17,150
17,160
17,170
17,180
17,190
17,200

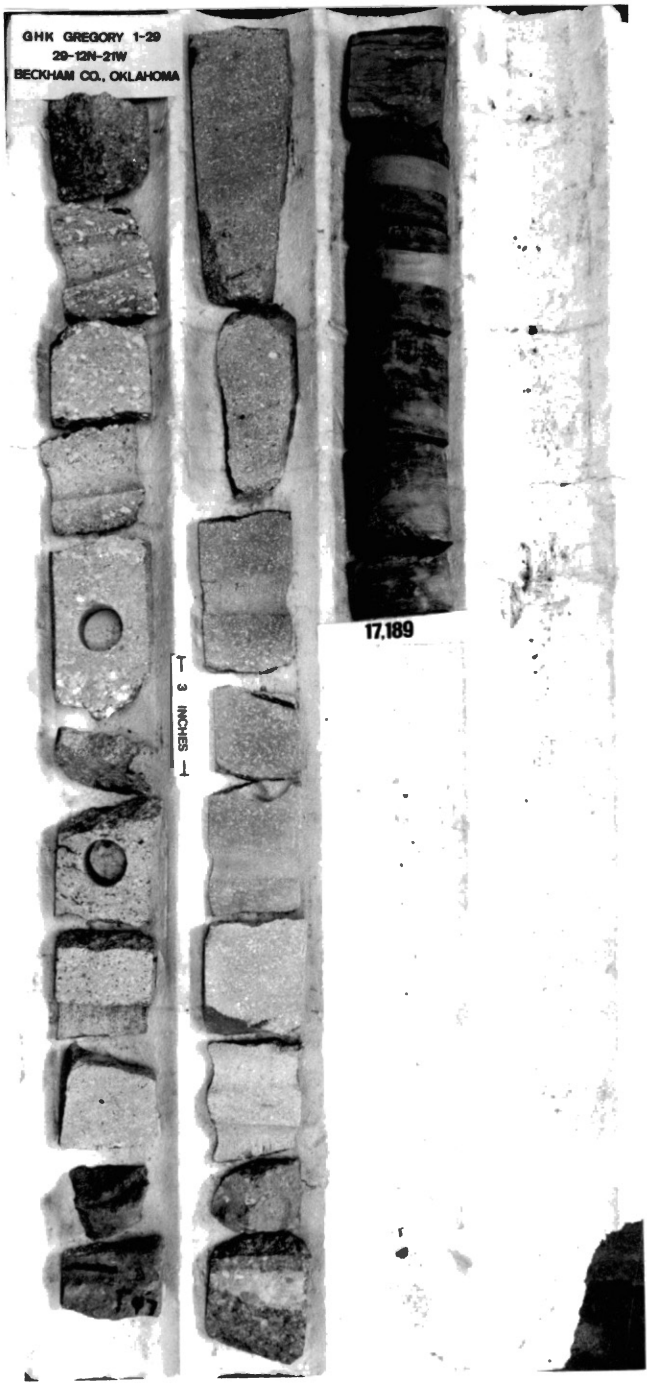
APPENDIX B

G.H.K.-APACHE GREGORY NO. 1-29 CORE PHOTOS


GHK GREGORY 1-29
29-12N-21W
BECKHAM CO., OKLAHOMA
17,125
17,131
17,137
3 INCHES

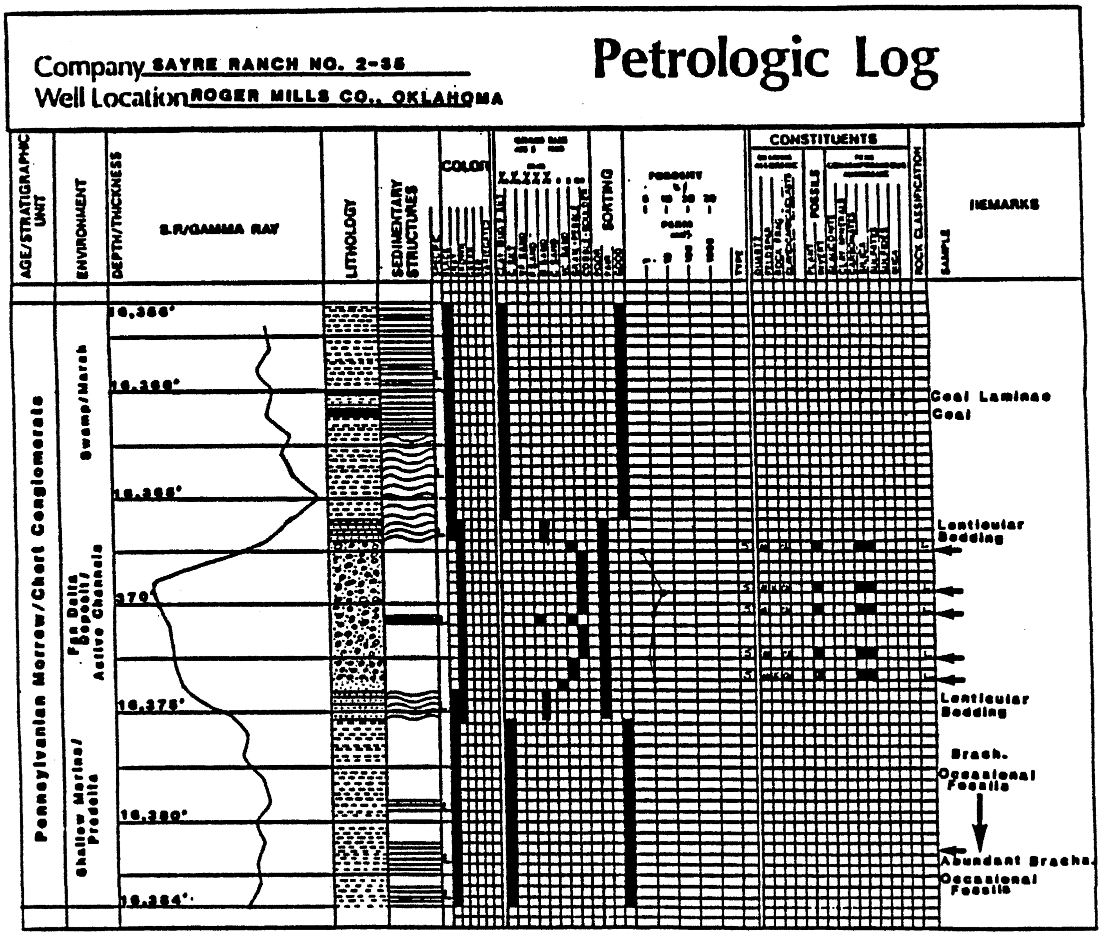

GHK GREGORY 1-29
29-12N-21W
BECKHAM CO., OKLAHOMA
17,149
3 INCHES


GHK GREGORY 1-29
29-12N-21W
BECKHAM CO., OKLAHOMA
17,165
3 INCHES
17,177


GHK GREGORY 1-29
29-12N-21W
BECKHAM CO., OKLAHOMA
3 INCHES
17,189

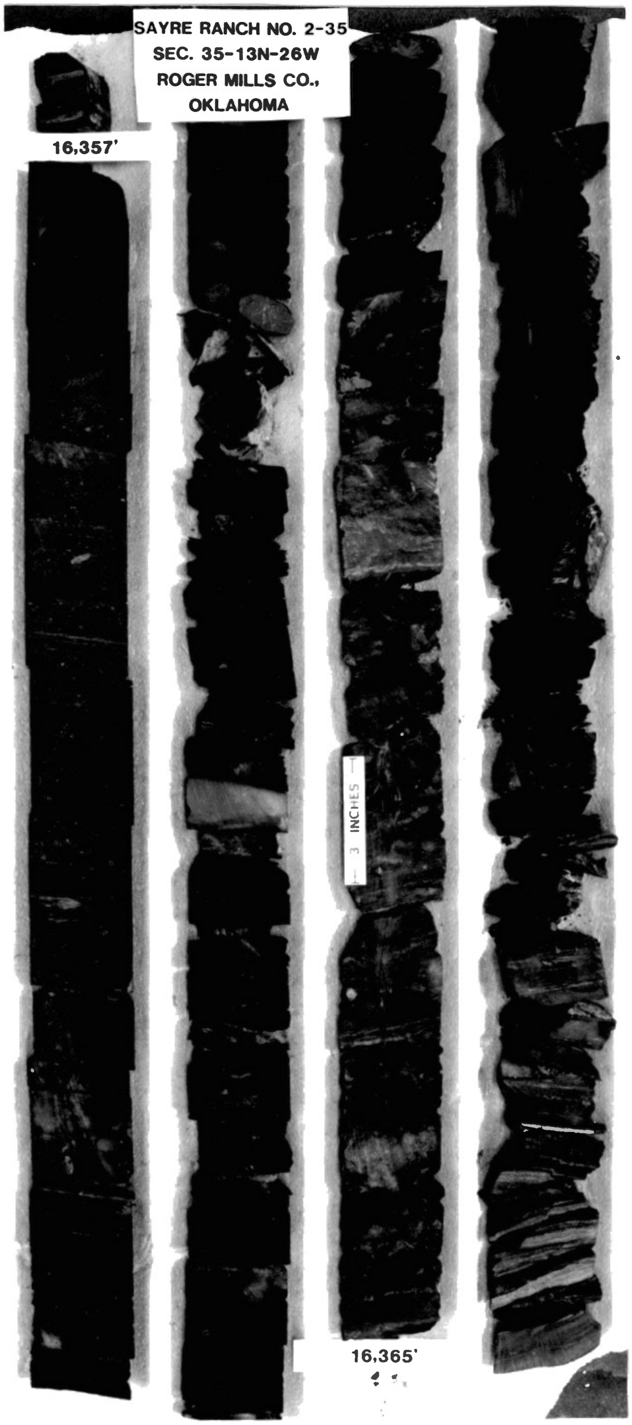
APPENDIX C

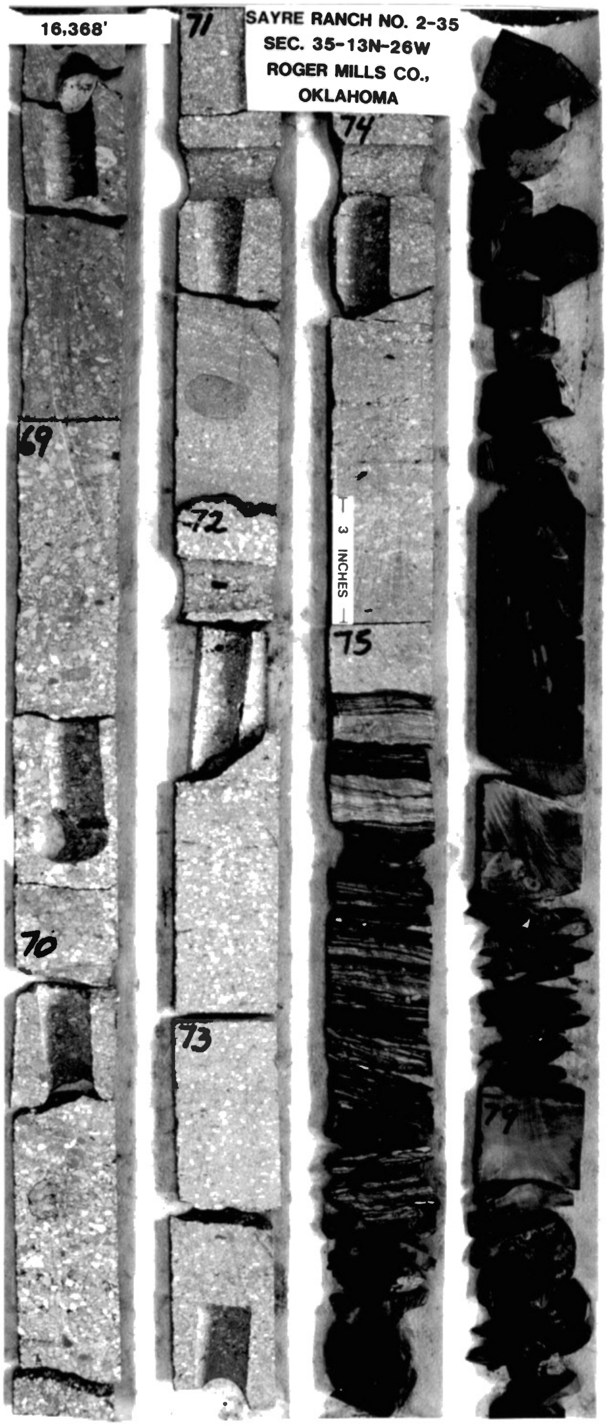
PETROLOG OF EXXON-SAYRE RANCH NO. 2-35


Petrologic Log
Company SAYRE RANCH NO. 2-35
Well Location ROGER MILLS CO., OKLAHOMA
AGE/STRATIGRAPHIC UNIT
ENVIRONMENT
DEPTH/THICKNESS
S.P./GAMMA RAY
LITHOLOGY
SEDIMENTARY STRUCTURES
COLOR
SORTING
POROSITY
PERM
TYPE
CONSTITUENTS
QUARTZ
FELDSPAR
ROCK FRAG.
FOSSILS
ROCK CLASSIFICATION
SAMPLE
REMARKS
Pennsylvanian Morrow/Chert Conglomerate
Swamp/Marsh
Fan Delta Deposit/ Active Channels
Shallow Marine/ Prodelta
16,356'
16,360'
16,365'
370'
16,375'
16,380'
16,384'
Coal Laminae
Coal
Lenticular Bedding
Lenticular Bedding
Brach.
Occasional Fossils
Abundant Brachs.
Occasional Fossils

APPENDIX D

EXXON-SAYRE RANCH NO. 2-35 CORE PHOTOS


SAYRE RANCH NO. 2-35
SEC. 35-13N-26W
ROGER MILLS CO.,
OKLAHOMA
16,357'
3 INCHES
16,365'


16,368'
71
SAYRE RANCH NO. 2-35
SEC. 35-13N-26W
ROGER MILLS CO.,
OKLAHOMA
74
69
72
3 INCHES
75
70
73
79


16,380'
SAYRE RANCH NO. 2-35
SEC. 35-13N-26W
ROGER MILLS CO.,
OKLAHOMA
3 INCHES
16,385'

VITA

Patricia Lynne Alberta

Candidate for the Degree of

Master of Science

Thesis: DEPOSITIONAL FACIES ANALYSIS AND POROSITY DEVELOPMENT OF THE (PENNSYLVANIAN) UPPER MORROW CHERT CONGLOMERATE "PURYEAR" MEMBER, ROGER MILLS AND BECKHAM COUNTIES, OKLAHOMA

Major Field: Geology

Biographical:

Personal Data: Born in Billings, Montana, August 2, 1962, the daughter of Mr. and Mrs. William M. Alberta.

Education: Graduated from Northbrook Senior High School, Houston, Texas, in May, 1980; received Bachelor of Science degree in Geology from The University of Texas at Austin in December, 1984; completed requirements for the Master of Science degree at Oklahoma State University in July, 1987.

Professional Experience: Research Assistant, University of Texas Bureau of Economic Geology, 1984; Graduate Research Assistant, OSU Well-Log Consortium, University Center for Energy Research (UCER), and OSU Geology Department, 1985-1986; Graduate Teaching Assistant, Geology Department, Oklahoma State University, 1986. Junior Member of the American Association of Petroleum Geologists.