Geology and Depositional Environments of the Mesaverde Group in the Capitan coal field Lincoln county, New Mexico

by

Erling Terry Jensen

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New Mexico Institute of Mining and Technology
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Abstract

The Mesaverde Group of the Capitan coal field represents some of the southeastern most exposures of Cretaceous rocks in New Mexico. The stratigraphic section can be subdivided into three lithologic lithosomes, each representing different depositional environments: Sandstone lithosome= a repetitive succession of prograding strandplain, barrier bar and lagoonal deposits modified by deltaic conditions; Lower shale-sandstone lithosome= a marine transgression; and Upper shale-sandstone lithosome= marginal marine to coastal swamp and fluvial coastal plain deposits.

The three lithosomes are stratigraphic equivalents to the upper Gallup Sandstone, Mulatto Tongue of the Mancos Shale and Crevasse Canyon Formation.

From the interpretations of environments of deposition coal prospects are indicated to the south and southwest of the study area.

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Introduction

The Mesaverde Group of Late Cretaceous age has been interpreted as a transition of nearshore marine deposits to continental deposits (Pike,1947; Allen and Balk, 1954). Within this transition minable coals make the Mesaverde Group of economic importance.

The objective of this study is to interpret the environments of deposition of the Mesaverde Group in the Capitan Coal Field which may be used for exploration and recovery of coal. This study integrates detailed local data with the regional stratigraphy of the Mesaverde Group. Methods used in this study

1) The measurement of partial stratigraphic sections in accordance to the methods proposed by Kottlowski (1965) are implemented to construct a complete composite stratigraphic column of the Mesaverde Group in the study area. Vertical trends of lithology, sedimentary structures and paleontology in the stratigraphic column are used to interpret the environments of deposition.

2) Identification of paleoflora and paleofauna is used for paleoecological and age significance.

3) Sedimentary structures and paleocurrent analysis are used to aid interpretation of depositional environments.

4) Lateral tracing of stratigraphic units in the field and on aerial photographs are used to construct a geologic map at a scale of 1:24000.

Location

The study area is in southeastern New Mexico in the south-central portion of Lincoln County (figure 1) and occupies the west-central portion of the Capitan 7 1/2' topographic quadrangle. It covers sections 31, 32, 33 of T8S, R14E and sections 4, 5, 6, 7, 8, 9, 16, 17 and 18 of T9S, R14E. U.S. Highway 380 crosses the study area from the northwest to the southeast into the town of Capitan. Numerous secondary roads used for recent real estate development traverse the study area making access excellent even in the most adverse weather. However, bedrock exposure in the area is poor. The occurrence of pinyon pine, juniper and associated grasses and shrubs, approximately 14-18 inches (35.6-45.2 cm.) annual precitation (Sprankle, in press) and weathering characteristics of local rock units all contribute to extensive alluvial and soil cover.

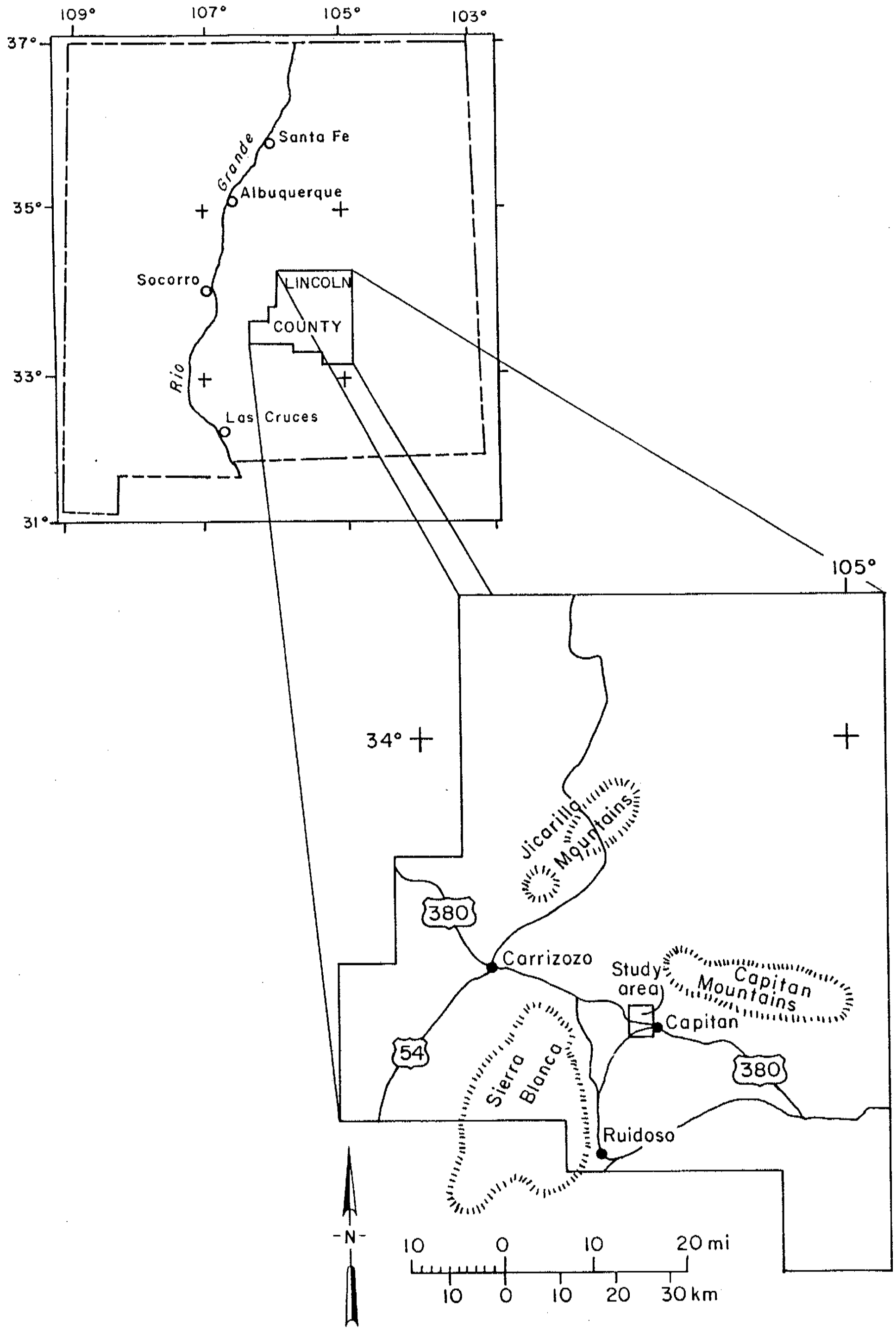


Figure 1. Location of Study Area

GENERAL GEOLOGY

Pre-Cretaceous rocks do not outcrop in the study area, but are present to the east. Table I shows the general geology of the study area including the rock units, rock types and periods of erosion. For summaries of the general geology of the surrounding area the reader is directed to Griswold (1959), Kelly (1971) and Allen and Kottlowski (1981).

The Cretaceous strata in the study area tilt to the west with varying dips of 5 to 30 degrees. These units were influenced by several tectonic events during the Tertiary Period. During the Eocene Epoch, deep seated warping, along the same lines of weakness that produced the older (Late Pennsylvanian to medial Permian) Pedernal Mountains, formed the Mescalero Arch and Claunch Sag, which are joined by a series of broad anticlines and synclines. The study area is part of the west limb of the Mescalero Arch (Kelley and Thompson, 1964).

Intrusions of dikes and sills related to the Sierra Blanca and Capitan plutons disrupted beds during the Late Eocene to Oligocene. In covered portions of the study area monoclinal flexing caused by these intrusions and faulting along the dikes has distorted the stratigraphic thickness of the upper Cretaceous Series.

ERA	GEOLOGIC AGE	ROCK UNITS	ROCK TYPES	
CENOZOIC	PLIOCENE	Continued faulting and extensive erosion	Alluvium, terraces Ogalalla pediment gravel	Qal
	5			
	MIOCENE			
	22.5			
	EOCENE	Dikes, Sills and Laccoliths	Basalt and gabbro to rhyolite and microgranite	TKi
		Sierra Blanca	Andesitic lavas and breccia	Tvi
	37.5	Folding of Sierra Blanca Basin and erosion		
	PALEOCENE			
	53.5			
	65	Cub Mountain	Pale sandstones to purplish siltstone	Tbc
MESOZOIC	CRETACEOUS "K"	Sight erosion		
		Mesaverde	Sandstone, shale and coal	Kmv
		Mancos	Shale and limestone	Km

Table I -General Geology of study area including Geologic ages (millions of years in duration), rock units, rock types, and periods of erosion (modified from Allen and Kottlowski, 1981).

During the Miocene, the study area was cut by numerous faults related to the Ruidoso and Capitan fault zones. The general trends of faults and dikes in the study area are NE-SW (Bodine, 1956; Elston and Snider, 1964). There are three major faults (east to west): the Magado fault, Coalora fault and Oso Creek fault, create a horst and graben structure. Possible minor faulting and monclinal flexing occurred during the Pliocene due to Basin and Range faulting (Allen and Jones, 1951; Kelly and Thompson, 1964).

Previous Work

The Capitan Coal Field was first mentioned in the literature in studies of the Sierra Blanca Coal District and its coal production. Campbell (1907) collected and identified plant fossil remains and described them as being of Laramie age, however Wegemann (1914) collecting near White Oaks suggested a post-Laramie age. Sidwell (1946) while studying the effects of igneous intrusions on sediments in the vicinity of Capitan and Lincoln briefly described the Mesaverde Group as probably comprising Point Lookout and Menefee Formation equivalents of the San Juan Basin.

The Upper Cretaceous Series in the vicinity of the study is subdivided from oldest to youngest into the Dakota Sandstone, Mancos Shale and the Mesaverde Group . The Dakota Sandstone outcrops just east of the study area as cliff forming sandstones whose thickness has been variably reported as 134 feet (40.8m) (Allen and Jones, 1951) to 189 feet (57.6m) (Kelley and Thompson, 1964).

The Mancos Shale comformably overlies the Dakota Sandstone and geomorphically forms wide valleys (see figure 2). Allen and Jones (1951) published a measured section which includes 389 feet (118m) of Mancos Shale. Cobban and Hook (1979) reported the following taxa from the Mancos

Figure 2. View of Capitan looking to the north showing ridge forming Dakota Sandstone (Kd), valley forming Mancos Shale (Km) and hill forming Mesaverde Group (Kmv).

Shale: Mammites depressus, Colignoceras woollgari regulare, C.woollgari woollgari and Lopha lugubris. Only uppermost portions of the Mancos Shale are exposed in the study area; ~~and~~ the Tres Hermanos Formation is not present.

The Mesaverde Group overlies the Mancos Shale and it outcrops west of the town of Capitan as a three-mile (4.5km) wide strip of cliff forming sandstones and valley forming shales and mudstones. Bodine (1956) informally subdivided the Mesaverde Group in the Capitan Coal Field into three members based on lithology of isolated exposures. Moreover Bodine (1956, p.6) felt lithostratigraphic and biostratigraphic " correlations are not sufficiently accurate to warrant carrying down the names used to the northwest."

Bodine (1956) described a lower sandstone member as comformably resting on the Mancos Shale. Above this contact the lower sandstone member consists of four sandstone units each about 20 feet (6.1m) thick, interbedded with shales and siltsones of equal thickness. The sandstones are described as clean, well rounded, massive, white and quartzose. From information gathered by Pike (1947) at Carthage, N.M. (Gardner, 1910) and White Oaks, N.M. (Wegemann, 1914) Bodine suggests that these lower sandstones correlate to the lower Gallup Sandstone. He (1956) further speculates Ostrea sp. and Inoceramus sp. are Mid-Carlile in age. This is a dubious speculation since no species was identified and generic ranges are rather long.

The middle member is described as a series of marine and terrestrial shales that overlie the uppermost sandstones of the lower member. The lower portion of the middle member consists of 95 feet (28.9m) of predominantly dark gray, fissile, marine shale with thin interbeds of limestone. The upper portion of the middle member is approximately 180 feet (54.9m) of carbonaceous shales, coal and thin beds of silty, poorly sorted sandstone.

Bodine (1956) described several fossil horizons within the marine or lower portion of the middle member which contain Volutaderma sp., Cardium pauperperculum, Baculites gracilis(?) and Inoceramus sagensis. These comprise of Coloradan (Cenomanian to middle Santonian) fauna.

The nonmarine or upper portion of the middle member contains plant fossils. The age of these plant fossils in the terrestrial shales are in disputed in early reports on the Capitan Coal Field. Campbell (1907) identified plant fossil remains to be Laramie (Maestrictian) age, while Wegemann (1914) reclassified the plant fossil remains to be post-Laramie age. This is in conflict with Pike (1947), Weimer(1960), Reeside and others (1963), to mention a few, who do not believe the Mesaverde Group to be younger than Montanan (Santonian-Campanian) age.

Bodine (1956) implied the lower marine portion of the middle member to be correlative with the Pescado Tongue of the Mancos Shale and the upper nonmarine portion of the middle member to represent the Dilco-Gibson Member of the Crevasse Canyon Fomation,in which case the upper Gallup Sandstone is not present in the Mesaverde Group in the Capitan coal field.

The upper member of the Mesaverde Group at Capitan is described by Bodine (1956) as a resistant, thick, massive, buff to white, quartzose sandstone with minor interbeds of fissile shale and cross-stratification near the top of the member. This unit's thickness varies from 30 feet (9.1m) in the northwest to 60 feet (18.2m) in the southwest portion of the study area. No fossils were reported in this unit and it was included in the Mesaverde Group due only to its lithologic similarity to the lower marine sandstone member.

Overlying the Mesaverde Group is the Cub Mountain Formation. Weber (1964) reports the term "Cub Mountain Formation" was first used to designate a thick interval of continential redbeds resting on the Mesaverde Group in the slopes of Cub Mountain, T9S.R10E in an unpublished manuscript (Weber, 1964). Bodine (1956) uses the term for correlative beds in the Capitan coal field. Bodine's paper has since served as a "loose" type definition even though this was not his purpose as a typographically omitted footnote explained. Weber (1964) formally defined the Cub Mountain Formation without a type section.

The Cub Mountain Formation consists of white to gray, yellow, buff, brown, massive to thin-bedded, fine- to coarse-grained poorly sorted arkosic sandstone which contains channels and some cross-bedding. Interbedded with the sandstone are variegated montmorillonitic mudstones and fine-grained sandstones. In the lower portion of the section there are thin conglomerate lenses (Bodine, 1956; Weber, 1964; Lochman-Balk, 1964). The upper portion contains coarse-grained graywackes. The Cub Mountain Formation is believed to be 2400 feet (731.5m) thick (Lochman-Balk, 1964; Weber, 1964). It is thought to be stratigraphically and lithologically equivalent to the McRae Formation east of Elephant Butte Reservoir, N.M. (Kelley and Thompson, 1964) or the Baca Formation west of Socorro, N.M. (Weber, 1964). These two formations are of different ages: the McRae Formation is considered to be latest Late Cretaceous to Paleocene and the Baca is considered to be Eocene. Except for small silicified woodchips, no fossil occurrences have been reported in the Cub Mountain Formation.

The Sierra Blanca Volcanics unconformably overlie the Cub Mountain Formation along the west edge of the study area. The Sierra Blanca Volcanics consist of an undifferentiated series of interbedded andesite flows, flow breccias, tuff breccias and lapilli tuffs. These volcanics were defined by Thompson (1964) and Weber (1964) and are believed to be of Miocene age. These units are not examined in this study.

Two episodes of Quaternary deposition are recognized in the study area. An early deposition of alluvial gravels caps a small mesa in S1/2 section 18 T9S and R13E. part of which has been excavated into a small abandoned gravel pit. The gravels contain cobbles and pebbles of sandstone, chert, quartz monzonites and andesites. These gravels may correlate with the Ogallala Formation which occurs further to the east and north (Bretz and Horberg,1949; Budding, 1964). The deposits of the more recent depositional episode consist of locally derived sediments occurring as valley fill. The vast majority of these sediments are fine-grained sands and silts with isolated lenses of gravels. Also numerous landslides and gravity slide deposits occur along the sandstone capped escarpments.

REGIONAL STRATIGRAPHY OF THE UPPER CRETACEOUS SERIES

The Upper Cretaceous Series in the western interior of the North America consists of intertonguing shales and sandstones that reflect fluctuations in the position of the shoreline. The intertonguing relationship occurs among the Dakota Sandstone, Mancos Shale and Mesaverde Group.

The Dakota Sandstone was named by Meek and Hayden (1862) for exposures in the hills near the town of Dakota, Dakota County, Nebraska. The Dakota represents the basal sandstones of the Upper Cretaceous Series in the Rocky Mountain Region (Hook, Cobban and Landis, 1980).

The Mancos Shale was named by Cross (1899) for exposures in the Mancos River Valley near the town of Mancos, in southern Colorado. The Mancos Shale represents offshore marine deposition (Pike, 1947).

The Mesaverde was described by Holmes (1877) for exposures in the San Juan River Valley in northwestern New Mexico and southwestern Colorado as consisting of three lithologic units. Cross and Spence (1899) redefined the Mesaverde in the Laplata quadrangle (Colorado) as a Formation. Collier (1919) replaced Holmes decriptive terms with geographic names, in ascending order: Point Lookout Sandstone, Menefee Formation and Cliff House Sandstone.

Sears (1925,1934) and Hunt (1936) included the Gallup Sandstone and members of the Crevasse Canyon Formation in the Mesaverde Formation from studies in the southern portion of the San Juan Basin. Allen and Balk (1954) raised the rank of the Mesaverde Formation to group status. The term Mesaverde has come to refer to a thick marine and non-marine section above the main Upper Cretaceous marine shale body and subsequently lost much of its orginal meaning by Holmes (Molenaar, 1973). For the purposes of this study only the Gallup Sandstone and the Crevasse Canyon Formation will be discussed.

The Gallup Sandstone was named by Sears (1925) for exposures near Gallup, New Mexico. The Gallup Sandstone is interpretted to represent prograding coastal barriers or delta fronts which represent a transition from marine to non-marine deposition.

Members of the Crevasse Canyon Formation were named by Sears (1934) for exposures on the southwest rim of the San Juan Basin. The Crevasse Canyon Formation was defined by Allen and Balk (1954) as a unit of the Mesaverde Group. The Crevasse Canyon Formation is a catch-all for predominantly nonmarine deposits above the Gallup Sandstone (Molenaar, 1977).

FIELD DESCRIPTIONS OF STRATIGRAPHIC COLUMN

Previous workers in environments of deposition have used a number of criteria to reach their conclusions. Factors such as lithology, sand body geometry, lithologic succession, sedimentary structures, paleocurrent direction and paleontology are all used to construct an interpretation of the depositional environment. These factors are described in ascending stratigraphic order in the chapter V and expanded upon in Chapters VI through Chapter XI.

A composite stratigraphic column of the Mesaverde Group and portions underlying and overlying beds in the study area is pictorially shown on Plate IIB. Construction of a composite stratigraphic column is required because of extensive cover and numerous faults within the study area. The composite stratigraphic column, Plate IIB, is constructed from observations made throughout the study area in association with 15 partial measured sections as illustrated on Plate IIA and described in Appendix IV. The partial section's locations and appropriate outcrop information are shown on Plate I.

As shown on Plate IIB, the Mesaverde Group is informally subdivided into three lithosomes which in ascending order are lower sandstone, lower shale-sandstone and upper shale-sandstone lithosomes. In this study, a lithosome is a three-dimensional rock mass of essentially uniform (or uniformily heterogenous) lithologic character, having intertonguing relationships in all directions with adjacent masses of different lithologic character (A.G.I. Glossary of Geology). Each lithosome is composed of numbered units which are numbered differently than units in the partial sections.

The following discussion begins with a description in the Mancos Shale, continues through the Mesaverde Group and terminates at the Cub Mountain Formation as defined by Bodine (1956) and Weber (1964).

Upper Mancos Shale Transition

Beginning approximately 60ft.(20 m.) below the contact with the Mesaverde Group, the Mancos Shale consists of thinly laminated olive-green claystones and mudstones. At this stratigraphic level, cone in cone structures and thin limestone beds occur with Collignoniceras woollgari woolgari and Prioncyclus (?) hyatti (Cobban, personal comm. 1982). Both specimens are small fragments of whorls and the referal to Prioncyclus hyatti is tenative.

The grain size gradually increases upwards to thinly laminated mudstone to siltstone with thin intercalations of fossiliferous, calcareous siltstones and silty, very fine-grained sandstones whose abundance and thickness increase upwards. Some trace fossils and other evidence of bioturbation occur. The decrease in clay size and silt size detritus to a predominately fine-grained feldspathic arenite defines the sharp conformable contact between the Mancos Shale and overlying unit 1 of the Mesaverde Group as defined in this study.

Lower sandstone lithosome

The lower sandstone lithosome is subdivided into four major units which represent different lithologies or lithologic transitions within the lithosome (see Plate IIA and IIB). Although vertical thickness varies laterally in these units; the paleontology, sedimentary structures and lithology remain relatively constant throughout the study area. (see partial stratigraphic columns 1, 2 , 3 and 4 in Appendix IV and Plate IIB).

Unit 1

Unit 1 consists of buff to white fine- to medium-grained sandstone with an upward increase in grain size. Intercalations of mudstones are absent above the contact. The lower beds in unit 1 are generally structureless or planar parallel bedded with solitary, small scale, tabular-shape sets of low angle, planar cross-beds with sharp nonerosional lower contacts (see Figure 3). Rare _Ophiomorpha (?) irregulaire_, _Thalassinoides sp_. and thin

Figure 3. Solitary, small scale, tabular-shape sets of low angle, planar cross-beds with sharp nonerosional lower contacts interbedded with planar parallel stratification in unit 1. (Knife is 9cm. or 3.5 inches long.)

lenses of fossil conglomerate consisting only of *Turritella sp.* occur. The occurrence of cross-bedding increases upward and changes to medium scale, tabular and wedge shape cosets of low angle, tangential cross-beds with sharp nonerosional lower contacts. Interbedded with the latter cross-bedded units are individual beds of planar parallel bedding (see Figure 3). Within unit 1, cross-bedding is more common in the southern portion of the study area and decreases in abundance due to a more common occurrence of planar parallel bedding to the north and west. Within the planar parallel bedded portion of unit 1 there are numerous Inoceramus prisms with rare solitary specimens of *Inoceramus deformis* (Plate III) and rare *Arenicolites sp.* and *Thalassinoides sp.* which cuts the bedding. Above this portion of the column, bedding is planar parallel or structureless with an upward increasing abundance of trace fossils. At the top of unit 1 is an extensively burrowed zone locally up to 2 ft. (60 cm.) thick containing *Teichichmus sp.* (see figure 4), *Ophiomorpha nodosa*, *Thalassinoides sp.*, *Arenicolites sp.* and *Asteroma sp.* These burrows are especially dense in NW 1/4 section 16 and gradually decrease to the north, south and west.

Figure 4. Examples of Techichimus sp. and Ophiomorpha nodosa at the contact between unit 1 and unit 2. (Knife is 9cm. or 3.5 inches long.)

Unit 2

Unit 2 is almost completely covered throughout the study area. The following descriptions are based on inspection of float and small outcrops of less than 2 ft.(60 cm.) in any dimension. The thickness of unit 2 increases to the west and north.

The lower half of unit 2 consists of thinly laminated olive green mudstones fining upward to claystones intercalated with fossiliferous, calcareous, very fine-grained sandstones, siltstones and silty limestones. The dominant fossils are oysters: Flemingostrea aff. prudencia and Ostrea anomioides with minor occurrences of Pleuricardia pauperculum, Cardium curtum, Arrhoges sp., Gyrodes and Turritella sp. The fossiliferous lithology is not laterally continuous and decreases in abundance upward. The fossils show little to no abrasion and commonly are complete.

Grain size increases upward in the upper half of unit 2. Litholgy becomes a friable, moderately sorted, fine-grained sandstone with rare Ophiomorpha irregulaire and Thalassinoides sp. usually near the lower contact (see Figure 5). Sandstone beds are generally structureless, but some bedding surfaces show lingoid ripple marks. The top of unit 2 is an oyster bed whose thickness varies between

Figure 5. Example of Thalassinoides sp. in unit 2. (Knife is 9cm. or 3.5 inches long.)

0.5ft. and 2ft. (15-60 cm.) and is composed of only <u>Flemingostrea aff. prudencia</u> and <u>Ostrea anomioides</u>. Along the upper contact of this bed are lingoid ripple marks. This bed can be traced laterally throughout the study area with increase of fossil density and thickness to the north. These fossils show little abrasion and are generally complete.

Unit 3

Like unit 2, the lower half of unit 3 is extensively covered throughout the study area. Unit 3 conformibly overlies unit 2 and consists of thinly planar, parallel bedded, friable, poorly to moderately sorted, fine-grained sandstone. Siltstone and claystone rip-ups are present. In the lower half of unit 3, grain size decreases upward and lithology becomes carbonaceous siltstones to claystones and shales. There are numerous fossil plant fragments. Carbonaceous sediments are found only in the southwestern portion of the study area. Above the carbonaceous shales in the upper half of unit 2, float indicates a friable, fine-grained sandstone with planar parallel beds, grading (?) upward into sandstones which display many small scale, wedge-shape sets and cosets of low angle, tangential crossbeds with locally undulate sharp erosional lower contacts. These structures are best exposed in partial stratigraphic section 4 location (see Appendix IV). These beds grade into beds exhibiting planar parallel bedding and medium scale, tabular shaped sets of low angle tangential and trough cross-beds with sharp non-erosional lower contacts. The later bedforms and herringbone cross-strata become more dominant to the north at the expense of the underlying beds. Fossil evidence consists of abraded Inoceramus prisms and pelecypod casts which are observed in planar parallel beds. Cross-stratification decreases upsection to planar parallel beds. At the top of unit 3 is an oyster bed similar to the one at the top of unit 2. Flemingostrea aff. prudencia and Ostrea anomioides are the only species observed. This unit thickens to the north and west.

Unit 4

Unit 4 conformably overlies unit 3 and consists near its base of bioturbated, friable fine-grained, poorly sorted, silty sandstones interbedded with calcareous, fossiliferous, fine-grained, poorly sorted silty sandsone and sandy siltstone. Contained fossils are Flemingostrea aff. prudencia and Ostrea anomioides with minor occurrences Pleuricardia pauperculum, Cardium curtum, Arrhoges sp., Gyrodes and Inoceramus prisms. The specimens vary from complete to abraded fragments. The fossil abundance decreases upward while there is an increase in clay clasts. Ripple marks occur along bedding planes in the finer grained lithologies and grain size decreases upward. IN SE 1/4 of Section 7 light gray siltstones and a thin (<.5 ft(15cm.) coal occur. The interval above the siltstones and coal is covered within the study area. Based on float there is a rapid upward increase in grain size to silty fine-grained sandstone with siltstones.

This covered interval is overlain by white to buff, fine-grained, moderately to well-sorted sandstones. The lower contact was not observed. The sandstone beds are structureless or planar parallel bedded and locally with medium scale, tabular-shape sets of low angle tangential crossbeds with gradational and sharp nonerosional lower conacts, Unit 4 is capped by numerous Skolithos (see Figure 6) whose abundance increases northward (east-west no ascertainable). Unit 4 pinches out to the northeast.

Lower shale-sandstone lithosome

The lower shale-sandstone lithosome is divided into four units, 5 through 8, as shown on the composite stratigraphic column (Plate IIB). This portion of the column is described in Appendix IV partial sections 5, 6 and 7 and Plate IIA.

Figure 6. Skolithos burrows at the top of unit 4.
(Knife is 9cm. or 3.5 inches long.)

Unit 5

The friable nature of unit 5 causes it to be covered in most of the study area. The following descriptions are from small outcrops in sections 5, 8 and 32. The lower portion of this unit consists of thin, discontinuous beds of buff fine-grained, moderately sorted sandstones that are otherwise lithologically similar to the top sandstone of unit 4. These sandstones are interbedded with poorly sorted, silty, very fine-grained sandstones. Grain size decreases upward to olive green, thinly laminated mudstones and shales similar to the Mancos Shale in appearance. Interbedded with these mudstones and shales are thin (<2 ft. (15 cm.)) beds of silty, fossiliferous conglomerate showing graded bedding and erosional lower contacts. The fossils are generally fragments of oysters, clams and gastropods with rare shark teeth. No lateral dimension of these beds can be established. Upsection, the conglomerates change to poorly sorted sandstone that may be barren of fossil evidence or have fossil fragments primarily of oysters and clam showing varying degrees of abrasion. These sandstones usually have sharp lower contacts and grade into interbeds of sandy siltstones that are bioturbated but barren of fossils. These beds are overlain by olive drab, unfossiliferous, thinly laminated mudstones and siltstones interbedded with thin (<.5 ft (15cm.)) beds of fossiliferous limestone conglomerates. The fossils occur as complete and abraded fragments of Pleuricardia paperculum, oyster fragments, shark teeth and Inoceramus prisms. The contacts between these units are undulatory and locally with asymmetrical ripple marks. At the top of unit 5 the siltstone and mudstone become interbedded with fine-grained, poorly sorted silty sandstones that increase in abundance and thickness upward.

Unit 6

Unit 6 consists of buff, fine-grained, well sorted sandstone with solitary, medium scale, tabular-shape sets of low angle tangential cross-beds wih sharp, curved erosional (?) lower contact in the lower portion of unit 6 that grade upward into "hummocky" cross-beds (see figure 7). In the lower portion of unit 6, fossils of Inoceramus deformis occur. Inoceramus prisms and rare Ophiomorpha nodosa are associated with the "hummocky" cross-beds. At the top of unit 6 there are large shell fragments of Inoceramus (?)deformis forming fossil conglomerate lenses. Unit 6 thins both to the south and north and is nonexistant in the eastern portion of the study area.

Figure 7. Hummocky cross-bedding in unit 6. (Pick is 27.9 cm. or 11 inches.)

Unit 7

The contact between unit 6 and unit 7 is sharp and undulatory. The base of unit 7 consists of fossiliferous pebble to cobble sandstone of variable induration. The fossil fragments show a wide variation in degree of abrasion from nearly complete unabraded specimens to rounded fragments. There is a slight decrease in grain size upward. Above this conglomerate, thinly laminated mudstones prevail with thin (<.5 ft (15cm.)) fossiliferous, silty, limestone pebble conglomerates. Both conglomerates in unit 7 contain Crassostrea (?) soleniscus, Pleuricardia pauperculum, Inoceramus prisms, Arrhoges sp., Gyrodes spillmani, Gryrodes americanus, Placenticeras-Stantonoceras and and shark teeth. The silty, limestone pebble conglomerates become thinner upsection along with a decrease in grain size to drab olive mudstones. Fossil abundance (number of individuals) diminishes but diversity (number of species) remains constant upsection in mudstones containing fossils of Placenticeras aff. planum, P. aff. meeki var. P. intercalare, Stantonoceras sp., Gyrodes spillmani, G. americanus, G. aff. petrosus, Stantonella sp., Arrhoges sp., Inoceramus subquadatrus, I. involutus and Pleuricardia pauperculum. At the top of unit 7 there are thin fine-grained poorly sorted silty sandstones that become more

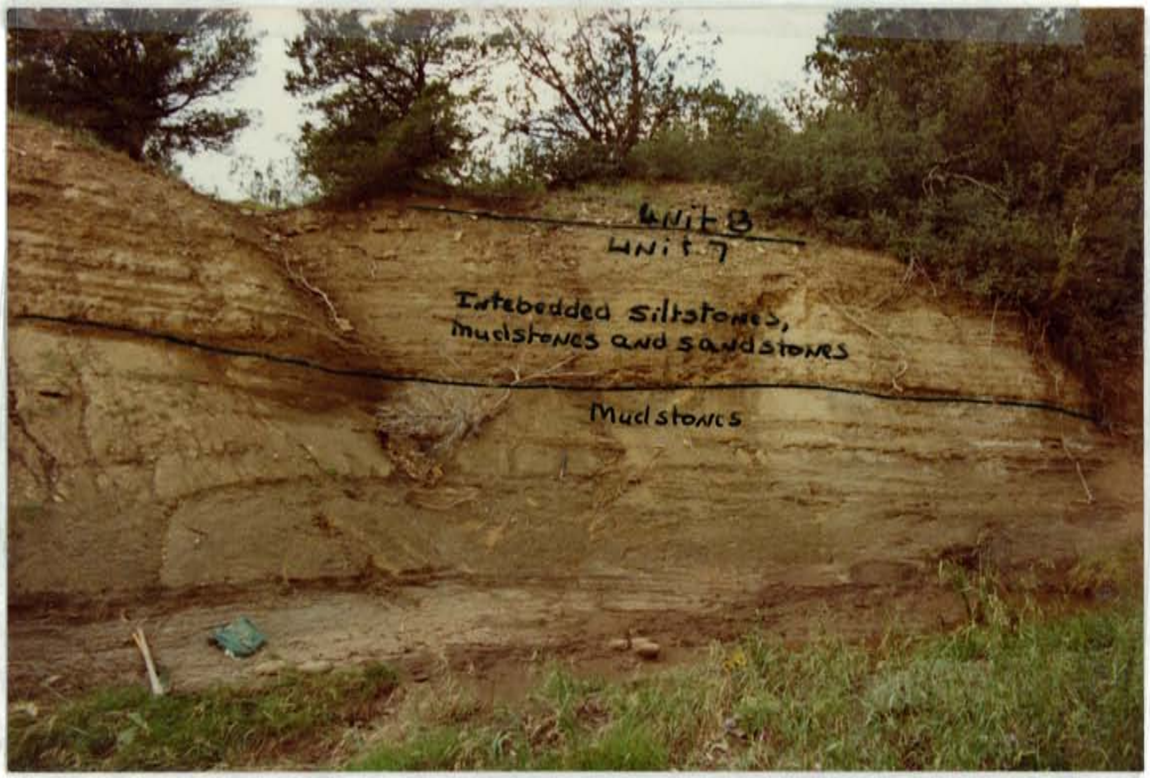


Figure 8. Transition from unit 7 to unit 8. (Pick is 27.9 cm. or 11 inches.)

common and thicken upward as mudstones no longer occur (see figure 8).

Unit 8

Unit 8 consists of a poorly to moderately sorted, fine- to medium-grained silty sandstone that varies from structureless to planar parallel bedded. Increasing in abundance upward are fossils of Cardium curtum, Drilluta sp. and Cymbophora sp. with minor occurrences of Gyrodes spillmani, G. americanus, Placenticeras sp., oyster fragments and brittle starfish. Fossil fragments of oysters, clams and snails increase in abundance southward. Grain size decreases upward with a gradual increase in carbonate cement. The top of unit 8 is a variably thick silty limestone with Cardium curtum, Drilluta sp. and minor oyster fragments. The limestone pinches out to the north and has an increase in clastic content to the south. At a similar stratigraphic position approximately five miles (7.5km) west of the study area at Indian Creek Divide is a clean limestone with only Cardium curtum and Drilluta sp..

Upper shale-sandstone lithosome

In the upper shale-sandstone lithosome it is extremely difficult to determine a stratigraphic order. The upper shale-sandstone lithosome lacks decernible marker beds and due to the friable, fine grained nature of the sediment exposure is poor. The following description is interpreted from partial stratigraphic sections 7 through 15, inspection of the float and observations at Indian Creek Divide.

Unit 9

Unit 9 in the southern portion of the study area consists predominantly of friable, poorly sorted, fine- to medium-grained silty sandstones with angular, clasts of claystone and siltstone interbedded with minor sandy siltstones and mudstones. At Indian Creek Divide, and in the northeast portion of the study area, the dominant lithologies are dark to light gray mudstones and shales with minor lenses oyster-bearing limestone and rare plant fragments. Upsection there is a general decrease in grain size and an increase in carbonaceous debris. Unit 9 is capped by coal deposition. The coal varies in thickness and quality from carbonaceous shales <.1ft.(2cm.) to coal 2 ft (0.6 m) thick. A coal seam can be traced laterally from section 17 T9S R14E north to section 33 T8S R14E. This seam in sections 17, 8 and 9 T9S R14E is a single seam (see figure 9). This coal seam splits into two seams to the north interbedded with fine-grained carbonaceous sediments. The lower seam is the thickest measuring 1 ft. (30 cm). Continuing north the fine-grained carbonaceous sediments thin and the upper seam disappears. The upper seam outcrops

Figure 9. Coal seam at the top of unit 9 in adit at SW1/4 NW1/4 SW1/4 Sec. 9. (Flashlight is 25.4cm. or 10 inches.)

to the west in section 18 and northward to section 6 T9S R14E. In section 18 the coal is two seams with the upper seam 2 ft. (60 cm.) thick. Tracing the coal northward one seam pinches out and by the northern portion of section 7 no evidence of coal was found. Further north in section 6 thin carbonaceous claystone and shales are found in the same stratigraphic position. Following these coals can be difficult because of cover and the tendency of the coal to pinch out. The coal is overlain in some locations by poorly to moderately sorted fine grained sandstones with abundant carbonaceous fragments, but these sandstones are not laterally continuous. The coal may also grade gradually into carbonaceous siltstone to claystones and shales. In many locations the coal is overlain by a diabase sill and the coal rank may have been improved by the igneous intrusion.

Unit 10

Unit 10 throughout the study area is a series of discontinuous poorly to moderately sorted, fine- to medium-grained silty sandstones showing a variable degree of chloritization, variable thickness, grading and reverse grade. These sandstones are interbedded with, and laterally grading into, siltstones, mudstones, shales and ironstones layers (see figure 10). Clay-clast conglomerates occur at the base of many these sandstones with brush marks, flute

Figure 10. Interbedded siltstones, mudstones, shales and ironstone layers in unit 10. (Knife is 9cm. or 3.5 inches long)

casts, load casts and ripple marks along the bedding planes. Interbedded with these sandstones, siltstones, mudstones and shales are thin lenses of carbonaceous shales and coal. The fossil plants Ficus planicostata, cf. Laurophylum sp., Vitus aff. stantoni and Cissus sp. occur in the sandstones; Sequoia cuneata, Araucarites sp., cf. Laurophylum and Carpites bauri occur in the finer grained lithologies.

Unit 11

Unit 10 has a gradational contact with unit 11 which consists of a series, poorly to moderately sorted, fine-grained sandstones interbedded with mudstones that have plant fragments, discontinuous septarian ironstone layers and thin (<.5ft.(6 cm.)) carbonaceous shale beds.

Unit 12

Unit 12 is a well sorted, fine- to medium-grained quartzose sandstone with well rounded grains. Unit 12 was defined as part of the Mesaverde Group by Bodine (1956) and Weber (1964) based on its lithologic similarities to the lower sandstone lithosome. Unit 12 displays large scale, tabular-shaped cosets of low angle, trough cross-beds with sharp, curved erosional lower contacts (see figure 11). Along the trough axes are angular mostly clay clasts that decrease in abundance upward. To the northwest, west and

Figure 11. Large scale, trough-shaped cosets of low angle tangential-shaped beds with sharp, curved erosional lower contacts. (Pick is 27.9cm. or 11 inches long)

southwest unit 12 appears to thicken and it pinches out toward the north and south. To the west unit 12 becomes increasingly difficult to distinguish from the lower portion of the Cub Mountain Formation. The upper contact is defined (Bodine, 1956 and Weber, 1964) by an abrupt increase in abundance of fine-grained silty sandstones with interbeds of variegated siltstones and claystones and lenses of angular chert pebble conglomerates. Where observed this abrupt contact appears conformable. Isolated petrified logs and palm leaves (Sabelites sp.) occur in the lower portion of the Cub Mountain Formation.

SEDIMENTARY STRUCTURES

Sedimentary structures are formed in situ so unlike many other paleoenvironmental indicators they are not transported into the study area (Selley, 1978). The following discussion of sedimentary structures in the study area is subdivided into three categories: pre-, syn- and post-depositional structure (Selley, 1978).

Pre-depositional structures

Flute casts occur in unit 10 and 11 associated with rippled beds of carbonaceous siltstones. These scooplike structures are casts in the bottom of sandstone beds from molds of erosional irregularities of freshly deposited mud (Blatt and others, 1973, Reineck and Singh, 1980). The observed flutes casts are irregular and appear to have gone through some post-depositional load casting.

Flute casts occur in numerous deposits including fluvial systems.

Syn-depositional structures

Syn-depositional primary structures are observed in the study area. These structures are indicative of unidirectional movement of a fluid. The size, shape and orientation of different bedforms are shown in figure 12. Their formation is controlled by relationships among grain

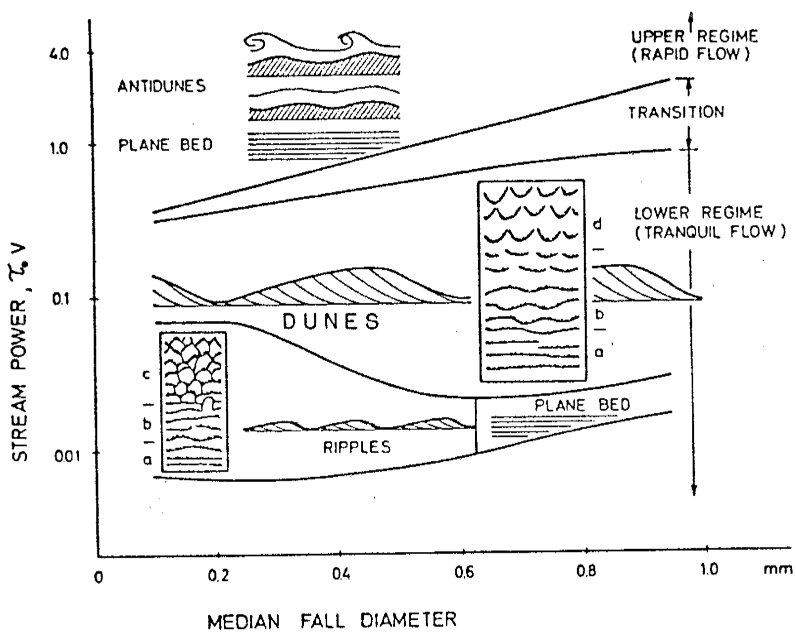


Figure 12. Schematic representation of various bedforms and their relationship to grain size (fall diameter=the diameter of a quartz sphere with same fall velocity as the bed material) and stream power (average velocity, V, times the bottom shear stress, T_o). Based on Simons and others (1965) and Allen (1968). a) straight-crested ripples or dunes; b) sinuous ripples or dunes; c) lingoid ripples or dunes; d) lunate ripples or dunes. For both ripples and dunes, crests tend to become discontinuous (three dimensional) with increasing stream power. Flume experiments show that dunes field pinches out at 0.1mm grain size. (Modified from Reineck and Singh, 1980).

sized of the bed material and ratio of mean flow velocity to mean flow depth. From figure 12 reported structures may be adapted to relative flow regimes.

Planar parallel stratification occurs in every unit in the section in the sudy area. Reineck and Singh (1980) and Pettijohn and others (1975) state this structure is found in all environments of deposition and is indicative of none. Blatt and others (1975) point out that planar parallel bedding occurs in both the lower and upper flow regime (see figure 12).

Symmetrical to asymmetrical (cross sectional symmetry) ripple marks displaying sinuous, well rounded, out of phase crestlines occur in the mudstones of unit 5 and unit 7. The horizontal form indexes generally range from 15 to 20 although some exceptions above 30 are observed. Measurements of the trend of crestlines of these ripple marks are N.W.-S.E. These bedforms are formed in the lower flow regime and are indicative of low stream power as shown in figure 12.

A confusing combination of asymmetrical, sinuous to lingoid ripple marks occur at the top of unit 2 and in the sediments of unit 10. These occur on the upper surface of fine-grained sandstone beds. In unit 10 these sandstones are interbedded with siltstone-mudstones which show some load or flute casting. Reineck and Singh (1980) consider sinous ripple marks to represent a transition from lower energy straight crested ripples to higher energy lingoid ~~small~~ ripples (see figure 12). Lingoid ripples seem restricted to shallow, rather turbulent environments such as stream and tidal channels (Reineck and Singh, 1980).

Cross-stratification has been described in units 1, 3, 4, 6, 10, and 12. Cross-stratification is formed by the lateral migration of bed forms. In units 1, 3 and 4, cross-stratification appears as small to medium scale, tabular- and wedged-shaped sets and cosets of low angle planar and tangential cross-beds with sharp erosional and nonerosioal lower contacts. These cross-strata are formed by the development of solitary banks and asymmetrical dunes in shallow water environments (Allen, 1963) such as those found in estuaries, beaches and braided stream systems (Allen, 1963). Associated with these cross-beds are Herringbone cross-strata which is interpreted to reflect the changes current flow direction in a tidal environment (Reineck and Singh, 1980).

Dominating unit 12 are medium to large scale, tabular-and trough-shaped cosets of low and high angle tangential cross-beds with sharp erosional and non-erosional lower contacts. Allen (1963) has demonstrated that these structures would be formed by the migration of trains of lunate and lingoid asymmetrical dunes. These cross-beds occur in estuaries, tidal flats, fluvial and eolian environments (Reineck and Singh, 1980). Ripple indices in the study area varied from 16-22 which indicates subaqueous environment. Eolian ripple heights in well sorted, fine-to medium-grain sandstones, such as the ones in unit 12, would be low (Reineck and Singh, 1980) which in turn cause larger ripple indices than those in the study area.

In unit 6 "Hummocky Cross-stratification" occurs as medium-scale tabular-and wedge-shaped cosets of low angle tangential and concave down cross-beds with sharp erosional (?) lower contacts(see figure 6). The term was coined by Harms and others (1975) but for identical structures Campbell (1966) used the term truncated wave ripple lamination.

Walker (1980) interprets "hummocky cross-stratification" to form below fair weather wave base due to the lack of reworking by waves or current formed small-scale cross-bedding. Harms and others (1975) and Hamblin and Walker (1975) suggest the hummocks are produced by the oscillatary motion of storm waves along the shelf bottom.

In unit 3 there are small scale tabular- to wedge-shaped cosets of low angle tangential cross-beds with elongated lateral dimension, sharp erosional and non-erosional lower contacts. On a cliff face exposure these cross-beds resemble cross-sectional descriptions in Reineck and Singh (1980) for structures produced by migration of lingoid ripples. The plan view of the bedding plane is not exposed.

Internally structureless beds occur throughout the section in the study area. This feature may actually be caused by bioturbation, by liquifaction or weathering. No environmental implications can be drawn from structureless beds. This structure has been further discussed by Blatt and others (1979) and Hamblin (1965).

A repetitve succession of large scale undulatory bedding surfaces occur in the lithologic transition at the top of unit 7. Sharp erosional lower contacts characterize the fine-grained sandstone that show large scale oscillations with a frequency of greater than three feet (1m.) and an amplitude up to a foot (20 cm.). In several of the troughs fossil fragments occur. These sandstones are grade upsection to thinly laminated or slightly fissile sandy siltstone to an erosional contact and the bedform repeats itself. Figure 13 shows these bedding

Figure 13. Large scale undulatory bedding surface in unit 8.
(Pick is 27.9cm.or 11 inches long)

characteristics.

Channel scale cut and fill structures are found in unit 10. The channels erode thinly laminated siltstone-mudstones and are filled with undulatory or slightly rippled beds of poorly- to moderately-sorted sandstone. Variably rounded clay clasts form a thin lag at the base of the channel and are distributed randomly throughout the unit. At or near the top of the channel are medium scale trough-shaped sets of low angle tangential cross-laminae and cross-beds with erosional and non-erosional lower contacts. In some cases these structures are repetitive and generally follow the criteria for active fill channels (Siemers, 1976)(see Appendix IV partial 14). In exposed locations the active fill channel is overlain by inactive fill channel. These are characterized by a planar gradational lower contact of siltstones to mudstones. These sediments fine upward, show only slight lamination and usually have rootlets and ironstone layers.

On a larger scale than the channel cut and fill structure are lateral accretion deposits which occur in unit 10 as a tabular moderately-sorted fine-grained sandstone body with internal medium scale, tabular-shaped sets of tangential cross-bedding with sharp erosional and non-erosional lower contacts (see figure 14). The sandstone

Figure 14. Lateral accretion deposit in unit 10.
(Pick is 27.9cm. or 11 inches long)

body laterally terminates with medium scale trough-shaped sets of cross-beds with a sharp erosional lower contact and changes in lithology laterally to mudstones and siltstones. The sandstone also grades upward to siltstones and mudstones (see Appendix parial section 14). The areal geometry is not determinable due to cover.

Siemers (1976) interprets the presence of active fill, inactive fill channels and lateral accretion deposits to represent deposition in a meandering channel system.

Graded bedding occurs in the uppermost portions of the Mancos Shale, unit 5, unit 7 and numerous outcrops of unit 10. In general it appears in beds less than a foot (30.5 cm.) thick as fine-grained sandstone decreasing in grain size upward (see Appendix IV partial section 9-15).

The decrease in grain size is probably caused by a waning current. Fluctuations in current velocity will result in irregularities including a reverse graded bed as observed in partial section 9, appendix IV. Graded bedded is observed in numerous depositional environments including turbidites and fluvial systems; the latter also has reverse grading.

Post-depositional structures

Cone-in-cone structures parallel to bedding planes occur in the upper portion of the Mancos Shale near the contact with the Mesaverde Group. These structures appear as stacked, inverted cones whose axes are normal to the bedding plane.

Cone-in-cone structures are considered to be diagenetically produced. Frank (1969) and MacKenzie (1972) suggest that in response to changes in the physiochemical environment during lithification fibrous calcite forms in partly consolidated muds near the sediment-water interface. It is theorized that organic remains may work as a catalyst to initate the growth of the calcite remains. It is concluded that the structures are a secondary phenomenon in response to stress during final lithification (Frank, 1969).

Load casts appear as bulbous protrusions of the lower contact of sandstones in unit 10. Reineck and Singh (1980) believe load casts to be the result of the deposition of sand on hydroplastic mud layers causing an overload of the mud and subsequent vertical adjustment by the sinking of the sand into the mud. No environmental interpretations can be drawn.

Bulbous limestone concretions occur in layers in the mudstones of the upper portion of the Mancos Shale and unit 7. These concretions can be up to 1 ft. (30.5 cm.) across. It is theorized that these structures formed during diagenesis where the calcite is precipitatied in pore spaces within the host sediment (Weeks, 1953 and Berner, 1968). Subsequently this constituent migrates in solution to reprecipitate around a common nucleus forming a concretion (Brownlow, 1979).

Isolated slump structures occur in unit 10 as distorted beds or small scale faults. These structured are possibly caused by overloading of sediments causing plastic deformation or brittle fracture (Reineck and Singh, 1980).

Also in unit 10 are ironstone layers with some septarian characteristics. These usually occur in close proximity to coal beds. Blatt and others (1980) suggest that iron layers such as these are formed by the migration of acidic organic-rich ground water. The precipitation of the iron oxide is caused by the migration of these soil or swamp derived waters into sediments that are more oxidizing and less acidic (Blatt and others, 1980). Siemers (1976) interprets these to occur in well-drained swamps.

PALEOCURRENT ANALYSIS

Within the study area, 269 paleocurrent direction measurements were taken. These measurements of orientation are of the azimuthal dip direction of tabular- and wedge-shape sets of tangential and planar cross-strata, and of the dip direction of the trough axis of trough-shape sets. The measurements of tangential cross-stratification were taken from the steepest portion of the cross-strata. A stereonet is used to remove the effect of local tectonic tilting of the strata.

Only four stratigraphic units have sufficient exposure to permit adequate measurement of cross-stratification; unit 1, upper portion of unit 3, unit 6 and unit 12. Readings were taken during measurement of stratigraphic sections and the lateral investigation of units. Units were traced horizontally up to a mile and paleocurrent measurements were taken wherever possible. At least twenty readings were taken per unit.

The rose diagrams in Figure 15(a,b,c,d,e,f) were compiled from the measurements in appendix III. Composite rose diagrams for each of the four units are illustrated beside the units on plate II. Appendix IV also contains the tabulation of the results and location of the measurements.

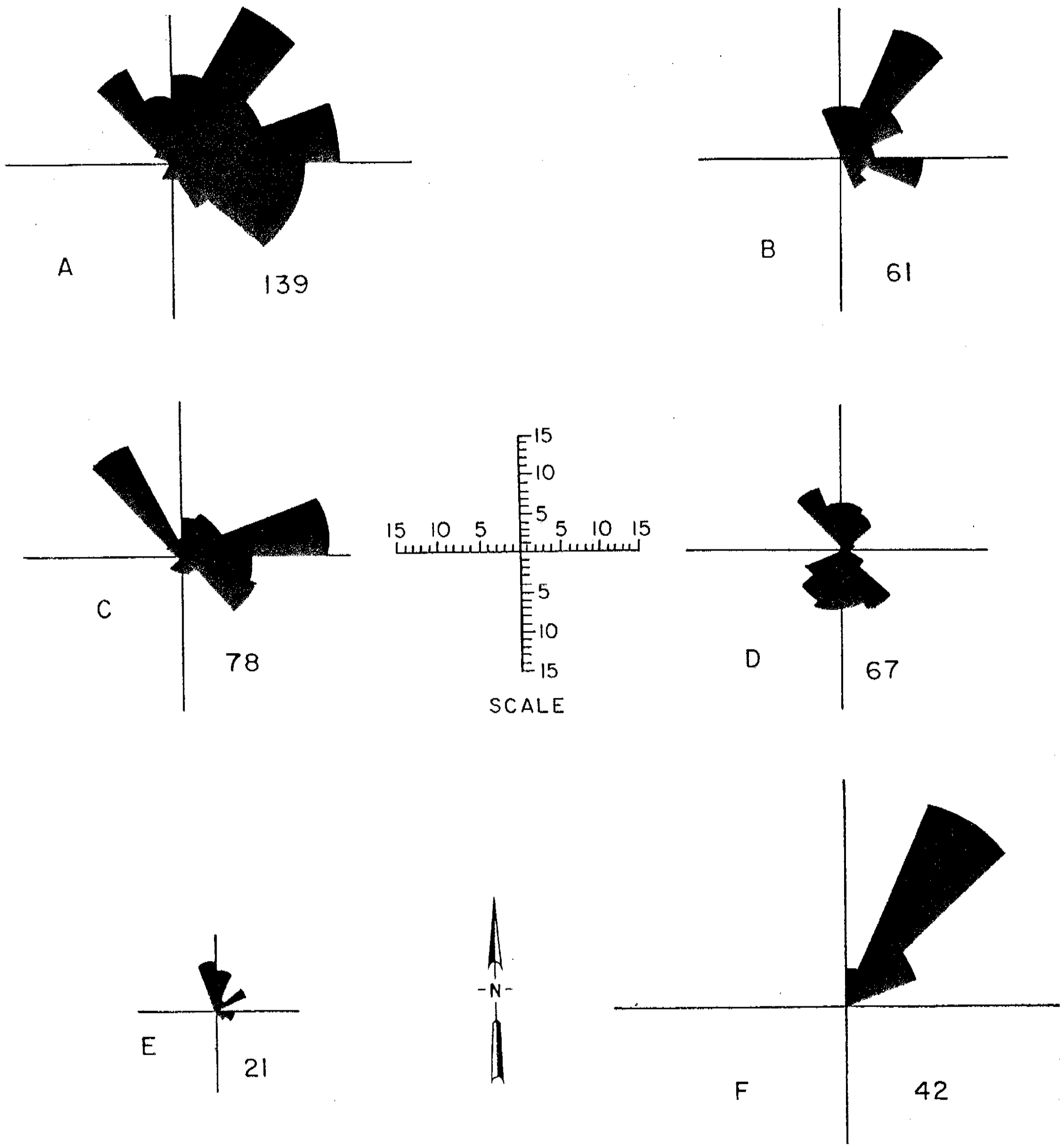


Figure 15. Paleocurrent rose diagrams
A) Paleocurrent direction for unit 1
B) Paleocurrent direction for western data of unit 1
C) Paleocurrent directions for eastern data of unit 1
D) Paleocurrent directions for unit 3
E) Paleocurrent direction for unit 6
F) Paleocurrent direction for unit 12

The rose diagram in Figure 15a is a composite of 139 paleocurrent measurements from unit 1. The measurements are from medium scale, low angle, tabular- and wedge-shaped sets of tangential cross-strata having primarily nonerosional lower contacts. The paleocurrent pattern appears unimodal to the northeast with greater than 90% of the readings between N45W and S45E. Figure 15b is a rose diagram constructed from portion of paleocurrent measurements shown in figure 15a. These measurements are from sections 5 and 32 of T8S and R14E and referred to here as the western data; Figure 15c is the other portion of 15a and the measurements are taken from sections 9 and 16 of T9S R14E and sections 4 and 33 of T8S R14E. Figure 15c is referred to here as the eastern data. The western data is unimodal to the northeast as shown in Figure 15b, but the eastern data appears to be bimodal to the northwest and the east as shown by the rose diagram in figure 15c.

Figure 15d is rose diagram of paleocurrent measurements from the upper portion of unit 3 in sections 5 and 32 of T8S R14E. A bimodal pattern to the north and south is shown from 67 measurements of trough axes and medium scale, tabular- and wedged-shaped sets of tangential and planar cross-beds with erosional and non-erosional lower contacts.

Figure 15e is a rose diagram for unit 6 of paleocurrent measurements with a possible bimodal trend to east and north. The dominant mode is toward the north and may be the mode of a unimodal pattern. Only 21 measurements were taken from "hummocky" type cross-strata in Oso Creek where unit 6 is well exposed.

The rose diagram in figure 15f is a low variablility, unimodal pattern to the NE. These measurements were taken from large scale sets of trough-shaped cross-strata and large scale tabular cosets of low angle tangential cross-beds with sharp erosional lower contacts. From unit 12 in the southern most portion of section 17 and in the central portion of section 8 T9S R14E. If individual rose diagrams are made from each location in unit 12, the same resulting pattern occurs.

Comparison of Figures 15a through 15c with tables in Selley (1968, p.14) and Pettijohn and others (1973, p. 140) indicate possible depositional environments for unit 1 to be meandering alluvial or deltaic deposition (Figures 15a and 15b) with shoreline or shelf redistribution for Figure 15c. Using these same tables, Figure 15d from unit 3 shows bimodal pattern and may represent shoreline or shelf environments. Unit 6 has a perpendicular bimodal pattern. This may also be interpretted as shoreline or shelf environments, but it must be noted that perpendicular bimodal paleocurrent patterns are very rare (Potter and others 1977) and with only 21 measurements taken at one location the interpretation should be viewed cautiously. Finally unit 12 with its low variablility unimodal characteristic can imply alluvial braided stream environment (Selley, 1968 and Pettijohn and others, 1973).

PALEOECOLOGY

The fossil collection of the study area shows a moderately high diversity throughout each facies. The diversity (number of species) and abundance (number of individuals) of certain species can be indicative of certain environments when these species are viewed as an association of organisms that must interact with the environment and each other (Kennedy, 1978). These environments are affected by a number of physical, chemical and biological factors which govern the association that exists within them. These factors are listed in Ager (1963, p. 22). The problem in studying a fossil association is that you are not necessarily observing the association where the organisms lived but where they were buried (Ager, 1963). Although in many instances, this is one and the same place, the observer must look for clues of transport. The species in the associations that are discussed below share the same environment in several ecologic niches and may show transitional changes in environment reflected by the taxa and related lithologies.

Stratigraphic locations where fossils are significantly broken and rounded will not be discussed in detail because it is the belief of the author that they show a coalescence of communities such that an accurate picture can not be determined (Reineck and Singh,1980).

LOWER SAND-MUD ASSOCIATION

The lower portion of unit 1 contains minor occurrences of the trace fossils of Ophiomorpha (?) irregulaire and (?) Thalassinoides sp.. Thin lenses of Turritella sp. also occur. Turritella is considered an infaunal particulate feeder (Kennedy, 1978). The trace fossil trails are near horizontal in their orientation.

The middle portion of unit 1 is nearly barren of fossil evidence except for Inoceramus prisms. This portion of the unit is abundantly cross-stratified.

In the upper portions of unit 1 there are complete fossils of Inoceramus deformis. This robust, marine benthonic suspension feeder is considered by Kauffman and others (1977) to occur in soft substrates of a relatively turbulent environment. In the upper portion of unit 1, trace fossils become more abundant and progressively change from vertical, through less vertical (diagonal), to nearly horizontal at the contact between unit 1 and unit 2. These trace fossils are, in decreasing order of abundance: Teichichmus sp., Ophiomorpha nodosa, Thalassinoides sp. and Asteroma sp..

The lower portion of unit 2 consists of thinly laminated mudstones that are interbedded with very fine-grained sandstones and fossiliferous limestones. Pleuricardia pauperculum occurs with a small unidentifiable oyster. P. pauperculum is a small near-shore pelecypod (Sohn, 1967). Rare occurrences of predatory gastropods Gyrodes americanus and G. spillmani are observed both in the limestones and fine-grained clastics. Associated with the previous epifaunal taxa is the infaunal Turritella sp.. The oysters Ostrea anomioides, Flemingostrea aff. prudencia and fragments of Crassostrea soleniscus also occur in the fine-grained clastics and limestones. These oysters increase in abundance upward.

In the lower portion of unit 1 the occurrence of Turritella implies a middle shoreface subenvironment (Scott and Taylor, 1977) which is substantiated by horizontal trace fossils, indicating a low energy environment below wave base (Frey, 1975; Howard, 1981 and Seilacher, 1978). Chamberlain (1978) reports that both Ophiomorpha and Thalassinoides are shoreface environment indicators. The subenvironment changes upward to a more turbulent environment demonstrated by the occurrence of rare fossil fragments and cross-strata.

In the upper portion of unit 1 the fossil association implies a decrease in relative turbulence; where complete Inoceramus deformis specimens are preserved. A decrease in sediment influx and deposition is suggested by the occurrence of infaunal organisms that burrowed upwards to keep pace with sedimentation (Howard, 1981). Furthermore it is implied by the trace fossil abundance and diversity that the water depth was shallow and sufficiently clear to allow light to penetrate and encourage the developement of algal thickets on which trace fossil organisms fed (Kennedy, 1978). The reported trace fossils (Chapter V) all in the shoreface environment (Chamberlain, 1978; Scott and Taylor, 1977).

In the lower portion of unit 2 the combined factors of thinly laminated silt to clay size sediments, increase in fossil diversity, excellent fossil preservation and the general small size of the fossil remains support the interpretation of low sediment influx into a low energy environment in which an increase in food supply and possible periods of quiescence. These periods of quiescence, meaning low or no clastic sedimentation, account for the formation of the thin fossiliferous limestones (Wilson, 1975). Finally the appearance and upward increase in occurrence of Crassostrea soleniscus, Ostrea anomioides and Flemingostrea aff. prudencia indicate brackish water conditions (Hook pers. comm.,1981).

OYSTER BED BIOSOMES (1) and (2)

The oyster bed biosomes occur as two mappable beds (see plate I, IIA and IIB) of variable fossil abundance. Oyster bed (1) at the top of unit 2 and oyster bed (2) at the top of unit 3 contain only Ostrea anomioides and Flemingostrea aff. prudencia. The oyster beds are composed of silty calcareous fine-grained sandstone exhibiting some undulatory bedding. The amount of abrasion and specimen's completeness is dependent on location. The beds thin and fossil abundance decrease to the south. In the northeastern portion of the study area, oyster bed (1) in some locations, has very little matrix, the oysters show no abrasion and appear to be cemented to each other in living position. The thickness and fossil abundance remains generally constant from east to west. The low diversity and high abundance of the oyster community implies a restricted brackish water environment, lagoonal conditions, where only these two species could survive (Ager, 1963 and Laporte,1979). The relative abundance of the oysters defines the extent of the lagoonal conditions.

SANDSTONE FOSSIL ASSOCIATION

On the top of unit 4 is a fine-grained sandstone bed that is densely burrowed with Skolithos sp. This bed reaches a thickness of 1 ft.(30 cm.). These burrows are vertical near the base of the bed but form a dense entanglement of diagonal and near horizontal burrows at the top. Below this bed the sandstone is barren of fossil evidence except for very rare Inoceramus prisms. The beds overlying the burrowed bed are covered, but float indicates interbedded, thinly-laminated siltstones and sandstones.

Like the top of unit 1 the implication left by the trace fossil evidence is an environment where there is a decrease in sedimentary influx where the water cleared allowing an increase in food supply. Assuming this increase in food supply and a decrease in coarse grain sediment input, these feeders rework the sediments faster than deposition (Frey, 1975; Kennedy, 1978).

Unbranched vertical or steeply inclined burrows form a buffer zone for suspension feeders from wave and current action or sudden changes in temperature and salinity (Seilacher, 1978). These burrows occur in distinct horizons of considerable concentration but remain at a low level of diversity controlled by the physical and/or chemical conditions of the environment (Seilacher, 1978). Skolithos is indicative of shoreface and foreshore environments (Chamberlain, 1978).

UPPER SAND-MUD FOSSIL ASSOCIATION

The base of the Upper sand-mud fossil association begins in the upper portion of unit 5 in the thinly-laminated mudstone and rare thin fossiliferous limestone. The mudstones are barren of fossil evidence whereas in the limestone numerous fossils of small benthonic organisms occur. Pleuricardia pauperculum, a small near-shore epifaunal pelecypod (Sohn, 1967), occurs in the limestones with predatory gastropods Gyrodes americanus and G. spillmani (Kennedy, 1978; Sohn,1967). Also in the limestones are oyster fragments and Inoceramus prisms with numerous other mollusk fragments including possible nektonic ammonite fragments of Placenticeras-Stantonoceras. The very top of unit 5 is characterized by siltstones that are interbedded with poorly-sorted, fine-grained sandstone. At the base of unit 6 Inoceramus deformis occurs in a moderately sorted, fine-grained sandstone. The number of fossils diminishes rapidly upsection until only rare Inoceramus prisms and Ophiomorpha nodosa occur. Ophiomorpha is considered to be marine indicator of the higher energy environments of the foreshore and shoreface (Chamberlain, 1978; Howard and Frey, 1978). Capping unit 6 are thin lenses of possible Inoceramus deformis fragments. At the base of unit 7 is a poorly-sorted fossiliferous pebble to cobble sandstone with fossils displaying a wide range of abrasion from rounded to unabraded specimens. A wide diversity of fossils occurs in this bed including crocodile armor, bones(?), sharks teeth, Gyrodes americanus, G. spillmani, Inoceramus prisms, Placenticeras fragments, coprolites and numerous unidentifiable remains. The sandstone grades upward into sandy siltstones that contain only rare fossils of Gyrodes americanus, G. spillmani and Ophiomorpha nodosa trails. Continuing upward the sand size grains disappear and the lithology becomes a thinly laminated mudstone with thin beds of fossiliferous limestone. The limestones contain numerous fossil fragments. Arrhoges sp., Pleuricardia pauperculum, Inoceramus prisms, Crassostrea (?) soleniscus fragments and rare shark teeth occur. In the mudstone the fossils are much rarer but both benthonic and nektonic-planktonic fossils occur. The benthonic fossils are Inoceramus subquadatrus, I. involutus, Arrhoges sp., Gyrodes americanus, G.spillmani, G. aff. petrosus and cf. Stantonella sp.. Ammonites represent the nektonic-planktonic organisms (Dane et al., 1968); these are Placenticeras aff. planum, P. aff. meeki var. P. intercalare and Stantonoceras sp. Near the top of unit 7 a thin bed of Exogyra sp. with Arrhoges sp. occurs. At the top of unit 7 thin beds of poorly-sorted sandstone with Ophiuroids, a brittle starfish, attached to Gyrodes and Cardium curtum fragments. Starfish are an indicator exclusively of normal marine salinities.

This association like the lower sand-mud association indicates a combination of several environments. With each change in environment a subsequent change occurs in the fossil association.

The occurrence in the limestone of Pleuricardia pauperculum, Gyrodes americanus, G. spillmani, Inoceramus prisms and oyster fragments with fragments of nektonic ammonites suggest a nearshore marine environment with some brackish influence. The larger fossils are fragments which suggest some transportation while the smaller fossils are complete. Predatory and deposit feeding gastropods imply an abundant food supply (Kennedy, 1978). These interpretations are substantiated by the occurrences of limestones which imply short periods low sediment input (Wilson, 1975). Increased coarse clastics with the appearance of Inoceramus deformis suggest an increase in turbulence (Kauffman and others, 1977). These turbulent conditions continue upward leaving only fragmented remains of Inoceramus and rare near vertical burrows of Ophiomorpha, both marine salinity indicators (Kauffman, 1976; Frey and Howard, 1981). More complete Inoceramus fragments occur at the top of unit 6, where the relative decrease in abrasion of preserved fossil remains both imply a decrease in turbulence (Laporte, 1981). At the base of unit 7, the fossiliferous pebble to cobble sandstone indicates a coalescence of several environments by the wide diversity of fauna from marine to brackish salinities. The reoccurrence of fossiliferous limestones containing fauna similar to those in the upper portion of unit 5 indicates a repetition of a similar low turbulence, low sediment influx environment with a possible greater number of brackish water fauna such as Crassostrea soleniscus. The finely-laminated mudstones are dominated by marine salinity benthonic fauna, usually with complete specimens while the nektonic ammonites, with one exception, are all fragments suggesting some transportation. Placenticeras is considered by Scott (1942) to be a shallow, marine ammonite of the epineritic zone (30 ft.(9m) to 120 ft. (40m) water depth). The thin fossiliferous limestones containing Exogyra sp. and Arrhoges sp. indicate a brief period of brackish water conditions. Modern ophiuroids are found in a wide range of marine environments. They may move by whip like action of their arms or burrow into soft sediment leaving only the tips of their arms protruding (Easton, 1960; Moore and others, 1952). Brittle stars may feed on detrital bits of organic matter or may be carnivorous (Moore and others, 1952).

LIMESTONE ASSOCIATION

The limestone association overlies the upper sand-mud fossil association and reflects the rapid change in lithology from mudstone to a poorly sorted medium-grained sandstone at the base of unit 8. Fossil evidence is rare at the base of unit 8 but upsection a number of fossils of benthonic organisms gradually appear. Upsection the grain size decreases and the dominant lithology becomes a silty limestone and corresponding with this change in lithology, the fossil diversity and abundance increases.

Two species seem to be predominant within the whole of unit 8. Cardium curtum which is considered to be epifaunal shallow marine pelecypod (Ryer,1977; Sohn, 1967 and Thorensen, 1957) and Drilluta sp. which is a large ornamented, fusiform, epifaunal, grazing gastropod (Sohn,1963). A number of other fossils occur in variable but minor abundance. Among these is Cymbophora sp., which is a shallow marine infaunal pelecypod (Ryer, 1977). Epifaunal predatory gastropods, Gyrodes americanus and G. spillmani, occur with the burrowing deposit feeder, Arrhoges sp.. These species show little abrasion while the oyster fragments and Inoceramus prisms that occur suggest transport.

The fossils in this association are shallow marine indicators and the oyster fragments indicate proximity of brackish water. The presence of the large grazing gastropod Drilluta sp. implies abundant algal growth to feed upon. Their increased abundance upsection appears to be regulated by a decrease in coarse grain clastic sediments.

PLANT ASSOCIATION

Numerous plant fragments occur in the study area above the oyster bed association in unit 3. Plant fragments and rootlets occur in the southern portion of the study area in the middle of unit 4. Identification of these flora is impossible due to extensive decay and abrasion of these plant fragments.

Fossils of Sequoia cuneata occur as small fragments in thinly-laminated claystones of the lower portion of unit 9. Thin oyster beds are associated with these fragments. Sequoia is a fresh water genera common in backwater swamps and marsh deposits (Parker, 1976; Tidwell and other, 1981; Robison, personal comm., 1981). In general it indicates warm humid lowland conditions (Tidwell, 1975). The Sequoia's occurrence with oysters and its fragmented nature and low abundance suggests that it was transported into an environment influenced by brackish water fauna.

In unit 10 the abundance of plant fossil fragments, rootlets, and complete fossil remains increases markedly. Cissus sp. and Vitus aff. stantoni occur in moderately sorted, fine- to medium-grained sandstone. Robison (per. comm., 1981) considers these genera to be common in channel margin deposits. Cf. Laurophylum sp. and Ficus plaincostata occur in thinly-laminated siltstone to fine-grained sandstones interpretted to represent active and inactive channel fill (see chapter VI). These species are common in poorly drained swamps and bottomland deposits (Robison, per.comm., 1981; Parker, 1976) and indicate a warm, temperate to subtropical climate (Tidwell, 1975). Thinly-laminated siltstones and fine-grained sandstone contain Sequoia cuneata and Araucarites sp., again indicating backwater swamp and marsh deposits (Parker, 1976) and generally considered to indicate warm humid lowland conditions. Sequoia is considered to be important tree of peat forming swamps (Tidwell and others, 1981). The plant fragments in unit 10 suggest a bottomland fluvial and swamp environment in a warm humid temperate to subtropical environment (Tidwell and others, 1981).

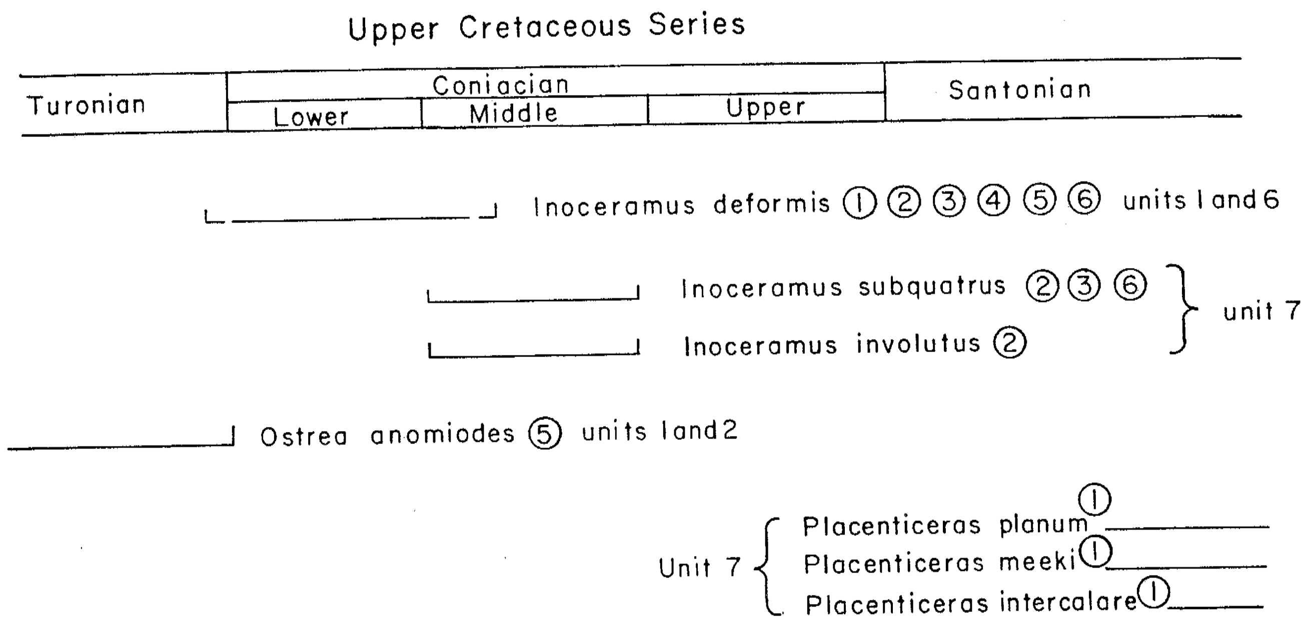
In the fine-grained sandstones just above unit 12 in the Cub Mountain Formation, fragments of Sabalites sp. occur. Tidwell and others (1981) postulate Sabalites to be similar to the modern Sabal which occurs in coastal lowland.

BIOSTRATIGRAPHY

Several of the reported fossils in chapter V (see Appendix II) are guide fossils for certain chronostratigraphic units of the Upper Cretaceous Series. Table 2 is a summary of several reported taxa, their respective published ranges gathered from the listed references and their study area rock units. Cobban (per. comm. 1981) considered the fossils, which he identified, to be standard Niobrara age. Table 2 uses European stages where the Niobrara Formation roughly covers the Coniacian and Santonian stages (Cobban and Reeside, 1952).

Summarizing, the lower sandstone lithosome (consisting of units 1 through units 4) contains the lowest occurances of Inoceramus deformis. I. deformis is considered by numerous authors to range from uppermost Upper Turonian to lower Middle Coniacian Stage (Reeside and Cobban, 1952; Scott and Cobban, 1964; Kauffman, 1975, 1977; Hattin and Cobban, 1977; Obradovich and Cobban, 1975). I. deformis occurs in units 1 and 6 of the study area which covers over 50% of the vertical thickness of the stratigraphic column. Cardium curtum is considered by Reeside and Cobban (1952) to cover the same time range as I. deformis and is found stratigraphically above the highest occurrence of I. deformis in the study area. Cadium curtum

Table II — Specific Ranges for several reported taxa, their respective reference and study area rock units of occurrence



References

① Cobban and Reeside, 1952

② Scott and Cobban, 1964

③ Kauffman, 1975

④ Obradovich and Cobban, 1975

⑤ Kauffman, 1977

⑥ Hattin and Cobban, 1977

occurs as isolated specimens in unit 2 and in abundance in unit 8. Ostrea anomioides, whose range is in some dispute (Cobban, per.comm.1981) is considered by Kauffman (1977) to be of middle to upper Cenomian or Turonian. Ostrea anomioides stratigraphically appears in this study in units 2 and 3. In this study O. anomioides will be considered Turonian in age because of its association with I. deformis. I. subquadatrus and I. involutus occur stratigraphically in unit 7 above the highest occurrence of I. deformis and in association with Cardium curtum and Placenticeras specimens. I. subquadatrus and I. involutus are reported to be middle Coniacian (Scott and Cobban, 1964 and Kauffman,1975, 1977). The reported species of Placenticeras are all found stratigraphically just above the highest occurrence of I. deformis and in the same location as Cardium curtum, I. subquadatrus and I. involutus. All of the reported Placenticeras species are of upper Coniacian through Santonian or higher. It must be noted that the majority of reported specimens are fragments, due to this and the ambiguities of the genus, exact identification is difficult (Reeside, 1926) and using Placenticeras for age correlation is questionable.

It is the belief of this author that stratigraphic units 1 through unit 4 (the lower sandstone lithosome) are uppermost Upper Turonian through Lower Coniacan because of the combined occurrence of *I. deformis* and *Ostrea anomioides*. The lower shale-sandstone lithosome (consisting of units 5 through unit 8) is considered to range from Lower Coniacan to Middle Coniacian because of the combined occurrences of *C. curtum*, *I. deformis*, *I. subquadatrus* and *I. involutus*. Above stratigraphic unit 8 (lower shale-sandstone lithosome) no accurate biostratigraphic information was obtained.

FACIES ANALYSIS

Introduced in prior chapters are physical and biogenic characteristic of each sedimentary unit. These characteristics can be grouped and described in terms of facies. With the exception of a limestone and a conglomerate in the study area, five facies, modified from Ryer (1977) can be recognized.

Facies 1 = Dark gray shale facies is characterized by dull, lead grayish, green shale or thinly laminated mudstone to claystone. There is a general increase in grain size upsection. Rare interbeds of graded, planar laminated, very fine-grained sandstones occur in the shales and mudstone-claystones. Also thin limestones and concretions occur. Fossil evidence is rare. This facies is regarded as indicative of open marine to offshore marine conditions(Campbell, 1979, Ryer, 1977; Reineck and Singh, 1980; Walker, 1980).

Facies 2 = Siltstone-silty sandstone facies is characterized by siltstones to mudstones interbedded with graded, silty sandstones. Fossil evidence includes various abundances of horizontal burrows, small oysters and marine clams. Overall there is an increase upsection in grain size and occurrence and thickness of silty sandstone. Bedding is usually planar parallel with rare cross-stratification. This facies is interpreted to be the offshore shoreface transition

(Campbell,1971, 1979; Davis et al., 1971; Molenaar, 1973; Reineck and Singh, 1980) or prodelta slope (Billingsley, 1978; Selley, 1978).

Facies 3 = Laminated to cross-stratified sandstone facies represents overall a shoreface environment (Ryer, 1977) but can be subdivided into three subfacies: lower laminated sandstone subfacies (3a), cross-stratified sandstone subfacies (3b) and upper laminated sandstone subfacies (3c) (Ryer, 1977).

The lower laminated sandstone subfacies consists of fine-grained sandstone that show planar parallel stratification with minor occurrences of Alpha-Beta cross-stratification (Allen, 1963). Abraded fragments and infaunal fossils are present. The interpreted environment of deposition for this subfacies is the lower shoreface (Campbell, 1971, 1979; Davis et al., 1971; Ryer, 1977; Selley, 1978) or delta platform (Billingsley, 1978; Selley, 1978).

The cross-bedded subfacies consists of fine- to medium-grained sandstone with sets and cosets of Alpha-, Beta-, Gamma-, and Omikron cross-stratification (Allen, 1963). Herringbone and hummocky cross-stratification occur locally. Fossil evidence is rare and limited to abraded fragments and vertical burrows. This subfacies represents upper shoreface (Campbell, 1971,1979; Davis et al., 1971; Molenaar, 1973; Reineck and Singh,1980) or surf zone (Ryer, 1977) or distributary channel (Billingsley, 1978; Molenaar, 1973; Selley, 1978) or tidal channel (Molenaar, 1973; Reineck and Singh, 1980).

The upper laminated subfacies consists of planar parallel stratified fine-grained sandstones. Fossil evidence increases upward and varies from abraded to complete specimens upward. Trace fossil evidence increases upsection and is characterized by few species but a great number of individuals. This subfacies is interpreted foreshore-swash zone (Campbell, 1971; Davis et al., 1971; Molenaar, 1973, Reineck and Singh, 1980; Ryer, 1977).
Facies 4 = Marginal marine facies consists of poorly to moderately sorted, very fine- to fine-grained silty sandstone, siltstone, mudstone, and claystone all of which display planar parallel and rippled beds, and shale. Thin limestones, fine-grain carbonaceous sediments and coal occur locally. Oysters are the dominant fossil although clams indicating normal marine conditions occur. Plant impressions and carbonaceous matter occur locally. Horizontal trace fossils occur. The interpreted depositional environment is lagoon and coastal swamp (Campbell, 1979, Davis et al., 1971; Reineck and Singh, 1980; Ryer, 1977; Warm, 1971).

Facies 5 = Fluvial facies is characterized by graded and reverse graded, poorly to moderately sorted sandstone interbedded with siltstone, mudstone, claystone and shales that contain various amounts of carbonaceous matter and plant fragments. Actively-inactively filled channels and lateral accretion deposits occur (Siemers, 1977). Thin, discontinuous coals occur in facies 5. Fossil evidence consists of terrestrial-freshwater plants. Graded, sheet sandstones and ironstone layers are present. This facies is interpreted coastal plain fluvial deposits (Weimer and Land, 1975; Ryer, 1977).

From these facies interpretations depositional environments are made using the following criteria : 1) the relationship of overlying, underlying and laterally equivalent lithotope-lithofacies, 2) grain size distribution; 3) bedding characteristics or primary sedimentary structures; 4) paleocurrent pattern and direction; and 5) the presence or absence of fossils including trace fossils (Molenaar, 1973). These five facies and subfacies with their respective environments are shown in figure 16. Table III is a summary of each unit and its respective facies and environment of deposition. Plate IIB shows a facies analysis of each unit. The following discussion is the interpretation of each unit using the above facies criteria.

Lower sandstone lithosome

Examining plate IIB the interpretations begin in the Mancos Shale. The Mancos represents facies 1 changing upsection to facies 2. At the Mancos Shale and Mesaverde Group (unit 1) contact, the facies changes to the laminated to cross-stratified sandstone facies with all three subfacies, present. The facies changes to the marginal marine facies at the top of unit 1 and remains in that facies to the middle of unit 3. Above the carbonaceous shale in unit 3 the facies returns to the laminated to cross-stratified sandstone facies with all subfacies present. The top of unit 3 is capped by oyster beds and a change to marginal marine facies. Above the carbonaceous shales of unit 4, the facies changes to the upper laminated subfacies (3c) of facies 3 and remains in this subfacies to the top of unit 4.

The portion of the Mancos Shale classified as facies 1 represents lower offshore marine environment (Ryer, 1977). The paleontology (see chapter V and VIII) and lithology follow criteria established by Davis and others (1971), Weimer and Land (1976), Selley (1978) and Rieneck and Singh (1980).

The uppermost portion of the Mancos Shale is classified as facies 2 (Ryer, 1977) and represents an offshore transition. This interpretation is based on lithology and paleontology and the criteria established by Davis and others (1971), Weimer and Land (1976), Selley (1978) and Rieneck and Singh (1980). Using these criteria it is also possible that deposition was prodeltaic, as indicated by the occurrence of a small amount of carbonaceous detritus and the limited amount of bioturbation that is observed. A possible coalesence of the offshore transition and prodelta can be interpreted (Weimer and Land, 1975; Selley, 1978; Blatt and others, 1979).

The interval of unit 1 to the middle of unit 3 as shown in plate II is similar to Ryer's (1977) idealized prograding sequence and the criteria set forth by Campbell (1971), Davies and others (1971), Molenaar (1973) for recognition of a barrier bar. There are also environmental similarities to columns drawn for river and wave dominated deltas (Billingsley, 1978; Reading, 1980; Selley, 1978; Walker, 1980).

Deltaic deposition is strongly implied by the broad paleocurrent pattern reported in chapter VII for unit 1, yet a number of other criteria is missing. Most delta deposits are capped by coal or fluvial deposits(Walker, 1980) but instead unit 1 is overlain by lagoonal deposition. Missing also are lag deposits, plant-wood fragment remains or erosional channels that would be expected in the cross-bedded subfacies (Billingsley, 1978 and Selley, 1978). The bioturbation that occurs at the top of unit 1 is not characteristic of deltaic deposition because sedimentation in deltas tends to be to rapid (Walker, 1980). The reported trace fossils are found in the foreshore environment of a barrier bar (Chamberlain, 1978; Frey, 1975).

Unit 2 contains thinly laminated very fine-grained sandstones, siltstone and mudstones interbedded with silty fossiliferous limestones. The fossils exhibit show an upsetion transition of nearshore marine and brackish water conditions to only brackish water conditions that continues to carbonaceous shales with plant remains (see chapter VIII), lower sand-mud association. This is interpreted to represent a restricted, relatively low energy environment with predominately brackish water conditions. With the interpreted presence of a barrier bar, plus the other characteristics previously described, unit 2 to the middle of unit 3 is interpreted to represent lagoonal deposition (Warm, 1971; Kraft and others, 1973; Wilson, 1975; Roehler, 1977 and Reineck and Singh, 1980). The overall evidence for unit 1 to middle of unit 3 implies a prograding barrier bar affected by some deltaic activity and overlain by lagoonal deposits.

The upper half of unit 3 is very similar to unit 1 in that it consists of the three subfacies of facies 3 (see plate IIB). Where exposed, the lower laminated sandstone subfacies contains the same primary sedimentary structures as the corresponding subfacies in unit 1. The differences lie in the cross-stratified sandstone subfacies. The cross-beds in section 5 T9S R14E are characterized as having a small scale, numerous erosional lower contacts and a bi-modal paleocurrent pattern. The erosional lower contacts show truncations of other cross-beds but are not indicating down cutting as would be expected of a distributary channel (Billingsley, 1978; Molenaar, 1973). These sets of cross-strata appear to be reworking of the sediments as would be found in surf zone (Davies et al., 1971; Reineck and Singh, 1980) or tidal channel (Molenaar 1973; Walker, 1980). As discussed in chapter VII the bi-modal paleocurrent pattern supports this interpretation (Molenaar, 1973; Potter and Pettijohn, 1977). In the northern exposures of unit 3 the cross-stratification is more similar to that in unit 1. The oysters capping unit 3, their enclosing lithology, their lateral trends of abundance and diversity (see chapter VIII) and bioturbation of the lower half of unit 4 suggest a return to lagoonal deposition. The occurrence of silt-clay rip-ups and a greater abundance of coarser grained sediments suggest a relatively higher energy environment of deposition than unit 2. The reoccurrence of carbonaceous shales indicates a return to a restricted environment of lagoonal deposition (Campbell, 1979).

The return to the upper laminated subfacies 3c of the facies 3 is interpreted as a return to the upper shoreface-surf zone environment. This interpretation is supported by the presence of Skolithos which occurs in shoreface and foreshore environments (see Chapter VIII, Sand association) (Chamberlain, 1978).

The repetition of the facies 3 is explained by minor transgressions caused by changes in clastic input due to delta lobe switching, destruction of barrier bar and/or changes in tidal inlets all conciding with regional subsidence caused by compaction of sediments. (Pike, 1947; Ryer, 1977; Walker, 1980).

Lower shale-sandstone lithosome

At the base of unit 5 a rapid return to facies 2 with possible fluctuations into facies of unit 1 occurs (see Plate IIB, Facies Analysis). The middle of unit 5 is assigned to facies 2. The upper portion of unit 5 returns to a transition between facies 1 and 2, finalizing at the top of unit 5 in facies 2.

As earlier described in chapter V the change in lithology above unit 4 is characterized by thin sandstones lithologically similar to the top of unit 4 interbedded with silty, very fine-grained sandstone. The grain size fines rapidly upsection to similar lithologic characteristics of the Mancos Shale found in facies 1. Interbedded in these mudstones and shales are thin fossiliferous conglomerates that indicate a mixture of brackish water conditions (oyster fragments) and normal marine salinities (shark teeth). These characteristics imply a return to deeper water conditions of the offshore-transition zone. The middle portion of unit 5 is assigned to facies 2. The overall grain size is coarser than observed at the uppermost portion of the Mancos Shale in unit 1 The fossils in the silty sandstone show abrasion and are indicative both of normal marine and brackish water conditions. This portion of unit 5 represents the upper portion of the off-shore transition or tidal delta deposition (Campbell, 1979, Molenaar, 1973; Selley, 1978; Rieneck and Singh, 1980).

The upper portion of unit 5 returns to a transition between facies 1 and 2. No fossils were found in the mudstones but interbedded with these sediments are calcareous, fossiliferous conglomerates whose fossils indicate dominantly nearshore conditions and normal marine salinities. This represents upper offshore marine depositional conditions (Ryer, 1977). Facies 2 caps the top of unit 5 with sandstones interbedded with mudstones, all of which are barren of fossil evidence.

Unit 6 is assigned to represent subfacies 3a-3b. The base of unit 6 is characterized by planar bedding and hummocky crossbedding with Inoceramus deformis that rapidly changes to only hummocky crossbedding with only Inoceramus prisms. As discussed in chapter VI hummocky cross-beds occur below fair weather wave base and are caused by the re-working during storms (Walker, 1980). An apparent quiesence is recorded at the top of unit 6 as indicated by the nearly complete Inoceramus fragments.

At the base of unit 7 is a fossiliferous pebble conglomerate. This conglomerate does not follow any of the facies criteria (see chapter VIII, Upper sand-mud association) Due to cover, examination of its lateral extent is very difficult, but from the float it appears to be localized. The fossil evidence indicates a coalescence of environments ranging from possible terrestial to marine conditions. It is suggested that this conglomerate represents a channel lag deposit that might be found in a delta distributary channel deposit (Billingsley, 1978) or tidal channel (Molenaar, 1973).

The remainder of unit 7 is assigned to facies 1. This portion of the unit follows the criteria closely except it has a greater density of fossils than other exposures of facies 1 in the study area. As discussed in chapter VIII these fossils are predominatly marine indicators. This portion of the section represents the upper offshore environment.

As described in chapter V the base of unit 8 consist of planar parallel beds of poorly to moderately sorted, fine- to medium- grained sandstone with a predominantly marine fossil assemblage. This sandstone is assigned to subfacies 3a. Its stratigraphic position, lithology and paleontology suggest a lower shoreface environment (Campbell,1971; Ryer, 1977; Rieneck and Singh, 1980). Upsection the clastic sediments wane and the dominant lithology is a silty limestone with the same fossil assemblage as the underlying sandstone. As mentioned in chapters V and VIII, there is an increase in coarse grained clastics, brackish water fauna and fossil abrasion to the south. The unit pinches out to the north. The limestone is interpreted to result from a decrease in clastic input allowing the deposition of carbonate shoals or barrier bars (Wilson,1975).

Bodine (1956) suggests in his discussion that this portion of the stratigraphic column, the lower shale-sandstone lithosome, represents a marine transgression. This is also suggested here for units 5 through 8 by the return to offshore marine-offshore transition environments. The normal marine salinities are indicated by the dominantly marine fossil assemblages reported in the lower sandstone-shale lithosome. The predominance of thinly laminated mudstone suggests deposition in a relatively low energy environment away from turbulence and coarser clastic input. The hummocky cross-bedding of unit 6 suggests deposition below fair weather wave base (Walker, 1980) and it can be further extrapolated that these sediments are below the surf zone possibly in the lower shoreface.

The absence of marginal marine deposits above shallow marine deposits, as represented by the upper portion of unit 4 and above, follows the models by Spieker (1946), Young (1955), Sabins (1964) and Selley (1978) as the expected trangressional sequence (Ryer, 1977).

The fossil assemblage suggests that the sediments of units 5 through 8 were deposited during lower to middle Coniacian Stage. A trangressive cycle is reported (Kauffman, 1977b and Molenaar, 1977) during the lower to middle Coniacian Stage.

Upper sandstone-shale lithosome

Unit 9 follows the criteria of marginal marine facies(Ryer, 1977). Thinly laminated mudstone and claystone having plant fragments are interbedded with silty sandstones and thin oyster-rich limestones. Its lithology, along with brackish water fauna associated with freshwater plants, suggest a restricted lagoonal environment (see Chapter VIII, Plant association) (Warm, 1971). As described earlier in the S.E.1/4 of section 6 and N.E. 1/4 of section 20 the dominant lithology in this portion of the stratigraphic section is silty sandstone interbedded with siltstones. This sand body can be interpreted as an interlagoonal delta or fluvial channel but, because of the overall covered nature of the outcrops, more detailed work is impossible such that this interpretation is only speculation. Capping unit 9 are fine-grained carbonaceous sediments and coal. Because of the stratigraphic position and associated environments of deposition, these carbonaceous deposits are regarded as a coastal swamp deposit (Stach and others, 1975; Frey and Basan, 1978).

Unit 10 represents the fluvial facies 5. This unit overlies the major coal beds and is a succession of cut and fill channel deposits, active and inactive channel fill deposits, lateral accretion deposits and thin coals. Associated with these sediments are plant fossils that are intepreted to occur in bottomland and back swamp deposits (see chapter VIII, Plant Association) (Robison, personnal comm. 1982). Weimer and Land (1975) and Siemers (1976) suggest the above lithologies are indicative of a meandering stream system on a coastal plain.

Unit 11 is a difficult portion of the stratigraphic column to interpret because of extensive cover. It consists of graded, poorly to moderately sorted, fine-grained sandstones, siltstones and mudstones. Ironstone layers within unit 11 can be traced laterally up to 1/4 mile (.4km). This unit suggests possible levee deposits and well-drained swamps on a coastal plain (Siemers, 1976; Reineck and Singh,1980).

Unit 12 as earlier described in Chapter V is characteristized by a well-sorted fine- to medium-grained quartzose sandstone with a variable abundance of angular clay clasts. Large scale, trough shaped sets of tangential cross-beds are present. Shown in chapter VII, these sedimentary structures have a low variability unimodal paleocurrent pattern to the N.E.. Based on its stratigraphic position and the forementioned characteristics, unit 12 represents a braided stream system, possibly on the upper coastal plain (Selley, 1978).

To summarize the environments of deposition of the Mesaverde Group at the Capitan coal field:

1) The lower sandstone lithosome is a repetitve succession of prograding strandplain, barrier bar and lagoonal deposits affected by deltaic conditions.

2) The lower shale-sandstone lithosome is intepreted to represent a marine transgression.

3) The upper shale-sandstone lithosome is interpreted as a transition from restricted marginal marine deposits into coastal swamp and fluvial coastal plain deposits.

4) A pictorial representation is shown in figure 16.

5) Deposition of the lower sandstone lithosome and lower shale-sandstone lithosome is interpreted to occur during the uppermost Turonian to the middle Coniacian stages.

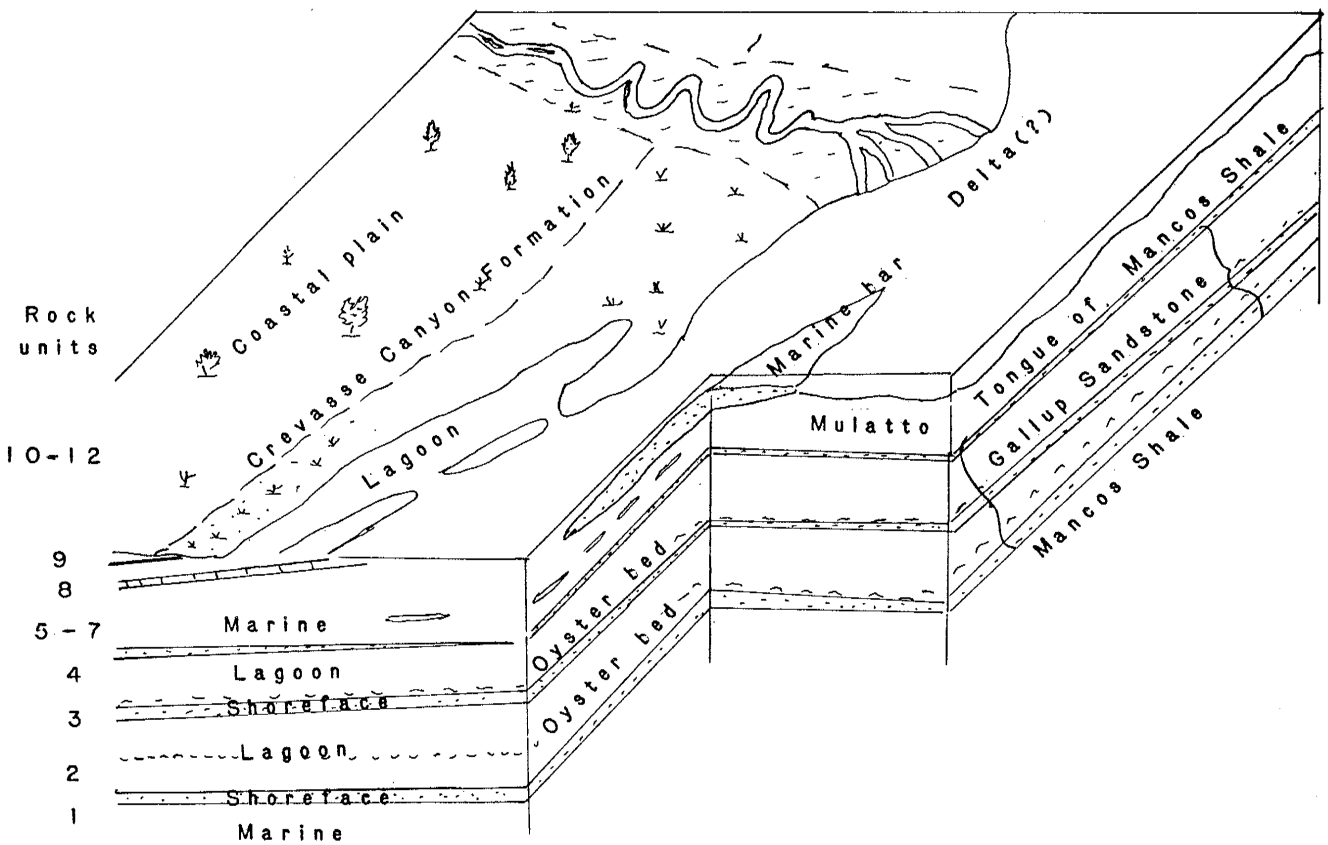


Figure 16. Reconstruction of the coastal geomorphic feature showing various environments of deposition, rock units and Cretaceous nomenclature used in the study area.

Table III

Facies Summary of each unit

unit	1	2	3			4	5	Environment
			a	b	c			
12							X	Fluvial–Braided stream system
11							X	Fluvial– (?)
10							X	Fluvial– Meandering stream system
9						X		Marginal marine–Lagoon to coastal swamp
8			X					Marine– Lower shoreface
7	X	X						Open marine to Offshore transition
6			X	X				Marine– Lower to middle shoreface
5	X	X						Open marine to offshore transition
4					X	X		Marginal marine–Lagoon to upper shoreface
3			X	X	X			Marine– Shoreface
2						X		Marginal marine– Lagoon
1			X	X	X			Marine–Shoreface

Stratigraphic Nomenclature

Prior to this study, the stratigraphic nomenclature of Mesaverde Group in the Capitan coal field was informally subdivided into three members (Bodine,1957). It is the suggestion of this author that the tripartite division remain but be redefined to the three lithosome divisions used in this study. The boundaries of these lithosomes are mappable on the basis of lithology and correspond to related depositional environments.

Sears (1925) described the Gallup Sandstone east of Gallup New Mexico as three massive sandstone beds interbedded with shale and coal. Molenaar (1974, 1977, in press) describes the upper Gallup Sandstone as a regressive marine and non-marine deposit during regional regressions of the late Turonian to early Coniacian time. Campbell (1971) and Molenaar (1974, 1977, in press) suggest the upper Gallup represents prograding strandplain or barrier sequence overlying the lower Mancos Shale.

The above criteria for the upper Gallup Sandstone is fulfilled in the study by the lower sandstone lithosome. Regionally the Gallup Sandstone has been correlated as far southeast as Carthage, New Mexico (Molenaar, 1974). Molenaar (1973) stated the upper Gallup Sandstone is present in the Caballo Mountains near Truth or Consequences and in the southern San Andres Mountains northeast of Las Cruces, New Mexico. Extension of the San Juan Basin nomenclature to Capitan, New Mexico does not present a problem since the precedent has been set.

The lower shale-sandstone lithosome is believed to represent a transgression in the study area. Regionally the Mulatto Tongue of the Mancos Shale overlies the upper Gallup Sandstone and underlies the Crevase Canyon Formation. Chronostratigraphically the trangression occured during the lower to middle Coniacian (Molenaar, 1977) which is indicated by the fossil evidence in this lithosome.

The upper shale-sandstone lithosome represents a marginal marine and fluvial succession equivalent to the Crevasse Canyon Formation.

Hook, Molenaar and Cobban (in press) have reported measured sections of Upper Cretaceous localities. Figure 17 shows their nomenclature and how it corresponds to nomenclature in the study area.

Thus it is suggested here that the sandstone lithosome, lower shale- sandstone lithosome and the upper shale-sandstone lithosome are stratigraphic equivalents to the upper Gallup Sandstone, Mulatto Tongue of the Mancos Shale and Crevasse Canyon Formation, respectively.

<table>
<tr><th colspan="2">Nutria Monocline</th><th colspan="2">Puerecito</th><th colspan="2">Riley</th><th colspan="2">Carthage</th><th colspan="2">Capitan</th></tr>
<tr><td colspan="8">Hook, Molenaar and Cobban (in press)</td><td colspan="2">This study</td></tr>
<tr><td colspan="2">Crevasse Canyon Formation</td><td colspan="2">Crevasse Canyon Formation</td><td colspan="2">Crevasse Canyon Formation</td><td colspan="2">Crevasse Canyon Formation</td><td colspan="2">Crevasse Canyon Fm.
Mulatto Tongue</td></tr>
<tr><td colspan="2">Gallup Sandstone</td><td colspan="2">Gallup Sandstone</td><td colspan="2">Gallup Sandstone</td><td colspan="2">Gallup Sandstone</td><td colspan="2">Gallup Sandstone</td></tr>
<tr><td rowspan="6">Mancos Shale</td><td rowspan="5">Juana Lopez Member</td><td></td><td>D Cross Tongue</td><td></td><td>D Cross Tongue</td><td></td><td>D Cross Tongue</td><td rowspan="8">Mancos Shale</td><td rowspan="5"></td></tr>
<tr><td rowspan="3">Tres Hermanos Formation</td><td>Fite Ranch Member</td><td rowspan="3">Tres Hermanos Formation</td><td>Fite Ranch Member</td><td rowspan="3">Tres Hermanos Formation</td><td>Fite Ranch Member</td></tr>
<tr><td>Carthage Member</td><td>Carthage Member</td><td>Carthage Member</td></tr>
<tr><td>Atarque Member</td><td>Atarque Member</td><td>Atarque Member</td></tr>
<tr><td rowspan="2">Mancos Shale</td><td>Rio Salado Tongue</td><td rowspan="2">Mancos Shale</td><td>Rio Salado Tongue</td><td rowspan="2">Mancos Shale</td><td>Rio Salado Tongue</td></tr>
<tr><td>Bridge Creek Ls</td><td>Bridge Creek Ls</td><td>Bridge Creek Ls</td><td>Bridge Creek Ls</td><td>Bridge Creek Ls</td></tr>
<tr><td colspan="2">Two Wells Member of Dakota Ss</td><td colspan="2">Two Wells Member of Dakota Ss</td><td rowspan="2">Mancos Shale</td><td rowspan="2">Lower Tongue</td><td rowspan="2">Mancos Shale</td><td rowspan="2">Lower Tongue</td><td rowspan="2"></td></tr>
<tr><td>Mancos Shale</td><td>Whitewater Arroyo Tongue</td><td>Mancos Shale</td><td>Lower Tongue</td></tr>
<tr><td colspan="2">Dakota Ss</td><td colspan="2">Dakota Ss</td><td colspan="2">Dakota Ss</td><td colspan="2">Dakota Ss</td><td colspan="2">Dakota Ss</td></tr>
</table>

Figure 17. Comparison of the study area proposed nomenclature to other Cretaceous localities.

Coal Potential

Coal mining occured at the Capitan coal field just before the turn of the century and continued until ~~it~~ abandonment during World War I. Those mines are now caved or have been bulldozed closed. The coal mining history of the district is summarized in Bodine (1956) and Wegemann (1914). Stratigraphically, the coal at the top of unit 9 is the source for the mining activity. A coal sample taken by the U.S.G.S. (d,d179835) at the Capitan No. 2 mine dump located at SE 1/4, SE 1/4, SE 1/4 section 5, T9S R14E gave the following results:

Proximate analysis (%):
Moisture: 1.20 Ash: 24.9 Volatile matter: 29.00
Fixed carbon: 44.90
Ultimate analysis (%):
Moisture: 1.20 Ash: 24.9 Carbon: 61.20 Hydrogen: 4.60
Nitrogen: 1.10 Sulfer: 0.50 Oxygen: 7.70
BTU: 11045
Moisture, mineral, matter free BTU: 15130.50
Sulfer: organic: 0.50 pyritic:00.0 sulfate: 00.0

These figures represent a high ash, low sulfer, low-volatile C bituminous coal. It must be emphasized that this is a sample taken coal mine dump which explains the low moisture content.

Conventional and in situ mining techniques are severely restricted in the study area. The discontinuous nature of the coal seams, the faults, dikes and friable nature of the rocks overlying the coal would make underground mining and in situ gasification extremely costly. The steeply dipping strata, generally greater than 15 degrees, would prohibit conventional strip mining methods. Bodine (1956) estimated that over 600,000 tons of coal had been removed during past underground mining activity and it is suspected that the shallow, thicker, more minable coal has been obtained, leaving only deep and thin(?) coals.

An additional problem in the study area is that the land is privately owned and subdivided into vacation-retirement real estate property. Land aquisition and local opposition to mining could prove to be a problem.

These problems limit the potential for further coal exploration or mining in the study area. Other possiblities in the surrounding vicinity exist. By using the information gathered in the study area depositional models can be used in the exploration to predict the location of a coal prospect. Coal is observed at the top of unit 9, and as ~~a~~ thin discontinuous seams in unit 10. Carbonaceous shales are observed in unit 3 and 4 associated with similiar lagoonal environments as interpreted in unit 9. Paleocurrent directions suggest that sediment source to be from the south to southwest. Two seams of coal outcrop in the southwestern portion of the study area (section 18) and thicken to the south. Cub Mountain, located 15 miles (24km) to the west has coal at the same stratigraphic position as the coal in the study area. It should be noted that to the west of the study area the dike swarms increase in occurrence. With this information the potential for additional coal deposits is hypothesized to increase to the south and southwest of the study area. At this location bedrock exposure consists of the upper portions of the Mesaverde Group and Cub Mountain Formation. Exploration drilling should target study area units 3, 4, 9 and 10 as potential stratigraphic locations for coal. The dike and fault problems exist to the south, although from field reconaissance appear to lessen, but still could prove to be a hinderance to exploration and mining. To the south of the study area more information is needed before the coal potential can be fully assessed.

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Appendix I

TERMS AND NOMENCLATURE USED IN MEASURED STRATIGRAPHIC SECTIONS AND TEXT

Grain size: based on Wentworth's (1922) size classification

Sorting: based on sorting images of Folk (1968)

Roundness: based on images from Powers (1953) in Pettijohn, Potter and Siever (1973)

Color: based on Rock-Color chart prepared by Geological Society of America (1979)

Sandstone classification: based on Dott's (1964) from Pettijohn, Potter, and Siever (1973)

Mudrock classification: based on Blatt, Middleton, and Murray (1972)

nonfissile	
abundant silt	siltstone
gritty when chewed	mudstone
smooth when chewed	claystone

Cross-stratification

Terms and classification of cross-stratified units is modified from Allen (1963):

1). Scale of set

a.) based on lateral length of a single cross-stratum

small = <1ft. (<30cm.)

medium= 1-20ft. (30cm-6m)

large= >20ft. (>6m)

2.) Shape of set

Tabular--upper and lower surfaces are planar and parallel to each other wedge--upper and lower surfaces are planar but at oblique angle to each other so eventually they intersect

Trough--lower surface is concave upward

3.) high angle > 20 degrees

low angle < 20 degrees

4.) Shape of cross-strata within the set

Planar--usually in tabular- or wedge-shaped sets but tangential may occur in those as well

Tangential--curved--concave up - typical in trough-shaped sets

5.) Thickness of cross-strata:

lamination <1cm.

bedding > 1cm.

Appendix II

Macroinvertebrate taxa, trace fossil, and fossil plants in Mesaverde Group at Capitan coal field, Lincoln county, New Mexico.

MOLLUSCA:	identified by
BIVALIA:	
MACTRIDAE:	
Cymbophora sp.	2
CARDIICAE:	
Cardium curtum Meek	2
Pleuricardia pauperculum Meek	2
INOCERAMUS:	
Inoceramus deformis Meek	1,2
I. involutus (Sowerby)	2
I. subquadatrus Schluter	2
OSTREIDAS:	
Ostrea anomioides (Meek)	1
Crassostrea (?) *soleniscus (Meek)*	1
Flemingostrea aff. prudencia	1
GASTROPODA:	
(?) Arrhoges sp.	4
(?) Stantonella sp.	4
(?) Drilluta sp.	4
Turritella sp.	4
Gyrodes spillmani Gabb	4
G. americanus (Wade)	4
G. petrosus (Mortan)	4
CEPHALOPODA:	
COSMOCERATIDAE:	
Placenticeras aff. planum	2,4
P. aff. meeki var. P. intecalare	2,4
Stantonoceras sp.	2
FOSSIL PLANTS:	
ARAUCARIAACEAE:	
Araucarites sp.	3
TAXODIOCEAE:	
Sequoia cuneata (Knownton)	3
ARECACEAE:	
(?) Sabalites sp.	4
MORACEAE:	
Ficus planicostata Lequeraux	3
LAURACEAE:	
cf. Laurophyllum sp.	3
VITACEAE:	
Vitus aff. statoni (Knownton)	3
Cissus sp.	3

"*Carpites baueri*"	3
BURROWS AND TRAILS:	
Ophiomorpha nodosa	4
Ophiomorpha irregulaire	4
Thalassinoides	4
Theichichmus	4
Arenicolites	4
Asteroma	4

1-identified by Dr. Stephen Hook, Getty Oil Co., Houston,Tx.
2-identified by Dr. William Cobban, U.S.G.S., Denver, Co.
3-identified by Dr. Colman Robison, Getty Oil Co., Houston, Tx.
4-identified by author

Appendix III

Fossil location

These fossil locations are where the identified taxa are best exposed and found in relative abundance.

Cardium curtum

Pleuricardia pauperculum

Cymbophora sp.

Inoceramus subquadatrus

I. (?) involutus

Dilluta (?) sp.

Stantonella (?) sp.

Arrhoges (?) sp.

Gyrodes spillmani

G. americanus

G. petrosus

Turritella sp.

Placenticeras aff. planum

Placenticeras aff. meeki var. P. intercalare

Stantonoceras sp.

Above taxa are found:

S1/2 SW1/4 NW1/4 Sec. 5 T9S R14E in Oso Creek arroyo

NE1/4 NE1/4 SE1/4 Sec. 6 T9S R14E in deep arroyo cross by road

NE1/4 SE1/4 SE1/4 Sec. 6 T9S R14E in two intersecting arroyos

As partial collections and fragments:

NE1/4 SW1/4 NW1/4 Sec. 18 T9S R14E in SE trending arroyo

SW1/4 SE1/4 NW1/4 Sec. 33 T8S R14E in SW trending arroyo at the base of southern hill side slope

Inoceramus deformis

This species is found as complete specimens and fragments along cliff faces W1/2 E1/2 Sec.4 T9S R14E, W1/2 SE1/4 and NE1/4 sec. 33 T8S R14E, W1/2 Sec. 16 T9S R14E, W1/2 NE1/4 Sec. 5 T9S R14E and at top and bottom of sandstone in Oso Creek at SE1/4 SW1/4 NW1/4 Sec. 5 T9S R14E.

Turritella sp.

This species is found at the same topographic locations as *I. deformis* (except Oso Creek location) in sandstones near the Mesaverde Group-Mancos contact.

Flemingostrea aff.prudencia

Ostrea anomioides

These species are found usually in laterally continuous beds of varying vertical thickness: W1/2 E1/2 Sec.4, W1/2 SE1/4 Sec. 33,SW1/4 NE1/4 Sec. 33, NE1/4 NE1/4 Sec. 33, S1/2 N1/2 Sec. 32, W1/2 SW1/4 NW1/4 Sec. 33 T9S R14E, NE1/4 SW1/4 Sec. 5 T8S R14E (see Plate I).

PLANTS

Ficus planicostata

Vitus aff. stantoni

These leave impressions are found in sandstone in arroyos in SW1/4 SE1/4 SW1/4 Sec. 16 T9S R14E.

Ficus planicostata

This species is found in arroyo in SW1/4 SE1/4 NW1/4 Sec. 7 T9S R14E.

Ficus planicostata

cf. Laurophyllum sp.

Cissus sp.

Vitus aff. stantoni

These species are found in sandstone thick sandstone in Oso Creek in SE1/4 NE1/4 NE1/4 Sec. 6 T9S R14E.

Sequoia cuneata

Araucarites sp.

"*Carpites baueri*"

These species are found in thinly bedded siltstones in dry creek bed in SE1/4 SW1/4 NE1/4 Sec. 8 T9S R14E.

Appendix IV

Partial Stratigraphic sections were measured using a Jacob staff and Brunton compass. The listed location for each column is in reference to the Capitan 7 1/2 minute quadangle. Partial stratigraphic sections 1 through 4, 5 through 7 and 8 through 15 are portions of the sandstone package, lower shale-sandstone package and the upper shale-sandstone package, respectively.

MEASURED STRATIGRAPHIC SECTIONS

SECTION 1

SE 1/4 OF NE 1/4 OF SE 1/4 SECTION 4 T9S R14E

UNIT	LITHOLOGY	THICKNESS (FT.) UNIT	CUMM.
14	Sandstone, fine-grained, indurated, well sorted rounded, medium brown (5YR4/4), subarkose, slight planar parallel bedding, lower contact covered.	3.+' (.9m)	
13	Cover: not determineable		
12	Sandstone, fine-grained, poorly indurated, moderately sorted, sub-rounded, grayish-orange(10YR7/4), subarkose, planar parallel bedding, lower contact covered.	2.7' (.8m)	114.7' (34.9m)
11	Cover: not determineable	16.4' (4.9m)	112.0' (34.1m)
10	Conglomerate, fossiliferous, indurated, poorly sorted, 60% fossils, 40% matrix: very fine-to fine-grained, subrounded, medium brown (5YR4/4), lithic arenite, fossil: abundant _Flemingostrea aff. prudencia, Ostrea anomioides_, which lie peni-concordant with bedding, upper and lower contact covered, limited exposure.	1.2' (.37m)	95.6' (29.1m)
9	Cover: mudstones, shales, olive gray thin intercalations of calcareous siltstones and limestones with variable fossil content, fossils: _Pleurcardia pauperculum, Inceramus sp, Ostrea anomioides_, Flemingostrea aff. prudencia, Turritella sp., _Arrhoges (Latiala) logata._	38.4' (11.7m)	94.4' (28.8m)

8 C	Sandstone, fine-grained, poorly indurated, well-sorted, rounded, pale brown (5YR5/2) to dusky yellow (5Y6/4), subarkose, slight planar parallel bedding varying densities of Ophiomorpha nodosa, Thalassinoides sp., Arenicolites sp. and Asteroma sp., gradational lower contact.	2.4' (.7m)	56.0' (17m)
8 B	Sandstone, fine-grained, poorly indurated, well-sorted, rounded, grayish orange (10YR7/4), subarkose, lower portion planar parallel bedding, upper portion Ophiomorphia nodosa, Thalassinoides sp., Arenicolies sp. and Asteroma sp., gradational lower contact.	1.1' (.3m)	53.6' (16.3m)
8 A	Sandstone, fine-grained, poorly indurated rounded, well sorted, grayish orange (10YR7/4), subarkose, cross-stratification: medium scale tabular shape cosets of low angle tangential cross beds with a sharp erosional lower contact, fossils: Inoceramus deformis, lower sharp undulatory lower contact.	3.7' (1.3m)	52.5' (16m)
8	Sandstones, fine-grained, friable, well-sorted, rounded, grayish orange (10YR7/4), subarkose, limonite-hematite stained, structureless, sharp lower contact.	1.5' (.5m)	48.8' (14.9m)
7	Sandstone, fine-grained, indurated, well-sorted, rounded, grayish orange (10YR7/4), subarkose, staining with limonite-hematite and manganese, thin planar parallel bedding, lower contact cover.	0.7' (.21m)	47.3' (14.4m)
6	Cover: from float; sandstone, fine-grained, friable, moderately sorted, subrounded, grayish-orange(10YR7/4), 75% quartz, 15% feldspar (altered), 10% porousity, <1% cement (clay), limonite-hematite staining, planar-parallel bedding(?), lower contact covered.	8.7' (2.7m)	46.6' (14.2m)
5	Sandstone, fine-grained, indurated, sub-rounded, moderately-sorted, light brown (5YR6/4), subarkose, limonite-hematite staining, thin planar parallel bedding, sharp lower contact.	1.2' (.4m)	37.9' (11.6m)
4 A	Siltstone,poorly sorted, quartose, medium gray (N-4),erosional upper	0.5' (.15m)	36.7' (11.2m)

	contact, gradational lower contact.		
4	Sandstone, very fine to fine-grained, grain size decreases upward, friable, moderately sorted, subrounded, subarkose, structureless, gradatiomal lower contact.	4.9' (1.5m)	36.2' (11m)
3 D	Sandstone, fine-grained, poorly indurated, moderately sorted, subrounded, subarkose to arkosic arenite, cross-stratification: medium scale tabular-wedge shaped cosets of low angle tangential cross-beds with gradational lower contact	1.5' (.46m)	31.3' (9.5m)
3 C	Sandstone, fine-grained, indurated, moderately sorted, subrounded, subarkose to arkosic arenite, cross-stratification: medium scale tabular sets of high angle planar cross beds with sharp erosion lower contact.	0.5' (.15m)	29.8' (9.1m)
3 B	Sandstone, fine-grained, poorly indurated, moderately sorted, subrounded, grayish orange (10YR7/4), cross-stratification: medium scale tabular and wedge low angle tangential crossbeds with gradational lower contact.	3.4' (1m)	29.3' (8.9m)
3 A	Sandstone, fine-grained, friable, moderately sorted, subrounded,grayish orange(10YR7/4), subarkose, structureless, sharp lower contact.	0.2' (6cm)	25.9' (7.9m)
3	Sandstone, fined-grained, poorly indurated, moderately sorted, subrounded, grayish orange(10YR7/4), subarkose, planar parallel bedding, lower contact covered.	3.4' (1m)	25.7' (7.8m)
	BASE OF MESAVERDE GROUP		
2 A	Cover: float indicates thin inter-beds of light olive gray(5Y5/2) siltstone and moderate yellowish brown(10YR5/4) very fine sandstone, lower contact not observed.	9.1' (2.8m)	22.3' (6.8m)
2	Siltstone, indurated, light olive gray (5Y5/2), no fossils observed, interbedded with sandstone,very fine-grained, moderately sorted, rounded, light brown (5YR6/4), feldspathic quartzwacke, of varying thickness .1 to.8 feet, undulating erosional upper and lower contacts	12.6' (3.8m)	13.2' (4.0m)

	and fossil population varying from rare to abundant pelecypods, fossil: unidentified oyster fragments and Pleuricardium pauperculum.		
1	Limestone, silty, medium gray (N-5), lower portion fossil fragments, fossils: unidentified oyster fragments, Pleurcardium pauperculum, sharp undulating erosional lower contact.	0.6' (.2m)	0.6' (.2m)
	COVER		

MEASURED STRATIGRAPHIC SECTIONS

SECTION 2

SW 1/4 OF NE 1/4 OF NE 1/4 SECTION 5 T9S R14E

UNIT	LITHOLGY	THICKNESS (FT./M) UNIT	CUMM.
16	Cover: not determineable		
15	Conglomerate, fossiliferous, indurated, poorly sorted, 50% fossils, 50% matrix: sandstone, fine-grained, rounded, medium brown (5YR4/4), subarkose, structureless, gradational lower contact, fossil: Flemingostrea aff. prudencia, Ostrea anomioides.	0.5-1.0' (.2-.3m)	140.0' (42.7m)
14	Sandstone, very fine-grained, poorly indurated, well sorted, rounded, grayish-orange(10YR7/4), subarkose, cross-stratification: medium scale tabular shape sets of low angle tangential crossbeds with gradational lower contact, units lower contact covered.	13.4' (4.1m)	139.3' (42.5m)
13	Cover: not determineable	29.9' (9.1m)	125.0' (38.1m)
12	Conglomerate, fossiliferous, indurated, poorly sorted, 60% fossils, 40% matrix: sandstone, fine-grained, rounded, medium brown (5YR4/4), subarkose, structureless, fossil: abundant Ostrea anomioides, Flemingostrea aff. prudencia, limited exposure uppper and lower contacts covered.	1.2' (.37m) (exposed)	96.0' (29.3m)
11	Cover: Mudstones and thin beds(<.5ft.) of very fine sandstones and limestones fossils: Ostrea anomioides, Crassostrea soleniscus, Pleurcardia pauperculum, Arrhoges (Latiala) logata, Gyrodes spillmani, G. americanus, Ophiomorpha	41.1' (12.5m)	94.8' (28.9m)

	nodosa (?) and Thalassinoides sp.		
10B	Sandstone, fine-grained, poorly indurated, well sorted, rounded, pale brown (5YR5/2), subarkose, slight planar parallel bedding, varying densities Ophiomorpha nodosa and Thalassiniodes sp., gradational lower contact, upper contact covered.	2.0' (.6m)	53.7' (16.4m)
10A	Sandstone, fine-grained, poorly indurated, well sorted, rounded, grayish orange (10YR7/4), planar parallel bedding, subarkose, gradational lower contact.	15.7' (4.8m)	51.7' (15.8m)
9	Sandstone, very fine-grained, indurated, moderately sorted,rounded, pale brown (5YR5/2) to moderate brown(5YR4/4) to dusky yellow (5Y6/4), subarkose, hematite-limonite staining, faint planar parallel bedding, gradational lower contact.	2.2' (.7m)	36.0' (10.9m)
8	Sandstone, fine-grained, poorly indurated, well-sorted, rounded, very pale orange (10YR8/2), subarkose, cross stratification: medium scale tabular cosets of low angle tangential cross beds with gradational planar and irregular erosional(?) lower contact.	12.8' (3.9m)	33.8' (10.3m)
7	Siltstone,limey,pelecypod fragments, structureless, medium brown(5YR4/4).	0.2' (6cm)	21.0' (6.4m)
6	Sandstone, partially cover fine-grained, poorly indurated, moderately sorted, subrounded,very pale orange (10YR8/2) to grayish orange (10YR7/4), subarkose, cross-stratification: medium scale tabular and wedge shaped tangential and planar(?) cross sets with gradational lower contacts. fossils: Inoceramus deformis, Inoceramus sp. prisms, and Ophiomorpha nodosa and Thalassinoides sp., lower contact covered.	9.6' (2.9m)	20.8' (6.3m)
5	Sandstone, fine-grained, friable, well-sorted, subrounded, grayish-orange(10YR7/4), subarkose, sparce Ophiomorpha nodosa and Thalassinoides sp., planar parallel and possible low angle planar(?)cross-bedding, lower contact covered.	3.5' (1.1m)	11.2' (3.4m)
4	Sandstone, fine-grained, poorly indurated, well-sorted, rounded, dark yellowish orange	0.9' (.3m)	7.7' (2.4m)

	(10YR6/6) to moderate brown (5YR4/4), feldspathic quartz graywacke, cross-stratification: medium scale tabular shaped cosets of low angle planar cross lamini with a gradational planar non-erosional lower contact.		
3	Sandstone, partially covered, very fine- grained,friable, well-sorted, subrounded, moderate yellowish brown (10YR52), subarkose, limonite-hematite staining, planar-parallel bedding, gradational lower contact.	5.7' (1.7m)	6.8' (2.1m)
2	Sandstone, very-fine grained, friable, moderately sorted, subrounded, structureless, subarkose, limonite-hematite staining, moderate yellowish brown (10YR5/2) to dark redish brown (10R3/4), structureless, sharp conformible lower contact.	1.1' (.3m)	1.1' (.3m)
	BASE OF THE MESAVERDE GROUP LOWER TOP OF THE MANCOS		
1	Claystone, silty, light olive gray (5Y5/2)	>10 (>3+m)	

MEASURED STRATIGRAPHIC SECTION

SECTION 3

SW 1/4 OF SE 1/4 OF SW 1/4 SECTION 9 T9S R14E

UNITS		THICKNESS(FT./M) UNIT	CUMM.
8	Cover?		
7	Conglomerate, fossiliferous, indurated, poorly sorted, angular to rounded, medium brown (5YR4/4), 60% fossils, 25% matrix: sandstone, very fine-to fine-grained, poorly indurated, moderately sorted, rounded, subarkose to sublithicarenite, structureless, fossils: Ostrea anomioides, Flemingostrea aff. prudencia, lower contact not observed.	1.1'(?) (3.3m)	73.8' (22.5m)
6	Cover: float indicates claystone, friable, dusky yellow green (5GY5/2), planar parallel lamination, fossil: Ostrea anomioides, Flemingostrea aff. prudencia, Pleurcardium pauperculum, Crassostrea soleniscus, Turitella	12.3' (3.8m)	72.7' (22.2m)

Units	Lithology	Unit	Cumm.
	sp. and Arrhoges (Latiala) logata, grain size increase upwards siltstone.		
5	Sandstone, fine-to medium-grain, poorly indurated, moderately sorted, rounded, pale brown (5YR5/2) to grayish orange (10YR7/4), subarkose, structureless to slight planar parallel bedding, increasing abundance of trace fossils upwards: Ophiomorpha nodosa, Thalassinoides sp., Arenicolites sp. and Asteroma sp. gradational lower contact.	1.7' (.5m)	60.4' (18.4m)
4	Sandstone, fine grain, poorly indurated, moderate to well sorted, rounded, grayish orange (10YR7/4), subarkose, planar parallel bedding, sharp erosional lower contact.	2.2' (.67m)	58.7' (17.9m)
3	Sandstone, fine grain, poorly indurated, moderately to well sorted, rounded, grayish orange (10YR7/4), subarkose, rare Arenicolites sp., Thalassinoides sp. and Inoceramus prisms, cross-stratification: medium scale tabular shaped coset of low angle planarcross beds with a sharp erosional lower contacts.	11.6' (9.9m)	56.5' (17.2m)
2	Cover: alluvium?	32.4' (9.9m)	44.9' (13.7m)
	MANCOS SHALE		
	contact not observed.		
1	Claystone, silty, light olive gray (5YR5/2).	>12.5' (3.8m)	

MEASURED STRATIGRAPHIC SECTION

SECTION 4

NE 1/4 OF SW 1/4 SECTION 5 T9S R14E

UNITS	LITHOLOGY	THICKNESS (FT./M) Unit	Cumm.
13	Sandstone, fine-grained, poorly indurated, moderately to well sorted, rounded, grayish orange (10YR7/4) to moderate brown (5Y R4/4), subarkose, planar parallel bedding, varying degrees of burrowing of Skolithos sp., densest burrowing the top of bed, gradational lower contact.	7.2' (2.2m)	180.2' (54.9m)
12	Sandstone, fine-grained to medium-grained, poorly indurated, well sorted, rounded, very light gray (N-8) to	32.2' (9.8m)	173.0' (52.7m)

	grayish orange (10YR7/4), quartz arenite, varying from structureless to planar parallel,cross-stratification: medium scale tabular shaped cosets of low angle tangential cross beds with non-erosional lower contacts, lower contact covered.		
11	Cover: float indicates sandstone,very fine-to fine-grained,friable, poorly sorted subrounded, in lower portion varying amount carbonate cement, bioturbation and angular clay clasts, interbeds with siltstones and mudstones, general decrease in grain size upwards to carbonaceous shales and possilble coal.	62.4'(?) (19.0m)	140.5' (42.5m)
10	Mudstones-shales interbedded with thin very fine sandstones, sandstone; < .5 ft., fossil conglomerates, bioturbated, gastropods and <u>Ostrea anomioides</u>, <u>Crassostrea solenscus</u>, <u>Flemingostrea aff. prudencia</u>, <u>Pleurcardia pauperculum</u>, irregular sharp lower contact.	3'(?) (.9m)	78.1' (23.8m)
9	Sandstone, fossiliferous,fine-grained, indurated moderately sorted, subrounded, moderate yellowish brown(10YR5/4), subarkose, limonite-hematite staining, fossils: <u>Flemingostrea aff. prudencia</u>, <u>Ostrea anomioides</u>, <u>Pleurcardia pauperculum</u>, varying lateral and vertical abundance, population density less than unit 3A, gradational lower contact.	0.3'-0.5' (.1-.2m)	75.1' (22.9m)
8	Sandstone,fine-grained, indurated, well sorted, rounded, grayish orange(10YR7/4), quartz arenite, structureless to planar parallel, decrease in grain size-increase in matrix up column, increasing hematite staining upwards to above unit, gradual lower contact.	4.9' (1.5m)	74.6' (22.7m)
7	Sandstone, fine-grained, poorly indurated well sorted, rounded, quartz arenite, bedding varying from planar parallel (<<) to medium scale low angle wedge and tabular shaped sets of tangential cross beds with sharp erosional and non-erosional lower contacts, sparce small <u>Ophiomorpha sp.</u> and <u>Thalassinoides sp.</u>, thin zones (>1ft.) of pelecypods casts.	14.2' (4.3m)	69.7' (21.2m)
6	Sandstone, partially covered, fine-grained, friable, well sorted, rounded, grayish	8.1' (2.5m)	55.5' (16.9m)

	orange (10YR7/4) bedding, subarkose, bedding varying from planar parallel to structureless, lower contact covered.		
5	Cover: float indicates sandstone, very fine to fine-grained, friable, poorly to moderately sorted, rounded, subarkose,planar parallel bedding, grain size decreased upwards to thin carbonaceous shales.	25.5' (7.8m)	47.7' (14.4m)
4	Sandstone, very fine-grained,well indurated, moderately sorted, rounded, medium brown (5YR4/4), subarkose, grain size decreases upward, undulating upper contact, possible lingoid ripple marks, pelecypod fragments, and burrows(?).	0.2'-0.4' (6cm-12cm) (variable)	21.9'
3B	Sandstone, fine-grained,indurated, well sorted, rounded, moderate yellowish brown (10YR5/4) to moderate brown (5YR4/4), subarkose, structureless fossil conglomerate at top: *Flemingostrea aff. prudencia*, *Ostrea anomioides*, gradational lower contact.	1.3' (.4m)	21.5' (6.6m)
3A	Sandstone, fine-grained,poorly indurated, well sorted, rounded, yellowish gray (5Y7/2), subarkose, cross-stratification: medium scale low angle tabular and wedge shaped sets of planar cross sets., fossil fragment (pelecypods) rare at base increasing with abundance upwards.	1.6' (.5m)	20.2' (6.2m)
2	Sandstone,very fine to fine-grained, friable, moderate to well sorted, rounded, grayish orange (10YR7/4), subarkose, clay rip-ups randomly scattered parallel to bed attitude, structureless to faint planar parallel, bioturbated.	7.9' (2.4m)	18.6' (5.7m)
1	Sandstone, partially covered, fine-grained, indurated, well sorted, rounded, grayish orange (10YR7/4) to light olive gray (5Y5/2), subarkose,limonite-hematite staining; structureless,fossil oyster fragments near top of unit,sparce burrows of *Ophiomorpha sp.* and *Thalassinoides sp.*, bioturbated, lower contact not observed.	10.7 (3.3m)	

MEASURED STRATIGRAPHIC SECTION

SECTION 5

SE 1/4 OF SW 1/4 OF NW 1/4 SECTION 5 T9S R14E

UNITS	LITHOLOGY	THICKNESS (FT./M) UNIT	CUMM.
6	Cover: not determineable		
5	Mudstone, silt to clay size with rounded pebbles, friable, poorly sorted, moderate yellowish brown (10YR5/4), pebbles are fossil fragments similiar to unit 4, thinly laminated, Ophimorpha irregulaire(?), gradational lower contact.	>2.0' (.6m)	26.1' (7.3m)
4	Sandstone, very fine-to fine-grained with pebble and cobble size fossil and lithic fragments, friable, poorly sorted, rounded, moderate yellowish brown (10YR 5/4), fossiliferous pebble sublithicarenite, fragments range from angular to rounded pebble and cobble size fragments, fossils: Crassostrea solenisus, Pleurcardia pauperculum, Inoceramus prisms, Arrhoges (Latiala) logata, Gyrodes spillmani, G. americanus, Placenticeras-Stantonoceras sp., sharks teeth, mammal teeth(?), crocidile armour, turtle plates, bone fragments and copolites, lower contact is sharp and erosional.	0.9' (.3m)	24.1' (7.3m)
3	Sandstone,fine-grained, friable to poorly indurated, well sorted, rounded, grayish orange (10 YR 5/4), subarkose, trace of glauconite; sedimentary structures vary from structureless to slightly planar parallel to cross stratified, cross-stratification: solitary medium scale tabular shaped-sets low angle cross beds with sharp nonerosional lower contacts; lower contact of unit sharp but gradational.	7.8' (2.4m)	23.1' (7.1m)
2	Sandstone, very fine-to fine-grainrd, friable, poorly sorted, rounded, grayish orange (10YR5/4), subarkose, sharp erosional lower contact, interbedded with mudstone, friable, poorly sorted, light olive gray (5Y5/2), thinly laminated, sharp lower erosional lower contact.	7.3' (2.2m)	15.4' (4.7m)
1	Mudstone, friable, poorly sorted, light olive gray (5Y5/2), thinly laminated to slight fissility in weathered portions, interbedded with thin (<.3 inchs) fossiliferous limestone conglomerates, fossils: Pleurcardia pauperculum, Arrhoges	8.1' (2.5m)	

(Latiala) logata, unidentified fossil fragments, lower contact covered.

MEASURED STRATIGRAPHIC SECTION

SECTION 6

NE 1/4 OF SW 1/4 OF NE 1/4 SECTION 5 T9S R14E

UNIT	LITHOLOGY	THICKNESS(FT./M) UNIT	CUMM.
11	cover: mudstone		
10	Limestone, fossiliferous, medium dark gray (N4),fossil: Cardium curtum, cf. Drilluta aff. major, Gyrodes americanus, G. spillmani, Ahhroges (latiala) logata, Cymbophora sp., faint laminations, gradational lower contact.	1.8' (.5m)	80.8' (24.6m)
9	Sandstone, fine-grained, friable, poorly sorted, rounded, moderate yellowish brown (10YR5/4),subarkose to sublithicarenite, carbonate cement increases up strata, slight planar parallel bedding to structureless,increase fossil abundance up strata,fossils: Cardium curtum, cf. Drilluta aff. major, Cymbophora sp.,Ophiomorpha nodosa, (near vertical), gradational lower contact.	4.3' (1.3m)	79.0' (24.1m)
8	Cover: sandstone, fine-grained, friable to poorly indurated, poorly sorted, rounded, moderate yellowish brown (10YR5/4), interbedded with mudstone, moderate yellowish brown (10YR5/4), gradational lower contact, increase in sandstone up strata.	9.6' (2.9m)	74.7' (22.8m)
7	Mudstone, friable to poorly indurated, olive gray (5Y4/1) to moderate brown (5YR4/4), thinly laminated, fissility increases with weathering, increased fossil abundance incomparison with units 6 and 6A, fossils: Placenticeras aff. planum, P.aff. meeki var. intercalare Stantonoceras sp., Inoceramus sp., I. subquatrus, I. involutus, horizonal burrows of Ophormorpha irregulaire, sand size grains increase up column, gradational lower contact.	21.9' (6.7m)	65.1' (19.8m)
6A	Mudstone, same as unit 6 but without limestone beds,gradational lower contact.	3.3' (1.0)	43.2' (13.2m)

MEASURSED STRATIGRAPHIC SECTION

SECTION 7

NE 1/4 OF SE 1/4 OF SE 1/4 SECTION 6 T9S R14E

UNITS	LITHOLOGY	THICKNESS (Ft./M) UNIT	CUMM.
5	Cover: float indicates claystone		
4	Limestone, with fine-grained sands decreasing in grain size upwards to silt size, poorly sorted, rounded, light olive brown (5Y5/6) to pale yellowish orange (10 YR 8/6) to medium gray (N5), gradational lower contact with decrease in clastic grains and increase in CaCO3 content, slight planar parallel bedding at base of unit, fossiliferous: *Cardium curtum*, *cf. Drilluta aff. major*, *Cymbophora sp.*, *Gyrode spillmani*, *G. americanus*, unidentified oyster fragments, possilble *Crassostrea sp.* and *Inoceramus sp.* fragments.	1.3' (.4m)	20.8' (6.3m)
3	Sandstone, fine-to medium-grain, friable, poorly sorted, angular to rounded, grayish orange (10YR7/4), subarkose to sublithicarenite, planar parallel bedding at base becoming more structureless upwards, fossiliferous: abundant *Cardium curtum* and *cf. Drilluta aff. major* with minor occurances of *Cymbophora sp.*, *Gyrode spillmani*, *G. americanus* and numerous oyster and clam fragments.	5.9' (1.8m)	19.5' (5.9m)
2	Sandstones, series of, very fine-to fine-grained, friable, poorly sorted, rounded, moderate yellowish brown (10YR5/4), lithic arenite rippled erosional lower contacts, interbedd with mudstones showing thin laminate bedding and slight fissility.	7.6' (2.3m)	13.6' (4.1m)
1	Claystone, light olive (10Y5/4), thinly laminated and weathers to slight fissility. COVER	>6.0?? (1.8m)	

MEASURED STRATIGRAPHIC SECTION

SECTION 8

NE 1/4 OF NE 1/4 OF NE 1/4 OF SECTION 6 T9S R14E

UNITS	LITHOLOGY	THICKNESS (Ft./M) UNIT	CUMM.
12	Cover: not determineable		
11	Sandstone, fine-to medium-grained, friable, poorly sorted, angular to rounded,	3.6' (1.1m)	54.7' (16.7m)

	subarkose, angular clay clasts, possible faint trough cross strata, gradational lower contact.		
10	Sandstone, fine-to medium-grained, friable, poorly sorted, angular to rounded, med. dark gray (N4) to greenish gray (5GY6/1), feldspathic lithic arenite, structureless, carbonaceous debris, rippled bedding, brush marks, plant casts.	10.1' (1.6m)	51.1' (15.6m)
9	Sandstone, partially covered, fine-grained, friable, moderately sorted, rounded, light olive gray (5Y6/1), sublithic arenite, carbonaceous debris, planar parallel bedding, erosional lower contact(?).	3.3' (.5m)	45.9' (14m)
8	Siltstone, partially covered, grain size decreases upwards to claystone, friable, moderate to well sorted, rounded (?), light olive gray (5Y6/1) to olive gray (5Y4/1), planar parallel lamination to structureless, plant fragments, gradational lower contact.	8.8' (2.7m)	44.3' (13.5m)
7	Ironstone, silt-clay size grains, well sorted, moderate dark brown (5YR3/4) to dark yellowish orange (10YR6/6), septarian characteristics in bedform, can be divided into 3 units of approx. equal thickness.	3.7' (1.1m)	35.5' (10.8m)
6	Sandstone, fine-grained, friable, well sorted, rounded, grayish orange (10YR7/4), subarkose, structureless, trough cross strata at top of bed, fossil plants found: Ficus planicostata, cf. Laurophyllum sp., Vitus aff. statoni and Cissus (?)sp., at least three undulating contacts with in the unit, difficult to follow because of cover, lower contact covered.	19.9' (6.1m)	31.8' (9.7m)
5	Claystone, partially covered, poorly sorted, olive gray (5Y4/1), gradational lower contact.	9.2' (2.8m)	11.9' (3.6m)
4	Sandstone, very fine- to fine-grained, friable poorly sorted, rounded, light olive gray (5Y5/6) to moderate olive brown (5Y4/4), arkosic wacke, graded, sharp erosional lower contact.	1.9' (.6m)	2.7' (.8m)
3	Claystone, silty, poorly sorted, light gray (N7), gradational lower contact.	0.1' (3cm)	0.8' (.2m)
2	Shale-claystone, lignitic, gradational lower contact.	0.4' (.1m)	0.7' (.2m)
1	Claystone, silty, poorly sorted, light olive gray (5Y6/1), lower contact covered. COVER	>0.3 (.1m)	

MEASURED STRATIGRAPHIC SECTION

SECTION 9

NE 1/4 OF NE 1/4 OF NE 1/4 SECTION 6 T9S R14E

UNITS	LITHOLOGY	THICKNESS(Ft./M) UNIT	CUMM.
17	Cover: not determineable.		
16	Sandstone, fine-grained, friable, poorly sorted, rounded yellowish gray (5Y8/1), subarkose, slighty chloritized, structureless, gradational lower contact.	>3.0' (.9m)	22.8' (6.9m)
15	Claystone, grain size increases upwards to siltstone,light olive gray (5Y5/2) to grayish yellow green (5GY7/2), structureless to planar parallel lamination, plant fragments, sharp lower contact.	6.5' (1.9m)	19.8' (6.0m)
14	Shale, brownish gray (5YR4/1), abundant coalified plant fragments, gradational lower contact.	0.3' (.1m)	13.3' (4.1m)
13	Siltsone, grainsize decreases upwards to claystone show some fissility, well sorted, light olive gray (5Y5/2), coalified plant fragments near top, sharp lower contact.	3.6' (1.1m)	13.0' (3.9m)
12	Ironstone, clay size grains, well sorted, moderate dark brown (5YR3/4) to dark yellowish orange (10YR6/6), variable thickness, septarian characteristics in bedform, gradational lower contact.	0.7-1.4' (.2-.4m)	9.4' (2.9m)
11	Sandstone, very fine-grained, grain size decreases upwards to siltstone, friable, moderately sorted, rounded, yellowish gray (5Y8/1), subarkose, slight fissility, gradational lower contact.	1.4' (.4m)	8.0' (2.4m)
10	Claystone, grain size increase upwards to siltstone, friable, light olive gray (5Y5/2), occational plant fragment, gradational lower contact.	0.8' (.2m)	6.6' (2.0m)
9	Claystone, friable, light gray (N7), gradational lower contact.	0.1' (3cm)	5.8' (1.8m)
8	Siltstone, friable, light olive gray (5Y5/2) to light gray (N7), structureless, plant fragments gradational lower contact.	0.5' (.2m)	5.7' (1.7m)
7	Sandstone, very fine-grained, friable,well sorted(?), well rounded, light olive gray (5GY6/1), subarkose, slightly chloritized, gradational lower contact.	0.3' (.1m)	5.2' (1.6m)
6	Claystone, silty, indurated, poorly sorted, light olive gray (5Y5/2), sharp irregular lower contact.	0.2' (6cm)	4.9' (1.5m)
5	Siltstone, friable, moderately sorted, light olive gray (5Y5/2), structureless,	1.8' (.5m)	4.7' (1.4m)

	randomly oriented plant fragments, sharp irregular lower contact.		
4	Shale, friable, brownish black (5YR2/1), carbonaceous, gradational lower contact.	0.7' (.2m)	2.9' (.9m)
3	Claystone, silty, friable, poorly sorted, brownish gray (5YR4/1), planar parallel lamination, plant fragments, gradational lower contact.	0.6' (.2m)	2.2' (.7m)
2	Siltstone, friable, well sorted, light olive gray (5Y5/2), slight planar parallel lamination, plant fragments and possible rootlets, gradational lower contact.	0.9' (.3m)	1.6' (.5m)
1	Siltstone, indurated, well sorted, light olive gray (5Y5/2), structureless, plant fragments ranging in size 1 mm. to > 20 cm.	0.7' (.2m)	
	COVER		

MEASURED STRATIGRAPHIC SECTION

SECTION 10

NW 1/4 OF SW 1/4 OF NW 1/4 SECTION 18 T9S RI4E

UNIT	LITHOLOGY	THICKNESS(FT./M) UNIT	CUMM.
9	Coal, silty, lignitic	2.+' (.6m)	
8	Mudstone, silty, friable, poorly sorted, grayish black (N2), rootlets at top of unit gradational lower contact.	0.8' (.2m)	7.9' (2.4m)
7	Sandstone, very fine grained, poorly indurated, poorly sorted, subrounded, light brownish gray (5YR6/1), feldspathic lithic arenite, structureless to slight planar parallel lamination, grain size decreases up column to next unit, sharp erosional lower contact.	0.4' (.1m)	7.1' (2.2m)
6	Mudstone, friable, poorly sorted, grayish black (N2), fissility at base decreasing upwards, grain size increasing upwards, gradational lower contact, rootlets present.	1.2' (.4m)	6.7' (2.0m)
5	Sandstone, fine grain, friable, poorly sorted subrounded, light brownish gray (5YR6/1), feldspathic lithic arenite, structureless to slight planar parallel lamination, sharp erosional lower contact.	.6' (.2m)	5.5' (1.7m)
4	Mudstone, poorly indurated, moderately to poorly sorted, medium gray (N 5) to medium dark gray (N4), increase in sand size	0.8' (.2m)	4.9' (1.5m)

	grains and grain size upwards, decrease in carbon content upwards, slightly fissile at base decreasing upwards, gradational lower contact.		
3	Coal, silty, lignitic	2.3' (.7m)	4.1' (1.3m)
2	Claystone, silty, poorly indurated, poorly sorted, grayish black (N2),carbonaceous, irregular fracture, rootlets, gradational lower contact.	0.8' (.2m)	1.8' (.5m)
1	Siltstone, poorly indurated, poorly sorted, medium gray (N5) to medium dark gray (N4), carbon increases upwards, rootlets, lower contact not observed.	1.+ (.3m)	1.+ (.3m)

MEASURED STRATIGRAPHIC SECTION

SECTION 11

NW 1/4 OF NW 1/4 OF SW 1/4 SECTION 9 T9S R14E

UNIT	LITHOLOGY	THICKNESS(FT./M) UNIT	CUMM.
8	Sandstone, fine grained, friable, poorly sorted, subrounded, very pale orange (10YR8/2) to grayish yellow (5Y8/4) to moderate brown (5YR3/4), subarkose, limonite-hematite staining, silt-clay rip-ups present with increased abundance at lower contact, erosional lower contact	0.6' (.2m)	16.6' (5.1m)
7	Siltstone, poorly sorted, friable, grayish black (N2) to dark gray (N3), carbonaceous(decreasing upwards), randomly oriented, plant fragments, angular fracture	2.1' (.6m)	16.0' (4.9m)
6	Coal, impure cleated fusin with limonite and gypsum in cleats,increased silt-clay content upwards, sharp lower contact, gradual upper contact	2.0' (.6m)	13.9' (4.2m)
5	Claystone, silty, poorly indurated,poorly sorted, medium gray(N4),randomly oriented plant(roolets)	2.5' (.6m)	11.9' (3.6m)
4A	same as below	0.6' (.2m)	9.5' (2.9m)
4	Sandstone, fine grained, poorly indurated, poorly sorted, subround to subangular, subarkose, grain size decreases upwards, plant fragments present, erosional upper and lower contacts	0.7' (.2m)	8.8' (2.7m)

3	Sandstone, very fine grain, friable, poorly sorted, subangular, light olive green (5Y6/1), lithic arenite, grain size decreases to clay size at top	3.6' (1.1m)	8.1' (2.5m)
2	Ironstone, structureless at base to septarian characteristics at top	1.5' (.5m)	4.5' (1.4m)
1	Sandstone, medium grained, friable, poorly sorted, subangular, light olive gray (5Y6/1), subarkose, slight planar parallel bedding, elongate pores up to .25ft long peniconcordant with bedding, plant fragments	3.+' (.9m)	3.+' (.9m)
COVER			

MEASURED STRATIGRAPHIC SECTION

SECTION 12

NE 1/4 OF SE 1/4 OF SE 1/4 SECTION 5 T9S R14E

UNIT	LITHOLOGY	THICKNESS(FT./M) UNIT	CUMM.
11	diabase sill	8.+	
10	Siltstone, poorly indurated, poorly sorted, medium light gray (N6)	.1' (3cm)	11.9' (3.6m)
9	Mudstone, friable, poorly sorted, grayish olive (10 Y 4/2), sharp lower contact,	.1' (3cm)	11.8' (3.6m)
8	Clay, grayish black (N 2), sharp lower contact	.1' (3cm)	11.7' (3.6m)
7	Shale, silty, friable, poorly sorted, grayish black (N 2), carbonaceous, gradational lower contact.	1.2' (.4m)	11.6' (3.5m)
6	Mudstone, friable, poorly sorted, grayish black (N 2), carbonaceous, plant fragments, gradational lower contact	2.4' (.7m)	10.4' (3.2m)
5	Coal,silty, lignite,sharp abrupt lower contact.	0.3' (.1m)	8.0' (2.4m)
4	Shale, friable, well sorted, grayish black (N 2), carbonaceous, plant fragments and rootlets(?), gradational but sharp lower contact.	3.4' (1.0m)	7.7' (2.3m)
3	Coal, lignite, sharp gradational lower contact.	1.1' (.3m)	4.3' (1.3m)
2	Claystone, silty, friable, poorly sorted, grayish black (N 2), carbonaceous, plant	0.2' (6cm)	3.2' (.9m)

Units	Lithology	Unit	Cumm.
	fragments gradational lower contact.		
1	Siltstone, clayey, friable, moderately sorted, medium gray (N 5) to medium dark gray (N 4), structureless, carbon content increases up strata, plant fragments and rootlets.	~ 3.+ (.9m)	

MEASURED STTRATIGRAPHIC SECTION

SECTION 13

NW 1/4 OF SW 1/4 OF SW 1/4 SECTION 9 T9S R14E

UNITS	LITHOLOGY	THICKNESS(FT/M) UNIT	CUMM.
4	Dike, diabase	>6'	
3	Sandstone, fine-grained, friable, poorly to moderately sorted, angular to round, light gray (N7), subarkose to sublithicarenite, slight chloritized, varying concretion of angular carbonaceous and clay fragments, possible trough shaped cross-beds, erosional lower contact, bed fractured.	6.6' (2m)	8.6' (2.6m)
2	Mudstone, decreasing in carbon upwards, dark gray (N3) to med. dark gray (N4), sharp lower contact possiblly erosional.	1.1' (.3m)	2.0' (.6m)
1	Coal, lower contact not observed.	0.9' (.3m)	

MEASURED STRATIGRAPHIC SECTION

SECTION 14

SE 1/4 OF SW 1/4 OF NE 1/4 SECTION 8 T9S R14E

UNITS	LITHOLOGY	THICKNESS(FT./M) UNIT	CUMM.
5	Mudstone, pale olive (10Y6/2), ironstone lenses, slight lamination, weathers to small angular blocks, sharp planar lower contact.	5.4' (1.6m)	16.3' (4.9m)
4	Mudstone, light gray (N7) increase plant fragments upsection gradational lower contact.	2.7' (.8m)	10.9' (3.3m)
3	Mudstone, pale olive (10Y6/2), ironstone lenses, slight lamination, weathers to small angular blocks, sharp planar lower contact.	3.6' (1.1m)	8.2' (2.5m)
2	Sandstone, fine-grained, friable, poorly to	4.1'	4.6'

	moderately sorted, subangular to rounded, subarkose, gray-yellow (5Y8/4), medium scale tabular shaped sets of low angle tangential cross-beds with sharp curved, erosional lower contact, some clay partings, clay rip-ups, slight decrease in grain size upward, small scale trough shaped cross-beds at top of unit.	(1.2m)	(1.4m)
1	Siltstone, friable, poorly sorted, light gray (N7) thinly laminated to thinly bedded with clay partings, plant fragments.	0.5' (15cm)	

MEASURED STRATIGRAPHIC SECTION

SECTION 15

SW 1/4 OF NW 1/4 OF NE 1/4 SECTION 8 T9S R14E

UNIT	LITHOLOGY	THICKNESS(FT./M) UNIT	CUMM.
4	Sandstone, very fine-to fine-grained, friable, well sorted, rounded, grayish orange (5Y7/2), rare medium light gray (N 6) clasts of siltstone-claystone in random locations, feldspaphic lithic arenite, medium scale low angle trough cross-beds with sharp curved, erosional lower contacts grading upwards into planar parallel bedding; lower contact covered.	32.3' (9.8m)	76.7' (23.4m)
----	BASE OF THE CUB MOUNTAIN FORMATION----		
3	Sandstone, fine-to medium-grained, poorly indurated, well-sorted, well rounded, yellowish gray (5Y7/2), Quartz arenite, (dolomitized), structureless to slightly planar parallel bedding at base of unit grading up strata to large scale low to high angle trough cross-beds with a sharp curved, erosional lower contact; retangular casts up to 5 cm. long and 2 cm. wide and thick, unit lower contacted covered.	6.7' (2.1m)	44.4' (13.5m)
2	Cover: sandstone,very fine-to fine-grained, friable, poor to moderate sorting, subrounded to subangular, light-olive gray (5 Y 5/2), composition similiar to unit 1, planar parallel bedding; interbedded with siltstones and claystones, light-olive gray (5Y5/2) to moderate olive brown (5Y4/4); thin intercalations of Ironstone displaying some septarian characteristics.	34.5' (10.4m)	
1	Sandstone, fine-grained, friable, moderately	3.2'	

sorted, subrounded to subangular, light-olive (9.6m)
gray (5 Y 5/2), 60% quartz, 17% altered whitish
green feldspar, 12% silt to clay size grains,
10% dark grains (carbonaceous debris,
lithic detritus, magnetite), slight bedding
observed, lower contact covered, top of bed
show sinuous approximately 1mm.in diameter
trails parallel to bedding.

Appendix V

Paleocurrent Data from stratigraphic sections and interpreted unit locations.

(Data in degrees)

Sandstone lithosome

Unit 1

Location: E1/2 Section 4 S9S R14E

Cross-stratification: Medium scale low angle, tabular- and wedge-shaped sets of tangential cross-strata with nonerosional lower contacts.

True bedding: N13E21W

Uncorrected structure attitude	Corrected Paleocurrent direction
N37E49NW	S48E12
N26E36NW	S53E11
N26E24NW	S76E18

Moving upsection

True bedding: N17E19W

Partial Section 1

N15W39SW	N10E10
N041W	N34E5
N46W22SW	S84E18

Moving north along the outcrop

True bedding: N9E23W

N19W28SW	N68E22
N23E23NW	N71E23
N31E32NW	S64E19
N79W21N	N332E17
N28E4NW	N7W1
N60E24N	N61E22
N15W26W	N73E23
N37E27W	N89E23

Moving north along the outcrop

True bedding: N11E11W

N56E18W	N83E12
N37E15NW	N76E12
N26E14NW	S84E12
N48E6W	N22E8

Moving north along the outcrop

True bedding: N20E15W

N26E16W	N85E16
N41W20NE	N15E10
N27W15W	S89E14
N8E13W	S78E13

Location:SW1/4 SE1/4 SW1/4 section 9 T9S R14E
True bedding: N60W10SW
Partial Section 3

Uncorrected structure attitude	Corrected Paleocurrent direction
N21W15SE	S20E11
N18W13NE	S30E12
N21E8SE	S23W6
N465E9SE	S14W8
N67W16SW	N88E4
N66W21SW	N81E2
N2W3W	N90E5

Location: SE1/4 SW1/4 SW1/4 Section 9 T9S R14E
True bedding: N26W7W

Uncorrected structure attitude	Corrected Paleocurrent direction
N82W21S	S77E8
N47W23SW	N54E3
N84W16S	S67E8
N65E7N	N69E6
N69E11W	N76E7

Location: SE1/4 NW1/4 SW1/4 Section 9 T9S R14E
True bedding: N66E8SW

Uncorrected structure attitude	Corrected Paleocurrent direction
N44W19SW	S26W5
N30W22SW	S10W8
N16E12NW	S54E8
N30E16NW	S58E7
N40E13NW	S73E6
N73W11S	S84E4

Location: W1/2 Section 16
True bedding: N64E6N

Uncorrected structure attitude	Corrected Paleocurrent direction
N41E10SE	N49W1
N47E5SE	N53W1
N44E12SE	N48W1
N37E15SE	N47W1
N55W12NE	N15E8
N61E8N	N45W1
N68W15N	N34E8
N58W16NE	N27E8

Location: W1/2 Section 16
True bedding: N64E6N

Uncorrected structure attitude	Corrected Paleocurrent direction
N67E11S	S68E1
N24E19W	N38W4
N61E7S	N63W1
N47E17S	N53W2

N53W14S
N60W10SW
N21W20SW
N1W4W
N65W21SW
N67W17SW
N41E9SE
N22E8SE
N32W9NE
N011E
N71W26SW
N26W8SW

N72E4
N80E4
N39E6
S87E3
N74E4
N80E4
N53W2
N43W3
N9W6
N24W5
N78E4
N66E5

Moving south along the outcrop
True bedding: N12W7W
Uncorrected structure attitude

N33W10NE
N14W11E
N60W9SW
N71W24SW

Corrected Paleocurrent direction

N20E2
N16E1
N60E8
N88E8

Moving south along the outcrop
True bedding: N4E14W
Uncorrected structure attitude

N68E10S
N49W17SW
N35E12NW

Corrected Paleocurrent direction

S18E4
N80E14
N54E13

Location: W1/2 NE1/4 Section 5
True bedding: N24E27NW
Uncorrected structure attitude

N7W32W
N89W37N
N57E19NW
N4W36W
N60E17NW
N82W36N

Corrected Paleocurrent direction

N57E28
S65E19
N20W20
N45E27
N13E17
S67E20

Moving south along outcrop
True bedding: N21E19NW
Partial Section 2
Uncorrected structure attitude

N2W8E
N7E7E
N69E9SE
N86W21N

Corrected Paleocurrent direction

N15W2
N17W2
S37E4
N36E17

Moving south along the outcrop
True bedding: N31E19W
Uncorrected structure attitude

N34W9SE

Corrected Paleocurrent direction

N12W7

N81E21N	N41E19
N86E14N	N15E14
N36E6SE	S32E1
N11E17NW	N89E18
N86W7S	S48E5
N39E10SE	S35E2
N80E19N	N36E18
N84W12S	S56E8
N24E23NW	N6W12
N21E23NW	N9E15
N6W20W	N72E19

Moving south along the outcrop
True bedding: N11E20W

Uncorrected structure attitude	Corrected Paleocurrent direction
N16W37SW	N40E17
N9W38W	N25E14
N24E23W	S71E18
N59E34NW	N87E20
N4E24W	N30E14
N34W22SW	S84E20
N3W30W	N32E14
N39E20W	N78E19

Moving south along the outcrop
True bedding: N26E20W

Uncorrected structure attitude	Corrected Paleocurrent direction
N27W322SW	N61E20
N9W16W	S79E17
N46E30NW	S77E16
N9E24W	N41E19
N1W29W	N36E19
N24E39NW	N24W1
N42E14NW	N4E11
N47W31SW	S73E16
N26W42SW	N49E20
N2E14W	S79E17
N31W16SW	S83E18
N32E20NW	N34E18
N17W35SW	N46E19
N31E22NW	S88E18
N18E20NW	N64E20
N63E13N	N2E13
N53E19NW	N43E19

Location: NE1/4 NW1/4 NE1/4 Section 5 T9S R14E
and SE 1/4 SW1/4 SE1/4 Section 32 T8S R13E
True bedding: N28E21NW

Uncorrected structure attitude	Corrected Paleocurrent direction
N84E18N	N25E19

N46E20W	N60E20
N69E65SE	S38E14
N86W24N	N35E19
N49E8NW	N18W4
N10W14E	N14W5
N62E18NW	N30E18
N5020NW	N51E21
N71W27N	N44E19
N25E20NW	N42E19
N38E19NW	N28E19
N60W29N	N25E19
N32E21NW	N16E18

Location: E1/2 NE1/4 Section 4 T8S R13E
True bedding: N36E13NW

Uncorrected structure attitude	Corrected Paleocurrent direction
N24W4NE	N26W3
N42E16NW	S67E6
N14W22W	N68E12
N13E18N	N59E14
N19W14SW	N77E12

Lower sandstone lithosome
Unit 3
Location: SW1/4 Section 5 T9S R14E
Cross-stratification: Trough shaped cross beds and medium scale,
tabular- and wedged-shaped sets of tangential and planar cross-beds
with erosional and non-erosional lower contacts.
True bedding: N14E13W

Uncorrected structure attitude	Corrected Paleocurrent direction
N19E21W	N18E7
N87W5S	S37E5
N24E16W	S41E8
N9W24W	N8E2
N45E26S	S68E1
N24E24W	S34E4
N60W21W	N85E13
N21E36SW	S22E2
N25E29SW	S33E5
N34W14W	S88E13
N16W11NE	N1E2
N21W15NE	N7E4
N7E9E	N10W1
N20E34SW	N36E11
N8W7E	S40E6
N21E15W	S59E10
N34W16NE	N14E6
N26E30SW	S35E5
N6W9E	N9W2

Location: NW1/4 section 32 T8S R13E
True bedding: N4E31W

Uncorrected structure attitude	Corrected Paleocurrent direction
N19E20E	S10E4
N12W16W	S17E8
N20W10SW	S15E6
N23E20W	N23E17
N35E17NW	N29E19
N27E20NW	N26E17
N31E20NW	N32E20

Location: N1/2, Starting on west side of east-west trending ridge and progressing eastward.
True bedding: N7E19E

Uncorrected structure attitude	Corrected Paleocurrent direction
N81W10N	N36W16
N76W9N	N34W16
N67E19SE	S55W18
N60W11N	N41W11
N6W13E	N24W6
N19W11NE	N39W9
N6W9E	N19W4
N53E12S	S33W11
N70E8S	S16W9
N59E2S	S2E1

Moving east along the outcrop
True bedding: N75W7S

Uncorrected structure attitude	Corrected Paleocurrent direction
N61W35SW	S60W1
N69E2SE	S55W2
N38W19SW	S19W7
N50W16SW	S30W6

Moving east along the outcrop
True bedding: N67W15SW

Uncorrected structure attitude	Corrected Paleocurrent direction
N44W21SW	S12W12
N26E22SE	S7W7
N2E26E	S18W11
N7E25E	S20W11

Moving east along the outcrop
True bedding: N62W12SW

Uncorrected structure attitude	Corrected Paleocurrent direction
N25W21NE	S27W5
N47W35SW	S30W5

Lower shale-sandstone lithosome
Unit 6
Location: SE1/4 SW1/4 NW1/4 Section 5 T9E R14E in Oso Creek
Cross-stratification: Hummocky cross-beds
True bedding: N19E5NW
Partial Section 6

Uncorrected structure attitude	Corrected Paleocurrent direction
N81E5N	N27E5
N9E7E	N15W1
N04E	N14W1
N15E14E	N17W1
N78W5S	S62E5
N65W4S	S60E4
N5W14E	N3W2
N11W20W	N3E3
N29E15W	S30E1
N71W15N	N49E6
N77W17N	N55E6
N15W12E	N1E2
N87W9N	N47E6
N53W13N	N31E5
N10E3E	N18W1
N36W6NE	N3E2
N21W9E	N49E6
N69W17N	S89E6
N71E18N	N3E2
N19W10E	N3E2

Upper shale-sandstone lithosome
Unit 12

Location: W1/2 NE1/4 Section 8 T9S R14E
Cross-stratification: Large scale, tabular cosets of low angle tangential cross-beds with sharp erosional lower contacts.
True bedding: N31E9NW
Partial Section 15 (First three measurements)

Uncorrected structure attitude	Corrected Paleocurrent direction
N6W18W	N36E9
N9W20W	N36E9
N3W16	N45E10
N11W17W	N51E10
N33W30W	N46W10
N31W32W	N54E10
N34W26W	N53E10
N37W31W	N37E9
N17W24W	N32E9
N20W36W	N34E9
N19W28W	N36E10
N76W17N	N42E10
N80W12N	N32E9

N73W15N	N37E9
N66W21N	N41E10
N67W19N	N39E10
N7W19W	N20E36
N69W22W	N26E9
N44W18NE	N19E8
N39W26NE	N21E8
N37W21NE	N18E8
N43W27NE	N26E9

Location: S1/2 SW1/4 Section 17 T9S R14E
True bedding: N7W10W

Uncorrected structure attitude	Corrected Paleocurrent direction
N68W2NE	N17E2
N62W11NE	N36E4
N72W20N	N52E8
N59E9N	N59E8
N70E8N	N23E2
N47E21NW	N32E4
N65W14NE	N41E6
N19W18NE	N34E4
N64W11N	N38E5
N72W10N	N39E9
N60W20N	N42E5
N48W23N	N37E6
N54W30N	N43E5
N52W29N	N42E5
N44W21N	N34E5
N45W28N	N35E8
N67W34N	N55E8
N79W13N	N51E7
N77W26N	N60W8