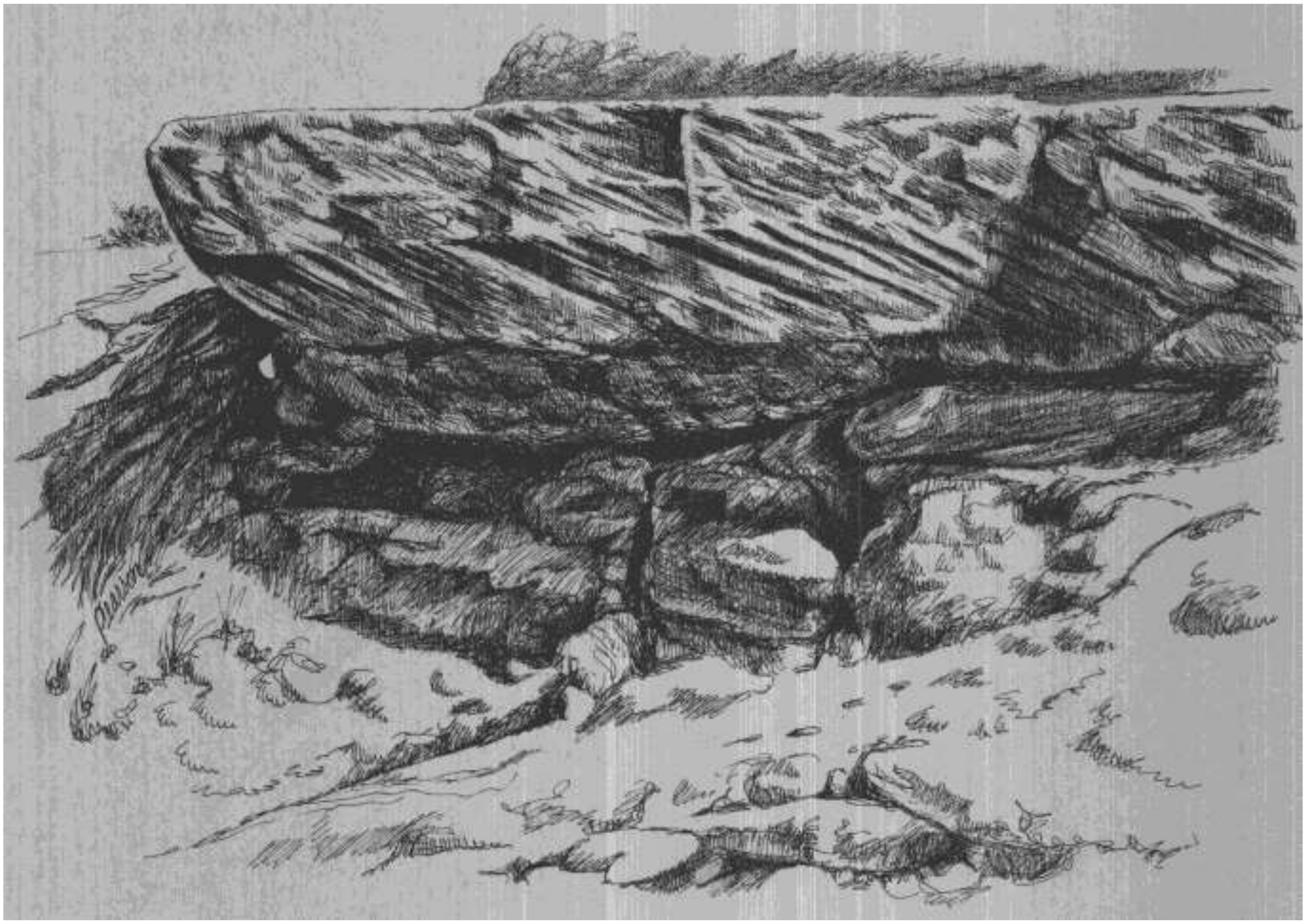
Circular 157 1977



Sedimentology of Mesa Rica Sandstone in Tucumcari Basin, New Mexico

by J. E. Gage and G. B. Asquith

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

documenting New Mexico mineral resources since 1927

Circular 157

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Sedimentology of Mesa Rica Sandstone in Tucumcari Basin, New Mexico

by J. E. Gage and G. **B.** Asquith

SOCORRO 1977

First printing, 1977

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-4
Printed by University of New Mexico Printing Plant, June 1977

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 Price $2.50

Contents

TABLES

FIGURES

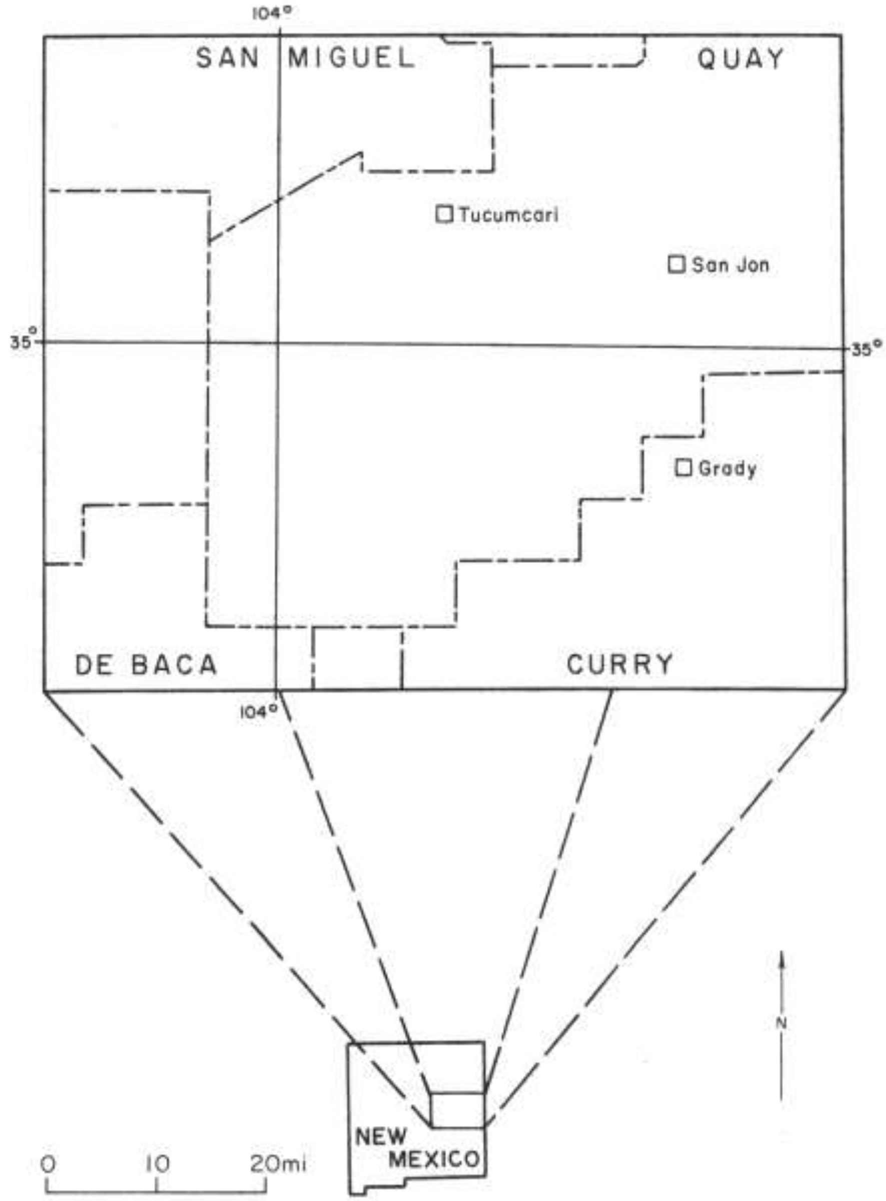


FIGURE 1—LOCATION OF STUDY AREA IN EAST-CENTRAL NEW MEXICO.

Abstract

The Mesa Rica Sandstone (Lower Cretaceous) in the Tucumcari Basin of east-central New Mexico represents deposits from a lobate sand-rich delta complex. Log-probability curves of the grain-size distributions when compared to the work of Visher (1969) indicate environments ranging from distributary channels to marine wave deposits.

The Mesa Rica delta prograded into the marine Tucumcari Basin from the north as shown by the south-trending to southwest-trending paleocurrent directions, and the decrease in mean grain size and thickness to the southeast, south, and southwest (lobate geometry). Also, a decrease in percent cross stratification to the southeast, south, and southwest (accompanied by an increase in percent bioturbation and burrowing) indicates a transition from predominantly fluvial to predominantly marine conditions. If the Mesa Rica Sandstone is correlative with the lower fluvial interval of the Dakota Sandstone north and northwest of the Tucumcari Basin as suggested by Scott (1970), then the Dakota Sandstone represents the fluvial facies of the Mesa Rica marine delta complex.

Introduction

LOCATION OF STUDY

The study area is located in east-central New Mexico (fig. 1). The area is rectangular with dimensions of 56 mi north-south and 69 mi east-west. The approximate geographic boundaries are the Texas-New Mexico border, the Canadian River, NM-129, and the northwestern escarpment of the Llano Estacado.

TECTONIC SETTING

Baltz (1965, p. 2041 and 2048) described the tectonic setting of Colorado and New Mexico. He concluded that the major Pennsylvanian and Permian tectonic highs in Colorado and northern New Mexico were the Wet Mountain-Apishapa uplift (southern extension of the Front Range geanticline; King, 1959, p. 105), the Sierra Grande uplift, and the San Luis uplift (southern extension of the Uncompaghre geanticline; King, 1959, p. 105). Late Paleozoic lows were the central Colorado Basin, Rowe-Mora Basin, Tucumcari Basin, and Gallina Basin. These late Paleozoic positive and negative areas were covered by later Paleozoic and early Mesozoic sediments.

Late Paleozoic positive areas were rejuvenated in the Early Cretaceous and constituted source areas for Early Cretaceous sandstones of northeast New Mexico (Jacka and Brand, 1973, p. 24; Gilbert and Asquith, 1976, p. 12). The Tucumcari Basin reformed during the Early Cretaceous when the accumulation of Tucumcari Shale, Mesa Rica Sandstone, and Pajarito Shale began.

According to Baltz (1965, p. 2042 and 2066), epeirogenic uplift occurred during the early Tertiary over the entire region. The present Sangre de Cristo Range, Wet Mountains, Apishapa Arch, Sierra Grande Arch, and Raton Basin are features resulting from Tertiary tectonism.

PREVIOUS WORK

Rothrock (1925) described and named the Purgatoire Formation for Lower Cretaceous rocks in northeastern New Mexico and the Oklahoma panhandle. DeFord (1927, p. 754) and Bullard (1928, p. 89) proposed that the Purgatoire Formation of northeastern New Mexico is equivalent to the Kiowa Shale and the Cheyenne Sandstone of Kansas. Dobrovolny, Summerson, and Bates (1946) divided the Purgatoire Formation of Quay County into the Tucumcari Shale, the Mesa Rica Sandstone, and the Pajarito Shale members. Mankin (1958) studied the pre-Graneros rocks of northeastern New Mexico and suggested that the Mesa Rica Sandstone and the Pajarito Shale of Quay County are correlative with the Cheyenne Sandstone and Kiowa Shale of Kansas. Scott (1970) reported that a detailed paleontological examination of the Cretaceous faunas of southwestern Kansas, southeastern Colorado, and northeastern New Mexico indicated that the Dakota and Mesa Rica Sandstones were equivalents. Brand and Mattox (1972, p. 103) and Jacka and Brand (1973, p. 46) studied the Mesa Rica Sandstone in the Tucumcari area and suggested that the Mesa Rica Sandstone represents deltaic sedimentation.

PURPOSE OF STUDY

Determining the geometry, transport directions, and delta type represented by the Mesa Rica Sandstone in the Tucumcari Basin area was the purpose of this study. Various techniques included utilizing grain-size analysis, paleocurrent analysis, isopach trends, and quantitative sedimentary structure analysis. An additional goal was to determine the relationship of the Mesa Rica Sandstone to the Dakota Sandstone north and northwest of the Tucumcari area.

METHODS OF STUDY

GRAIN-SIZE ANALYSIS

Five samples were randomly collected from 10 sections (fig. 2) for grain-size analysis. A portion of each sample was crushed, washed, dried, and checked for disaggregation. Using one-quarter phi intervals, approximately 30 grams of prepared sample was sieved down to 4.50 phi. Fifteen minutes were used as a constant Ro-Tap shaking time in this study. Each of the sieved quarter phi intervals was weighed to the nearest one-hundredth of a gram and the data was processed by a Fortran computer program, *GZSZ (Asquith, 1974). This program calculated the Folk and Ward (1957) statistical parameters (mean, phi deviation, skewness,

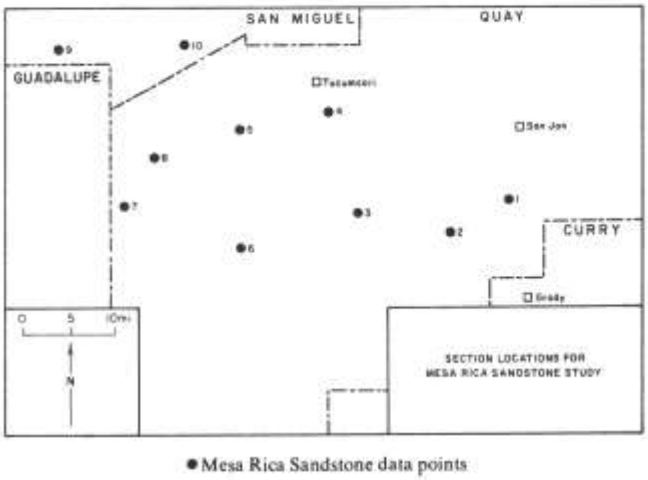


FIGURE 2—SECTION LOCATION MAP FOR MESA RICA SANDSTONE STUDY, TUCUMCARI AREA.

and kurtosis) and also calculated the cumulative percent of grain-size distributions at quarter phi intervals. The cumulative percent data was plotted on log-probability paper as recommended by Visher (1969) for environmental interpretation.

PALEOCURRENT ANALYSIS

Twenty-five paleocurrent readings were measured with a Brunton compass from trough axes and planar foresets at each of the 10 sections (fig. 2). Trough cross stratification was used, when available, in preference to planar cross stratification to obtain a more reliable indicator of mean paleocurrent direction (High and Picard, 1974, p. 166). A Fortran computer program, *CURT (Asquith, 1974), was used to process the data. This program calculated vector mean direction, standard deviation, and consistency ratio (magnitude of mean vector in percent). The program also performed a Raleigh test (Durand and Greenwood, 1958, p. 230) which compared the data to a uniform distribution at a 95 percent level of confidence. All 10 sections differed significantly from a uniform distribution; therefore the vector mean directions are statistically significant.

SEDIMENTARY STRUCTURE ANALYSIS

Each stratigraphic section (fig. 2) was measured with a Brunton compass and a tape measure. The thickness of each variety of sedimentary structure in each section was recorded and later transferred to a lithic log (fig. 3). A Fortran computer program, *SED (Asquith, 1974), processed the data. This program calculated the percentage of each type of sedimentary structure in the measured sections and calculated percentage data for three component sedimentary structure facies plots.

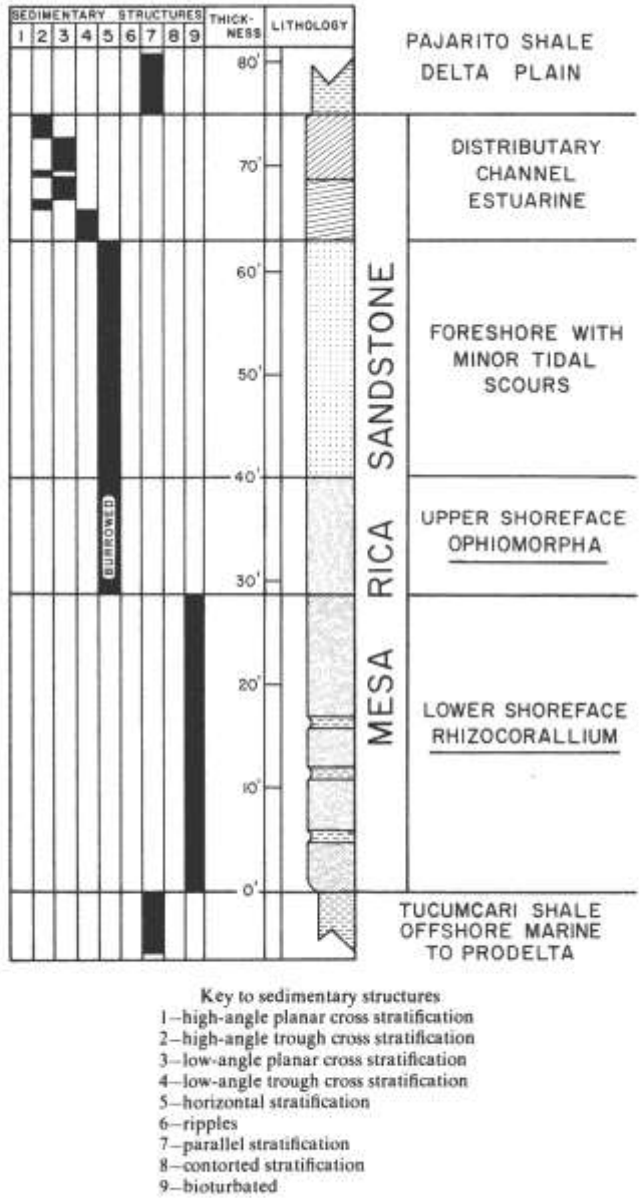


FIGURE 3—STRATIGRAPHIC SECTION OF THE MESA RICA SANDSTONE, PALOMAS SECTION (FIG. 2), TUCUMCARI AREA.

ACKNOWLEDGMENTS

The authors are grateful to the New Mexico Bureau of Mines and Mineral Resources for providing financial support for the field work. Critical reading of the manuscript and suggestions came from Franklin W. Daugherty and Gerald E. Schultz, West Texas State University and John R. MacMillan, New Mexico Institute of Mining and Technology. Joe K. Tipton and Leroy W. Fail are thanked for their assistance in the field. Special thanks are due the ranchers of the Tucumcari area who were most cooperative in allowing access to their land.

Stratigraphy

INTRODUCTION

The term Purgatoire Formation was extended by Rothrock (1925) from southwestern Colorado into the northeastern corner of New Mexico and the Oklahoma panhandle. He differentiated the Purgatoire into a lower sandstone and an upper shale with interbedded thin sandstones. *De*Ford (1927, p. 754) and Bullard (1928, p. 89) suggested correlation of the lower sandstone and upper shale of the Purgatoire Formation with the Cheyenne Sandstone (Lower Cretaceous) and Kiowa Shale (Lower Cretaceous) of Kansas. Dobrovolny, Summerson, and Bates (1946) subdivided the Purgatoire Formation of Quay County into three members which (in ascending order) are: Tucumcari Shale, Mesa Rica Sandstone, and Pajarito Shale. Mankin (1958, p. 98) supported the subdivisions of Dobrovolny, Summerson, and Bates in the southern part of his study area and proposed that the Kiowa Shale is equivalent to the Pajarito Shale, and Cheyenne Sandstone is correlative with the Mesa Rica Sandstone. Scott (1970, p. 1233) believed that the correlation of Mankin (1958, p. 89) was incorrect and suggested that the Mesa Rica is equivalent to the Dakota and both are younger than the Kiowa and Cheyenne. Griggs and Read (1959, p. 2007) recommended that the usage of Purgatoire Formation be abandoned in Quay County and that the members described by Dobrovolny, Summerson, and Bates (1946) be raised to formational rank as a part of the Purgatoire Group.

PURGATOIRE GROUP

TUCUMCARI SHALE

The Tucumcari Shale (Lower Cretaceous) lies unconformably on the Morrison Formation (Jurassic) according to Jacka and Brand (1973, p. 44). The lower 10 ft is thin-bedded fissile shale, the middle portion is predominantly gray shale and yellow to brown clay, and the upper portion is interbedded shales and sandstones which are lithologically similar to the Mesa Rica Sandstone (Brand and Mattox, 1972, p. 101). Brand and Mattox (1972, p. 101) also reported that the lower 10 ft contains dwarfed pelecypods and other macrofossils which are Albian in age. They believed the environment was euxinic, similar to the top of the Kiamichi Formation of the Texas panhandle, and probably developed in a Cretaceous estuary cutoff from normal marine circulation. The basal shales are overlain by 40 to 50 ft of shale and interbedded sandstone, here interpreted to represent a normal marine to prodelta environment. Brand and Mattox (1972, p. 101) reported that these upper shales contain a normal marine macrofossil fauna which is also Albian in age.

MESA RICA SANDSTONE

The Mesa Rica Sandstone lies unconformably on the Tucumcari Shale (Lochman-Balk, 1972, p. 7) or Morrison Formation. The Mesa Rica Sandstone forms the rimrock on mesas and buttes in the Tucumcari area (Brand and Mattox, 1972, p. 103) and has been used as a term to describe cliff-forming formations as far west as the Creston Range in the Las Vegas, New Mexico area (Brand and Mattox, 1972, p. 103). Brand and Mattox (1972, p. 103) reported that the Mesa Rica Sandstone exhibits both fluvial and marine characteristics and they believed it resembled sediments deposited in a prograding deltaic environment.

The Mesa Rica Sandstone is a lobate sand body. The major rock type is a white to yellowish-brown, fine-grained to very fine grained, moderately well rounded, and moderately well sorted quartz arenite cemented by calcite, limonite, and clay.

Sedimentary structures present throughout the area include bioturbation (fig. 4), horizontal stratification, and planar (fig. 5) and trough (fig. 6) cross stratification. Parallel stratification (suspension deposits) occurs as small stringers in the lower and upper portions of the unit and becomes more abundant as the Mesa Rica Sandstone grades into the Pajarito Shale. Current ripples are rare to absent.

Most fossil evidence found in the Mesa Rica Sandstone is in the form of trace fossils. Burrows of subshoreface *Rhizocorallium (fig.* 7) and subshoreface to shoreface *Ophiomorpha* (fig. 8) are found at the Palomas section. Bioturbation and burrowing occur in the

FIGURE 4—BIOTURBATED SHOREFACE OF THE MESA RICA SANDSTONE, SAN JON (section I).

FIGURE 5—HIGH-ANGLE PLANAR CROSS STRATIFICATION TRUNCATED BY HORIZONTAL STRATIFICATION IN DISTRIBUTARY CHANNEL FACIES OF MESA RICA SANDSTONE, TUCUMCARI MOUNTAIN (section 4).

FIGURE 6—HIGH-ANGLE (GREATER THAN 10 DEGREES) TROUGH CROSS STRATIFICATION IN TIDAL CHANNEL OF MESA RICA SANDSTONE SAN JON (section 1).

FIGURE 8—*Ophiomorpha*, A VERTICAL SUBSHOREFACE TO SHOREFACE SUSPENSION FEEDER (WEIMER, 1973, p. 98) IN THE MESA RICA SANDSTONE, PALOMAS (section 5).

lower portion of all but one section (table 1). Thin oyster-rich layers, along with *Trigonia emoryi* and sharks' teeth are frequently present in this lower bioturbated interval. Silicified wood fragments to 2 ft long can be found in the cross stratified portions of the Mesa Rica Sandstone.

North and northwest of the Tucumcari Basin, the Dakota Sandstone lies unconformably on the Morrison Formation. Jacka and Brand (1972, p. 106), along with Mankin (1958, p. 116), subdivided the Dakota into three intervals. They inferred that the lower interval is a braided fluvial sheet composed of cross stratified sandstone with conglomerate lenses. The middle interval represents a meanderbelt sequence which contains lenticular, point-bar sandstones and interbedded carbonaceous shales. The upper interval represents a transgressive marine succession containing fine-grained, horizontally stratified, and burrowed marine sandstones. Gilbert and Asquith (1976, p. 12) determined that the source areas for the braided fluvial interval of the Dakota Sandstone were the San Luis and Apishapa uplifts of New Mexico and Colorado and that this interval changes from proximal to distal facies in a southeasterly direction in northeast New Mexico.

FIGURE 7—*Rhizocorallium*, A HORIZONTAL SUBSHOREFACE FILTER FEEDER (WEIMER, 1973, p. 98) IN MESA RICA SANDSTONE, PALOMAS (section 5). Approximately 2.5 cm between arrow tips.

TABLE 1—SEDIMENTARY STRUCTURE DATA FOR MESA RICA SANDSTONE, TUCUMCARI AREA.

Section	Cross stratification (percent)	Horizontal stratification (percent)	Bioturbation + burrowing (percent)
1—San Jon	16.7	11.1	72.2
2—Duke Ranch	16.7	48.6	34.7
3—Mesa Redondo	27.4	45.2	27.4
4—Tucumcari Mountain	81.6	9.5	8.9
5—Palomas	13.3	33.3	53.4
6—Saddle Back Mesa	41.1	15.9	43.0
7—Luciano Mesa	36.7	30.3	33.1
8—Montoya	36.8	22.4	40.8
9—Isidore	75.0	25.0	0.0
10—Mesa Rica	61.7	24.1	14.2

Scott (1970, p. 1235) correlated the marine Mesa Rica Sandstone with the nonmarine fluvial portion of the Dakota Sandstone and placed both the Mesa Rica and Dakota sandstones in the Upper Cretaceous. However, Brand and Mattox (1972, p. 98) concluded that the Mesa Rica Sandstone is older than the Dakota Sandstone and placed both the Mesa Rica and Dakota Sandstones in the Lower Cretaceous.

PAJARITO SHALE

The Pajarito Shale lies conformably on the Mesa Rica Sandstone (Lochman-Balk, 1972, p. 8) and is unconformably overlain by the Ogallala Formation (late Tertiary). The Pajarito Shale consists of interbedded shale and light-yellow to white cross-stratified sandstone with numerous plant and wood fragments.

The following information and conclusions concerning the Pajarito Shale were provided by Brand and Mattox (1972, p. 103). The shale is light gray, poorly laminated, and bentonitic. The upper unit of this formation is a sandstone similar to the Dakota Sandstone. The Mesa Rica Sandstone and Pajarito Shale in the San Jon area exhibit a lateral facies relationship to each other; the Mesa Rica Sandstone represents channel deposits and the Pajarito Shale represents the associated deltaic plain. *Lopha quadriplicata* in the shaly portions of the Pajarito suggests an Albian age.

Sedimentology

INTRODUCTION

The Mesa Rica Sandstone is believed by Brand and Mattox (1972, p. 103) to have been deposited by a prograding delta. The term delta, as defined by Moore and Asquith (1971, p. 2566), is a subaerial and submerged, contiguous sediment mass deposited in a body of water (ocean or lake) primarily by the action of a river. Evidence suggesting a deltaic origin for the Mesa Rica Sandstone is the rapid transition both vertically and laterally from marine to fluvial (distributary channel) deposits. Fluvial-deltaic influx into the Tucumcari Basin is also suggested by log-probability curve shape analysis (Visher 1969) which indicates that the Mesa Rica Sandstone consists of distributary channel and marine wave deposits.

PALEOCURRENT ANALYSIS

Statistical analysis of 250 paleocurrent readings (25 readings per section) illustrates that the transport direction for the Mesa Rica Sandstone was to the south and southwest (fig. 9). All calculated vector mean directions show low dispersion and are unimodal. The consistency ratio (L) is high throughout the area and varies from 78.5 to 92.0 percent. The standard deviation ranges from 23.9 to 41.3. A summary of paleocurrent data is available in table 2.

TABLE 2—PALEOCURRENT DATA FOR MESA RICA SANDSTONE, TUCUMCARI AREA.

Section (25 readings per section)	Vector mean direction	Consistency ratio (percent)	Standard deviation
1—San Jon	76.2°	92.0	23.9
2—Duke Ranch	242.6°	78.8	40.8
3—Mesa Redondo	245.3°	82.8	35.9
4—Tucumcari Mountain	237.8°	81.2	37.6
5—Palomas	197.5°	83.4	34.7
6—Saddle Back Mesa	260.0°	80.7	38.8
7—Luciano Mesa	201.4°	78.5	41.3
8—Montoya	220.2°	86.5	33.1
9—Isidore	39.1°	88.6	28.9
10—Mesa Rica	184.6°	81.2	37.2

The vector mean direction in the San Jon area, approximately 20 mi east of Tucumcari (fig. 9), is to the northeast and is related to tidal processes. The channel sandstones that locally fill scours in the shoreface sandstones at the San Jon section (fig. 10) are interpreted to be tidal channel deposits, rather than distributary channel deposits. This conclusion is based on their mean paleocurrent direction which is approximately 180 degrees to the fluvial transport directions (fig. 9) and the presence of local cross-stratification sets with cross-stratification reversals. Vector mean direction in the Isidore area, approximately 30 mi west of Tucumcari (fig. 9), indicates a current reversal similar to that of the San Jon area but cross-stratification and Visher (1969) log-probability curves reveal that the sandstones at Isidore are of fluvial (distributary channel) origin and therefore possibly represent a different influx area. No

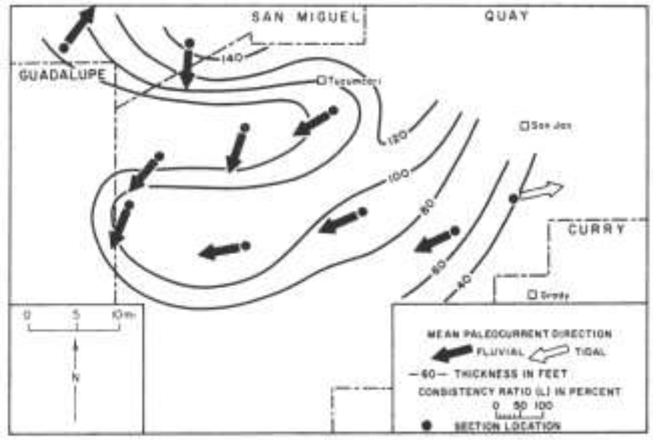


FIGURE 9—VECTOR MEAN PALEOCURRENT DIRECTIONS (length of arrow proportional to consistency ratio) AND ISOPACH MAP OF MESA RICA SANDSTONE, TUCUMCARI AREA. Note, the south to southwest transport directions and the decrease in thickness southward into the Tucumcari Basin.

further evidence is available to support this conclusion because of the lack of outcrops west of the study area.

The isopach trends of the Mesa Rica Sandstone support the inferred paleocurrent directions (fig. 9). They exhibit a lobate geometry into the Tucumcari Basin with thinning to the southeast, south, and southwest (fig. 9). A summary of the measured thicknesses of each section is available in table 3.

TABLE 3—THICKNESS DATA FOR MESA RICA SANDSTONE, TUCUMCARI AREA.

Section	Thickness (ft)
1—San Jon	40
2—Duke Ranch	75
3—Mesa Redondo	85
4—Tucumcari Mountain	84
5—Palomas	75
6—Saddle Back Mesa	109
7—Luciano Mesa	113
8—Montoya	76
9—Isidore	82
10—Mesa Rica	141

FIGURE 10—HIGH-ANGLE PLANAR CROSS STRATIFICATION IN TIDAL CHANNEL SCOURED INTO SHOREFACE SANDSTONES OF MESA RICA SANDSTONE, SAN JON (section 1). Paleocurrent 180 degrees from fluvial transport direction and must represent flood-tide currents.

GRAIN-SIZE ANALYSIS

Fifty random samples were collected from the Mesa Rica Sandstone (five from each section) and grain-size analysis, using the statistical parameters of Folk and Ward (1957), was performed. A summary of the data is presented in table 4.

TABLE 4—Grain-size data for Mesa Rica Sandstone, Tucumcari area.

Section (5 samples per section)	Mean grain size (phi)	Mean standard deviation	Mean skewness	Mean kurtosis
1–San Jon	3.15	0.52	+0.06	1.03
2–Duke Ranch	2.55	0.44	+0.09	1.23
3–Mesa Redondo	2.87	0.49	+0.21	1.28
4–Tucumcari Mountain	2.62	0.44	+0.29	1.33
5–Palomas	2.85	0.37	–0.08	0.97
6–Saddle Back Mesa	3.66	0.52	+0.18	1.09
7–Luciano Mesa	3.22	0.52	+0.15	1.21
8–Montoya	2.96	0.58	+0.30	1.24
9–Isidore	2.61	0.54	+0.35	1.43
10–Mesa Rica	2.79	0.51	+0.25	1.28

Mean grain size ranges from 2.55 to 3.66 phi units (fine to very fine sand). The values for mean grain sizes of the Mesa Rica Sandstone decrease to the southeast, south, and southwest (fig. 11). Mean standard deviation (phi deviation) ranges from 0.37 to 0.58 and represents well-sorted to moderately well sorted sand. No distinct trend in any other grain-size parameter was noticed across the study area.

The Visher (1969) log-probability curves indicate that the Mesa Rica Sandstone represents environments of deposition ranging from fluvial to marine. These 50 curves can be grouped into four Visher types (figs. 12-15). Fluvial (distributary channel) deposits (fig. 12) represent 44 percent of the Visher curves while marine wave deposits represent 56 percent of the Visher curves (figs. 13-15). The marine wave deposits consist of two types: wave zone deposits (48 percent; figs. 13 and 14) and surf zone deposits (8 percent; fig. 15).

SEDIMENTARY STRUCTURE ANALYSIS

Predominant sedimentary structures observed in the Mesa Rica Sandstone are planar (figs. 5 and 10) and trough (fig. 6) cross stratification, horizontal stratification, and bioturbation plus burrowing (fig. 16). Percentage data for the sedimentary structures is summarized in table 1. Planar and trough cross stratification are common varieties of sedimentary structures and range from 13.3 to 81.6 percent. Horizontal stratification varies from 9.5 to 48.6 percent. Bioturbation plus burrowing is present in the lower portion of each section with the exception of the Isidore area and ranges from 8.9 to 72.2 percent. Parallel stratification (suspension deposits) and current ripples are scarce. Cross stratification (fig. 5) is associated with the distributary channel deposits, and bioturbation plus burrowing (figs. 4, 7, 8) is associated with the shoreface wave deposits.

Bioturbation plus burrowing percentages increase to the southeast, south, and southwest indicating an increase in marine shoreface deposits (fig. 17). Concomitantly, there is a decrease in cross stratification and

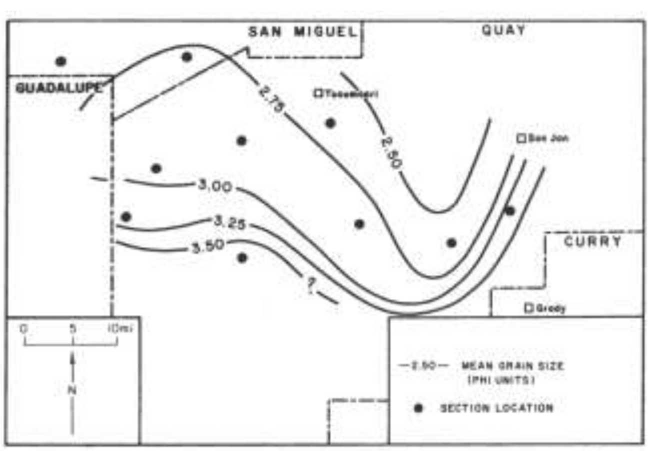


FIGURE 11—Map showing mean grain size (phi units) for Mesa Rica Sandstone, Tucumcari area. Note, mean grain size decreases southward into the Tucumcari Basin.

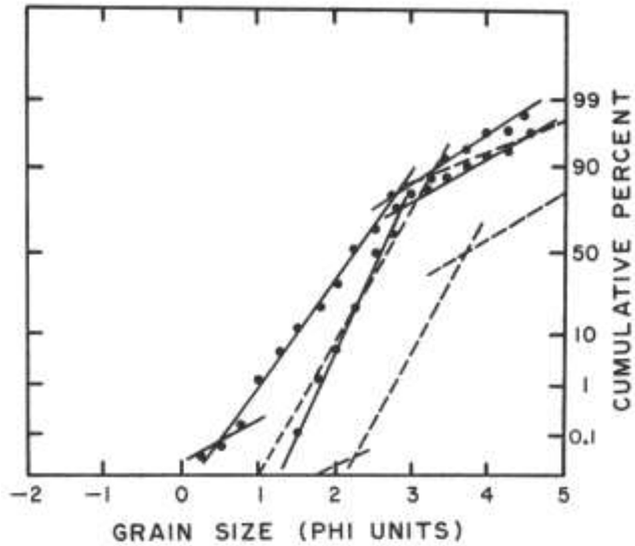


FIGURE 12—Log-probability curves for Mesa Rica Sandstone (solid lines): dashed lines from modern distributary channel deposits (Visher, 1969, p. 1088).

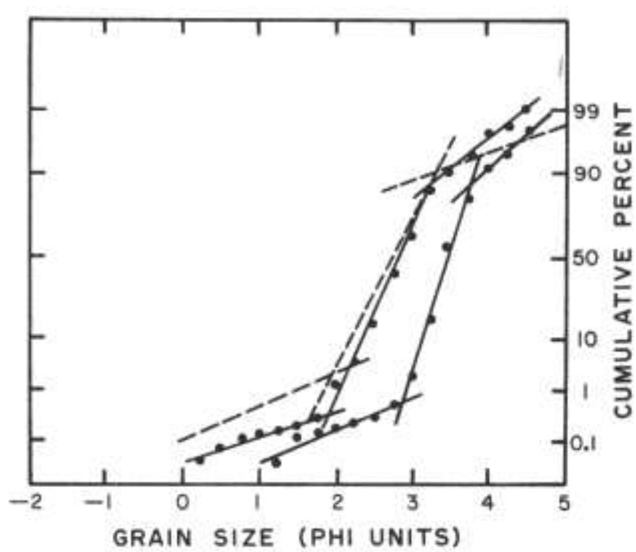


FIGURE 13—Log-probabiilty curves for Mesa Rica Sandstone (solid lines): dashed lines from modern distributary mouth bar shallow marine wave zone (Visher, 1969, p. 1088).

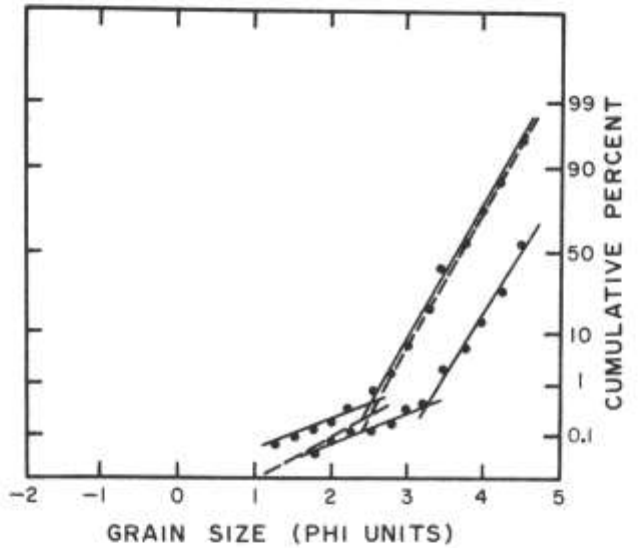


FIGURE 14—Log-probability curves for Mesa Rica Sandstone (solid lines): dashed lines from modern distributary mouth bar shallow marine wave zone (Visher, 1969, p. 1088).

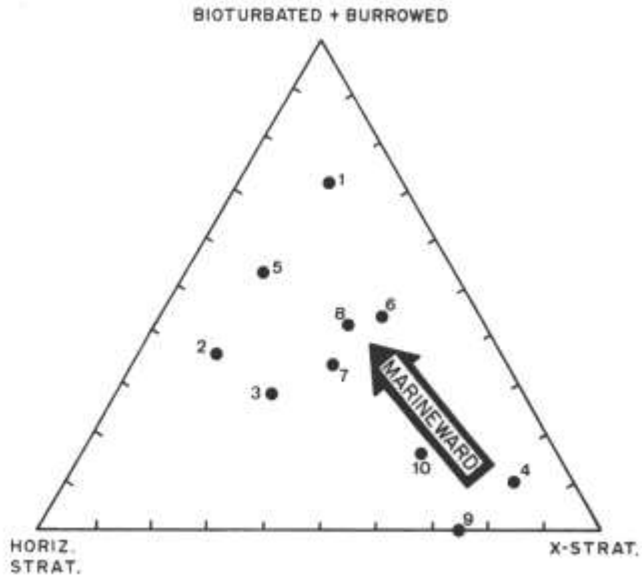


FIGURE 16—Three component sedimentary structure facies plot (bioturbated + burrowed – horizontal stratification – cross stratification).

consequently a decrease in fluvial influence (fig. 18). Figs. 17 and 18 both exhibit a similar lobate shape to that noted on the Mesa Rica isopach map (fig. 9). The lobate shape of the Mesa Rica Sandstone suggests a sand-rich lobate delta (Brown, Cleaves, and Erxleben, 1973, p. 13, fig. 9). Further evidence which substantiates this conclusion is the thinness of the prodelta facies (upper 40 to 50 ft of the Tucumcari Shale) and the lack of penecontemporaneous deformational structures (Brown, Cleaves, and Erxleben, 1973, p. 25, fig. 20B).

Cross section ***A-A'*** (fig. 19) illustrates the progradation of younger distributary channel facies of the Mesa Rica Sandstone over the previously deposited marine shoreface and foreshore facies. Cross section ***B-B'*** (fig. 20) demonstrates the decrease from north to south in the fluvial (distributary channel) facies for the Mesa Rica Sandstone. Both cross sections, ***A-A'*** and ***B-B'*** (figs. 19 and 20), illustrate rapid transition from cross-

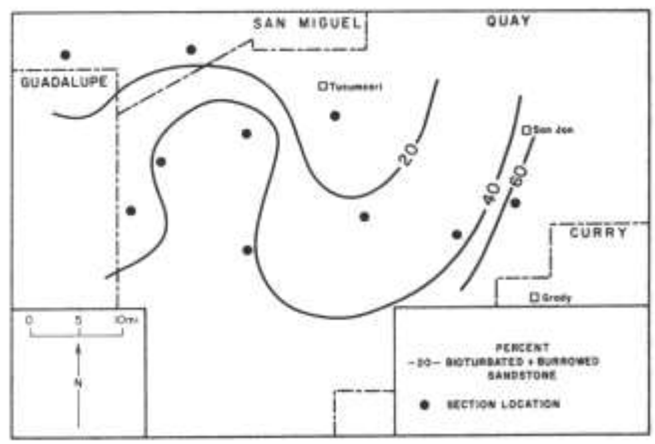


FIGURE 17—Map showing percent bioturbated + burrowed Mesa Rica Sandstone, Tucumcari area. Note, increase in marine conditions southward into the Tucumari Basin.

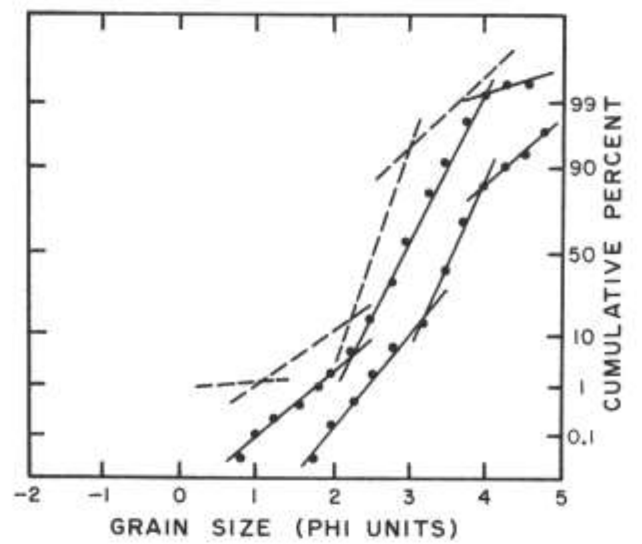


FIGURE 15—Log-probability curves for Mesa Rica Sandstone (solid lines): dashed lines from modern surf zone (Visher, 1969, p. 1086).

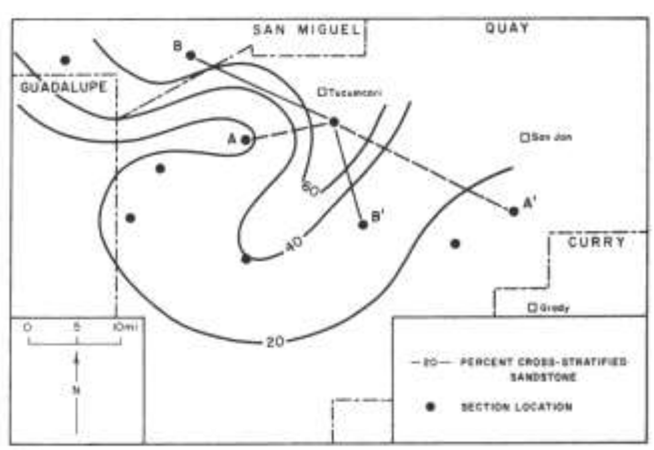


FIGURE 18—Map showing percent cross stratification Mesa Rica Sandstone, Tucumcari area. Note decrease in cross-stratified fluvial sandstones southward into the Tucumcari Basin. Cross sections *A-A'*, *B-B'* located for reference.

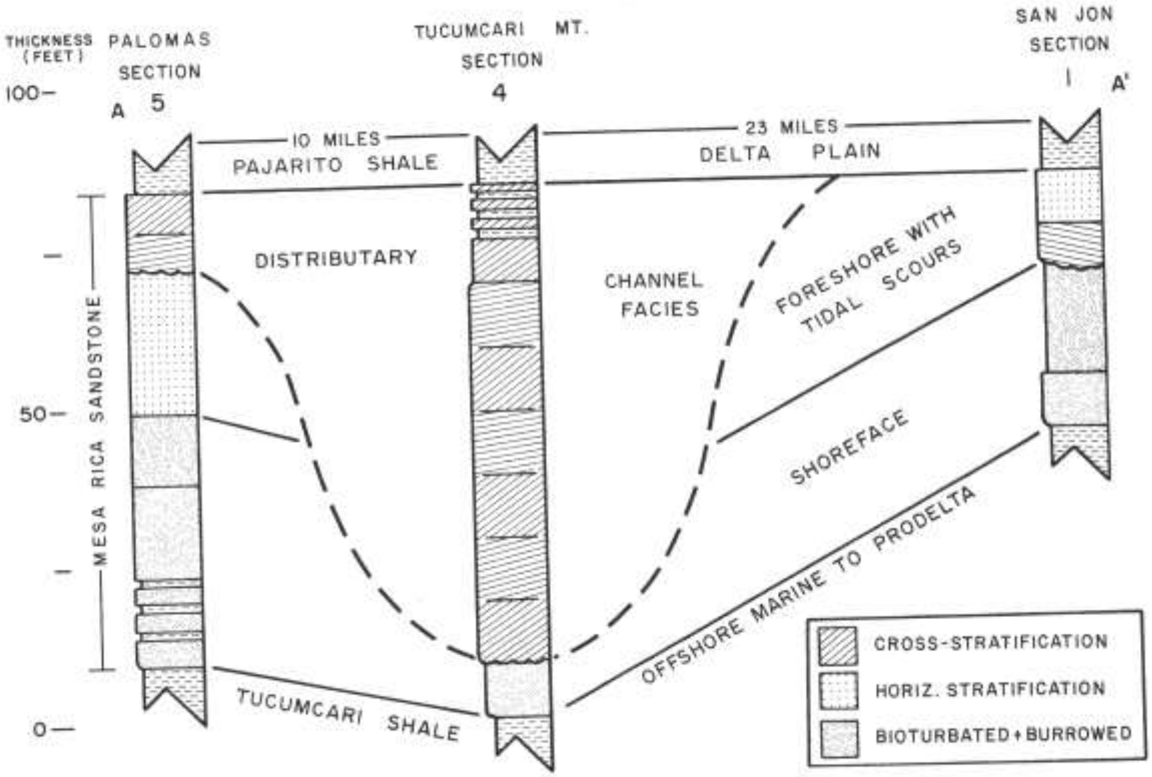


FIGURE 19—Cross section *A-A'* of Mesa Rica Sandstone, Tucumcari area, illustrating younger distributary channel facies prograding over previously deposited marine facies. The line of the section is across the axis of the Mesa Rica delta.

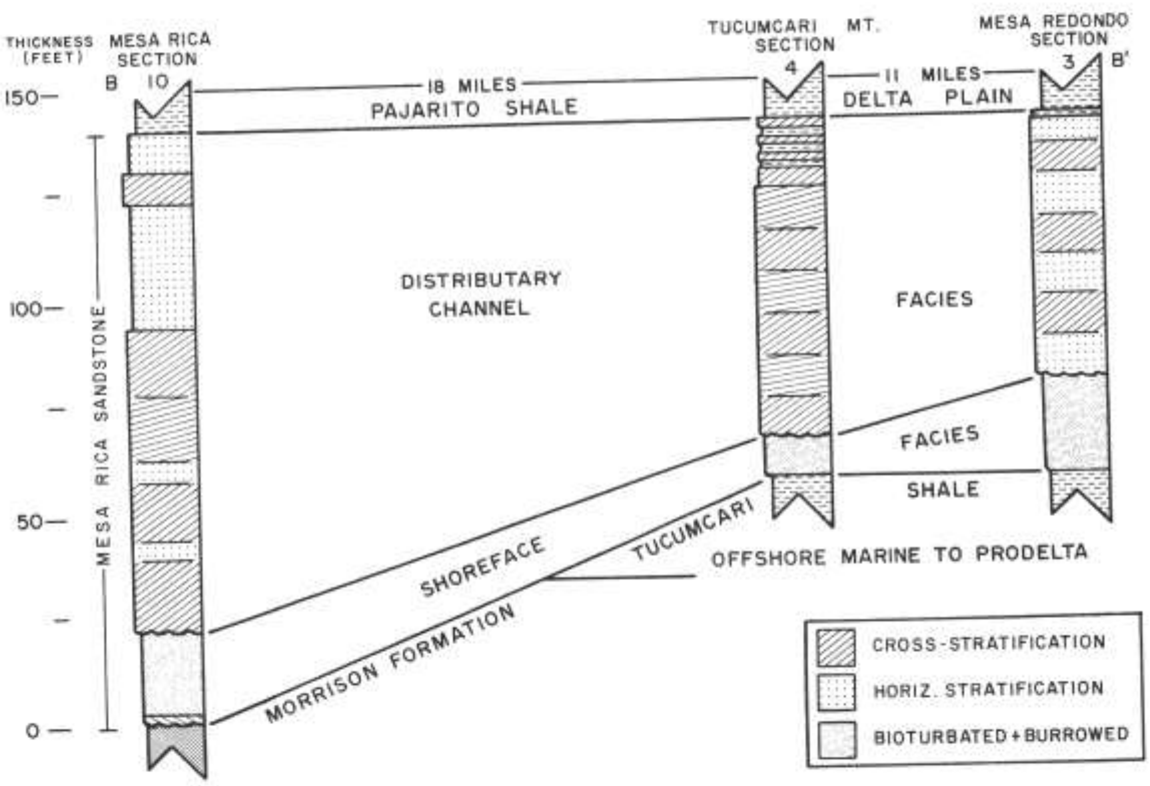


FIGURE 20—Cross section *B-B'* of Mesa Rica Sandstone, Tucumcari area, illustrating decrease in fluvial (distributary channel) facies from north to south. The line of the section (fig. 18) is more parallel to the axis of the Mesa Rica delta than section *A-A'*.

stratified fluvial (distributary channel deposits) to bioturbated and burrowed marine wave deposits. This, along with the Visher curves which indicate distributary channel and shallow marine wave deposits (figs. 12-15), suggests that the Mesa Rica Sandstone represents a prograding delta with some reworking by waves.

The vertical sequence of sedimentary structures and trace fossils present in the Mesa Rica Sandstone (figs. 3 and 19) is similar to that of the Fox Hills Sandstone in the Rock Springs uplift of Wyoming described by Weimer (1973, p. 98). He interpreted the Fox Hills Sandstone as a barrier island complex with prograding estuarine fluvial sandstones. However, because of the lobate shape of the Mesa Rica delta (figs. 9, 17, and 18) progradation must have been more pronounced than in the Fox Hills Sandstone.

Fig. 21 is a paleogeologic map of northeastern New Mexico during deposition of the Mesa Rica and Dakota Sandstones. This interpretation is based on Scott's correlation (1970, p. 1235). Isopach trends, paleocurrent directions, grain-size analysis, and sedimentary structure analysis are the basis of a deltaic interpretation for the Mesa Rica Sandstone in the Tucumcari Basin.

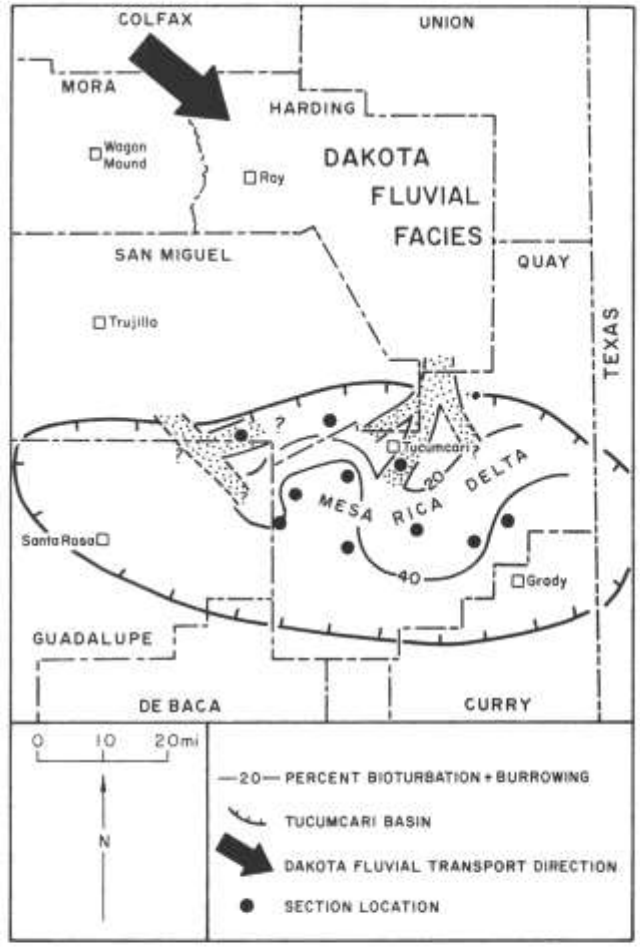


FIGURE 21—Paleogeologic map of northeastern New Mexico during deposition of the Mesa Rica Sandstone and braided fluvial interval of the Dakota Sandstone. Correlation of Mesa Rica and Dakota Sandstones after Scott (1970, p. 1235) and paleocurrent data for fluvial facies of the Dakota Sandstone after Gilbert and Asquith (1976).

Summary

The Mesa Rica Sandstone in the Tucumcari Basin represents deposition from a lobate sand-rich delta complex. Log-probability curves of the grain-size distributions indicate environments ranging from distributary channel to marine wave and surf zones. This, plus the rapid transition both laterally and vertically from cross-stratified fluvial distributary channel deposits to bioturbated and burrowed horizontally stratified marine wave deposits, indicates that the Mesa Rica Sandstone represents a prograding delta with some reworking by waves.

The Mesa Rica delta prograded into the marine Tucumcari Basin from the north as indicated by the south-trending to southwest-trending paleocurrent directions, and the decrease in mean grain size and thickness to the southeast, south, and southwest (lobate geometry). Also, a decrease in percent cross stratification in the same directions accompanied by an increase in percent bioturbation and burrowing is indicative of a transition from predominantly fluvial distributary channel deposits to predominantly marine shorezone deposits. The prograding Mesa Rica delta is similar to the Fox Hills Sandstone (Upper Cretaceous) of the Rock Springs uplift in Wyoming described by Weimer (1973, p. 98). If Scott's correlation (1970, p. 1235) of the Dakota with the Mesa Rica is valid, then the Dakota Sandstone represents the fluvial system which supplied sediments for the Mesa Rica deltaic-marine complex.

Composition: Text in 8 and 10 pt. Times Roman, leaded one-point; subheads 12 pt. Times Roman
Index in 8 pt. Press Roman, leaded one-point
Display heads in 24 pt. Times Roman, letterspaced

Presswork: Miehle Single Color Offset (text)
Harris Single Color Offset (cover)

Binding: Saddlestitched

Paper: Cover on 65 lb. Talisman (autumn gold)
Text on 60 lb. White Offset