DEPOSITIONAL ENVIRONMENTS AND SANDSTONE TRENDS OF THE PENNSYLVANIAN MORROWAN SERIES, SOUTHERN MAJOR AND WOODWARD COUNTIES, OKLAHOMA

By

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PREFACE

This study deals with the depositional environments and sandstone trends of the Pennsylvanian Morrowan Series of the Anadarko basin. Determination of environment was accomplished through core analyses and preparation of correlation sections, isopach, sandstone thickness, and structural contour maps.

This thesis was financed in part by ERICO, Inc. Special appreciation is extended to Professor John W. Shelton, thesis adviser, whose constructive guidance throughout this study proved invaluable. Dr. Gary Stewart, who also served on the thesis committee, provided valuable assistance with correlations and stratigraphic problems. Thanks are due to Professor John D. Naff, who provided inspiration during the study, as well as throughout my academic career. Eldon Cox, of the Oklahoma Geological Survey Core Library, provided valuable core used in the study. Dr. Richard G. Thomas and Dr. Curtis D. Conley are gratefully acknowledged for their help in core description and interpretation. Appreciation is expressed to Mr. Herbert G. Davis and to fellow graduate students, who offered helpful comments during the course of the study. Mr. Mike Knapp and Mr. Glenn Diehl, of ERICO, Inc., made helpful comments and provided assistance in retrieving log data from the Oklahoma Well Log Library in Tulsa. Mr. Dave Huey is complimented for his aid in drafting and preparation of various figures. Thanks is extended to the ladies of the O.S.U. Audio-Visual photo development center for their quality photographic work and Jeanne Vale, who typed the final manuscript.

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CHAPTER I

ABSTRACT

The Lower Pennsylvanian Morrowan Series of the northeastern Anadarko shelf area, in the subsurface of northwest Oklahoma, contains sandstone units that are discontinuous in their areal extent and variable in thickness. Electric-log data from over 600 well were analyzed. Five correlation sections were constructed from selected well logs. These sections, with information derived from nine detailed core analyses, indicate that lower and upper Morrowan strata of this area represent a variety of coastal and shallow shelf environments.

In plan view, the lower Morrow sandstone bodies comprise a branching channel system. Core data suggest these sand bodies were deposited within a fluvio-deltaic distributary-channel environment. The channel system prograded southward and developed upon a southward-dipping undulatory pre-Pennsylvanian surface. Terrigenous detritus was transported through an entrenched north-south trending clastic channel system, the "Woodward channel".

A major transgressive event during Morrowan time is evidenced by a marked change to shallow marine lithologies, and a thin transgressive conglomeratic unit is present at the base of the marine sequence. Across the study area this transgression extended from late early Morrowan in the southwest to early late Morrowan to the northeast.

Sandstone units in the upper part of the Morrow contain abundant

glauconite and are moderately bioturbated. Coastal processes transported and reworked some of the sand and deposited it as an onlapping series of bars and/or sheets.

The quartzarenitic sandstones of the Morrowan Series were derived from a cratonic source that probably included the Central Kansas uplift, which was structurally high during this time interval.

CHAPTER II

INTRODUCTION

The Morrowan Series of the northeastern Anadarko shelf area contains sandstones that are discontinuous in areal extent and variable in thickness. Although many geologists have studied the Morrow sandstones as hydrocarbon reservoirs, most results have not been published. However, several published regional studies, noted in a subsequent section, represent a framework for this study of the Morrowan sandstone trends and depositional environment.

The area of study consists of 33 townships in parts of Woodward and Major Counties, Oklahoma (Fig. 1). Subsea elevations to the top of the Morrowan Series range from 4550 ft in the northeastern part of the area to 7600 ft in the southwest.

Objectives and Methods

The principal objectives of this study are to determine the depositional environments of Morrowan sandstones and to achieve an understanding of the sandstone trends.

Subsurface data includes various wireline logs, especially dual induction-laterologs, spontaneous potential logs, conventional resistivity logs, and gamma-ray logs in the preparation of the correlation sections (Plates 1 to 5) and subsequent maps (Plates 6 to 10). These were used to establish stratigraphic relationships, especially those which controlled

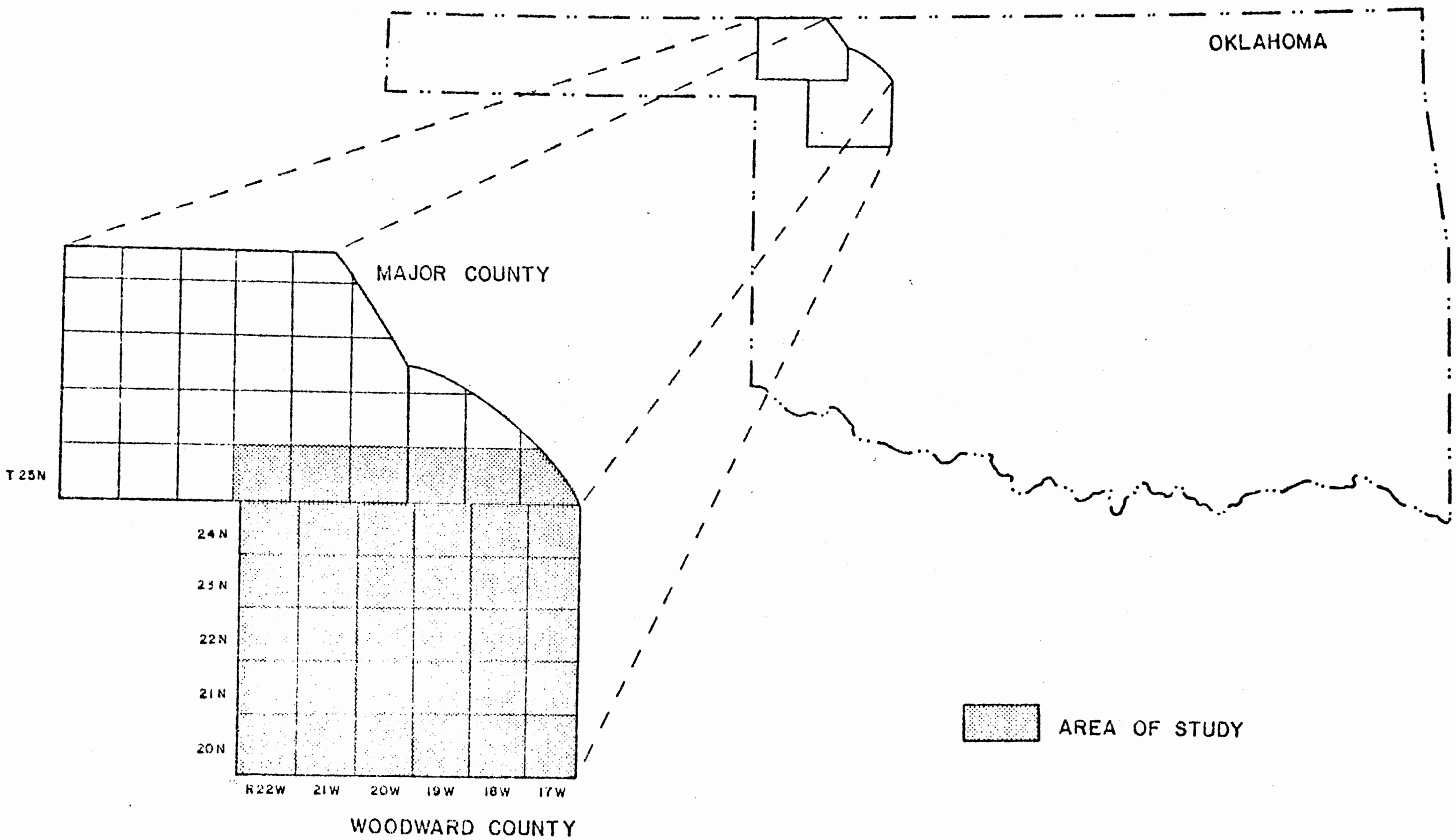


Fig. 1.--Location map of study area.

or influenced sand deposition in the study area. Sonic logs and density logs were used to plot porosity curves of the cored intervals on the petrographic logs.

Internal features of the Morrowan Series were determined by a detailed examination of nine cores. An estimate of the depositional environment was made from the integration of internal features (sedimentary sequences, lithologies, constituents) and geometry of the sandstone units together with regional stratigraphic correlations.

Previous Investigations

The type locality of the Morrowan Series is in northwest Arkansas, where the lithology is predominantly limestone (Moore, 1944). Regional correlations and stratigraphic problems are discussed by Moore (1944). Abels (1962) presented a subsurface lithofacies study of the Morrowan Series in the northern Anadarko basin. Rascoe (1962) presented a regional stratigraphic analysis of Pennsylvanian and Permian rocks of the Midcontinent. He ruled out the Sierra Grande and Amarillo-Wichita uplifts as source areas for the Morrow shelf sediments because of the absence of an arkosic facies. These uplifts, according to Rascoe, were lowland masses during early Morrowan time.

Busch (1959) demonstrated subparallelism of Morrow sandstone trends in northwestern Oklahoma. He described the sandstones as en-echelon in trend, with each sandstone wedging out not only updip against the Mississippian unconformity but also basinward. He considered these to represent shoreline stages or beach sands in a series of cyclic transgressions. Forgotson (1967) noted that dark shales and bioclastic limestones interbedded with quartzose sandstones suggest oscillations between open marine and lagoonal conditions.

Busch (1959), Forgotson (1967), Khaiwka (1968), and Breeze (1970) all noted that Morrow sandstone distribution appeared to be related to the pre-Pennsylvanian topography. Forgotson (1967) locally identified a south-trending channel in R20W (Woodward County), which apparently transported sand southward from the Central Kansas uplift. Swanson (1967, 1979) recognized "embayments" of thicker Morrowan sections which he interpreted as deltaic deposits.

Breeze (1970), in a study of Morrow reservoir pressures in northwestern Oklahoma, suggested that normal and subnormal pressured zones present in the study area show evidence of once being overpressured, but that osmosis reduced those pressures. Khaiwka (1968) generally followed Busch's (1959) ideas; namely, that barrier island systems and beach sandstones were formed along the shorelines of the transgressive Morrowan seas.

Diagenetic studies of the Morrow have been conducted by Adams (1964), Breeze (1970) and Kasino and Davies (1979). They summarized a diagenetic sequence and noted that the Morrow reservoir sandstones are very susceptible to formation damage through indiscriminant fluid injection methods.

CHAPTER III

GEOLOGIC SETTING

The area of study is located on the north flank of the Anadarko basin (Fig. 2). The basin is bounded on the north by a broad stable craton which includes the Central Kansas uplift, and on the south by the frontal Wichita fault system. On the west it is bounded by the Cimarron arch and the Las Animas arch on to the northwest. The Nemaha ridge lies to the east.

The Anadarko basin contains a maximum of 45,000 ft of strata just north of the Amarillo-Wichita uplift (Rowland, 1974). Strata thin substantially to the north and northwest onto the stable shelf areas. A large portion of oil and gas in the basin is trapped in anticlines and stratigraphic traps near the basinal edges, suggesting updip migration of hydrocarbons (Swanson, 1967).

A regional structural map of the study area (Plate 6) prepared on the top of the Morrowan Series, indicates general structural uniformity and simplicity. Strike is west-northwest, and the dip is fairly constant toward the south-southwest. It averages slightly less than 100 ft per mile. The surface is only slightly undulatory with broad noses and saddles present as broad features.

The northeastern limit of the Morrow Formation is within the study area and is thought to be a result of truncation of Morrowan strata by Atokan units.

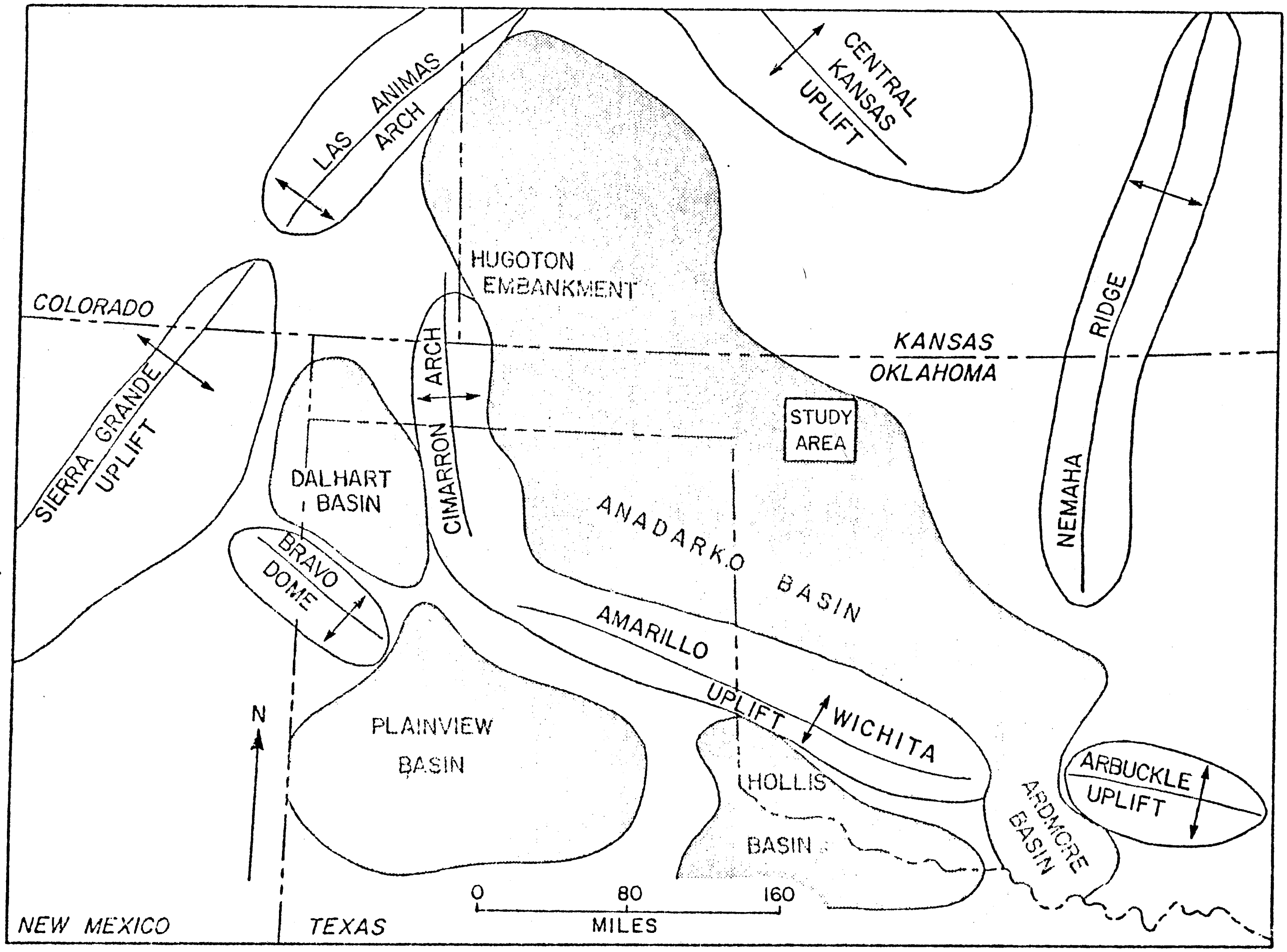


Fig. 2.--Geologic setting of study area.

CHAPTER IV

STRATIGRAPHIC FRAMEWORK

In this study, strata which have been defined by previous investigators as the Morrow Formation are herein defined as the Morrowan Series. It is the stratigraphic section above the top of the Mississippian Chester limestone or Springer sandstone (where present) and below the "Thirteen Finger" Limestone of the Atokan Series. The Morrow has been subdivided into lower and upper units in this thesis; further subdivision is not thought to be practical for the entire area.

In much of the area, the Morrow formed after a transgression over the eroded Chester limestone. The Chester shows high resistivity and is quite irregular in thickness.

The Morrow is overlain unconformably by Atokan beds, specifically the "Thirteen Finger" Limestone in some of the area. In the north and east part of the study area, where the Morrow is absent, the Atoka overlies the Chester.

The Morrowan section is subdivided into upper and lower units based on log features (which are not unique). However, the upper unit generally has a higher percentage of shale than the lower unit.

Regional stratigraphic correlation sections were prepared to show characteristics of the Morrow and its relationships with underlying and overlying units (Fig. 3 and Plates 1 to 5). The base of the "Thirteen Finger" Limestone was used as a marker because of its lateral continuity

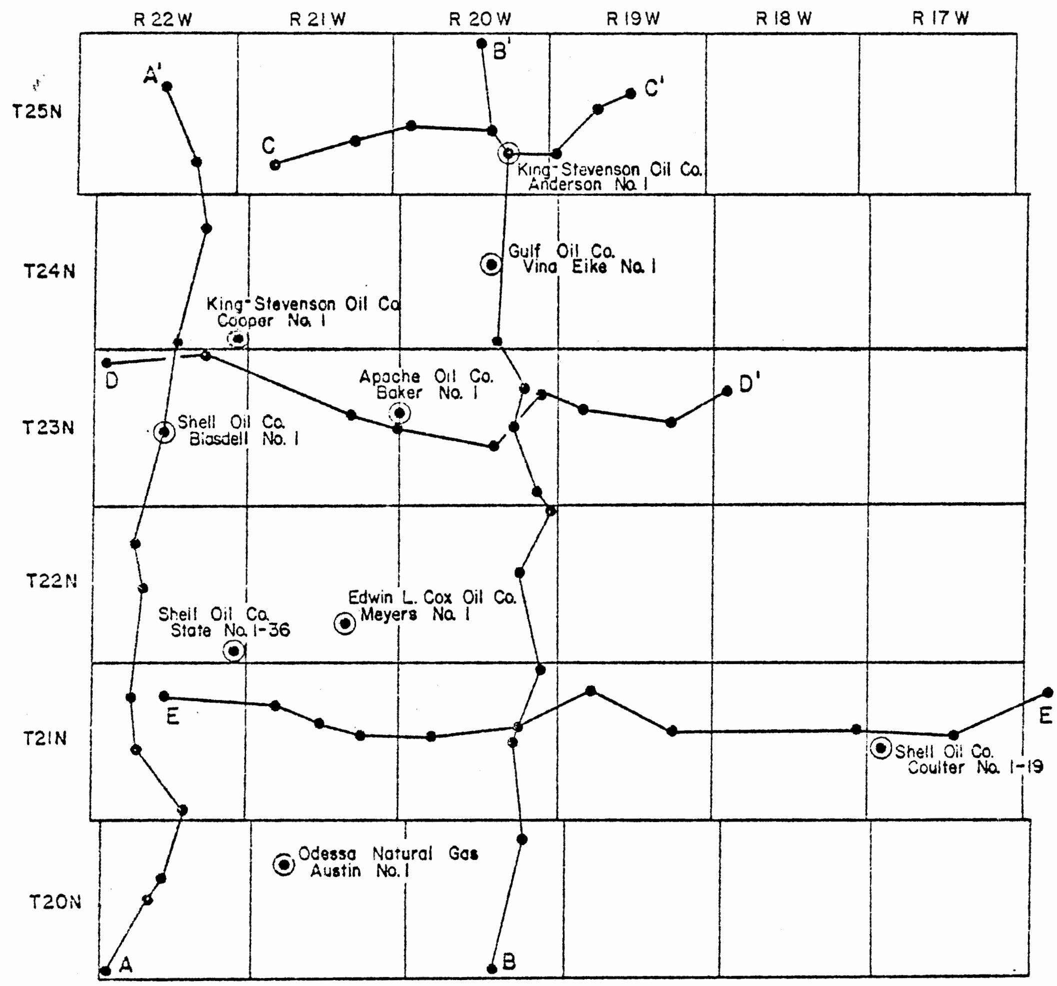


Fig. 3.--Location map of correlation sections and cores used in the study.

across the area. Although truncation of upper Morrowan beds by Atokan exists, it is thought that this contact is a marker bed that is useful for mapping structural geology.

Total thickness of both lower and upper Morrow intervals ranges from zero in the northeast to greater than 900 ft in the southwest. Thickness of the upper unit is less variable. The upper unit extends farther to the northeast than the lower unit.

Sandstones in both the lower and upper Morrow units are commonly recognized by well-log characteristics, but they are not everywhere distinguishable on logs from the Chester limestone below. In some local areas, individual sandstones can be delineated; for example, in the "Woodward channel" area.

CHAPTER V

GEOMETRY OF MORROWAN SERIES

Gradual southwestward thickening of both the lower and upper Morrow units is shown in Plates 7 and 8. The lower unit thickens from zero in the east to greater than 250 ft in the south and west; the upper Morrow unit ranges from zero in the east to greater than 700 ft in the southwest. The lower Morrow unit isopach map portrays the presence of a broad, well defined south-trending channel-like feature in T23-25N, R20W. The "Woodward channel" or "Woodward trench" are local names applied to this area of anomalous thickening of Morrowan strata.

Generally, net-sandstone content increases to the south and southwest in both the upper and lower Morrow units (Plates 9 and 10). Net sandstone is defined as that interval with significant SP and gamma-ray deflections and associated resistivity values greater than 10 ohm-m, or conductivity values less than 100 millimhos/m.

Thickness of sandstone in the lower Morrow unit is greatest in the "Woodward trench" area and in the southwest part of the study area. The latter reflects overall thickening of the section in tht direction. Maximum thickness is greater than 180 feet. Sandstone within the "Woodward channel" locally is almost as thick as 75 ft. Length of the channel is greater than 20 miles, and width is less than 5 miles. Electric-log characteristics and core analysis indicate sandstone there shows sharp basal contacts, whereas upper contacts are gradational with siltstones and shales. Based on correlation sections, lateral contacts also appear sharp.

Another area of sandstone thickening in the lower Morrow unit occurs in the southwest part of the study area. Areas of thicker sandstones trend south and west and are arranged in a branching pattern; length and width for the general area of thick sandstone are on the order of 25 miles. Individual belts have lengths greater than 20 miles and widths of 2 to 5 miles; thickness ranges from about 100 feet to greater than 200 ft. Logs show the basal and lateral contacts to be sharp; the upper contacts also appear to be sharp, although not as sharp as the lower.

Overall sandstone development in the upper Morrow unit is less than that of the lower unit and fewer trends are recognizable. A local belt of thick sandstone in the "Woodward channel" area is similar in length, width, and trend to the lower sandstone in the same area, although the sandstone thickness in the upper unit is generally less than 60 ft. Based on electric-log characteristics and core data, lower contacts are predominantly gradational; however, sharp boundaries are common. Upper and lateral boundaries are gradational. Another sandstone belt trends southward in the southwest portion of the study area. Length is greater than 20 miles; width ranges from 2 to 4 miles. Thickness ranges from less than 60 ft in the north to greater than 180 ft in the southern part of the study area. Upper and lower contacts of sandstones appear to be sharp, but gradational contacts are common. Lateral boundaries are thought to be gradational.

CHAPTER VI

INTERNAL FEATURES

Sedimentary Structures and Texture

Generally, there are three groups of sedimentary structures and associated textural features present in the Morrow sandstones. They are cross-bedding with flowage, bioturbated and cross-bedded/ripple-laminated sandstones, and interlaminated siltstones, sandstones, and shales, with burrows and horizontal lamination.

The sedimentary structure assemblage of cross-bedding with flowage characterize the Morrow fluvio-deltaic deposits. Cross-bedding generally is medium-scale. It usually occurs in fine- to medium-grained, moderately sorted sandstones. Flowage features include those derived from fluidization processes and minor slumping (Figs. 7b and 11b). The King-Stevenson Anderson No. 1 core (Figs. 10 and 11) shows examples of this group of structures, one from 7080-7144 (Fig. 11b) and another from 7191-7230 (Fig. 11c).

The group characterized by bioturbation with cross-beds and laminae is thought to be characteristic of tidal ridges and shoals. Bioturbation includes horizontal and vertical burrowing; it ranges in intensity from slight to moderately heavy, commonly masking the original structures. Ripple lamination is more common than medium-scale cross-bedding; flowage features are present but uncommon. This zone typically occurs in coarse silt to very fine-grained sandstones with fair sorting, and commonly, skeletal limestone lenses are present. The Edwin L. Cox Myers No. 1 (Fig. 6, 8748-8795 ft) and the Shell State No. 1-36 (Fig. 20, 9130-9150 ft) are examples of this group which is common in sandstone units of the Upper Morrow.

Interlaminated siltstone and shale with burrows and horizontal and ripple lamination are thought to be indicative of a tidal flat environment. Horizontal burrows occur in moderate intensity; flowage is present as a minor feature. This group of structures is present in the Odessa Austin No. 1 core (Fig. 14, 9900-9908 ft) and the Shell State No. 1-36 (Figs. 20 and 21) at the following intervals: 9112-9128 ft, 9234-9250 ft, and 9283-9290 ft.

Fossils

Lenses containing abundant fragments of marine fossils are present in various sandstone bodies of the Morrow and to a lesser extent in the siltstone/shale and shale sequences. Crinoid stems and echinoderm debris are the dominant body-fossil constituents, although pelecypods, bryozoans, and brachiopods are present.

Trace fossils are common throughout bioturbated intervals of Morrow sandstones. All of them are thought to be shallow marine forms.

Constituents

Sandstones of the Morrowan Series, based on thin section studies, are classified as quartzarenites, feldspar, metamorphic rock fragments, and heavy minerals are accessories. Intraformational clasts include skeletal limestone clasts and ooliths, clay grains and isolated pebbles of phosphate, clay and sideritic clay. Matrix components include patchy concentrations of clay and calcite cement. Silica cement and overgrowths are very common in the well-sorted sandstones.

Core Description

Each core is described herein in terms of internal features and stratigraphic position. Detailed descriptions are on petrographic logs, accompanied by photographs.

Apache Baker No. 1, Sec. 13, T23N, R21W

The cored interval in the Apache Baker No. 1 contains 80 ft of upper Morrow unit sandstone, siltstone, and shale, and 16 ft of lower Morrow unit sandstone (Figs. 4 and 5).

Overlying a basal shale, the sandy interval in the upper unit (7782-7820 ft) contains abundant glauconite, fossil debris, and limestone fragments of small pebble size. The unit is predominantly very fine- to fine-grained shaly sandstone with abundant calcite cement. Bioturbation and flowage are present along with some ripple and medium-scale cross-bedding. The unit may represent a shallow-marine sand sheet or coastal bar.

The sandstone in the lower Morrow unit is very fine- to medium-grained, locally conglomeratic, quartzarenitic in composition and characterized by abundant carbonaceous material. Flowage and medium-scale cross-bedding predominate in the lower part whereas the upper part is bioturbated. The lower unit was probably deposited in a deltaic distributary environment, but the bioturbation suggests shallow marine conditions.

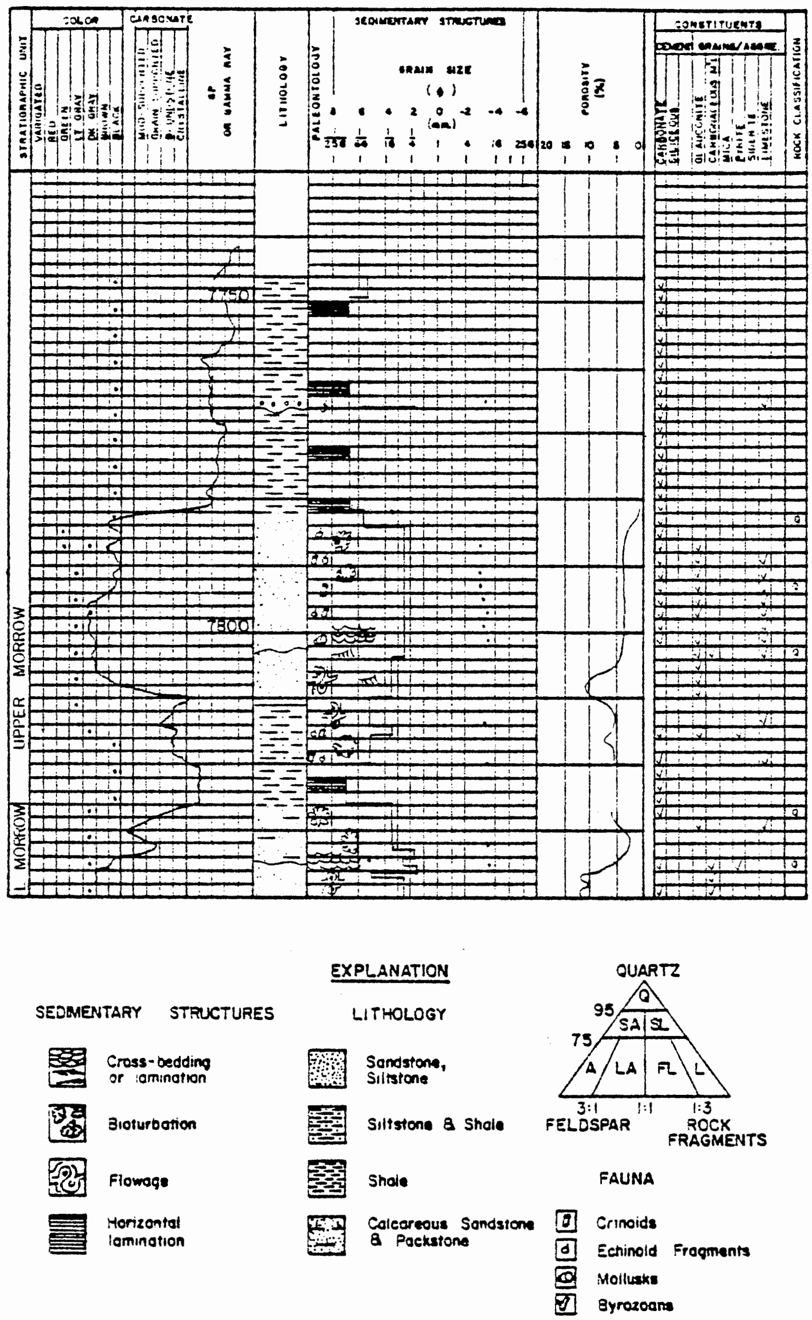


Fig. 4.--Core description of the Apache Baker No. 1.

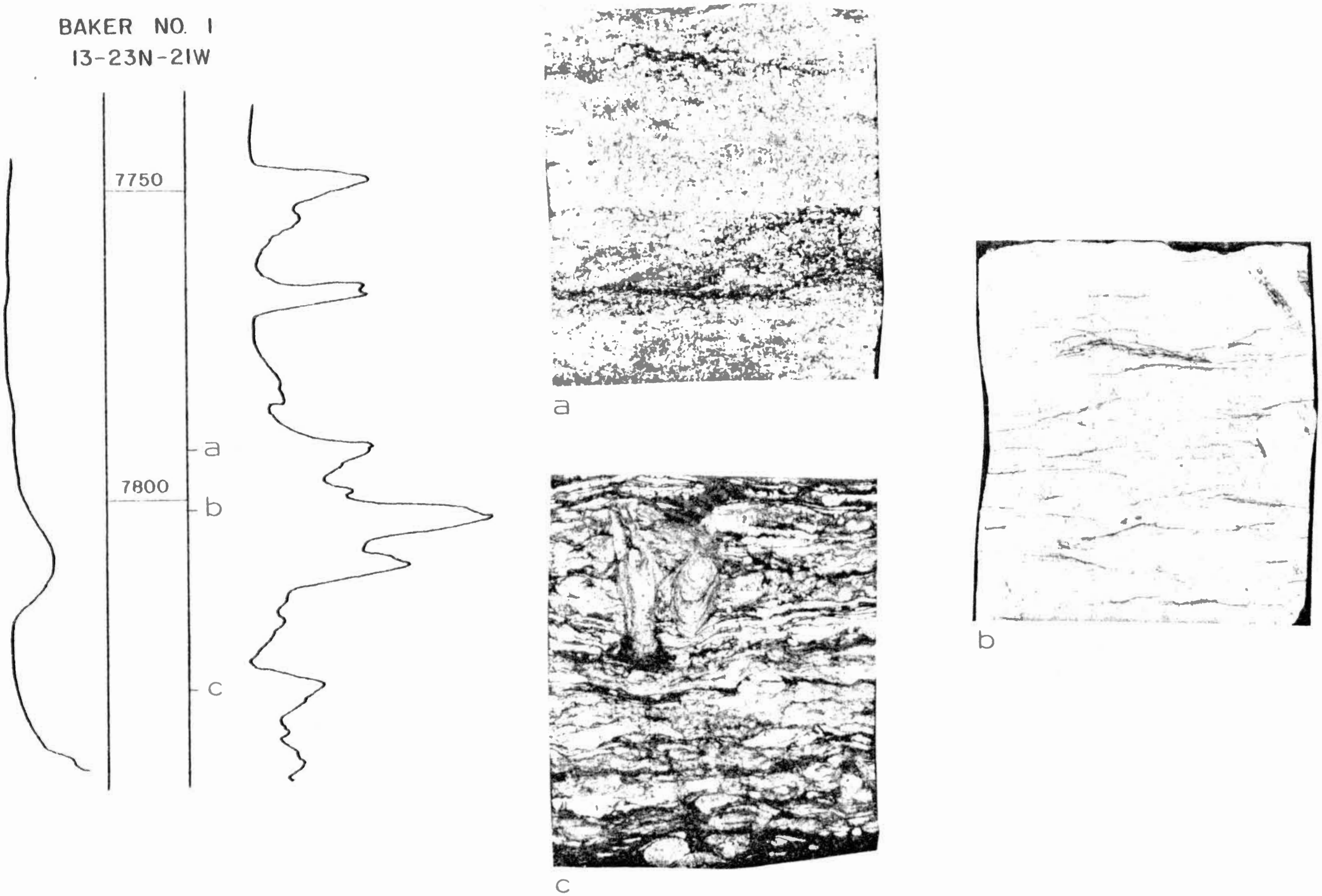


Fig. 5.--Sedimentary features include limestone conglomerate (a) and ripple lamination (b) in sandstones in the upper unit of the Morrowan SEries and burrows (c) in sandstones of the lower unit of the Morrowan Series.

Edwin L. Cox Myers No. 1, Sec. 27, T22N, R21W

The Edwin L. Cox Meyers No. 1 cored interval consists of 78 ft of the upper unit and 10 ft of lower unit (Figs. 6 and 7).

The upper unit, with its base at 8807 ft, overlies 7 ft of fossiliferous shale. It is very fine- to medium-grained sandstone (quartzarenite) and contains abundant glauconite and calcite cement. Local concentrations of fossil and limestone fragments are present. The interval is characterized by abundant bioturbation and ripple-lamination in the upper part (8748-8807 ft) and medium-scale cross-bedding and flowage in the lower part (8784-8807 ft).

The thin sandstone (8814-8822 ft) in the lower Morrow unit consists of a pebbly, medium-grained sandstone with carbonaceous material, siderite and phosphate pebbles. This unit overlies carbonaceous shale.

It is thought that the abundant bioturbation, glauconite, ripple cross-lamination, fossil fragments and phosphate pebbles are features suggestive of a shallow marine setting. More specifically, the lower Morrow sandstone displays features similar to a tidal channel and the thick upper Morrow sandstone section probably represents a tidal ridge or shoal complex. Sandstone in the lower Morrow unit (at 8814-8822 ft) represents a transgression.

Gulf Vina Eike No. 1, Sec. 15, T24N, R20W

The core in the Gulf Vina Eike No. 1 contains 29 ft of the upper Morrow unit and 20 ft of the lower Morrow unit (Figs. 8 and 9).

Sandstone in the upper unit (at 7384-7399 ft) is very fine- to medium-grained quartzarenite and contains abundant glauconite. The intense bioturbation and glauconite suggest a shallow marine sand bar

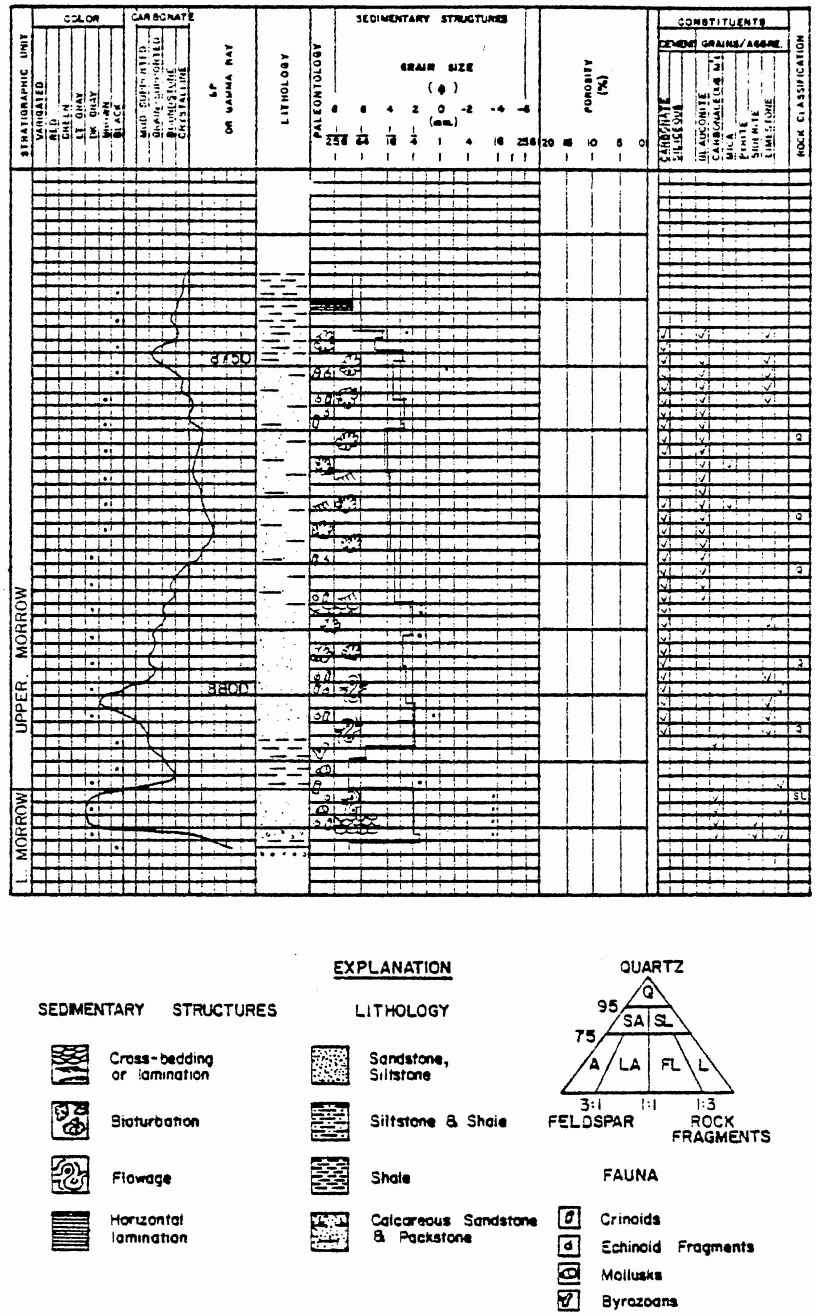


Fig. 6.--Core description of Edwin L. Cox Meyers No. 1.

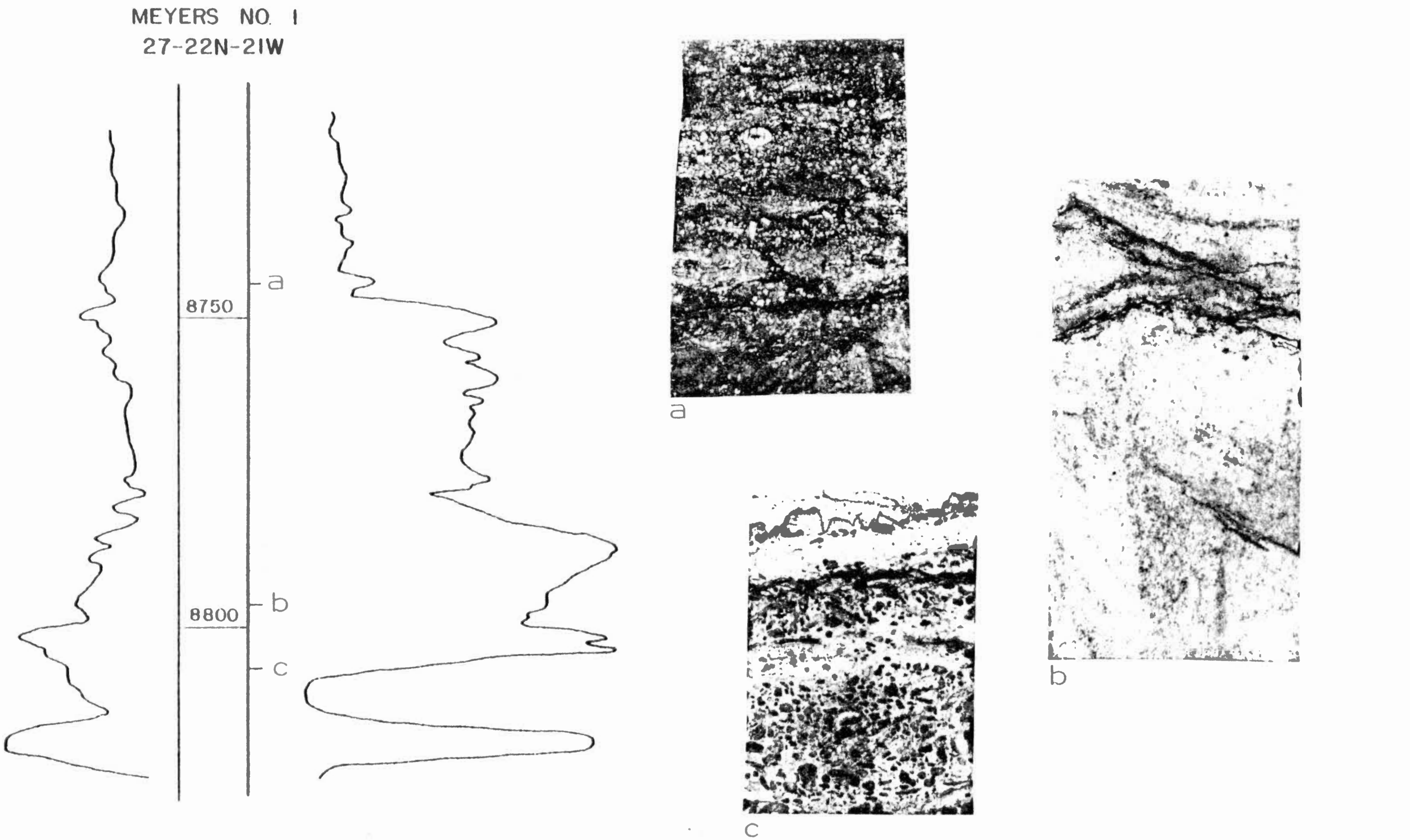


Fig. 7.--Sedimentary features include bioturbation (a) and flowage of cross-bedded unit (b) in sandstones of the upper unit of the Morrowan Series and basal conglomeratic lens (c) in the sandstones of lower unit of the Morrowan Series.

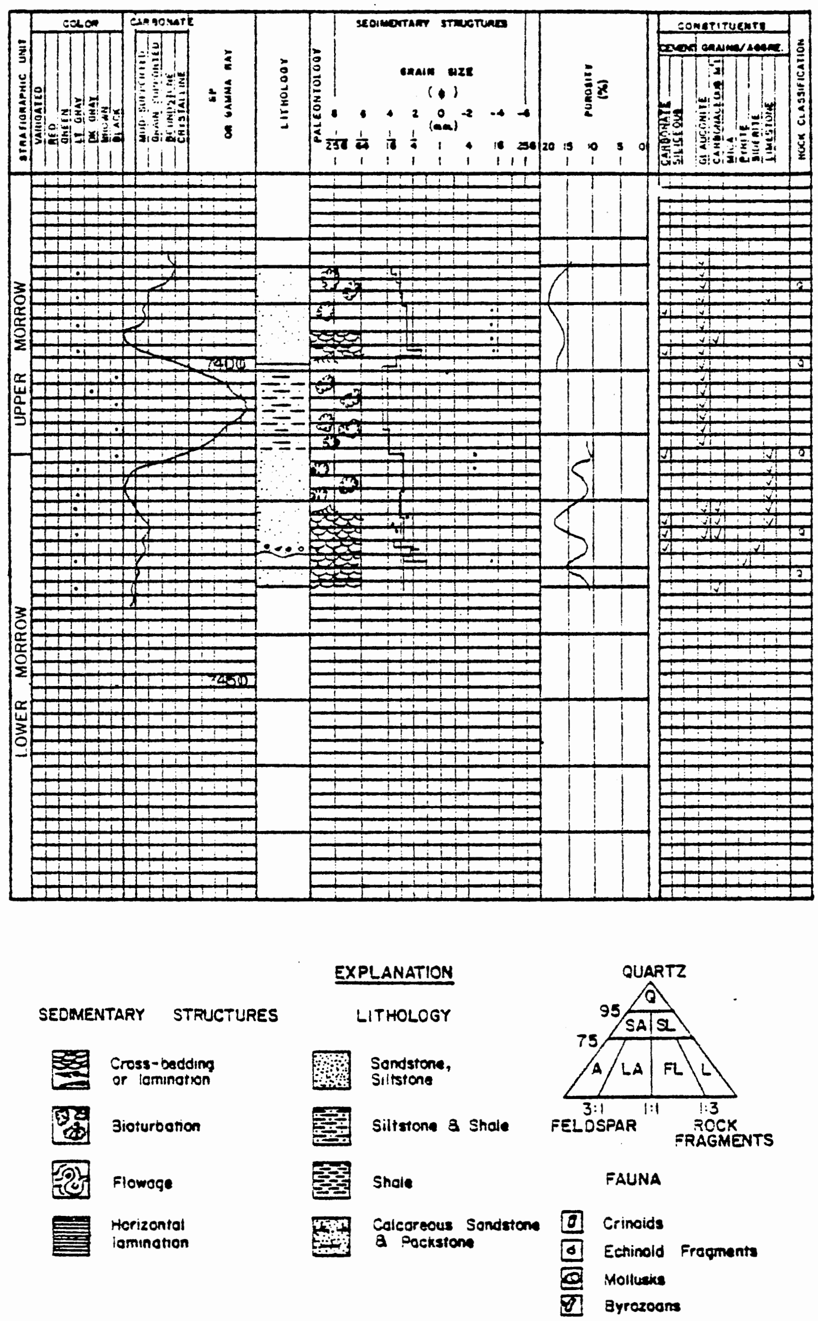


Fig. 8.--Core description of the Gulf Vina Eike No. 1.

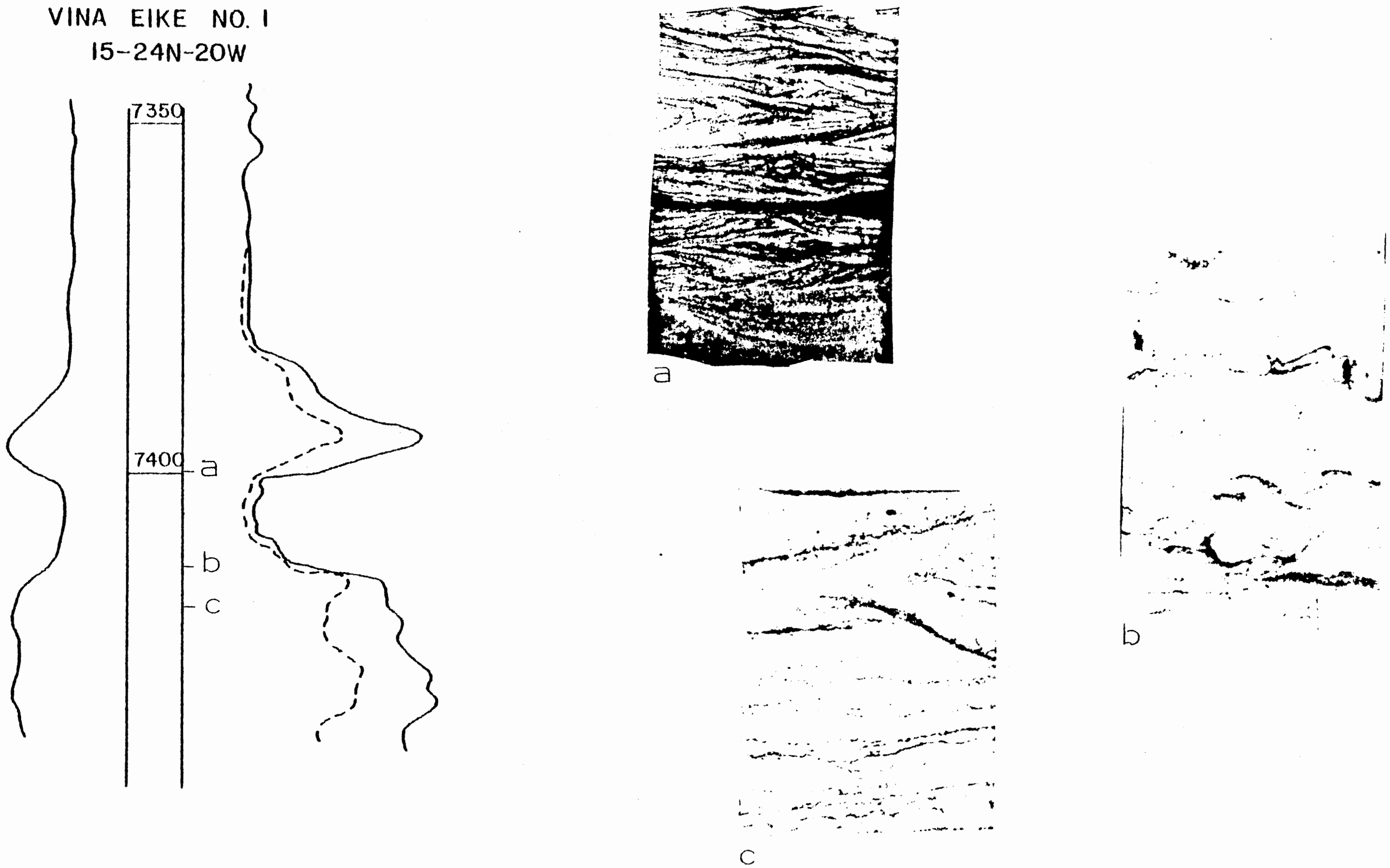


Fig. 9.--Selected sedimentary features include ripple cross-lamination (a) in the sandstones of the upper unit of the Morrowan Series and burrows (b) and medium-scale cross-bedding (c) in the sandstones of the lower unit of the Morrowan Series.

environment. The pebbly unit (7393-7398 ft) containing medium-scale cross-bedding and carbonaceous matter is thought to be indicative of a channel environment, possibly a tidal channel.

Sandstone in the lower unit (at 7412-7433 ft) is quartzarenitic and fine- to medium-grained; it contains carbonaceous material at the base. Sedimentary structures include medium-scale cross-bedding, ripple cross-lamination and local burrowing. A conglomeratic lens directly overlies a possible scour surface at 7428 ft.

It is thought that the sandstone in the upper Morrow unit is the result of a marine transgression and subsequent bar sand development over a lower Morrow channel system.

King-Stevenson Anderson No. 1, Sec. 26, T25N, R20W

The King-Stevenson Anderson No. 1 core contains 27 ft of the upper unit and 144 ft of the lower unit (Figs. 10 and 11).

In the interval 7054-7105 ft, very fine- to fine-grained sandstones are interbedded with shales. Glauconite is abundant and minor amounts of carbonaceous material, pyrite and bioclastic debris are present. Common sedimentary structures include bioturbation and ripple cross lamination. These features suggest a shallow-marine sand sheet, and the medium-scale cross-bedded sand at 7093-7099 ft may represent a tidal channel.

The sandstones from 7105-7138 ft are very fine- to coarse-grained and locally conglomeratic; they contain abundant carbonaceous material and limestone clasts. Predominant sedimentary structures include medium-scale cross-bedding and ripple lamination, flowage and graded conglomeratic lenses at the base of the core (at 7146 ft).

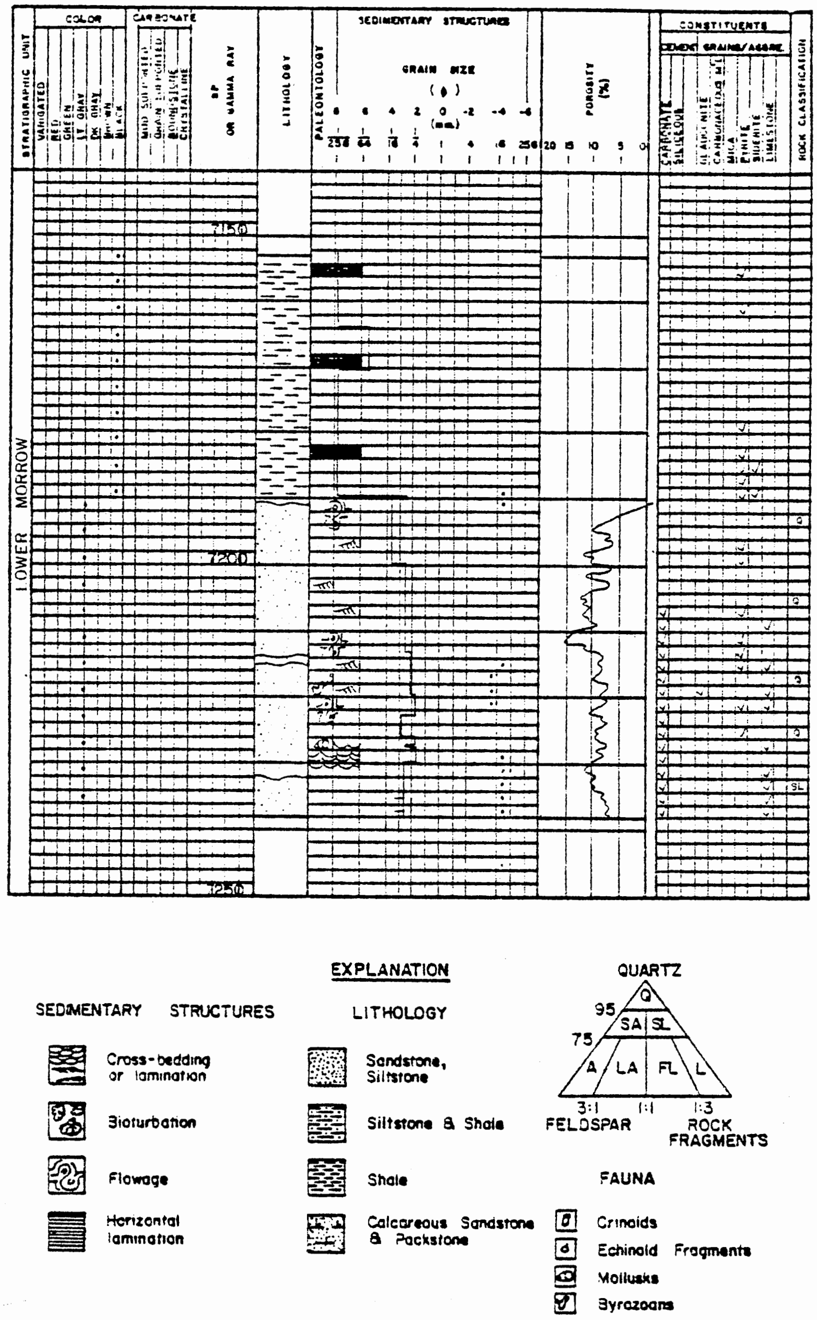


Fig. 10.--Core description of the King-Stevenson Anderson No. 1.

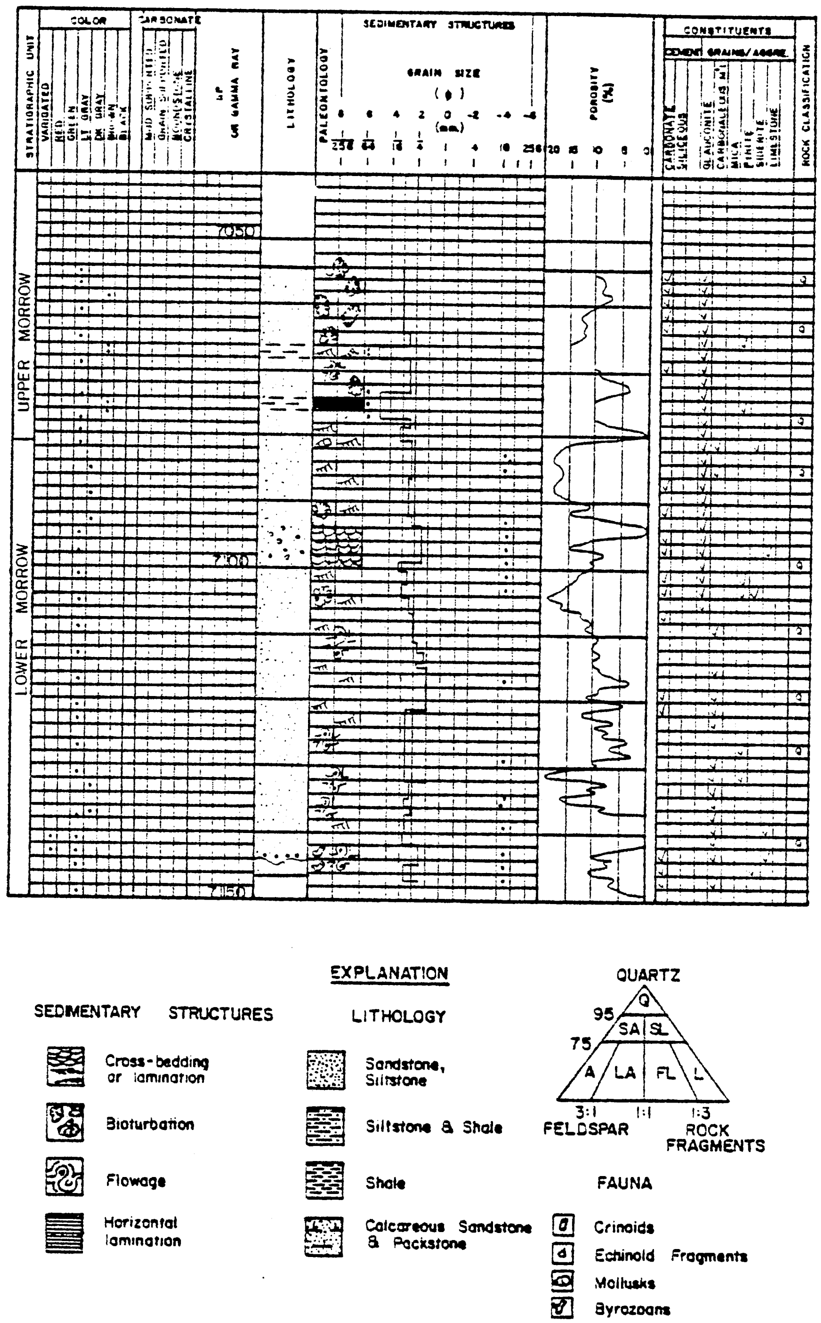


Fig. 10.--(Continued).

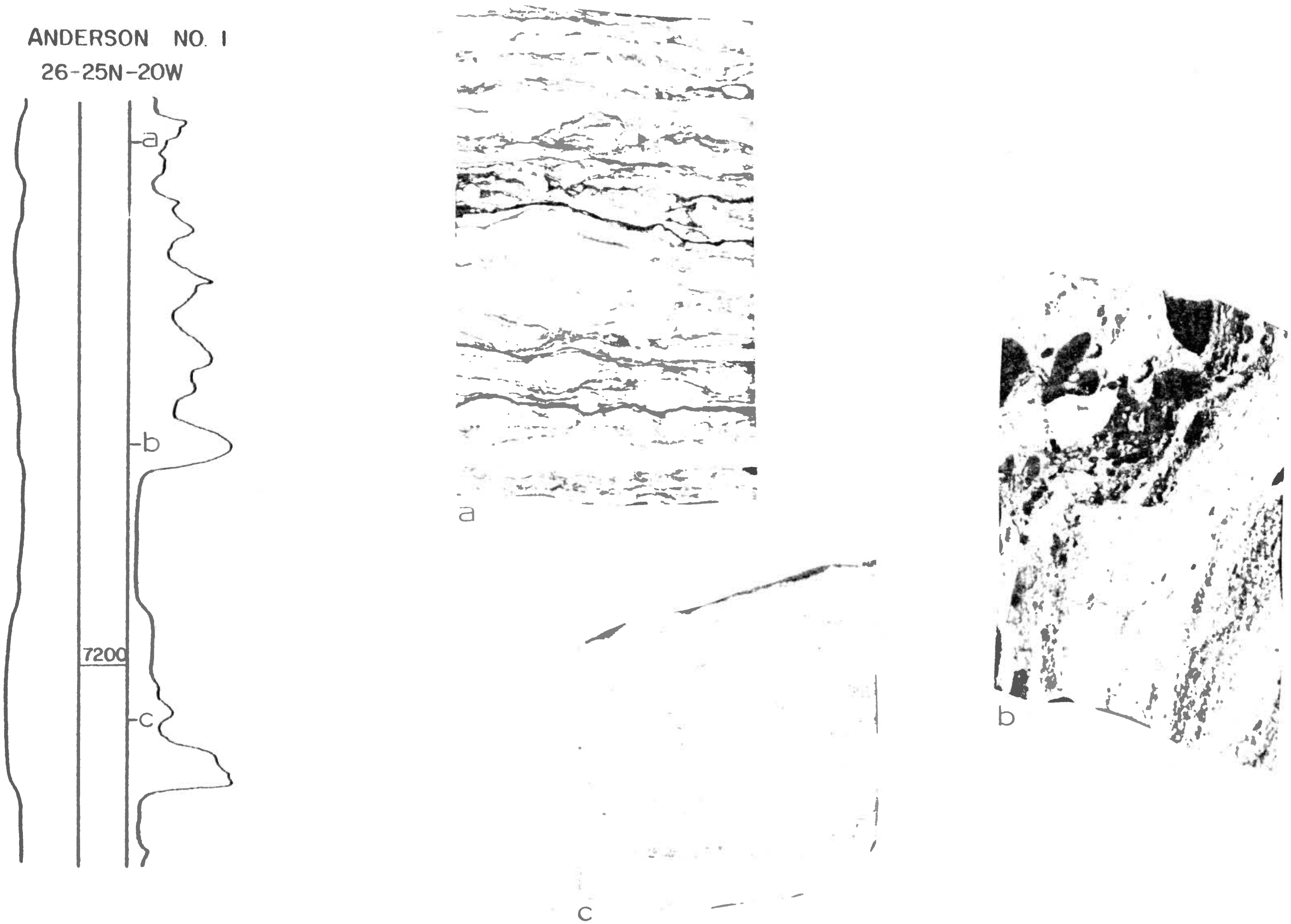


Fig. 11.--Bioturbation (a) in sandstones of the upper unit of the Morrowan Series and flowage (b), medium-scale cross bedding (c) in sandstones of the lower unit of the Morrowan Series.

It is thought that these structures represent a channel deposit of a fluvio-deltaic system. The abundant bioclastic debris and limestone rock fragments in the interval 7210-7238 ft may represent Chester limestone fragments eroded by the Morrow channel. Locally abundant glauconite (7109-7144 ft) suggests a gradual increase of marine conditions upward in the core.

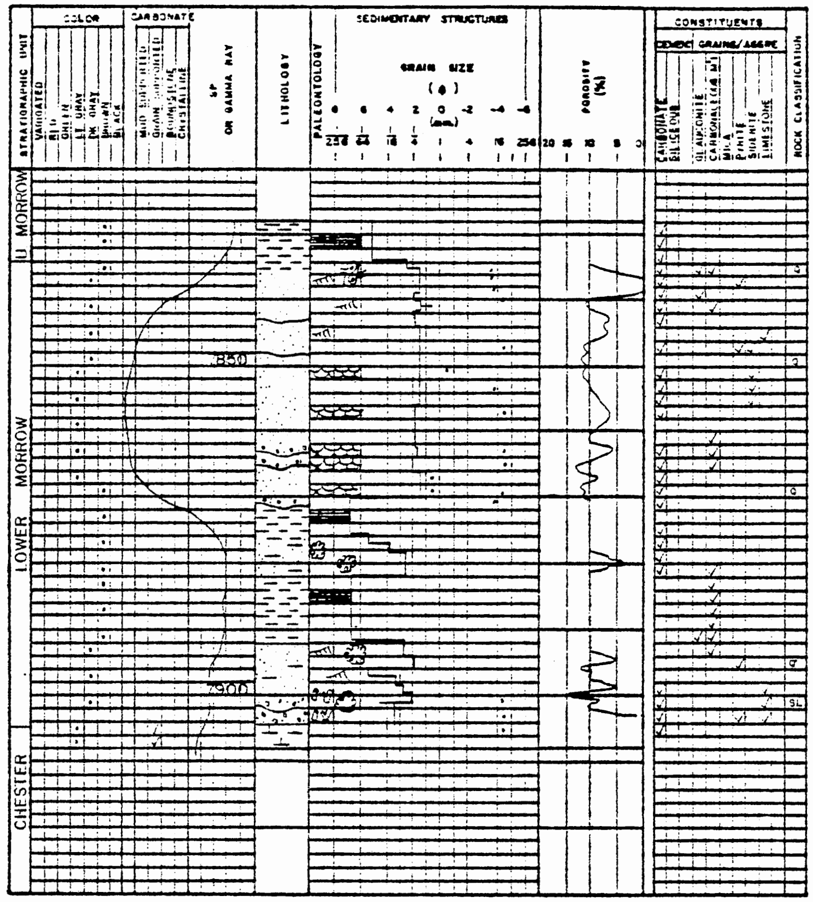
King-Stevenson Cooper No. 1, Sec. 36, T24N, R22W

The King-Stevenson Cooper No. 1 core consists of 71 ft of the lower Morrow unit, including a thick, medium-grained sandstone from 7835-7871 ft (Figs. 12 and 13). Constituents include abundant calcite cement and carbonaceous material with lesser amounts of limestone and siderite pebbles. Both ripple and medium-scale cross-bedding are prevalent in the unit along with some flowage.

The subjacent unit is a marine shale which contains a clayey, fine-grained, bioturbated sandstone (7876-7882 ft) with abundant carbonaceous materials.

The lowermost part of the cored interval (7892-7904 ft) consists of very fine- to medium-grained sandstone. It contains abundant fossil fragments and calcite cement; ripple cross-lamination and bioturbation are present. This marine unit rests directly on Chester limestone.

Ripple and medium-scale cross-bedding, flowage, abundant carbonaceous material, lack of glauconite and fossil fragments (except at the base) are features which suggest a deltaic distributary environment for the sandstone.



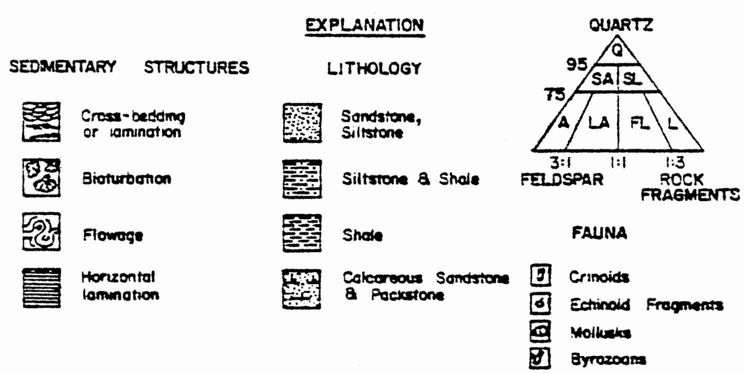


Fig. 12.--Core description of the King-Stevenson Cooper No. 1.

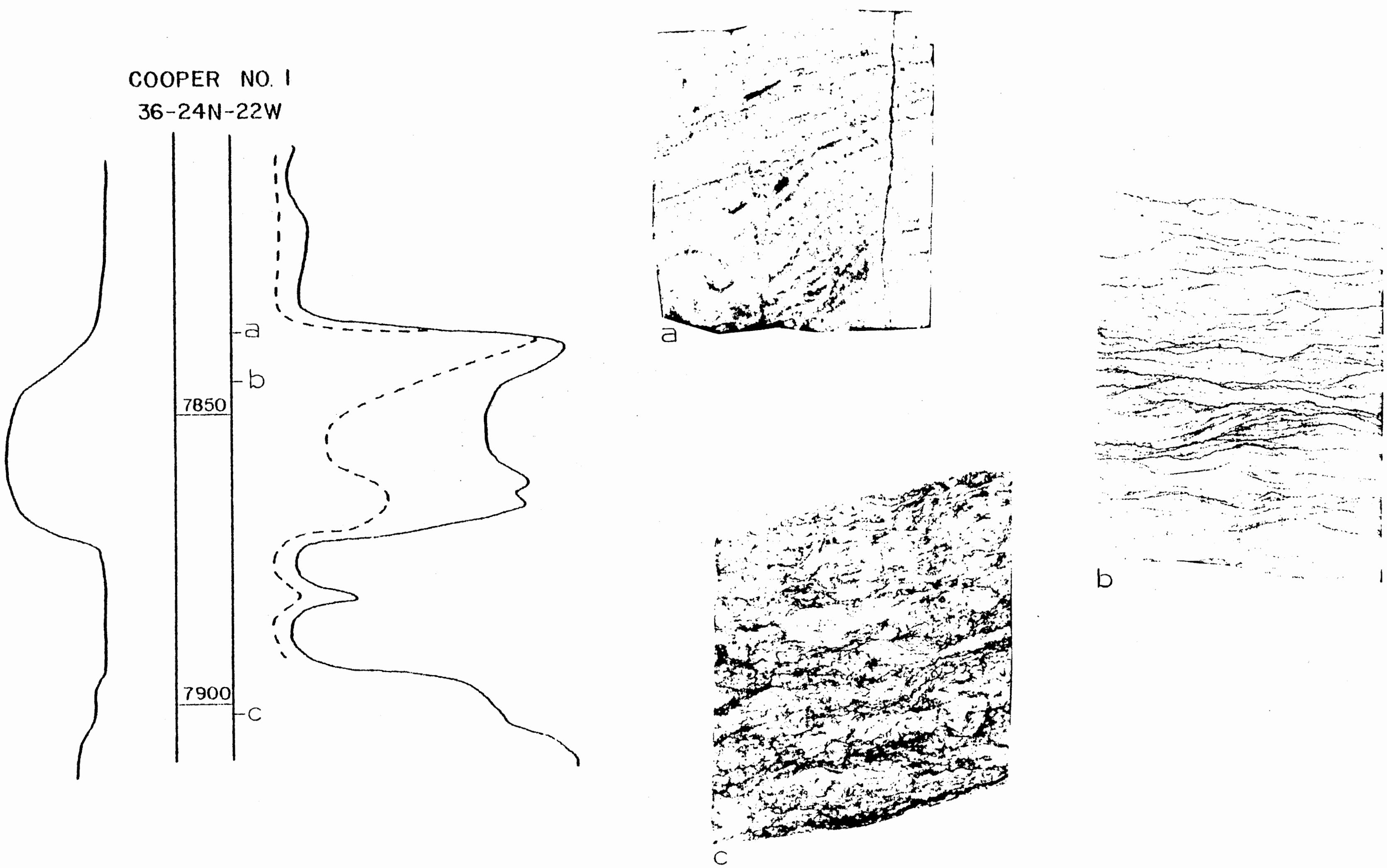


Fig. 13.--Sedimentary features in sandstones of the lower unit of the Morrowan Series include convolute bedding (a), ripple cross-lamination (b), and bioturbation (c).

Odessa Austin No. 1, Sec. 8, T20N, R21W

The Odessa Austin No. 1 contains core from the upper Morrow unit which shows alternating bioclastic sandstone and siltstone-shale facies (Figs. 14 and 15). The sandstones are fine- to coarse-grained; they commonly contain limestone pebbles, fossil debris, glauconite and pyrite. The whole interval contains abundant calcium carbonate cement. Sedimentary structures include abundant bioturbation and horizontal lamination, and minor amounts of ripple cross lamination and flowage.

These features suggest deposition in the distal portion of a shallow marine sand sheet.

Shell Blasdell No. 1, Sec. 21, T23N, R22W

The Shell Blasdell No. 1 core consists of 37 ft of the upper Morrow unit and 60 ft of the lower unit (Figs. 16 and 17).

Core of the upper unit shows horizontally laminated shale which increases upward in sand content (to 8170 ft). The sandiest portion (at 8170-8177 ft) consists of a bioturbated, very fine- to fine-grained sandstone with calcite cement and siderite pebbles. This sequences is overlain by a horizontally laminated shale containing pyrite and siderite.

Core of the lower Morrow unit consists mostly of fine- to coarse-grained sandstone, which in places is quite shaly. Carbonaceous material is common throughout, and limestone fragments are present at the base. Shaly units contain considerable amounts of pyrite and are usually calcite cemented. Sedimentary structures include ripple and medium-scale cross-bedding, flowage and minor bioturbation. The sandstone immediately overlying the shale base is commonly conglomeratic with scour surfaces.

Conglomeratic lenses, ripple and medium-scale cross-bedding, flowage,

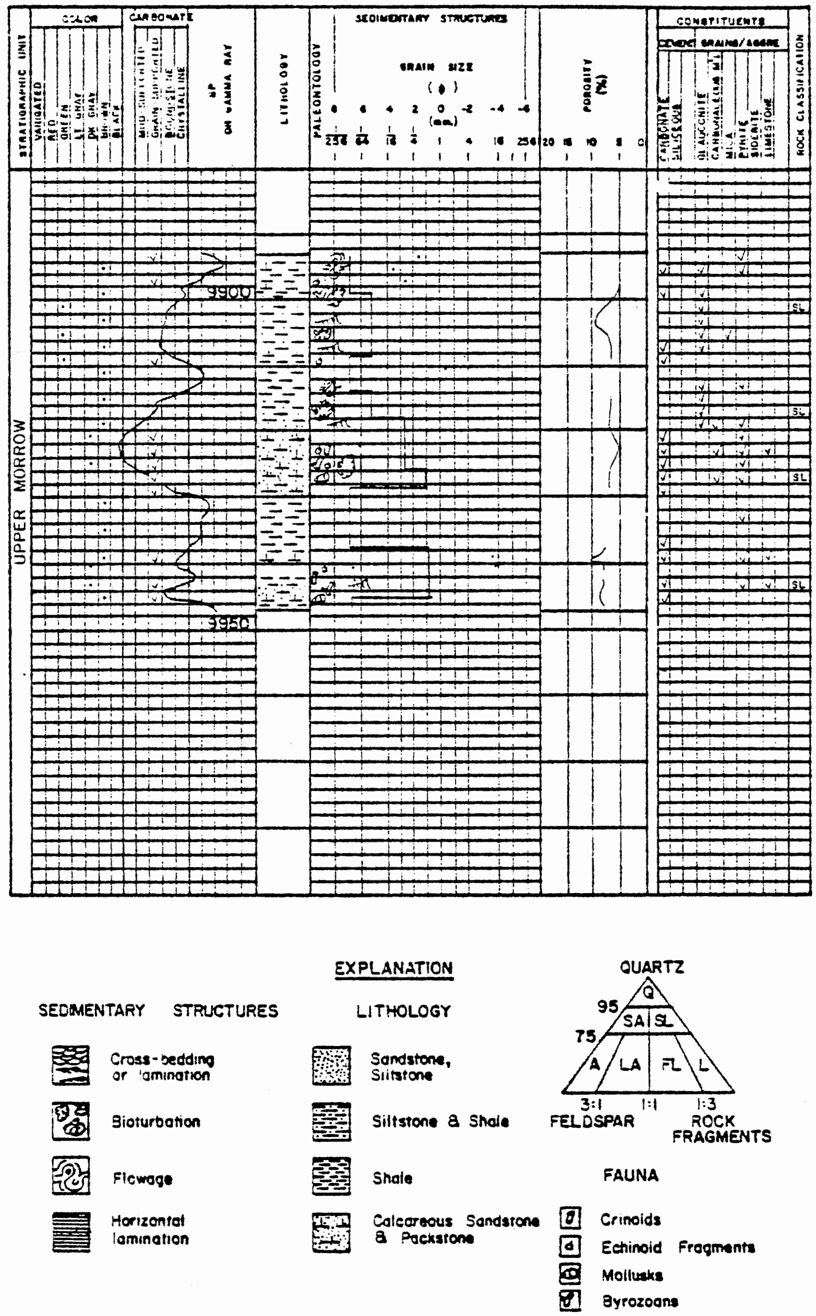


Fig. 14.--Core description of the Odessa Austin No. 1.

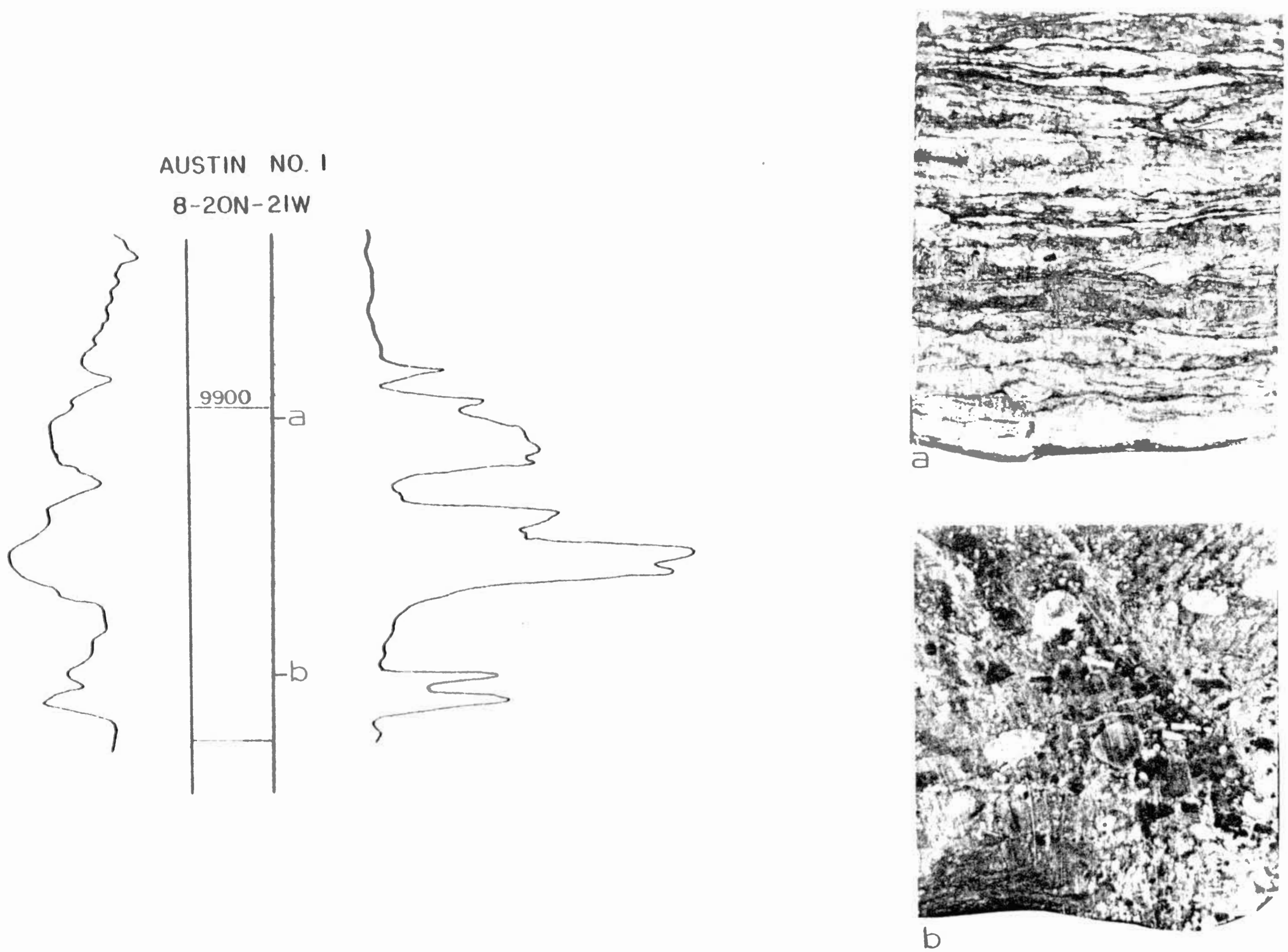


Fig. 15.--Selected sedimentary features of sandstones in the upper unit of the Morrowan Series include bioturbation of ripple cross-laminated unit (a) and limestone conglomerate unit (b).

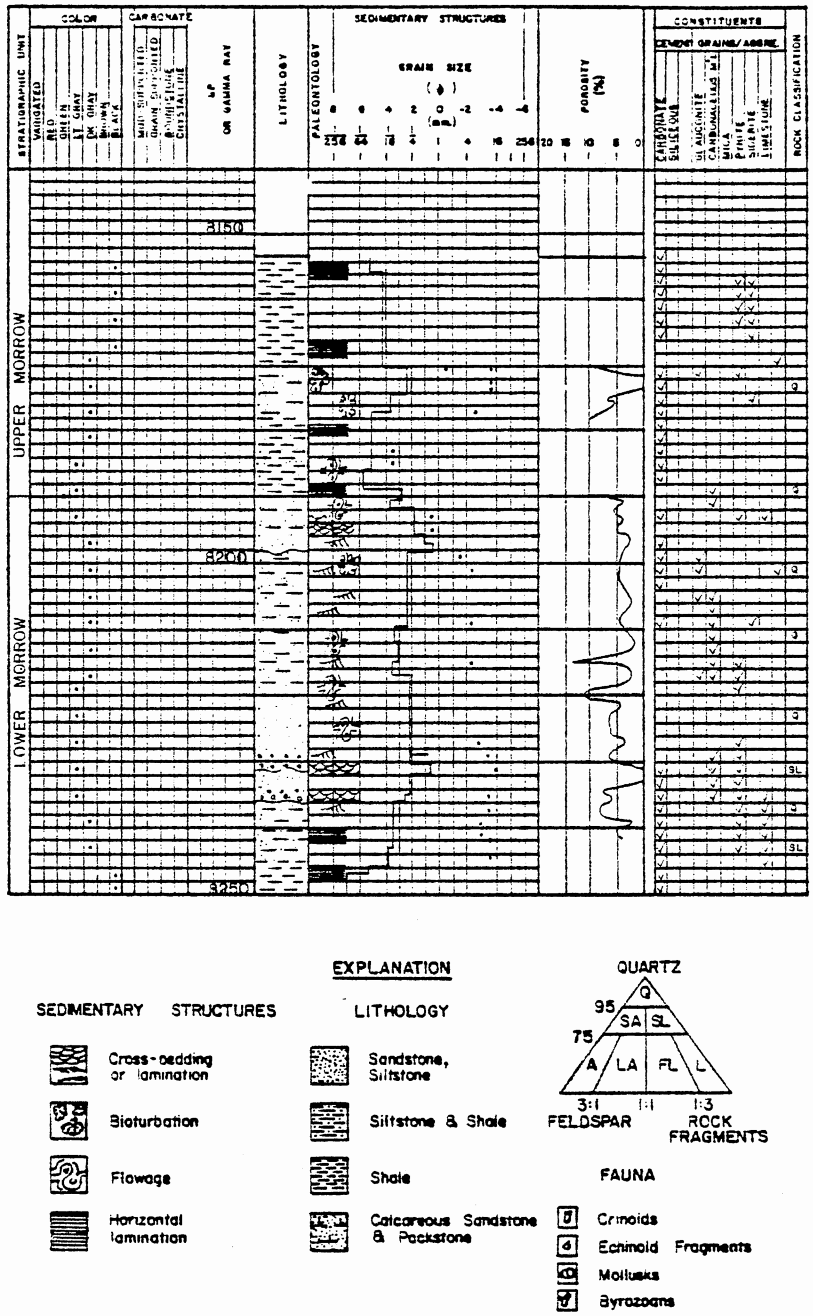


Fig. 16.--Core description of the Shell Blasdell No. 1.

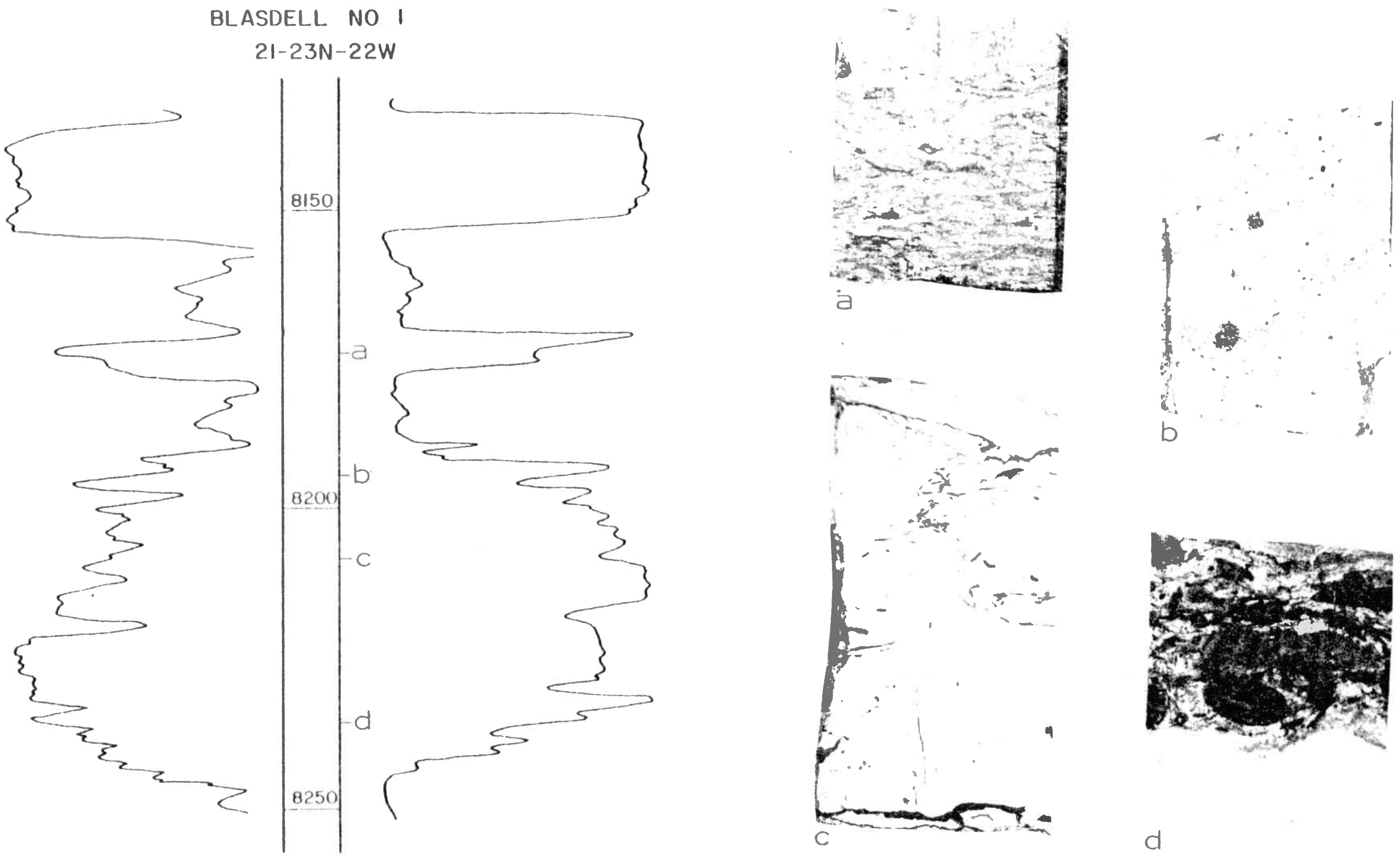


Fig. 17.--Bioturbation (a) in sandstones of the upper unit of the Morrowan Series and medium-scale cross-bedding (b), flowage (c) and conglomerate overlying scour surface (d) in sandstones of the lower unit of the Morrowan Series.

and abundant carbonaceous material suggest channeling features in a deltaic setting for the sandstones in the lower Morrow unit (at 8200-8236 ft). Bioturbation increases, and sand content decreases upward into the upper Morrow section, suggesting deposition in shallow-marine bar conditions.

The overall sequence indicates deltaic progradation across shallow marine shales and then a gradual transgression resulting in deposition of shallow marine sands, silts and muds.

Shell Coulter No. 1-19, Sec. 19, T21N, R17W

The Shell Coulter No. 1 cored interval contains 48 ft of the upper Morrow unit overlying 3 ft of Chester limestone (Figs. 18 and 19).

Core of the upper unit consists primarily of dark gray shales with a bioclastic, grain-supported limestone unit (grainstone) at 7898-7903 ft. The base of this unit is conglomeratic and overlies carbonaceous shales.

The carbonaceous shale (7904-7909 ft) represents a swamp or marsh-type environment. The bioclastic limestone represents a shallow marine coastal sand sheet that formed during transgression.

Shell State No. 1-36, Sec. 36, T22N, R22W

The Shell State No. 1-36 core contains 50 ft of the upper Morrow unit and 86 ft of the lower unit. The former consists of sandstones, siltstones, and shales; the latter, sandstones and shales.

Core of the upper Morrow unit (9112-9162 ft) contains a poorly developed, very fine-grained sandstone (9128-9150 ft) with locally abundant fossil and limestone rock fragments. Dominant constituents include calcite cement, glauconite, mica and pyrite. Bioturbation is

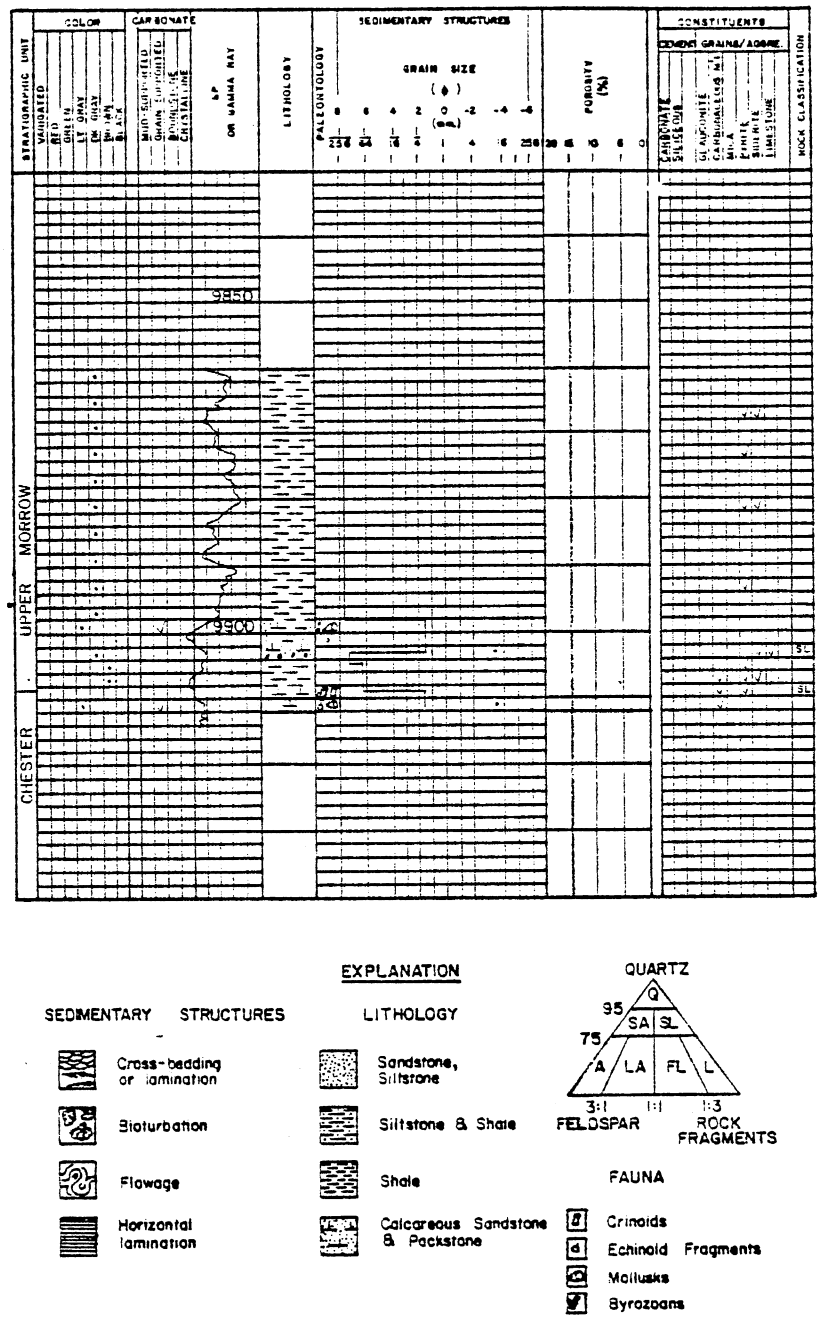


Fig. 18.--Core description of the Shell Coulter No. 1-19.

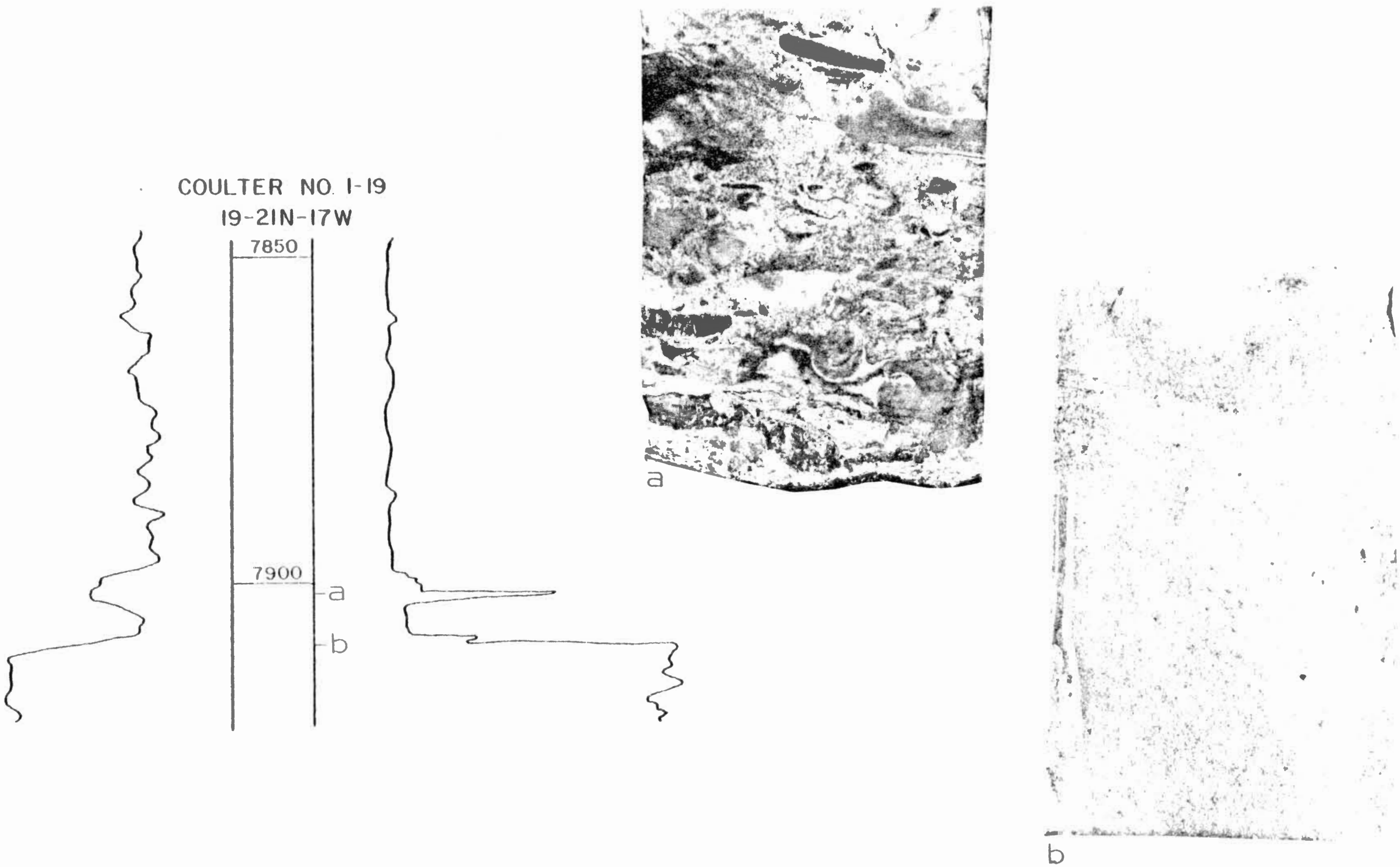


Fig. 19.--Selected features of the upper unit of the Morrowan Series include limestone-pebble conglomerate (a) and packstone unit (b).

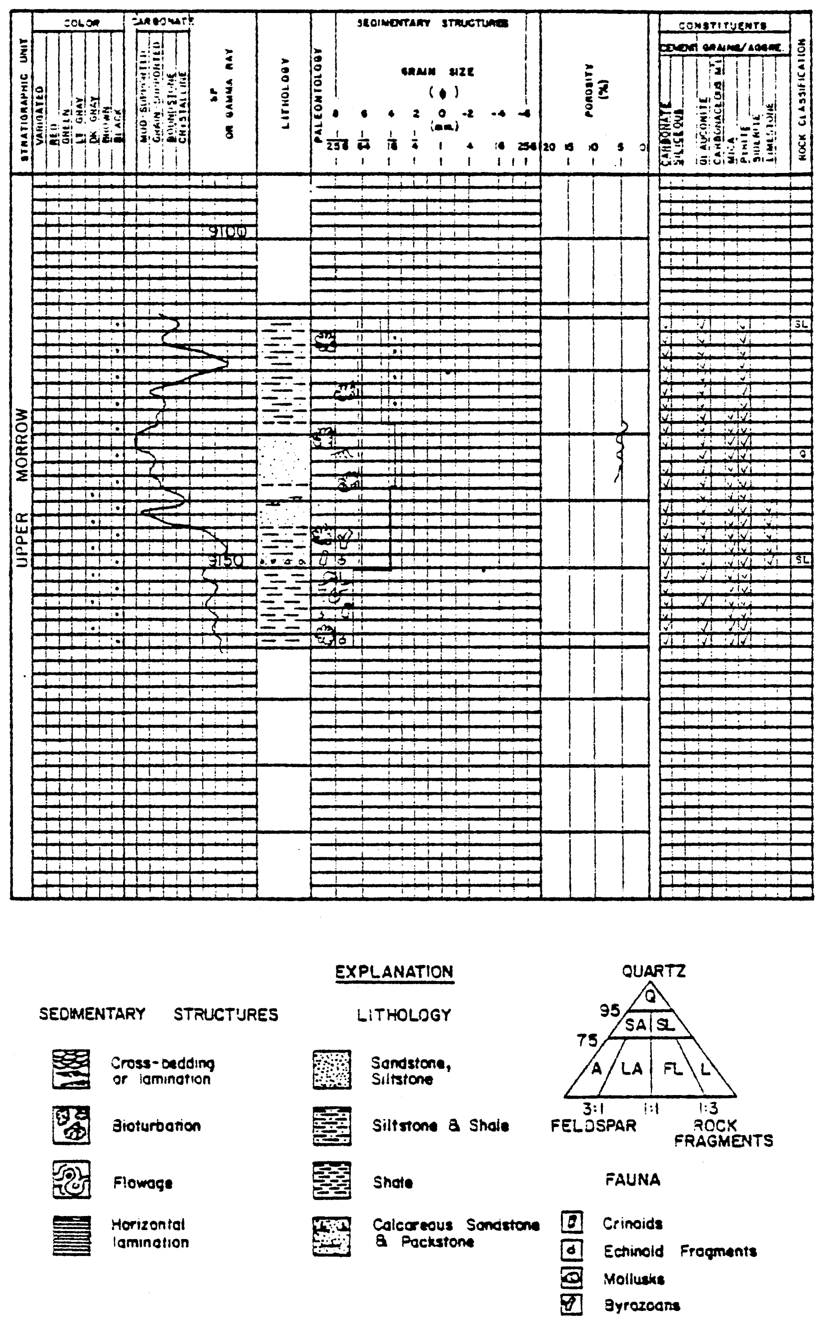


Fig. 20.--(Continued).

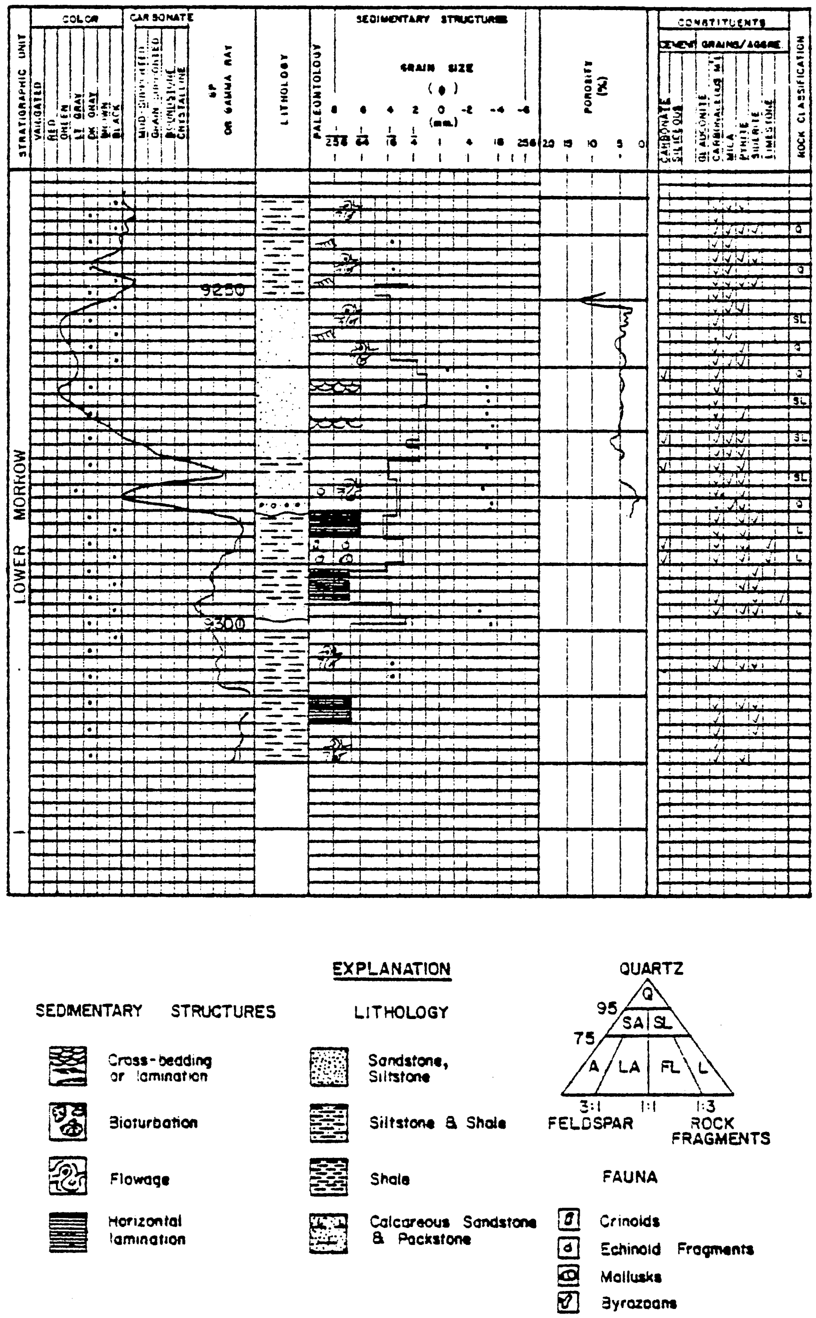


Fig. 20.--Core description of the Shell State No. 1-36.

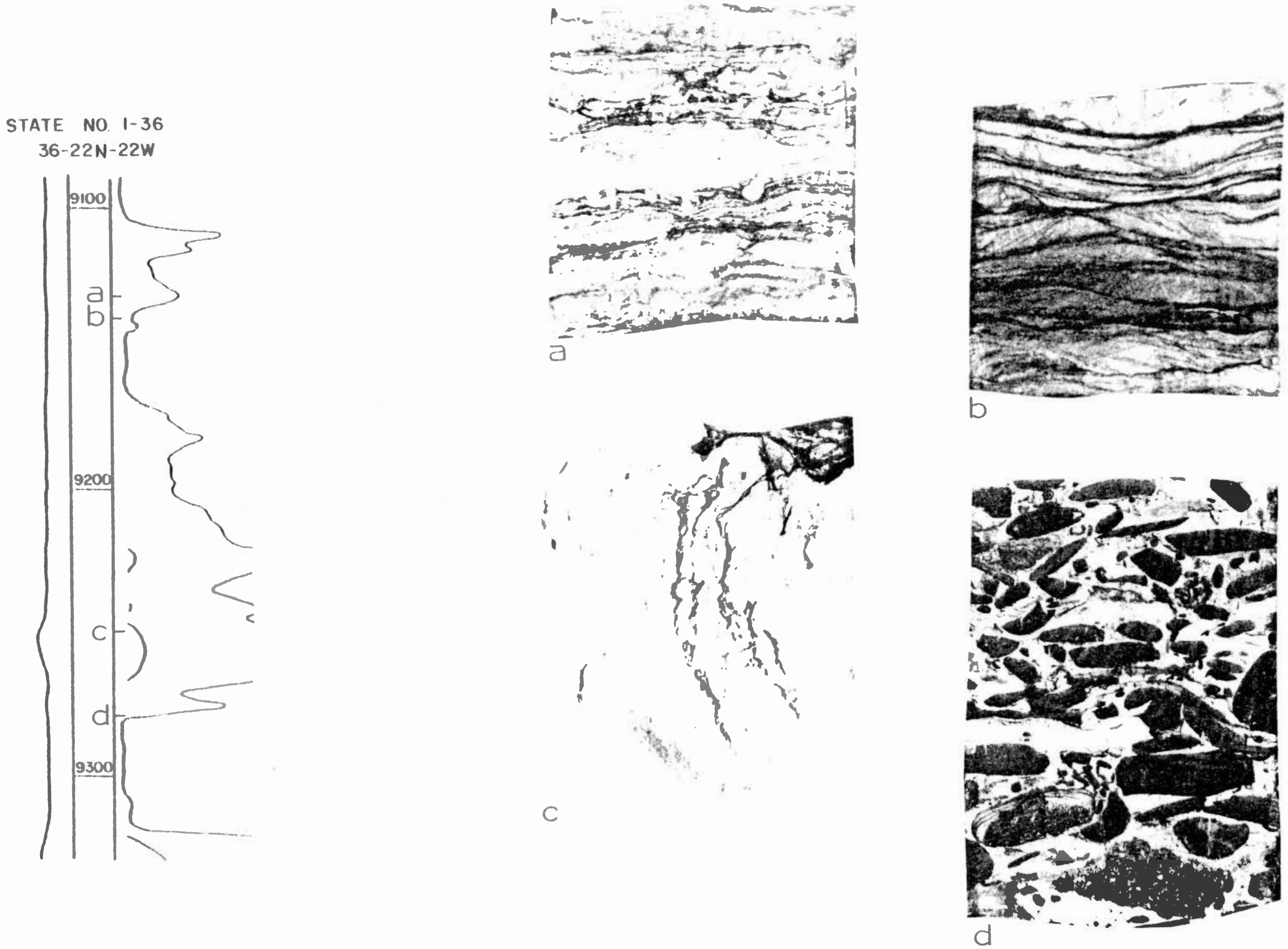


Fig. 21.--Selected features include bioturbation (a) of sandstones in the upper unit of the Morrowan Series and ripple cross-lamination (b), flowage (c), and basal conglomeratic unit in sandstones in the lower unit of the Morrowan Series.

common throughout, and flowage and ripple cross lamination are locally present. The sand is overlain and underlain by interlaminated siltstones and shales. The sand unit represents deposition in either a tidal-flat environment or the distal edge of a shallow marine sand sheet.

Core of the lower Morrow contains a multistoried sequence of very fine- to coarse-grained sandstone with abundant carbonaceous material. It is conglomeratic in places and shows ripple and medium-scale cross-bedding and flowage. The unit is underlain by a shaly unit containing lenses of very fine-grained sandstone with abundant skeletal limestone material. It contains some carbonaceous material. Sedimentary structures include horizontal lamination (in shale lithologies) and flowage features.

The sand unit at 9249-9274 ft is thought to have been deposited as a deltaic distributary. The mudstone unit (at 9300-9320 ft) represents shallow marine units over which the deltaic sands advanced.

CHAPTER VII

DEPOSITIONAL ENVIRONMENTS

The internal features and general geometry of the Morrowan Series permit recognition of two major environments of sand deposition. Fluvio-deltaic conditions were operative predominantly during deposition of the lower Morrowan unit. Transgression by the Morrowan sea resulted in a dominance of shallow-marine deposition during formation of the upper Morrowan unit. However, the "Woodward channel" still existed during deposition of this unit.

The fluvio-deltaic quartzarenites of the lower unit are generally moderately to poorly sorted, fining-upward sequences; individual units commonly contain a basal conglomerate. They generally are multistoried and have sharp bases with underlying units. Dominant constituents include carbonaceous material and clay and siderite pebbles. Typical sedimentary structures include ripple and medium-scale cross-bedding and flowage. In map view (Plates 7 and 9 , a channel-like pattern is present in the "Woodward channel" area. To the southwest, branching patterns (Plate 9) are suggestive of deltaic distributaries. Examples of this type of deposit are in cored intervals in the King-Stevenson Anderson No. 1 from 7080-7150 ft and the Shell State No. 1-36 from 9250-9282 ft.

Associated with the fluvio-deltaic sandstones are interdistributary bay deposits. They commonly consist of fine-grained sandstones and siltstones interlaminated with shales. Horizontal bedding is the most abundant type of structure although lenticular bedding and ripple bedding are common. Skeletal limestone deposits and bioturbation are also present. Examples of this type of deposit, with close association to the fluvio-deltaic sandstone sequences, are cored from the Shell State No. 1-36 (9234-9250 ft and 9282-9290 ft), the Gulf Vina Eike No. 1 (7400-7412 ft), and the Shell Blasdell No. 1 (8177-8190 ft).

Another deposit representative of the general fluvio-deltaic setting in the study area during deposition of the lower unit is the distributary mouth bar. This interpretation is made on the basis of a sequence of thin beds of well-sorted, fine-grained sandstones with thin laminations of plant debris as well as small amounts of glauconite. Predominant structures include flowage and trough cross-bedding and ripple lamination. Such intervals are thin but present throughout fluvio-deltaic sequences. Examples are present in the Shell Blasdell No. 1, in the interval from 8204-8220 ft, and in the Apache Baker No. 1, in the interval from 7830-7840 ft.

Marine bar and sheet sandstones of the upper unit are poor to moderately sorted and have transitional bases with underlying silts and shales. Lower parts of these sandstones consist of shaly siltstones and sandstones that contain abundant glauconite. Bioturbation is most common throughout; ripple and horizontal lamination are also present. These beds grade upward into glauconitic siltstones and shales. No evidence was found to support emergence at the tops of the bar sands. Examples of bar deposition is in the Apache Baker No. 1 (from 7782-7810 ft) and in the Edwin L. Cox Meyers No. 1 (from 8750-8784 ft).

The bar sequence commonly contains very thin sandy conglomeratic lenses which contain crinoid and bryozoan fragments along with intraformational pebbles. These lenses are thought to represent storm deposits, possibly in very shallow storm-surge channels which cut through the bars. Two examples are in the Apache Baker No. 1 (at 7766 ft and at 7800 ft).

Sandstones of the Morrowan Series were deposited during an overall transgression, the initial phases of which were influenced by inherited paleotopography on the eroded Mississippian surface. However, it is thought that the isopach maps of the units and of sandstones within them do not support the existence of a dendritic drainage pattern on the Chester limestone surface. Rather, they seemingly suggest a combination of paleotopography and southwestward depositional slope with increase in subsidence rates in that direction (Plates 7 and 8). With introduction of sand-sized sediments, overall transgressive conditions apparently became regressive as depositional rates exceeded subsidence rates. However, in some cases, marine influence on early Morrowan sedimentation increased. In the Edwin L. Cox Meyers NO. 1, the Apache Baker No. 1, and the Shell State No. 1-36, there are upward increases in glauconite, bioturbation and marine fossil fragments, which is suggestive of subsidence rates exceeding depositional rates.

CHAPTER VIII

SUMMARY

The principal conclusions of this study are as follows:

1. The Morrowan Series may be divided into two units based on log characteristics.

2. The internal features and general geometry of the Morrown permit recognition of two major environments of sand deposition.

3. Sandstones of the lower unit were deposited primarily in fluvio-deltaic environments. The "Woodward channel" is a major part of this system.

4. Maximal sandstone thickness in the lower unit exceeds 75 ft in the "Woodward channel" and exceeds 200 ft in the system of branching deltaic distributaries in the southwestward part of the area. The latter reflects overall thickening of the section in that direction.

5. The fluvio-deltaic sandstones are characterized by multistoried, moderately to poorly sorted, fining-upward sequences with sharp bases. They commonly contain carbonaceous material and conglomeratic lenses. Dominant structures include ripple and medium-scale cross-bedding and flowage features.

6. Sediment influx apparently modified the overall transgressive conditions so that most lower Morrowan sandstones are probably regressive in nature. In most of the area, the fluvio-deltaic channel system prograded southward; it was developed on an eroded, undulatory surface of

of the Mississippian Chester limestone.

7. Interdistributary bay deposits are associated with the fluvio-deltaic sequences and are characterized by interlaminated, very fine-grained sandstones, siltstones, and shales containing horizontal and ripple bedding; moderate bioturbation and skeletal limestone lenses are also common.

8. Transgression, evidenced by a marked change to shallow marine strata, affected the southwestern part during deposition of the lower unit and the northeastern part during deposition of the upper unit.

9. Most sandstone units in the upper unit were deposited as shallow marine bar sands and/or sheets; they contain abundant glauconite and are moderately bioturbated. They have transitional lower and upper boundaries with siltstones and shales and contain ripple and horizontal lamination throughout.

10. Sandstone thickness of the upper unit is more than 60 ft in the "Woodward channel" area and more than 180 ft in the southwestern part of the study area.

11. Total thickness of both lower and upper units ranges from zero in the northeast to greater than 900 ft in the southwest. Interval thickness of the upper unit is more uniformly distributed; it extends farther to the northeast than the lower Morrowan unit.

12. The northeastern limit of the Morrowan Series is thought to be a result of truncation of Morrowan strata by Atokan units, which unconformably overlies the Morrowan.

13. Three groups of sedimentary structures and associated textural features are present in the Morrowan sandstones. They are sandstones with cross-bedding and flowage, bioturbated and cross-bedded/ripple

laminated sandstones, and interlaminated siltstones, sandstones and shales with burrows and horizontal lamination.

14. Sandstones are classified as quartzarenites; they commonly are patchy concentrations of clay and calcite cement. Silica cement and overgrowths are very common in the well sorted sandstones.

15. Intraformational clasts include skeletal limestone clasts and oolith, clay, isolated pebbles of phosphate, and sideritic clay.

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APPENDIX

NAMES AND LOCATIONS OF WELLS USED IN CORRELATION SECTIONS

No.	Operator-Well Name	Location
	South-North Correlation Section A-A'	
1.	Jones & Pellow, Braum #1	C-SE-NW, Sec. 31, T20N, R22W
2.	Alamo, Lynes #1	C-NE, Sec. 20, T20N, R22W
3.	Cabeen, Cabeen State #1	C-SE-NW, Sec. 16, T20N, R22W
4.	Huzer, Stoddard #1	C-SW-NE, Sec. 34, T21N, R22W
5.	Hanover, Marston #1	C-NE-SW, Sec. 20, T21N, R22E
6.	Anson, Adams #1	C-NE-SW, Sec. 8, T21N, R22W
7.	Shell, Howeiler #1-20	NE-SE-NW, Sec. 20, T22N, R22W
8.	Sun, Feerer #1	C-NE-SW, Sec. 8, T22N, R22W
9.	Shell, Blasdell #1-19	C-SW-NE, Sec. 19, T23N, R22W
10.	Woods, Blasdell #1	C-SW, Sec. 34, T24N, R22W
11.	Pan Am, Board of Affairs	C-SW, Sec. 11, T24N, R22W
12.	Pan Am, Cooper #1	C-SE-NW, Sec. 26, T25N, R22W
13.	Texas O & G, Young #1	C-NW, Sec. 15, T25N, R22W
	South-North Correlation Section B-B'	
1.	Vierson-Cockran, Griffith #1	NE-SW-NW, Sec. 34, T20N, R20W
2.	Jet, Mobil #1	C-SW, Sec. 2, T20N, R20W
3.	Hamilton Logan #1-14	C-SW-SW, Sec. 14, T21N, R20W
4.	Southport, Buhrmann #1	C-SE-NW, Sec. 2, T21N, R20W
5.	Union, McCormick #1	SE-SE-NW, Sec. 14, T22N, R20W
6.	Apexco, Crites #1	C-NE, Sec. 1, T22N, R20W
7.	Shenandoah, White #1-36	C-SW, Sec. 36, T23N, R20W
8.	Pickens, Lawrence #1	C-SW-SW, Sec. 14, T23N, R20W
9.	Coquñna, Schroebeler #1	C-NW-SE, Sec. 11, T23N, R20W
10.	Trigg, Withgott #1-34	C-NW-SE, Sec. 34, T24N, R20W
11.	King-Stevenson, Anderson #1	SE-SE-NW, Sec. 26, T25N, R20W
12.	Lammerts, Hayes #1	NW-NE-SE, Sec. 22, T25N, R20W
13.	Hudson, White #1	C-NW, Sec. 3, T25N, R20W
	West-East Correlation Section C-C'	
1.	Cleary, Smith #2-29	C-NW-SE, Sec. 29, T25N, R21W
2.	Oklahoma Natural Gas, Smith #1	C-SE, Sec. 23, T25N, R21W
3.	Shell, Smith #1-19	C-SW-NE, Sec. 19, T25N, R20W

4.	Lammerts, Hayes #1	NW-NE-SE, Sec. 22, T25N, R20W
5.	King-Stevenson, Anderson #1	SE-SE-NW, Sec. 20, T25N, R20W
6.	Shell, Munson #1	C-SW-NW, Sec. 30, T25N, R19W
7.	Duncan, Bennett	C-SE, Sec. 17, T25N, R19W
8.	El Paso, Selman	C-NE, Sec. 16, T25N, R19W

West-East Correlation Section D-D'

1.	King-Stevenson, Tune #1-6	C-NE-SW, Sec. 6, T23N, R22W
2.	DAvis, Vloedman #1	C-NW, Sec. 2, T23N, R22W
3.	Cobra, Ferguson #1	C-SE-NE, Sec. 15, T23N, R21W
4.	Apache, Baker #1-24	C-N½-NE, Sec. 24, T23N, R21W
5.	Rogers, Knabbe #1	C-NE-SW, Sec. 22, T23N, R20W
6.	Woods, Young #1-12	C-SW, Sec. 12, T23N, R20W
7.	Woods, Richard #1-18	C-NE, Sec. 18, T23N, R19W
8.	Black, Trissel #1	C-SW, Sec. 14, T23N, R19W
9.	Ricks, Trissel #1-7	SW-NE-SW, Sec. 7, T23N, R18W

West-East Correlation Section E-E'

1.	Tuthill, Adams #1	C-NW-SE, Sec. 9, T21N, R22W
2.	Pan Am, Roger #1	C-NE-SW, Sec. 8, T21N, R21W
3.	Pan Am, Miller #1-16	SW-SE-NE, Sec. 16, T21N, R21W
4.	Eason, Baird #1	C-NW-SE, Sec. 14, T21N, R21W
5.	Carter, Phillips #1	C-NW, Sec. 17, T21N, R20W
6.	Pan Am, Snow #14-1	SW-SE-NW, Sec. 14, T21N, R20W
7.	Lee, Benbrook #1	NW-SW-NE, Sec. 8, T21N, R19W
8.	National Coop. Ref., Merklin #1	C-SW, Sec. 14, T21N, R19W
9.	Sunray, Ellington #1	C-NW-SE, Sec. 13, T21N, R18W
10.	Hill, Battel #1-15	C-SW-SW, Sec. 15, T21N, R17W
11.	Shell, Shell et al. #1	SE-SW-SW, Sec. 8, T21N, R16W

VITA

Stephen Thomas Godard

Candidate for the Degree of

Master of Science

Thesis: DEPOSITIONAL ENVIRONMENTS AND SANDSTONE TRENDS OF THE PENNSYLVANIAN MORROWAN SERIES, SOUTHERN MAJOR AND WOODWARD COUNTIES, OKLAHOMA

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PLATE I.

NORTH-SOUTH CORRELATION SECTION
A-A'
Through R22W

HORIZONTAL SCALE - None

VERTICAL SCALE 0 – 100 – 200 (Feet)

PLATE 2.

NORTH-SOUTH CORRELATION SECTION
B-B'
Through R20W

PLATE 3.

EAST-WEST CORRELATION SECTION
C-C'
Through T25N

HORIZONTAL SCALE - None

VERTICAL SCALE

200
100
0
(Feet)

PLATE 4.

EAST-WEST CORRELATION SECTION
D-D'
Through T23N

HORIZONTAL SCALE - None

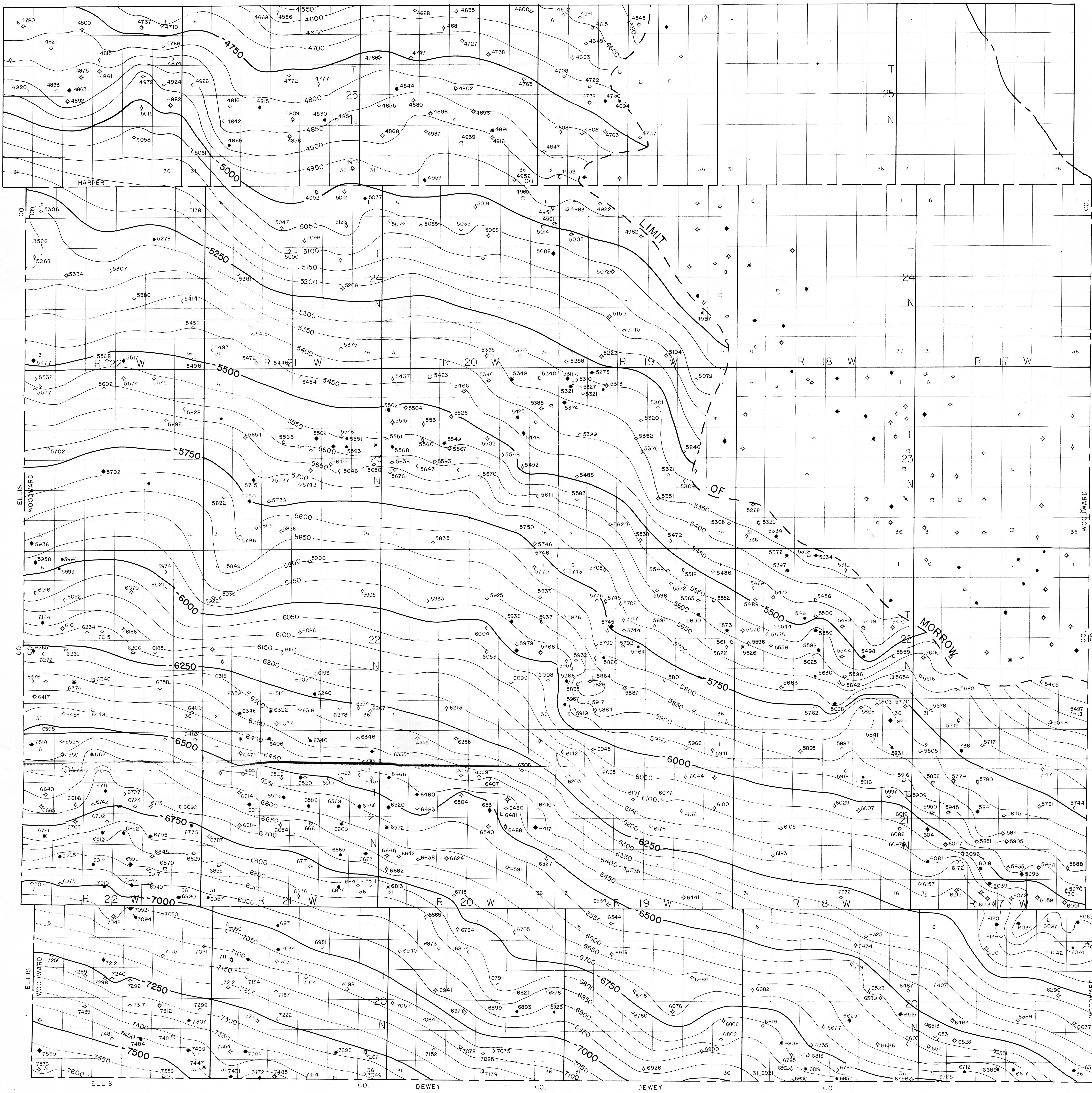
VERTICAL SCALE 200 100 0 (Feet)

PLATE 5.

EAST-WEST CORRELATION SECTION
E-E'
Through T21N

HORIZONTAL SCALE- None

VERTICAL SCALE 0 100 200 (Feet)



0 1 2 3 4 5 6 Miles

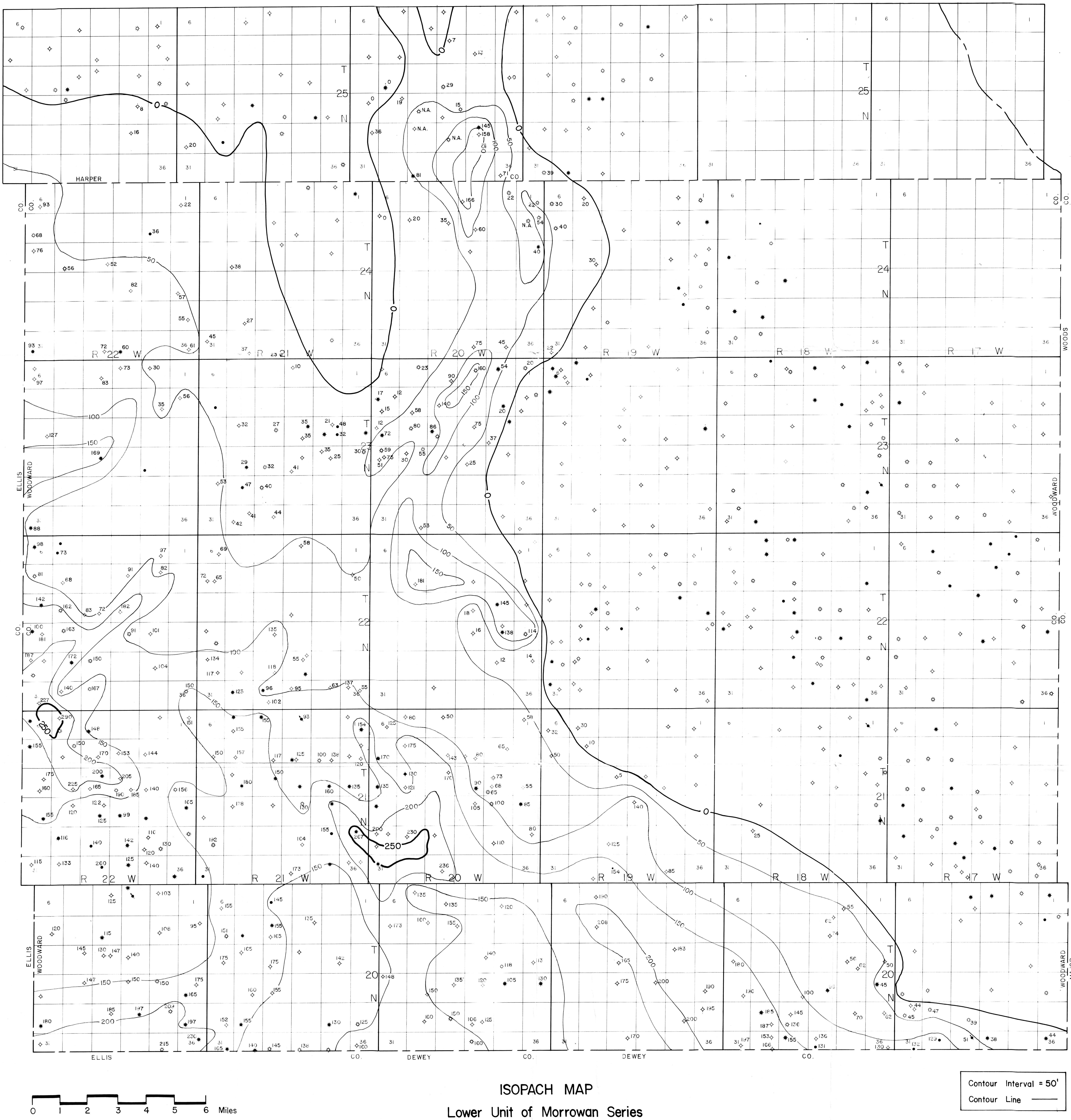
STRUCTURAL CONTOUR MAP
Top of Morrowan Series

All Elevations Subsea Level

Contour Interval = 50'
Contour Line

Thesis 1981 G577d

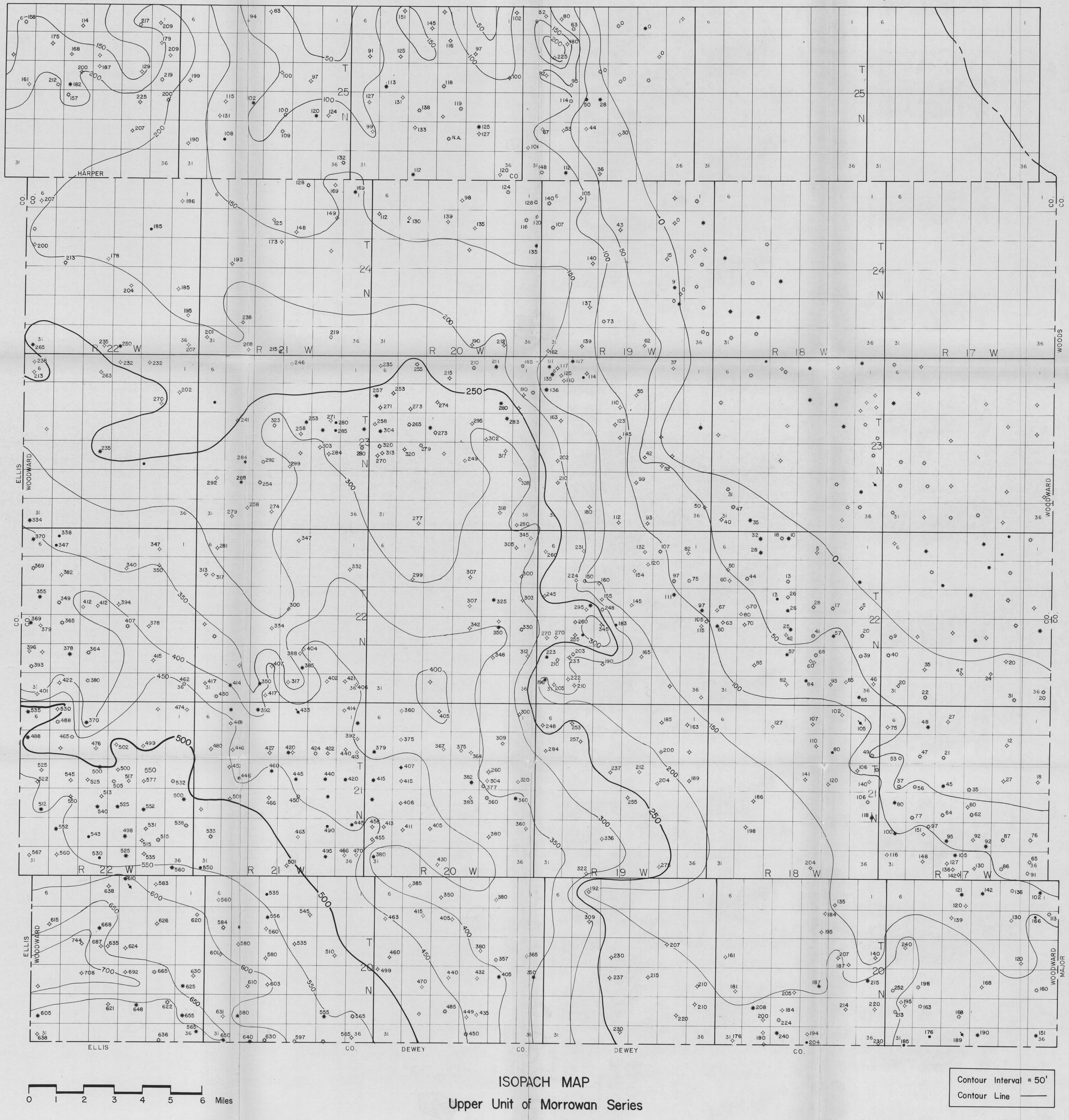
Plate 6.



ISOPACH MAP

Lower Unit of Morrowan Series

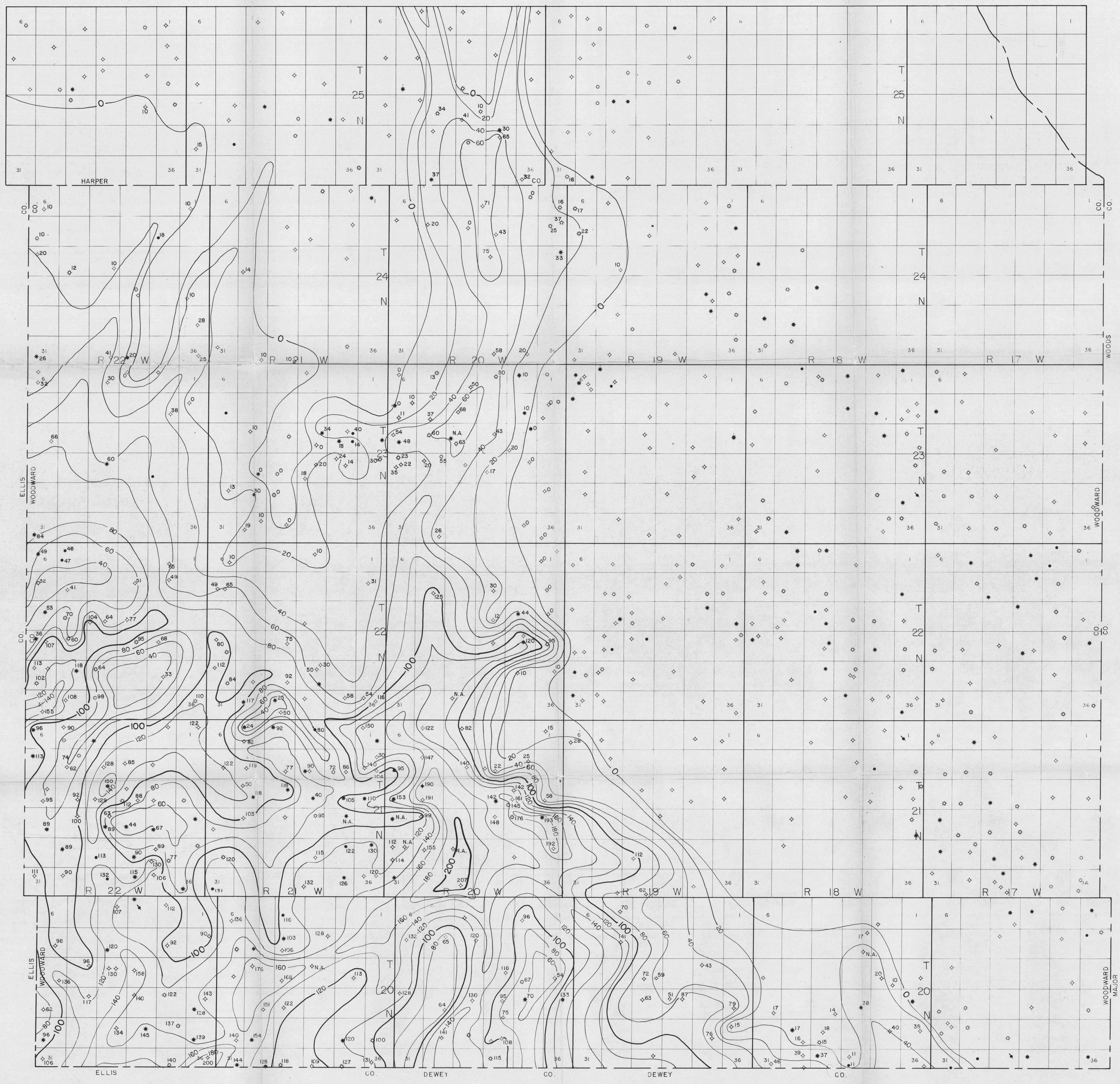
Plate 7.



ISOPACH MAP

Upper Unit of Morrowan Series

Plate 8.



0 1 2 3 4 5 6 Miles

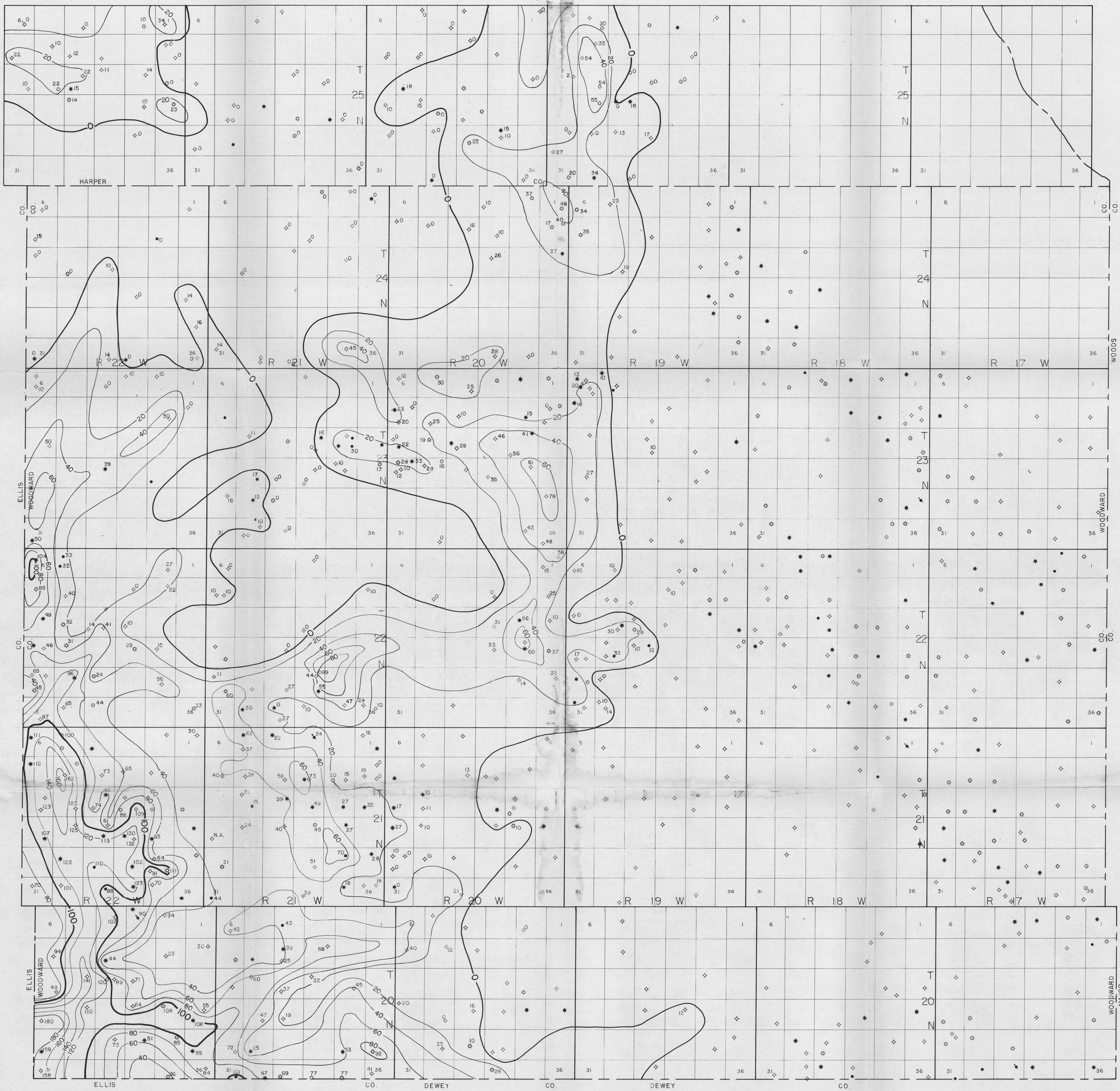
Contour Interval = 20'

Contour Line

NET-SANDSTONE-THICKNESS MAP

Lower Unit of Morrowan Series

Plate 9.



0 1 2 3 4 5 6 Miles

NET-SANDSTONE-THICKNESS MAP
Upper Unit of Morrowan Series

Contour Interval = 20'
Contour Line ———

Plate 10.