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LOWER CRETACEOUS STRATIGRAPHY, DEPOSITIONAL ENVIRONMENTS, AND SEDIMENT DISPERSAL IN SOUTHWESTERN NEW MEXICO

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ABSTRACT. Lower Cretaceous rocks in southwestern New Mexico were deposited in a west-northwest-trending basin which was a northwestern extension of the Chihuahua trough. The sediment wedge thickens southward from 50 to 3200 m. The predominance of terrigenous clastic sediment and a high sedimentation rate indicate Early Cretaceous tectonism near southwestern New Mexico. In extreme southwestern New Mexico, Lower Cretaceous rocks are separated into three conformable stratigraphic units, which in ascending order are the Hell-to-Finish (Aptian(?)), U-Bar (upper Aptian to middle Albian), and Mojado (upper Albian to lowest Cenomanian) Formations. These formations are correlated with other Lower Cretaceous units in southwestern New Mexico, and for purposes of interpretation of depositional environment and sediment dispersal, the Lower Cretaceous series is separated into three informal stratigraphic intervals and seven subintervals.

Limestone- and chert-cobble conglomerate ($\leqslant 42$ m thick) of the basal Hell-to-Finish subinterval was deposited by alluvial fans or by proximal braided streams and records initial uplift and erosion of variable-relief source areas in southwestern New Mexico. Facies belts in the upper Hell-to-Finish subinterval include northwestern braided-stream, intermediate coastal-plain, and southeastern shallow-marine, which indicate, along with grain-size, imbrication, and crossbed paleocurrent data, southward sediment transport. Southward to southeastward sediment dispersal is also indicated by facies and grain-size distributions in the shallow-marine, mixed clastic and carbonate lower U-Bar subinterval. The rate of detrital influx diminished in the upper U-Bar subinterval, resulting in deposition of marine carbonates.

Detrital sedimentation resumed in the Mojado interval, and by middle Mojado time an alluvial plain prograded eastward as far as the Big Hatchet Mountains. By late Mojado time, shoreline and shelf facies of the Sarten and Beartooth Formations onlapped the Burro uplift.

Southward sediment dispersal and arkosic composition of Hell-to-Finish and U-Bar intervals indicate derivation from the Precambrian-crystalline-cored Burro uplift of west-central New Mexico. However, paleogeography changed during deposition of the Mojado interval. Eastward and southeastward paleocurrents, quartz-rich composition, and onlap of the core of the Burro uplift during the Mojado interval indicate new source terrane(s) located to the west or northwest of southwestern New Mexico.

INTRODUCTION

Lower Cretaceous sedimentary rocks in southwestern New Mexico unconformably overlie Paleozoic and Precambrian rocks and range in thickness from 50 to 3200 m. Early Cretaceous sediment was deposited in a west-northwest-trending basin which extended southeastward into west Texas and northern Mexico and northwestward into southeastern Arizona (Kottlowski, 1965; Hayes, 1970; Greenwood, Kottlowski, and Thompson, 1977). This basin was a northwestward extension of the Chihuahua trough. The location of the thickest Lower Cretaceous sedimentary rocks coincides with the hinge line of the late Paleozoic Pedregosa basin, suggesting late Mesozoic reactivation of a structural feature that was present in late Paleozoic and may have originated in Precambrian (Kottlowski, 1965; Titley, 1976; Greenwood, Kottlowski, and Thompson, 1977; Drewes, 1981). Predominance of terrigenous clastic sediment and a sedimentation rate (80-150 m/my) similar to rates in foreland or rift basins suggest tectonism near southwestern New Mexico in Early Cretaceous time (Schwab, 1976). Elston (1958) suggested that the source area for Lower Cretaceous sediment was the basement-cored Burro uplift in west-central New Mexico, based on the fact that in the Burro Mountains the Lower(?) Cretaceous Beartooth Formation lies unconformably on Precambrian crystalline rocks (fig. 1; Hewitt, 1959). However, a Burro uplift source has not yet been documented for Lower Cretaceous formations by sedimentologic data.

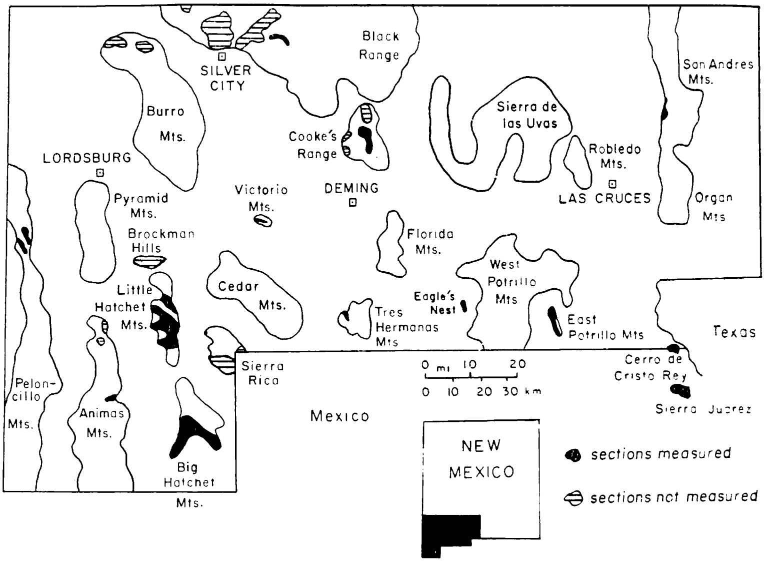
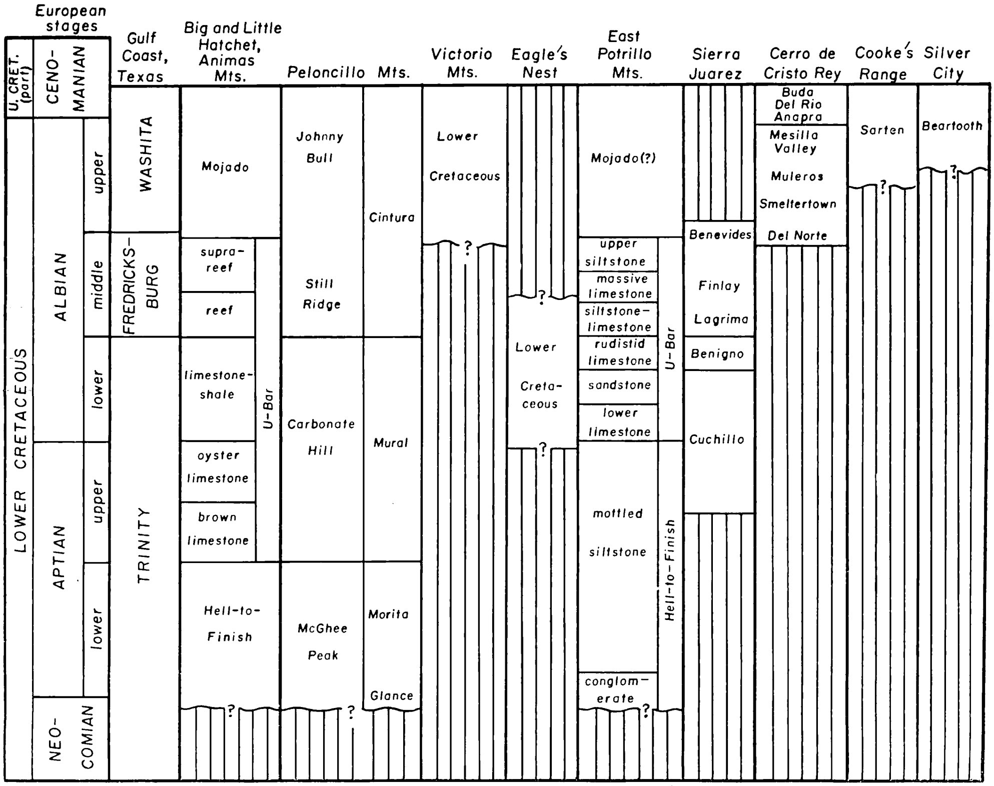


Fig. 1. Index map of the major mountain ranges in southwestern New Mexico and Sierra Juarez, Mexico. Shaded areas represent sections measured in this study; lined areas are lower Cretaceous exposures not measured in this study.

The goal of this study was to interpret Early Cretaceous depositional environments and sediment dispersal patterns in southwestern New Mexico. In order to fulfill this goal, it was necessary to establish regional correlations. Previously published biostratigraphic work was combined with biostratigraphic and lithostratigraphic data from this study to develop a correlation chart of Lower Cretaceous rocks in southwestern New Mexico (table 1). Within the context of the stratigraphic framework, sedimentologic data were used to determine facies, grain size, and paleocurrent trends. Sandstone petrographic data are discussed briefly; a rigorous presentation of the petrographic data is beyond the scope of this

TABLE 1

Correlation of Lower Cretaceous rocks in southwestern New Mexico and Sierra Juarez, Mexico



European stages			Gulf Coast, Texas	Big and Little Hatchet, Animas Mts.		Peloncillo Mts.		Victorio Mts.	Eagle's Nest	East Potrillo Mts.		Sierra Juarez	Cerro de Cristo Rey	Cooke's Range	Silver City
U. CRET. (part)	CENOMANIAN												Buda Del Rio Anapra	Sarten	Beartooth
LOWER CRETACEOUS	ALBIAN	upper	WASHITA	Mojado		Johnny Bull	Cintura	Lower Cretaceous		Mojado(?)			Mesilla Valley Muleros Smeltertown Del Norte	?	?
		middle	FREDERICKSBURG	supra-reef reef	U-Bar	Still Ridge		?	?	upper siltstone massive limestone siltstone-limestone	U-Bar	Benevides Finlay Lagrima			
		lower	TRINITY	limestone-shale		Carbonate Hill	Mural		Lower Cretaceous	rudistid limestone sandstone lower limestone		Benigno Cuchillo			
	APTIAN	upper		oyster limestone brown limestone					?	mottled siltstone	Hell-to-Finish				
		lower		Hell-to-Finish		McGhee Peak	Morita Glance			conglomerate					
	NEOCOMIAN			?		?				?					

Relationship between European stages and Texas Gulf Coast groups is from Cobban and Reeside (1952). The following references were used: Big Hatchet Mountains: Zeller (1965) and Weise (ms); Little Hatchet Mountains: Zeller (1970); Animas Mountains: Zeller and Alper (1965); Peloncillo Mountains: Gillerman (1958), and Drewes and Thoroman (1980a,b); Victorio Mountains: Griswold (1961); Eagle's Nest: Hoffer and Hoffer (1933); East Potrillo Mountains: Bowers (ms), and Seager and Mack (in press); Sierra Juarez: Cordoba (1969), Craig (1972), and Swift (1972); Cerro de Cristo Rey: Lovejoy (1976); Cooke's Range: Clemons (1982); Silver City: Jones, Hermon, and Moore (1967).

paper. The result of this study is a refinement of Early Cretaceous paleogeography in southwestern New Mexcio.

METHODS

Thirty-three sections of Lower Cretaceous sedimentary rocks were measured at 11 different mountain ranges in southwestern New Mexico (fig. 1; table 2). The combined measured sections total just under 8 km thick. The sections ranged from 50 m for the Beartooth Formation near

TABLE 2

Location and thickness of Lower Cretaceous rocks measured in this study

Mountain Range	Formation	Thickness (m)	Location	Geologic Map
Peloncillo Mountains	Cintura	611	NW¼,Sec34,T24S,R21W	Drewes and Thorman (1980).
	Mural	66	SW¼,Sec34,T24S,R21W	
	Morita	105	SE¼,Sec34,T24S,R21W	
	Glance	32	SE¼,Sec9,T25S,R21W	
Animas Mountains	Hell-to-Finish	145	SE¼,NW¼,Sec3,T31S,R18W	Zeller and Alper (1965).
	U-Bar	345	NW¼,Sec2,T31S,R18W	
	Mojado	1570	SW¼,Sec2 and SE¼,Sec13, T31S,R18W	
Little Hatchet Mountains	Mojado	1276	Sec14,T28S,R16W	Zeller (1970).
	Hell-to-Finish	580	SE¼,Sec33,T27S,R16W	
Big Hatchet Mountains	Mojado	1584	S½,Sec20,T32S,R15W	
	Hell-to-Finish	480	NW¼,SE¼,Sec2 and NW¼,Sec11,T32S,R15W	Zeller (1965).
Victorio Mountains	Lower Cretaceous	235	NE¼,Sec30,T24S,R12W	Griswold (1961) and Thorman and Drewes (1980).
Tres Hermanas Mountains	Lower Cretaceous	114	SE¼,Sec31,T27S,R9W NE¼,Sec6,T28S,R9W	Balk (1961).
Eagle's Nest	Lower Cretaceous	266	NW¼,Sec34,T27S,R5W	Hoffer (1976).
East Potrillo Mountains northern section	Mojado(?)	15	NE¼,NE¼,Sec8,T28S,R2W	
	U-Bar			
	siltstone-limestone	81	SW¼,Sec35,T27S,R2W	
	rudistid limestone	13	NE¼,SW¼,Sec2,T28S,R2W	
	sandstone	66	NE¼,SW¼,Sec2,T28S,R2W	
	lower limestone	30	NE¼,SE¼,Sec3,T28S,R2W	
	Hell-to-Finish			
	mottled siltstone	168	NW¼,SE¼,Sec11,T28S,R2W	
	conglomerate	39	NW¼,SE¼,Sec11,T28S,R2W	
	U-Bar			Seager and Mack (in press).
southern section	upper siltstone	15	NE¼,Sec36,T28S,R2W	
	massive limestone	133	NE¼,Sec36,T28S,R2W	
	siltstone-limestone	90	NE¼,Sec25,T28S,R2W	
	rudistid limestone	6	NE¼,Sec25,T28S,R2W	
	sandstone	25	NE¼,Sec25,T28S,R2W	
	lower limestone	13	NE¼,Sec25,T28S,R2W	
	Hell-to-Finish			
	mottled siltstone	119	NE¼,Sec25,T28S,R2W	
	conglomerate	1	NE¼,Sec25,T28S,R2W	
Cooke's Range				
northern section	Sarten	227	NW¼,Sec17,T21S,R8W	Clemons (1982).
southern section	Sarten	140	SW¼,SE¼,Sec29,T21S,R8W	
Santa Rita	Beartooth	50	Sec30,T17S,R11W	Jones, Hermon, and Moore (1967).
San Andres	Sarten	90	Sec30,T20S,R4E	Seager (1981).

Santa Rita east of Silver City to 1584 m for the Mojado Formation in the Big Hatchet Mountains. In addition, studies by Weise (ms) on the U-Bar Formation in the Big Hatchet Mountains, by Chafetz (1982) on the Beartooth Formation in the Silver City range, by Pickens (1984) on a rudistid biostrome in the East Potrillo Mountains, by Swift (1972) and Craig (1972) on Lower Cretaceous rocks in the Sierra Juarez, and by Lovejoy (1976) on Lower Cretaceous rocks at Cerro de Cristo Rey, Mexico and New Mexico, are incorporated into the regional facies analyses. Outcrop descriptions were supplemented by examination of 368 thin sections, 201 of which are of sandstones and the remainder of which are of limestones and siltstones.

CORRELATION OF LOWER CRETACEOUS ROCKS

Southwestern Domain

Lower Cretaceous rocks in southwestern New Mexico fall naturally into three stratigraphic domains: southwest, southeast, and north. The southwestern domain has the thickest section of Lower Cretaceous rocks and has close stratigraphic affinity with the Bisbee Group in Arizona (Hayes, 1970). The most complete Lower Cretaceous sections in the southwestern domain are in the Big Hatchet, Little Hatchet, Animas, and Peloncillo Mountains (fig. 1). Only an incomplete section of the uppermost formation crops out in the Brockman Hills, and in the Sierra Rica structural complications and contact metamorphism make the sections unsuitable for sedimentologic study.

In the Big Hatchet, Little Hatchet, and Animas Mountains, Lower Cretaceous rocks are divided into three conformable formations, which in ascending order are the Hell-to-Finish, U-Bar, and Mojado Formations (fig. 1, table 1; Zeller, 1965, 1970; Zeller and Alper, 1965). Complete sections of the Hell-to-Finish Formation are exposed in the Big Hatchet Mountains (480 m thick) and in the Animas Mountains (145 m thick), whereas a 580 m-thick section in the Little Hatchet Mountains has faulted lower and upper contacts. At the base of the Hell-to-Finish Formation is a diagnostic limestone- and chert-cobble conglomerate that reaches a maximum thickness of 30 m in the Animas Mountains. The remainder of the Hell-to-Finish Formation consists of conglomerate, arkosic sandstone, siltstone, shale, and rare limestone. The U-Bar Formation is a mixed clastic and carbonate unit, which reaches a maximum thickness of 1200 m in the Big Hatchet and Little Hatchet Mountains, although the U-Bar Formation in the Little Hatchet Mountains is poorly exposed, faulted, and locally contact metamorphosed (Zeller, 1965, 1970). In the Animas Mountains the U-Bar Formation is 345 m thick. Zeller (1965) subdivided the U-Bar Formation in the Big Hatchet Mountains into five members. The lower three members, the brown limestone, oyster limestone, and limestone-shale members, consist of interbedded limestone, shale, and sandstone. The upper two members, the reef and suprareef members, are primarily limestone. The Mojado Formation is composed of quartz-rich sandstone and shale but has a few limestone beds near the base and top.

The Mojado Formation is 1584 m thick in the Big Hatchet Mountains and 1276 m thick in the Little Hatchet Mountains. The thickness of the Mojado Formation in the Animas Mountains has been estimated at 1570 m by Zeller and Alper (1965), although only 365 m at the base and 300 m at the top are exposed. Zeller (1965) subdivided the Mojado Formation into lower and upper members, but in this study the Mojado Formation was separated into a lower thin-bedded, sandstone, shale, and limestone unit, a middle thick-bedded sandstone and slope-forming shale unit, and an upper thin-bedded, sandstone, shale, and limestone unit. The three informal members used in this study provide a more easily recognizable subdivision of the Mojado Formation than the two-fold subdivision of Zeller (1965).

Fossils in the oyster limestone member and in the limestone-shale member of the U-Bar Formation correlate with the Trinity Group of Texas (Zeller, 1965; table 1). The Aptian-Albian boundary may be at the contact between the oyster limestone and limestone-shale members, based on ammonites (Zeller, 1965). Foraminifera and mollusks in the reef and suprareef members are middle Albian in age (Zeller, 1965; Weiss, ms). Fossils in the upper part of the Mojado Formation correlate with the Washita Group of Texas and indicate a late Albian to earliest Cenomanian age (Zeller, 1965, 1970; Zeller and Alper, 1965). No index fossils have been found in the lower portion of the Mojado Formation, but Zeller (1965) suggests that the lower portion may be equivalent to the uppermost Fredricksburg Group. The Hell-to-Finish Formation also lacks index fossils but is assumed to be Aptian or older, because of its conformable contact with the U-Bar Formation.

In the central Peloncillo Mountains, Gillerman (1958) defined four Lower Cretaceous map units: the McGhee Peak, Carbonate Hill, Still Ridge, and Johnny Bull Formations. Armstrong and others (1978) used three of Gillerman's units in their map of the central Peloncillo Mountains, having found it expedient to combine the Still Ridge and Johnny Bull Formations into one map unit. Drewes and Thorman (1980a, b) extended Arizona stratigraphic terminology into the Peloncillo Mountains, applying the names Glance Conglomerate and Morita Formation for the McGhee Peak Formation, Mural Limestone for the Carbonate Hill Formation, and Cintura Formation for the Still Ridge and Johnny Bull Formations. The Glance Conglomerate and Morita Formation correlate lithologically with the Hell-to-Finish Formation, with the Glance equivalent to the basal Hell-to-Finish conglomerate (table 1). The Carbonate Hill Formation in the Peloncillo Mountains has upper Aptian ammonites in the basal part and was correlated by Hayes (1970) with the upper Aptian to lower Albian Mural Limestone of southeastern Arizona, suggesting that the Carbonate Hill Formation is coeval with the lower three members of the U-Bar Formation (table 1). The Still Ridge and Johnny Bull Formations are lithologically similar to the Mojado Formation, although the lower part of the Still Ridge Formation is probably coeval with the upper U-Bar Formation (table 1).

Northern Domain

The northern stratigraphic domain has the thinnest Lower Cretaceous section. For this study, sections in the Cooke's Range, San Andres Mountains, Burro Mountains, and the Silver City area are used (fig. 1; table 2). In the Cooke's Range and southern San Andres Mountains, Lower Cretaceous is represented by the Sarten Formation, which is composed of quartz sandstone and dark gray shale 97 to 227 m thick. The Sarten Formation unconformably overlies Paleozoic rocks and is conformably(?) overlain by the Upper Cretaceous Colorado Shale. Upper Albian ammonites were collected by Stephen C. Hook from the Sarten Formation in the Cooke's Range (Clemons, 1982). The Sarten Formation correlates lithologically and biostratigraphically with the upper part of the Mojado Formation (table 1). The Beartooth Formation in the Burro Mountains and Silver City area is lithologically similar to and occupies the same stratigraphic position as the Sarten Formation. Although the Beartooth Formation lacks index fossils, it has been designated as Lower Cretaceous by Darton (1917), Upper Cretaceous by Hewitt (1959) and by Chafetz (1982), or at the Lower-Upper Cretaceous boundary by Jones, Hermon, and Moore (1967). Even if the Beartooth Formation is not exactly coeval with the Sarten Formation, it must be very close to it in age. In terms of depositional facies it appears to be more similar to the Sarten Formation than it does to the Colorado Shale. For these reasons the Beartooth Formation is included in this study.

Southeastern Domain

The southeastern domain is characterized by sections of intermediate thickness. These sections generally are less well exposed and have less biostratigraphic control than sections in the other domains. The best exposures of Lower Cretaceous rocks in the southeastern domain are in the East Potrillo Mountains, at Cerro de Cristo Rey, Mexico and New Mexico, and in the Sierra Juarez, Mexico (fig. 1).

In the East Potrillo Mountains, the first rigorous stratigraphic work was by Bowers (ms), who separated the Lower Cretaceous section into the basal Noria, the Little Horse, and the Restless Formations. Seager and Mack (in press) found the stratigraphic units of Bowers to be unsatisfactory map units and applied the names Hell-to-Finish, U-Bar, and Mojado to the East Potrillo Mountains section. The Hell-to-Finish Formation was subdivided into two map units, the conglomerate member at the base (1-39 m thick) and the mottled siltstone member (119-168 m). The Hell-to-Finish Formation is the same as the Noria Formation of Bowers (ms). The U-Bar Formation was separated into six informal members, which in ascending order are the lower limestone member (13-30 m), the sandstone member (25-66 m), the rudistid limestone member (6-13 m), the siltstone-limestone member (90 m), the massive limestone member (133 m), and the upper siltstone member (15 m). The lower three members are equivalent to the Little Horse Formation of Bowers (ms), and the upper three members are equivalent to the Restless Formation of

Bowers (ms). The uppermost Lower Cretaceous formation consists of 15 m of poorly exposed, medium-grained quartzarenite, which is tentatively assigned to the Mojado(?) Formation.

Paleontologic evidence for the age of the Cretaceous rocks in the East Potrillo Mountains is scanty. The faunal collection of Bowers (ms) consisted of 13 species, most of which are long-ranging forms and are not useful as index fossils (W. A. Cobban, 1985, personal commun.). The most important index fossil in the East Potrillo Mountains is the foraminifera *Orbitolina,* which ranges from latest Aptian to early Albian (Douglass, 1960). Lokke (1964) identified the species *Orbitolina gracilis* and Craig (1972) identified *Orbitolina texana* (Roemer) in the East Potrillo Mountains. Samples collected during this study were sent to R. C. Douglass, who identified *Orbitolina gracilis* from the lower limestone member of the U-Bar Formation and *Orbitolina grossa* from the rudistid limestone member of the U-Bar Formation. The presence of *Orbitolina* suggests an early Albian age for at least the lower three members of the U-Bar Formation (Douglass, 1960). Regional correlation of the upper three members of the U-Bar Formation, as well as the Hell-to-Finish and Mojado Formations, is based on lithology and upon previous correlations (Craig, 1972).

In the Sierra Juarez, the lowest exposed Cretaceous unit is the Cuchillo Formation, which consists of a lower clastic unit, a middle carbonate unit, and an upper clastic unit (Swift, 1972) and is Aptian and early Albian in age (Cordoba, 1969). The Cuchillo Formation correlates with the upper part of the Hell-to-Finish Formation and the lower part of the U-Bar Formation in the East Potrillo Mountains (Craig, 1972; table 1). The Cuchillo Formation is overlain by the Benigno Formation (lower Albian), which consists of shale and thin-bedded limestone at the base and top and a cliff-forming rudistid biostrome in the middle (Cordoba, 1969). The Benigno Formation probably correlates with the early Albian, *Orbitolina*-bearing members of the U-Bar Formation in the East Potrillo Mountains (table 1). Overlying the Benigno Formation in the Sierra Juarez are thin-bedded limestone and shale of the Lagrima Formation (lower middle Albian), the Finlay Limestone (middle Albian), and shale and limestone of the Benevides Formation (middle to late Albian) (Cordoba, 1969; Craig, 1972). The Lagrima, Finlay, and Benevides Formations correlate lithologically with the upper three members of the U-Bar Formation in the East Potrillo Mountains (table 1).

About 12 km north of the Sierra Juarez at Cerro de Cristo Rey, Mexico and New Mexico, the Finlay Limestone is overlain by shale and limestone of the Del Norte Formation, which has a Fredericksburg fauna (Lovejoy, 1976). Overlying the Del Norte Formation are sandstone, shale, and limestone of the Smeltertown, Muleros, and Mesilla Valley Formations, which are late Albian in age and correlate with the Mojado and Sarten Formations (table 1). Overlying the Mesilla Valley Formation are sandstone and siltstone of the Anapra Formation, shale and some limestone of the Del Rio Formation, and limestone of the Buda Formation, which are Cenomanian in age and may be coeval with or younger than the uppermost part of the Mojado Formation (table 1).

The remainder of Lower Cretaceous sections in the southeastern stratigraphic domain are poorly exposed and incomplete. At Eagle's Nest about 281 m of Lower Cretaceous rocks are informally subdivided into four units. The basal 137 m has a concealed lower contact and is composed of siltstone, fine sandstone, and limestone. The middle unit is a 27 m-thick rudistid and oolitic limestone, which is overlain by 70 m of poorly-exposed conglomerate, sandstone, and shale. The remaining unit consists of 47 m of massive, cliff-forming limestone, which is considered by Hoffer and Hoffer (1983) to be the highest stratigraphic unit. However, recent mapping by W. R. Seager (1984, personal commun.) revealed a fault between the cliff-forming limestone and the rest of the section. Hoffer and Hoffer (1983) collected *Orbitolina* from the middle limestone unit, suggesting an early Albian age (Douglass, 1960). Hoffer and Hoffer (1983) correlated the upper three units at Eagle's Nest with the lower three members of the U-Bar Formation in the East Potrillo Mountains, a correlation followed here (table 1).

Lower Cretaceous rocks in the Victorio Mountains are 235 m thick and lie unconformably above the Silurian Fusselman Dolomite and are overlain unconformably by Tertiary conglomerate and sandstone (fig. 1; Griswold, 1961; Thorman and Drewes, 1980). The Victorio Mountains section is primarily siltstone and fine sandstone but also contains limestone and conglomerate, including a 2 m-thick, basal limestone- and chert-cobble conglomerate. A few poorly-preserved fossils can be found in the lower half of the section, from which F. E. Kottlowski (see Griswold, 1961) collected the pelecypod *Trigonia emoryi*, a late Albian index fossil; thus, Lower Cretaceous rocks in the Victorio Mountains are tentatively correlated with the Mojado and Sarten Formations (table 1).

A 467 m-thick section of sedimentary rocks in the Tres Hermanas Mountains was correlated by Kottlowski and Foster (1962) with Lower Cretaceous rocks of southern New Mexico. The section was subdivided by Kottlowski and Foster (1962) into five units: (1) basal conglomerate, sandstone, siltstone, limestone (114 m thick); (2) lower limestone (120 m thick); (3) quartz sandstone (12 m thick); (4) upper conglomerate (118 m thick); (5) upper limestone and dolomite (103 m thick). Although this section is still cited as Lower Cretaceous (Hoffer and Hoffer, 1983), recent work raises serious doubts about the stratigraphic relationships. The unit that most closely resembles Lower Cretaceous rocks is the basal unit, which is similar to the Hell-to-Finish Formation. Because the basal unit is poorly exposed and contact metamorphosed, only grain-size data are used in this study. The lower limestone (unit 2) is too recrystallized to allow confident correlation, and Kottlowski and Foster (1962) cite the possibility of a fault at the base of unit 2, which further complicates its stratigraphic relationship. The quartz sandstone (unit 3) is also too poorly exposed for confident correlation. The upper conglomerate (unit 4) is somewhat similar to the basal conglomerate of the Hell-to-Finish Formation but is thicker and contains more interbedded sandstone. The upper conglomerate more closely resembles exposures of the Tertiary(?) Lobo Formation in the Florida Mountains. W. R. Seager, R. E. Clemons, and one of us (Mack) have recognized a thrust fault between the upper limestone and dolomite (unit 5) and the upper conglomerate (unit 4). Furthermore, Middle Permian (Leonardian) conodonts were discovered in the upper limestone and dolomite unit (Thompson, 1982), suggesting a correlation with the Colina Limestone and/or the Epitaph Dolomite of southwestern New Mexico (Zeller, 1965) or with the San Andres and/or Yeso Formations of south-central New Mexico (Seager, 1981). It should be apparent from this discussion that there is a high degree of uncertainty in the stratigraphy of the Tres Hermanas section, and consequently it is omitted from the correlation chart pending further work.

DEPOSITIONAL ENVIRONMENTS AND SEDIMENT DISPERSAL

For convenience of discussion of regional facies and dispersal patterns, Lower Cretaceous rocks in southwestern New Mexico are separated into three stratigraphic intervals and seven subintervals. These subdivisions are informal and are implemented solely to aid in paleogeographic reconstruction. The lowest interval corresponds to the Hell-to-Finish Formation and its stratigraphic equivalents (table 1). The Hell-to-Finish interval is subdivided into the basal conglomerate and into the section above the basal conglomerate. The next stratigraphic interval corresponds to the U-Bar Formation and its stratigraphic equivalents, which are subdivided into lower and upper subintervals. The lower subinterval includes the lower three members of the U-Bar Formation in the Big Hatchet Mountains and their stratigraphic equivalents, and the upper subinterval includes the upper two members of the U-Bar Formation in the Big Hatchet Mountains and equivalents (table 1). The highest stratigraphic interval corresponds to the Mojado Formation, which is divided into lower, middle, and upper subintervals. The lower Mojado subinterval consists of the Mojado beds that are transitional with the underlying U-Bar Formation, as well as the lower middle Cintura Formation and the Del Norte and Smeltertown Formations (table 1). The middle Mojado subinterval refers to the thickest portion of the Mojado Formation, which consists of thick-bedded sandstone and slope-forming shale, and also includes the middle Cintura Formation and the Muleros and Mesilla Valley Formations (table 1). The upper Mojado subinterval corresponds to thin-bedded sandstone, shale, and limestone in the upper part of the Mojado Formation in the Big Hatchet and Little Hatchet Mountains, the Sarten Formation, the Beartooth Formation, and the Anapra, Del Rio, and Buda Formations at Cerro de Cristo Rey (table 1).

Deposition of the Hell-to-Finish Interval

Basal conglomerate subinterval.—The basal conglomerate of the Hell-to-Finish Formation and its stratigraphic equivalents consists of grain-supported pebble, cobble, and boulder conglomerate with a matrix of moderately well-sorted, medium-to-coarse-grained sandstone. Discrete beds of sandstone are rare. Gravel-sized clasts are well rounded carbonate and chert. In the East Potrillo Mountains the clasts in the conglomerate member are identical to underlying Permian limestones, indicating local derivation. Imbrication is difficult to recognize because the original shape of the limestone clasts was modified by weathering. The grain-support, rounding, and imbrication of the conglomerate indicates that it was waterlaid. The conglomerate reaches a maximum thickness of 42 m in the Peloncillo Mountains and displays large thickness variations over short distances, which suggests deposition on a surface of variable relief.

The basal conglomerate is difficult to interpret in terms of depositional environment, because it is exposed in so few places and because it contains so few features diagnostic of depositional processes. Consequently, two depositional models are presented. One possibility is deposition as alluvial fans by streamflood. This model is supported by coarse grain size, variable thickness, and local provenance. Features of the basal conglomerate that may contradict an alluvial fan model are the absence of debris-flow and sheetflood facies and the relative thinness (⩽ 42 m) of the sediment. Another possibility is deposition of the basal conglomerate as a thin veneer by proximal braided streams. In proximal braided streams, termed the Scott-type by Miall (1977), monotonous vertical sequences of grain-supported conglomerate with little or no interbedded sand result from superposition of shallow gravel channels.

Upper Hell-to-Finish subinterval.—The Hell-to-Finish Formation and equivalent stratigraphic units above the basal conglomerate can be separated into three facies belts (fig. 2). The northwestern facies belt, represented by sections in the Little Hatchet and Peloncillo Mountains, consists of interbeds of conglomerate, sandstone, sandy siltstone, and limestone that display a vertical cyclicity. Thick-bedded to massive, lime-

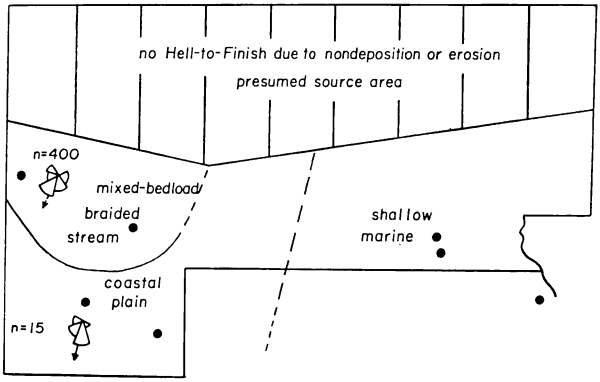


Fig. 2. Distribution of facies and paleocurrent data for the upper Hell-to-Finish subinterval. Paleocurrent data in the braided-stream facies belt represent 50 imbrication measurements at 8 stratigraphic intervals, totalling 400, measured in the Little Hatchet Mountains. Imbrication data are shown on the paleocurrent rose as the pole to the strike of the AB plane. Paleocurrent data in the coastal plain facies belt represent trough-crossbed measurements from point-bar sandstones following the technique of De Celles, Langford, and Schwartz (1983). Paleocurrent roses are in 30 degree intervals.

stone- and chert-pebble and cobble conglomerate 0.5 to 15 m thick make up the base of each cycle. The conglomerate is grain-supported, has a medium- to coarse-grained sand matrix, and is imbricated. The lower contact of the conglomerate is generally disconformable, and some conglomerate beds pinch out laterally, although most can be traced for hundreds of meters. Conglomerate is overlain by brown, medium-grained arkosic sandstone, which has a maximum thickness of 8 m and generally is less than 5 m thick. The conglomerate-sandstone contact is sharp or gradational, and locally sandstone layers occur as lenses within the conglomerate. The sandstone is massive, crossbedded, or has horizontal laminations with parting lineation. Asymmetrical ripple laminations and rip-up clasts are rare. Sandstone beds commonly are overlain by red sandy siltstone or silty very fine-grained sandstone, which range in thickness from 1 to 25 m. This fine-grained facies is generally massive, but asymmetrical ripple laminations were observed in a few beds. The paucity of sedimentary structures is due in large part to numerous calcareous nodules, which have irregular shapes and appear to have grown in situ. A pedogenic or very early diagenetic origin for the nodules is indicated by the fact that rip-up clasts of red siltstone with carbonate nodules are found in the sandstone facies. In thin section the nodules are seen to be composed of micrite and microspar, and some display faint circular to elliptical rings. The least common facies consists of massive, gray, silty micrite in beds less than 5 m thick. Allochems are rare and include oncolites, intraclasts, charophytes, wavy structures interpreted to be the result of blue-green algae, and indistinct cellular structures of unknown affinity.

The northwestern facies belt is interpreted to have been deposited by a mixed-bedload braided stream system, which had well-developed vertical zonation of channels (Miall, 1977). Conglomerate was deposited in the lowermost active channels, whereas in higher level channels sand was transported and deposited as dunes, sandwaves, and upper plane beds. On the highest-level surfaces and in interchannel areas, sandy siltstone was deposited during floods by low-velocity currents or from suspension. The siltstone was later modified by pedogenic or very shallow diagenetic processes. Small lakes on the highest-level surfaces or in interchannel areas precipitated micrite but were short-lived due to rapid shifting of channels. The carbonate-lake sediment is similar to lacustrine rocks in the Lower Cretaceous Peterson, Draney, and Kootenai Formations of Idaho, Wyoming, and Montana (Holm, James, and Suttner, 1977). Carbonate precipitation in the northwestern facies belt was favored by calcareous source rocks in the drainage basin and by the influence of possible blue-green and green algae (Collinson, 1978).

The intermediate facies belt, represented by sections in the Big Hatchet and Animas Mountains, has more shale and limestone and less sandstone and conglomerate than the braided stream facies belt (fig. 2). The intermediate facies belt has only one conglomerate bed near the base of each section, although lenses and scattered clasts of gravel are found near the base of some sandstones. Sandstone beds range in thickness from 0.5 to 10 m. The thickest sandstone beds are medium- to coarse-grained, trough crossbedded, and fine upward. Thinner sandstone is massive or horizontally laminated. Sandstones are interbedded with thick intervals (up to 12 m) of either red or dark gray shale. Associated with the shale is limestone, which generally is in beds less than a meter thick, although a 4 m-thick limestone exists in the Animas Mountains. The limestone is similar to limestone in the northwestern facies belt, with the addition of local chert replacement and scattered dolomite rhombs.

The intermediate facies belt is interpreted to be a coastal-plain environment, which was occupied by meandering streams and lakes. A meandering fluvial model is supported by the thickness of shale, representing vertical accretion deposits, and by crossbedded, fining-upward sandstones, which are point-bar deposits (Allen, 1965). Thinner sandstones interbedded with floodplain shale were probably deposited by crevasse splays. Limestone represents carbonate-precipitating lakes on the floodplain.

The southeastern facies belt, which includes sections in the East Potrillo Mountains, represents deposition in a shallow-marine environment (fig. 2). The dominant lithologies are calcareous siltstone and very fine- and fine-grained sandstone, which are massive, horizontally-laminated, or hummocky-laminated. The siltstone and sandstone are moderately to heavily bioturbated and have scattered bivalve and gastropod shells or discrete shell layers less than 20 cm thick. These features are characteristic of modern sediment on the Atlantic and Gulf of Mexico continental shelves of the United States (Bouma and others, 1982). Especially characteristic of a shallow-marine setting is hummocky stratification, which is interpreted to be the result of oscillatory flow generated by storm waves (Harms and others, 1975; Harms, Southard, and Walker, 1982). Storms may also be responsible for thin (0.5 m) intraformational conglomerates. A few micrites and bivalve, gastropod wackestones are also consistent with a shallow-marine setting. One 6 m-thick bed of crossbedded, fossiliferous, granular coarse-grained sandstone in the East Potrillo Mountains is interpreted to be a shallow-marine bar, for reasons that will be discussed more fully below.

The change from braided-stream facies in the Peloncillo and Little Hatchet Mountains (northwestern facies belt) to coastal plain facies in the Animas and Big Hatchet Mountains (intermediate facies belt) suggests a southward paleoslope for the alluvial plain (fig. 2). This interpretation of paleoslope is supported by fluvial paleocurrent data, which have a strong southward to southwestward component (fig. 2). A strong southward component to sediment dispersal in the northwest and intermediate facies belts is also indicated by the grain size contour map (fig. 3). The change from nonmarine facies in the northwest and intermediate facies belts to shallow-marine facies in the southeastern facies belt suggests that an eastward or southeastward paleoslope prevailed in the south-central portion of the study area (fig. 2). However, a southward decrease in grain

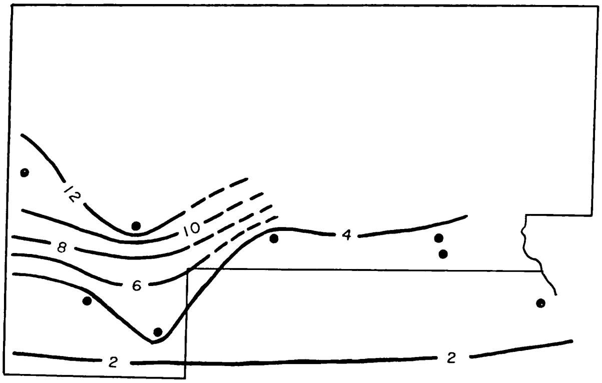


Fig. 3. Grain-size contour map of the upper Hell-to-Finish subinterval. Data points represent the average of measurements of the long axis of the ten largest clasts per conglomeratic bed. Total number of measurements is 630. Contours are in cm.

size (fig. 3) and a south-southeastward decrease in thickness and in the sandstone/siltstone ratio of the mottled siltstone member of the Hell-to-Finish Formation in the East Potrillo Mountains are consistent with south-southeastward siliciclastic sediment dispersal in the southeastern facies belt.

Deposition of the U-Bar Interval

Lower U-Bar subinterval.—The lower U-Bar subinterval is transitional with the underlying Hell-to-Finish interval and consists of interbedded limestone, shale, siltstone, and sandstone. In general the amount of sandstone decreases upsection. Throughout southwestern New Mexico the lower U-Bar subinterval appears to be shallow-marine or shoreline in origin, and two facies belts can be delineated (fig. 4). Limestones in the western facies belt are fossiliferous wackestone, oolitic and bioclastic grainstone, and stromatolitic micrite (Weise, ms). Interbedded with the limestone is fossiliferous shale and siltstone, as well as thin sandstone that

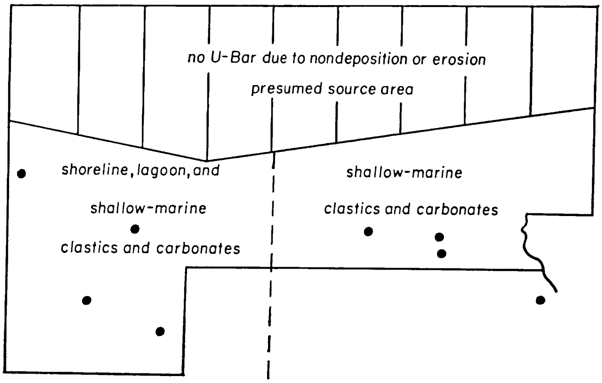


Fig. 4. Distribution of facies in the lower U-Bar subinterval.

is crossbedded, horizontally-laminated, or hummocky-stratified. The highest ratio of sandstone to limestone is in the Peloncillo Mountains, which is also the thinnest section in the lower U-Bar subinterval. Depositional environments in the western facies belt show a change upsection from shoreline and shallow lagoon with restricted circulation to shallow-marine with more open circulation (Weise, ms).

The eastern facies belt has a higher ratio of clastic to carbonate rocks than the western facies belt and consists of discrete carbonate intervals and clastic-rich intervals. These rocks were deposited in a shallow-marine environment. In the East Potrillo Mountains, the lower limestone member is a oolitic grainstone that changes southeastward into a fossiliferous wackestone. Rudistid biostromes exist in the East Potrillo Mountains (rudistid limestone member), at Eagle's Nest, and in the Benigno Formation of Sierra Juarez, although they are not necessarily coeval (Cordoba, 1969; Swift, 1972). Detailed study of the rudistid biostrome in the East Potrillo Mountains by Pickens (1984) revealed monopleurid rudistid colonies at the base of the biostrome, which were replaced by caprinid rudistids. The caprinids subsequently declined and were replaced by monopleurids. The biostrome is overlain by turritellid gastropod packstone.

The detrital portions of the eastern facies belt are composed primarily of massive to horizontally-laminated, to hummocky-stratified siltstone and very fine- and fine-grained sandstone, which contain scattered bivalve and gastropod shells and are moderately to heavily bioturbated. Crossbedded gravelly sandstone and conglomerate 3 to 12 m thick are interbedded with the fine-grained facies in the sandstone member in the East Potrillo Mountains and in the upper clastic unit at Eagle's Nest (table 1). The coarse-grained facies is similar to the crossbedded facies described in the southeastern facies belt of the upper Hell-to-Finish subinterval. The coarse-grained facies coarsens upward and locally has a thin zone of intraformational rip-up clasts at the base. The dominant sedimentary structure is trough crossbedding, and pelecypod and gastropod shell fragments are common. One bed in the sandstone member of the U-Bar Formation in the East Potrillo Mountains contains oolites mixed with detrital grains. Four distinct beds of gravelly sandstone and conglomerate occur in the East Potrillo Mountains and at Eagle's Nest. The coarse-grained facies is interpreted to have been deposited as offshore marine bars, because it is interbedded with fine-grained shallow-marine facies and because it shows no evidence of shoreline or nonmarine processes. The best modern analog is storm-generated shallow-marine bars on the Atlantic Shelf of the United States (Duane and others, 1972; Swift, Duane, and McKinney, 1973; Stubblefield, Lavelle, and Swift, 1975; Swift and Field, 1981). Offshore bars have also been described in Jurassic and Upper Cretaceous rocks of the western interior of Wyoming, Colorado, and northern New Mexico (Brenner and Davies, 1974; Porter, 1976; Brenner, 1978; La Fon, 1981).

The distribution of facies belts in the lower U-Bar subinterval suggests an eastward or southeastward paleoslope (fig. 4). Shoreline sediments in the western facies belt and their absence in the eastern belt reflect westward transgression parallel to the axis of the basin, although shallow-marine conditions prevailed throughout the southern part of the study area by the time of deposition of the limestone-shale member of the U-Bar Formation in the Big Hatchet Mountains (Weise, ms). The distribution of gravel-sized siliciclasts suggests that their source was to the north or northwest (fig. 5). Southward to southeastward detrital sediment dispersal is also indicated by a south-southeastward decrease in thickness of the sandstone member of the U-Bar Formation and by a south-southeastward decrease in the sandstone/siltstone ratio of the siltstone-limestone member of the U-Bar Formation in the East Potrillo Mountains. A topographically high region in the northern part of the study area is further supported by the fact that, despite marine inundation of the entire southern portion of the study area, marine sediment did not onlap the northern part of the study area.

Upper U-Bar subinterval.—The upper two members of the U-Bar Formation in the Big Hatchet Mountains and their stratigraphic equivalents consist of medium- to thick-bedded or massive marine limestone with only minor interbedded shale, siltstone, or sandstone. In the Big Hatchet Mountains the reef member of the U-Bar Formation is a rudistid biostrome, deposited in a shallow-marine environment (Weise, ms). The suprareef member consists of fossiliferous wackestone and oolitic grainstone and was deposited in a shallow-marine environment or in a shallow lagoon (Weise, ms). Most of the massive limestone member of the U-Bar Formation in the East Potrillo Mountains is too recrystallized for microfacies analysis, but a few beds near the base are fossiliferous wackestone. In the Peloncillo Mountains, pelecypod and gastropod wackestone and packstone are interbedded with fine-grained sandstone and shale.

The upper U-Bar subinterval represents a time of diminished detrital influx. The increase in the carbonate/clastic ratio, which began in uppermost Hell-to-Finish and lower U-Bar subintervals, reaches a climax in the

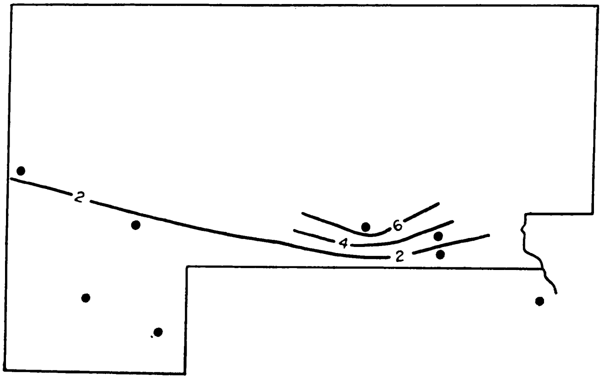


Fig. 5. Grain-size contour map of the lower U-Bar subinterval. Data points represent the average of measurements of the long axis of the ten largest clasts per conglomeratic bed. Total number of measurements is 200.

upper U-Bar subinterval. Indeed, the only sand in the upper U-Bar subinterval is in the Peloncillo Mountains.

Deposition of the Mojado Interval

Lower Mojado subinterval.—The lower Mojado subinterval is transitional with the U-Bar Formation and consists of several hundred meters of shale, limestone, and sandstone interbedded on the scale of 1 m. Limestones are fossiliferous wackestone and packstone, and the sandstones are massive to hummocky-stratified, bioturbated, and have scattered pelecypod and gastropod shells. The Del Norte and Smeltertown Formations at Cerro de Cristo Rey are composed of dark gray shale, fossiliferous packstone, and a few thin, fine-grained sandstones near the top of the Smeltertown Formation. The lower Mojado subinterval is shallow marine everywhere it is exposed. A change in sealevel is not necessarily required for the transition from upper U-Bar to lower Mojado, but there was an increase in the rate of detrital influx.

Middle Mojado subinterval.—In the Peloncillo, Animas, Big Hatchet, and Little Hatchet Mountains the middle Mojado subinterval is as much as 800 m thick and is characterized by thick (10 m) sandstones interbedded with equally-thick, poorly-exposed, red or green shales, which may have thin (≤ 1 m) fine sandstone or siltstone interbeds. The thick sandstones commonly fine upward and display a vertical change from trough crossbeds in the lower part to horizontal laminations or ripple laminations in the upper part. The shale is massive and may contain calcareous nodules. Thin sandstone and siltstone interbedded with shale are massive, horizontally-laminated, or ripple-laminated, and are commonly bioturbated. These facies indicate deposition by meandering streams (fig. 6). Thick sandstones were deposited as point bars, whereas shale and thin sandstone or siltstone represent floodplain and crevasse-splay deposition (Allen,

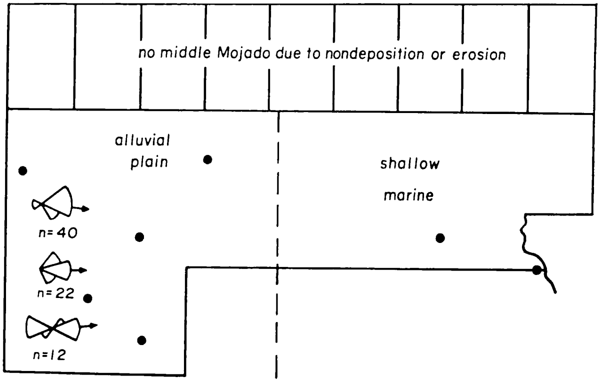


Fig. 6. Distribution of facies belts and paleocurrent data of the middle Mojado subinterval. Upper two paleocurrent roses represent trough-crossbed measurements from the Little Hatchet section (n = 40) and Animas section (n = 22), following the method of De Celles, Langford, and Schwartz (1983). The lower paleocurrent rose is for parting lineation in the Animas section and is represented as bipolar. Paleocurrent roses are in 30 degree intervals.

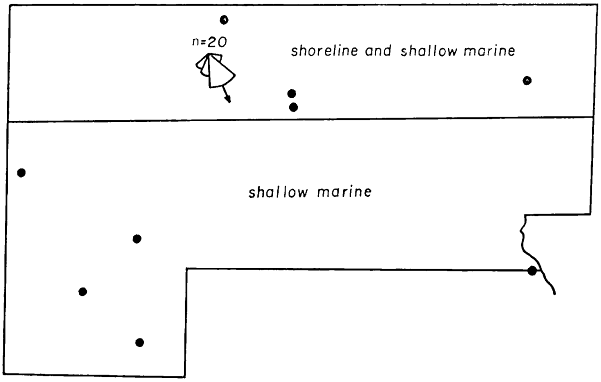


Fig. 7. Distribution of facies belts in the upper Mojado subinterval. Paleocurrent rose is for trough-crossbed measurements from fluvial sandstones of the Sarten Formation in the Cooke's Range. Paleocurrent rose is in 30 degree intervals.

1965; fig. 6). The Muleros and Mesilla Valley Formations at Cerro de Cristo Rey consist of oyster-bearing wackestone and packstone, siltstone, shale, and a few thin sandstone beds in the upper part of the Mesilla Valley Formation and were deposited in a shallow-marine environment (fig. 6).

The eastward change from nonmarine to marine facies in the middle Mojado subinterval indicates an eastward paleoslope (fig. 6). Unlike the upper Hell-to-Finish subinterval, there is no evidence in the fluvial facies of the middle Mojado subinterval of southward sediment dispersal. Indeed, the facies and grain size characteristics of the middle Mojado subinterval are virtually identical in the Peloncillo, Little Hatchet, Big Hatchet, and Animas sections. Furthermore, crossbed and parting lineation paleocurrent data collected from point-bar sandstones indicate eastward sediment transport (fig. 6).

Upper Mojado subinterval.—The upper Mojado subinterval is subdivided into two facies belts (fig. 7). The southern belt includes outcrops in the Peloncillo, Big Hatchet, and Little Hatchet Mountains, as well as the Anapra, Del Rio, and Buda Formations at Cerro de Cristo Rey, and consists of interbedded fine sandstone, shale, and limestone. The rocks in the southern facies belt of the upper Mojado subinterval are similar to the lower Mojado subinterval and were deposited in a shallow-marine environment. The northern facies belt includes both shallow-marine and shoreline facies. In the Cooke's Range the Sarten Formation consists of three regressive beach cycles (Hyde, ms). The lowest cycle changes systematically upsection from lower offshore shale and siltstone to upper shoreface sandstone, whereas the upper two cycles change systematically upward from lower-offshore to fluvial facies. The Sarten Formation in the southern San Andres Mountains exhibits two regressive beach cycles, the lower of which is incomplete (offshore to upper shoreface) and the upper of which is complete (offshore to fluvial) (Hyde, ms). Chafetz (1982) examined the Beartooth Formation northwest of Silver City and interpreted it as prodelta and distributary mouth-bar sediment deposited during regional transgression.

The Sarten and Beartooth Formations onlap Paleozoic and Precambrian terranes that had been sites of erosion during Hell-to-Finish and U-Bar time. The east-west boundary between shoreline and shallow-marine facies probably resulted from northward transgression and onlap of the Burro terrane. Sediment transport was probably southeastward as the trough-crossbed paleocurrent data from fluvial facies of the Sarten Formation in the Cooke's Range suggest (fig. 7).

EARLY CRETACEOUS PALEOGEOGRAPHY, SOUTHWESTERN NEW MEXICO

Early Cretaceous sedimentation in southwestern New Mexico reflects the interplay between terrigenous clastic influx and eustatic sealevel changes. Terrigenous sediment dispersal for the Hell-to-Finish and U-Bar intervals was southward or southeastward, although the depositional basin had a southeasterly component of paleoslope (fig. 2, 3, 4, 5). Dispersal data indicate a northerly source area, which corresponds to the Burro uplift of Elston (1958). That the Burro uplift was cored by crystalline rocks is indicated by arkosic composition of Hell-to-Finish and lower U-Bar sandstones and by the fact that in the Burro Mountains the Beartooth Formation unconformably overlies Precambrian granites and gneisses (Hewitt, 1959). By late U-Bar time, however, the influx of terrigenous sediment diminished dramatically, resulting in deposition of thick, marine carbonate rocks. The decrease in detrital influx reflects wearing down of the Burro uplift.

Concomitant with uplift and erosion of the Burro Mountains, an early Aptian eustatic rise in sealevel spread marine water west-northwestward through the basin (Kauffman, 1977; Harris and others, 1984). By late Hell-to-Finish time only the southeastern portion of the study area was occupied by marine water (fig. 2), but by early U-Bar time the entire southern portion of the study area was inundated (fig. 4). U-Bar sedimentary rocks display no evidence of a late Aptian eustatic regression (Kauffman, 1977; Harris and others, 1984). Apparently basin subsidence and/or the decrease in detrital influx counteracted a worldwide sealevel fall, and transgression was continuous in southwestern New Mexico during Aptian and early Albian time.

Detrital sedimentation resumed in the Mojado interval, beginning first in the Peloncillo Mountains with deposition of the Still Ridge Formation. By middle Mojado time an alluvial plain prograded eastward at least as far as the Big Hatchet Mountains (fig. 6), a regression that probably reflects a combination of a middle late Albian eustatic fall of sealevel (Kauffman, 1977; Harris and others, 1984) and an increase in the influx of detrital sediment from the west. By late Mojado time, the sea covered the entire study area, and shoreline and shallow-marine sediment of the Sarten and Beartooth Formations onlapped the Burro uplift (fig. 7). The final transgression appears to be the result of a latest Albian-earliest Cenomanian eustatic rise of sealevel (Kauffman, 1977; Harris and others, 1984).

Provenance and sediment dispersal of the Mojado interval are different from that of the Hell-to-Finish and U-Bar intervals. The re-establishment of detrital sedimentation in the Mojado interval, following the very low rate of detrital influx during late U-Bar time, implies a major change in the paleogeography. Furthermore, the Mojado interval displays an upsection decrease in and eventual absence of detrital feldspar and an upsection increase in monocrystalline quartz. The compositional trends combined with the onlap of the Burro uplift by late Mojado time clearly reflect the decline through time in the importance of the Burro uplift as a sediment source. Consequently, other source terranes were required to supply sediment to the Mojado interval. Sediment in the Mojado interval, in general, is finer-grained than sediment in the Hell-to-Finish and lower U-Bar intervals, suggesting that the Mojado source terrane(s) were of lower relief or were farther away than the Burro uplift. Another significant difference between the Mojado and Hell-to-Finish and U-Bar intervals is the strong easterly or southeasterly paleocurrent modes in the Mojado interval (fig. 6, 7).

There are several possibilities for the location of the source terrane for the Mojado interval. The distribution of facies and paleocurrent trends for the middle Mojado subinterval indicate eastward sediment dispersal, an interpretation that supports a source area located to the west of southwestern New Mexico. This paleogeographical model is consistent with derivation from an orogenic terrane in Arizona (Hayes, 1970). The east-west-trending boundary between facies belts and the southeasterly paleocurrent data of the upper Mojado subinterval may support a source area to the north or northwest. If there were a source terrane to the north or northwest, however, it was not the crystalline basement-cored Burro uplift. The Mojado source terrane must have been north or northwest of the former crest of the Burro uplift. Furthermore, this source terrane was composed primarily of sedimentary rocks, as indicated by the predominance of quartzarenites in the Mojado interval. Two possibilities for source terranes north or northwest of the Burro uplift are the fold and thrust belt in Nevada, western Utah, and western Arizona or an uplift in the Mogollon region of west-central New Mexico.

CONCLUSIONS

1. Up to 3200 m of Lower Cretaceous sedimentary rocks were deposited in southwestern New Mexico in a west-northwest-trending basin which was a northwestern extension of the Chihuahua trough. High sedimentation rates (80-150 m/myr) suggest tectonic activity near southwestern New Mexico.

2. In extreme southwestern New Mexico, Lower Cretaceous rocks are separated into three conformable stratigraphic units: Hell-to-Finish (Aptian(?)), U-Bar (upper Aptian to middle Albian), and Mojado (upper Albian to lowest Cenomanian) Formations. These formations are cor-

related with other Lower Cretaceous rocks in southwestern New Mexico.

3. Limestone- and chert-cobble conglomerate of the lower Hell-to-Finish subinterval was deposited by alluvial fans or proximal braided streams and records initial uplift and erosion in southwestern New Mexico. The upper Hell-to-Finish subinterval is separated into a northwestern mixed-bedload braided stream facies belt, an intermediate coastal-plain facies belt, and a southeastern shallow-marine facies belt. The distribution of facies belts, grain-size trends, and paleocurrent data indicates southward sediment dispersal away from the Burro uplift.

4. The lower U-Bar subinterval consists of interbedded limestone, shale, siltstone, and sandstone, which were deposited in shoreline and shallow-marine environments. Facies and grain-size data also indicate southward to southeastward sediment dispersal. Shallow-marine carbonate rocks dominate the upper U-Bar interval and indicate a period of reduced terrigenous clastic influx.

5. Interbedded sandstone, shale, and limestone of the lower Mojado subinterval represent shallow-marine conditions, whereas by middle Mojado time an alluvial plain prograded eastward as far as the Big Hatchet Mountains. Middle Mojado paleocurrent data indicate eastward sediment transport. Shoreline and shallow-marine facies of the Upper Mojado interval onlapped the Burro uplift.

6. Southward and southeastward sediment dispersal and arkosic composition of the Hell-to-Finish and U-Bar intervals indicate derivation from the Precambrian-crystalline-cored Burro uplift. The decrease in siliciclastic sedimentation during late U-Bar time reflects wearing down of the Burro uplift. Renewed siliciclastic influx, eastward and southeastward sediment transport, quartz-rich composition, and onlap of the Burro uplift during Mojado time indicate a major shift in regional paleogeography and suggest that the new source terrane was to the west or northwest of the old Burro uplift.

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