DEPOSITIONAL ENVIRONMENTS OF THE EOCENE DOMENGINE FORMATION NEAR COALINGA, FRESNO COUNTY, CALIFORNIA

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ABSTRACT

The upper lower through lower middle Eocene Domengine Sandstone crops out in the southern Diablo Range in the Alcalde and Big Blue Hills. These deposits are the result of a westward transgression across an eastward-sloping shoreline. They were derived from a sedimentary source terrain, possibly the Paleocene and Mesozoic rocks to the west.

In the Alcalde Hills, the Domengine was deposited on a fluvial-dominated delta. It contains interdistributary bay beach, swamp, distributary channel and levee, and storm deposits. North of Los Gatos Creek in the Big Blue Hills, the base of the formation is marked by a transgressive lag consisting of black chert and fossil fragments. The majority of the Domengine was deposited on a low energy shoreline and consists of lower shoreface and transition zone deposits.

INTRODUCTION

The Domengine Formation crops out along the Diablo Range and portions of Mount Diablo and the southern Sacramento Valley. The depositional environments of the formation at its southernmost extent have not been extensively studied and are the primary objective of this report. The formation is divided into distinct lithosomes which are interpreted according to their paleontologic and sedimentologic features. Kappeler (1984) described the environments found within the Avenal Formation which crops out approximately 20 km to the south of the study area. A secondary objective of this report is to determine how the environments found in the Avenal link up to those of the Domengine. The Avenal and Domengine Formations were shown to be continuous with each other in the subsurface (Harun, 1984). The name Avenal has priority, however, for the sake of clarity the name Domengine will be used throughout this report.

The Domengine Formation consists predominantly of muddy sandstone and siltstone and contains over 30 species of marine molluscs. The name "Domijean" was used by Anderson (1905) for exposures of sandstone of the Domengine and Cantua Formations in the Oil City area. The sequence of rocks currently referred to as the Domengine Formation was defined by Clark in 1926. Clark did not formally designate a type section, but he based his description upon exposures in the Domengine Creek area . The Domengine Formation in the study area is of late early through early medial Eocene age. For a detailed review of the age determination and correlation see Roush (1986).

The Domengine is overlain by the early medial Eocene (Milam, 1984) Canoas Siltstone member of the Kreyenhagen Formation. The Domengine unconformably overlies the Joaquin Ridge member of the late Cretaceous Panoche Formation south of Los Gatos Creek, as well as the Upper Cretaceous and Paleocene age Moreno Shale. It also overlies the late Paleocene-early Eocene Arroyo Hondo Shale Member of the Lodo Formation at Los Gatos Creek. The Eocene Yokut Sandstone underlies the Domengine throughout most of the study area. This contact is recognized by a resistant fossiliferous pebble bed at the base of the Domengine which is believed to be unconformable within the study area (Clark, 1926; White, 1940). However, the erosion represented by the laterally continuous basal pebble bed was probably of short duration. This bed becomes discontinuous and consists of small pebble stringers north of Salt Creek. The Domengine and Yokut Formations eventually become undivided approximately 16 km north of Salt Creek (Nilsen, 1981).

Methods

Six stratigraphic sections (Fig. 1) were measured by the tape-and-brunton method and additional exposures between the sections were examined. Figure 2 shows the explanation for the drafted measured sections in Figures 3 through 5. Laboratory work included the examination of thin sections, heavy minerals, conglomerate clasts, macrosfossils and microsfossils, and the determination of size distribution by dry sieving and pipette analysis. Thin sections were cut from 24 rock samples. The heavy minerals from seven samples were analyzed and the conglomerate clasts from three samples were described. Macrofossils, collected from thirteen localities (Table 1), were curated and identified with the help of R. L. Squires and are stored at California State University, Northridge. Twenty-five rock samples were disaggregated and analyzed for the presence of siliceous and calcareous microfossils. Nine samples contained foraminifera (Table 2) and some highly recrystalized radiolaria. Distinctive species were identified with the help of Alan Hershey, consulting biostratigrapher.

Grain size classification is from Wentworth (1922), rounding from Powers (1953), and grain shapes are based on Zingg (1922). Environmental definitions and nomenclature are based on Reineck and Singh (1975). Rock names, sorting, and maturity are based on Folk (1974).

DEPOSITIONAL ENVIRONMENTS

The lithosomes found in Coalmine Canyon (Fig. 3) differ significantly from those found throughout the other sections and include fluvial dominated delta deposits such as swamp, interdistributary bay beach, distributary channel, and levee. Coal seams within the Domengine are common in Coalmine Canyon, but are restricted to the Alcalde Hills (Fig. 1). These environments differ significantly from those to the north which consist predominantly of low energy shoreline deposits such as lower and middle shoreface, storm deposits, and transition zone (Fig. 4 and 5).

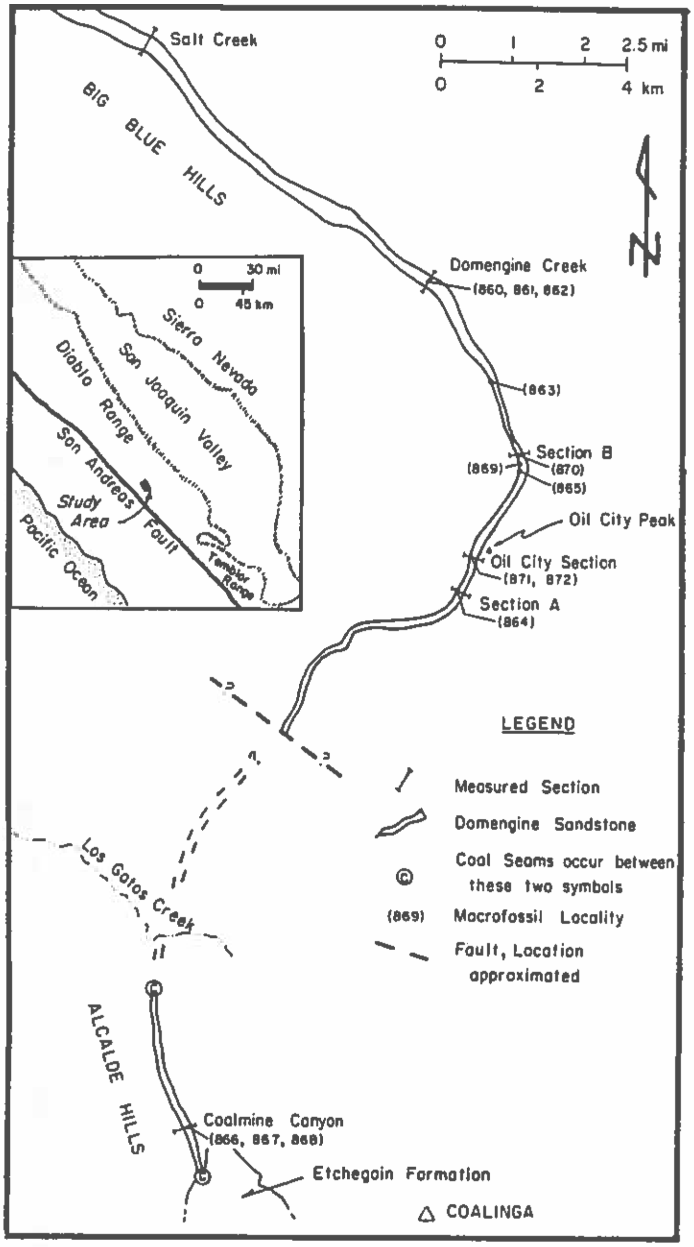

FIGURE 1 Location of measured sections (geology modified from Dibblee, 1971a, 1971b).

Fluvial Dominated Delta

Swamp Deposits (Coal and Carbonaceous Mudstone)

Description: Exposures of coal seams within the Domengine Formation occur in Coalmine Canyon and approximately 3 km to the north (Fig. 1). The coal beds are tabular, average 35 cm in thickness, and consist predominantly of lignite (Fig. 3).

Description: The carbonaceous mudstone lithosome occurs in the middle portion of the section and is in gradational contact with the coal and *Ostrea*-bearing sandstone lithosome. The unit is predominantly structureless, however, it does contain carbonaceous material and coal pods which comprise 5 to 10% of the unit. The carbonaceous material occurs as small fragments which vary in size and are scattered throughout the lithosome. Low grade-lignite occurs in irregular pods which lie predominantly parallel to bedding. The unit consists of poorly sorted sandy mudstone.

Interpretation: The coal was formed in a poorly drained swamp (Reineck and Singh, 1975; Blatt, 1982). Coal is especially characteristic of deltas (Selley, 1982) and is formed in nonmarine swamps. To maintain a low sedimentation rate, the swamp must be protected from major inundations of the sea and river flood waters. The coal seams found in Coalmine Canyon were therefore formed behind a seaward barrier such as a beach or levee. Landward of the swamp, a lowland caught most of the fluvial sediment and allowed uninterrupted peat formation. The Coalmine Canyon region was slowly subsiding so that a continuous rise of the groundwater table allowed the formation of peat.

The carbonaceous mudstone lithosome was also deposited in an environment similar to that which formed the coal lithosome, however, the deposition of organic material was periodically interrupted by the deposition of fine clastics. The gradational basal contact of the lithosome with the coal seams indicates that the clastic influx slowly increased until it eventually exceeded the rate at which vegetation was accumulating.

Poorly drained swamps commonly consist of sandy mudstone (Fisk and McFarlan, 1954) and contain black mud and a high percentage of carbonaceous material. Although occasional thin stringers of peat are present in the mud, the majority of structures are destroyed by bioturbation. The plant material is well preserved in the reducing swamp environment. The resulting swamp deposits, therefore, consist of a homogeneous mixture of sand, silt, clay, and plant remains (Fisk and McFarlan, 1954; Coleman and others, 1964; Kolb and VanLopik, 1966; Reineck and Singh, 1975) much like the deposits of the carbonaceous mudstone lithosome.

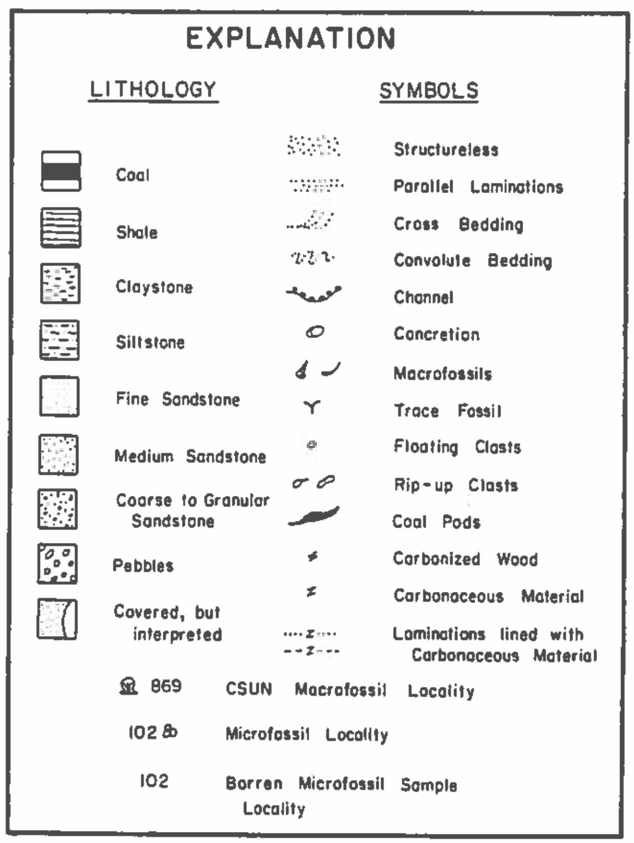

FIGURE 2 Explanation for stratigraphic columns.

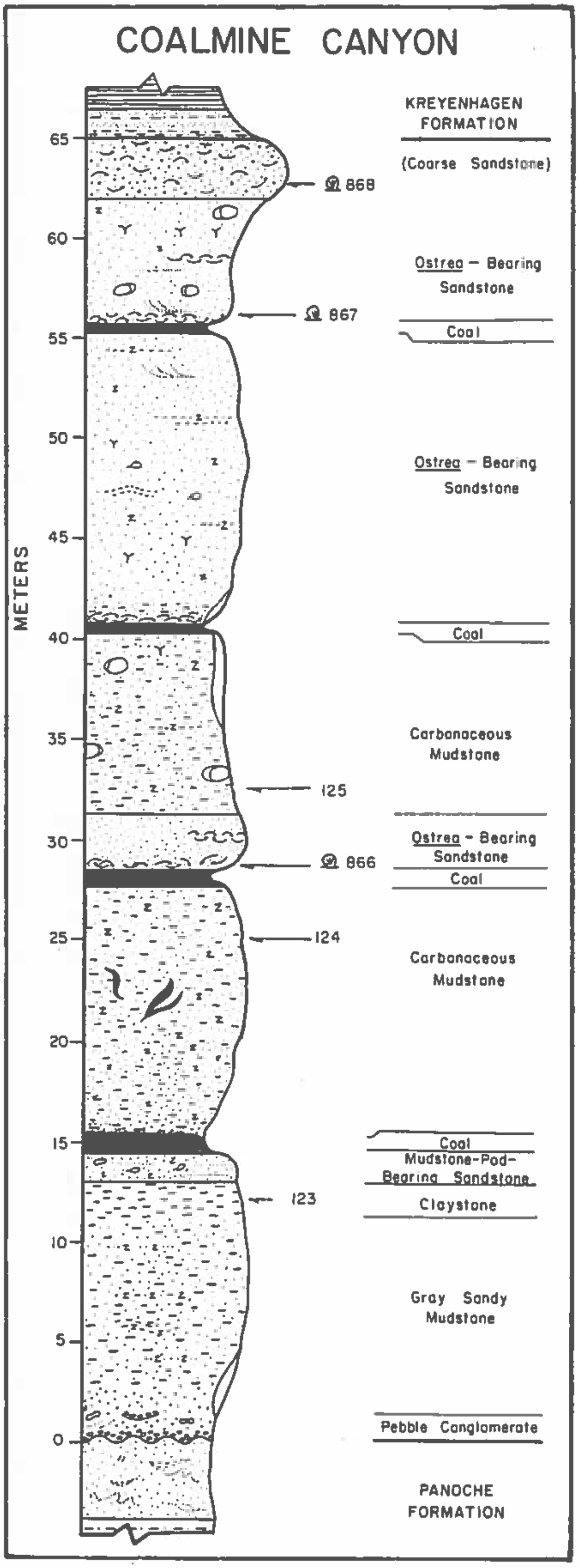

FIGURE 3 Stratigraphic column for the Coalmine Canyon section.

Overbank Flood Deposits (Claystone)

Description: The claystone lithosome occurs in the lower half of the Coalmine Canyon section and consists entirely of pure claystone. Carbonaceous material is present and makes up less than 1% of the unit.

Interpretation: The claystone lithosome was formed by overbank flooding upon the upper delta plain. Overbank flooding is a process which operates during a flood. The flood water spills over the channel banks as sheet flow. The fine-grained suspended sediment is then deposited over the delta plain. Any coarser sediment is confined to the margins of the levee (Coleman, and others, 1964; Elliott, 1974; Reading, 1978).

Overbank flooding deposits, like that of the claystone lithosome, are associated with the coarser levee deposits and are finely laminated. These laminations may be destroyed by bioturbation however (Elliott, 1974; Reading, 1978).

Distributary Channel Deposits (Pebble Conglomerate)

Description: The pebble conglomerate lithosome crops out at the base of the formation and consists of pebble conglomerate (20%) and medium-grained sandstone (80%). The unit contains three to four pebble conglomerate beds which are laterally continuous within 4 m. The base of the conglomerate lenses show scour and fill structures. The conglomerate grades into medium-grained sandstone, forming a slight fining-upward cycle. The sandstone portion of the lithosome contains a variety of sedimentary structures including parallel laminations and low-angle cross bedding which average 6 to 25 cm in height. Some of the laminations are lined with carbonaceous material and the largest cross beds are outlined by mudstone rip-up clasts.

The sandstone portion of the lithosome varies between fine- and medium-grained sandstone and is poorly sorted. The pebble conglomerate has a median grain size of very coarse sand and is very poorly sorted. The majority of the clasts are poorly sorted and matrix supported (70%) in coarse-grained sandstone. The clasts constitute 10% of the unit and range in size from granule to pebble, averaging pebble. The majority of the clasts consist of black chert, shale, or sandstone. The black chert fragments are usually the largest. The shale clasts include Panoche Formation siltstone fragments that occur approximately 5 m below the basal contact.

Interpretation: The pebble conglomerate lithosome is similar to modern distributary channel deposits described by Reineck and Singh (1975). These deposits have erosive bases lined with a basal channel lag (Reading, 1978) and contain clay fragments. The most common sedimentary structures are cross bedding and scour-and-fill structures (Coleman and others, 1964; Reineck and Singh, 1975; Davis, 1978; Coleman, 1982). Carbonaceous material occurs along parallel laminations. A fining-upward sequence is characteristic of the sandy units (Coleman, 1982). A predominancy of coarse material interbedded with fine sandstone and clay is characteristic of distributary channel deposits. Clay layers are not always preserved and may be eroded and incorporated within the deposit as rip-up clasts (Coleman and others, 1964; Reineck and Singh, 1975; Coleman, 1982). These same features are found in the pebble conglomerate lithosome.

Subaerial Levee Deposits (Gray Sandy Mudstone and Mudstone-Pod-Bearing Sandstone)

Description: The gray sandy mudstone lithosome crops out near the base of the section and weathers to small gray balls which cover approximately 80% of the lithosome. The unit contains approximately 1% carbonized bits which occur along parallel and wavy laminations. They are the only structures within the lithosome. The unit consists of sandy mudstone: immature subarkose, and is poorly to very poorly sorted.

Description: The mudstone-pod-bearing sandstone lithosome occurs in the lower half of the Coalmine Canyon section and consists of sandstone (95 to 98%) and mudstone (2 to 5%). It averages 1 to 2 m in thickness and is tabular in shape.

Sedimentary structures within the lithosome include parallel and wavy laminations and small scale, low angle cross bedding. Mudstone occurs within the lithosome lining parallel and wavy laminations and in pods and lenses. Carbonaceous material and wood fragments comprise 1 to 2% of the lithosome and occur along laminations and scattered throughout the unit. The sandstone consists of moderately sorted, medium- to fine-grained sandstone.

Interpretation: The gray sandy mudstone lithosome represents a transition in grain size from the underlying distributary channel (pebble conglomerate) deposits to the overlying overbank flood (claystone) deposits. The contacts with both of these lithosomes are gradational. The gray sandy mudstone lithosome represents subaerial levee deposits of a distributary channel. Levee deposits must be present stratigraphically between channel and overbank flood deposits (Reading, 1978).

Subaerial levee deposits consist of poorly sorted sand and silt. They generally contain abundant sedimentary structures such as climbing ripples, parallel and wavy laminations, and cross bedding (Coleman and others, 1964; Reineck and Singh, 1975; Van Heerden, 1982). Intense burrowing by plants and animals, however, may obscure these structures (Coleman and others, 1964), as in the gray sandy mudstone lithosome. Plant remains and organic matter are abundant and may occur along laminations and bedding (Kolb and Van Lopik, 1966; Coleman and others, 1964). Structureless deposits are most commonly formed in areas where the levee was covered by vegetation.

The mudstone-pod-bearing sandstone lithosome was formed in an environment similar to that which formed the gray sandy mudstone lithosome, however, there was very little vegetation on the levee during the deposition of the mudstone-pod-bearing sandstone. This lack of vegetation resulted in the preservation of the characteristic structures and features of the subaerial levee environment. Wavy laminations are abundant and are commonly produced by interference from grass roots or other organic material (Coleman and others, 1964; Coleman, 1982).

Interdistributary Bay Beach (*Ostrea*-Bearing Sandstone)

Description: The *Ostrea*-bearing sandstone lithosome occurs in the upper half of the section (Fig. 3) and consists of fine-grained sandstone (95%) and fossiliferous lenses (5%). Approximately 75% of the lithosome is structureless. The unit does contain

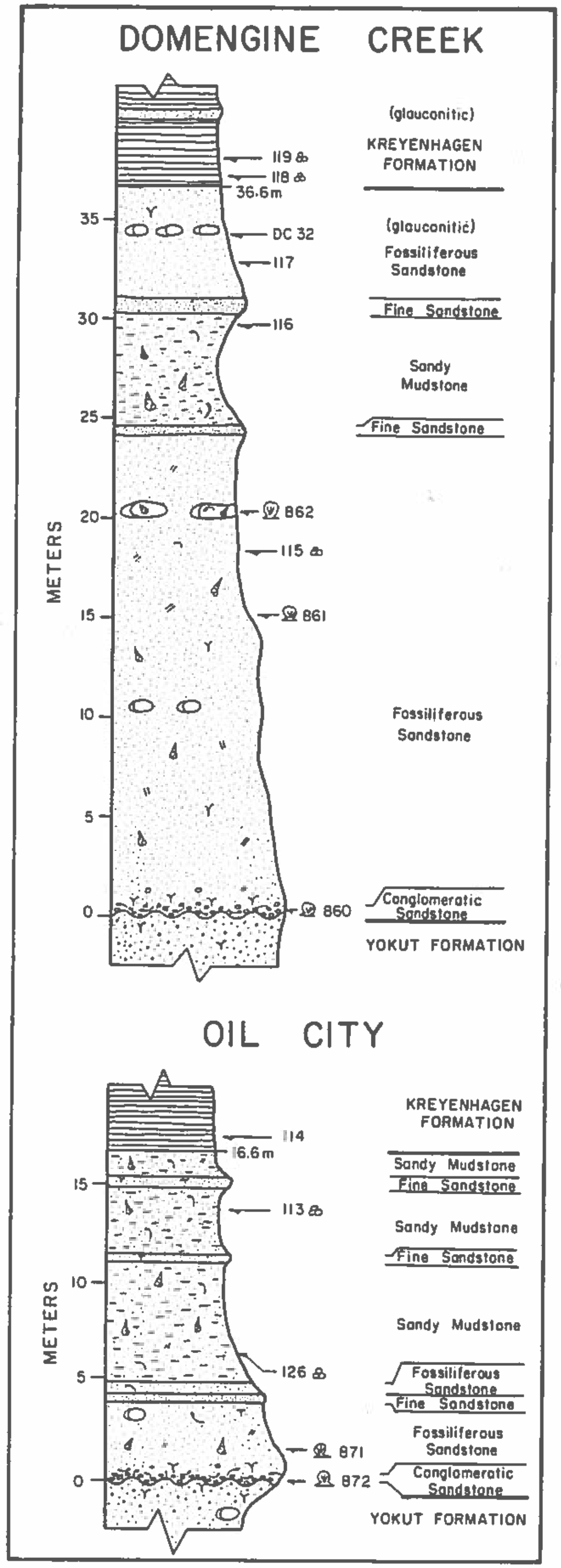

FIGURE 4 Stratigraphic columns for the Domengine Creek and Oil City sections.

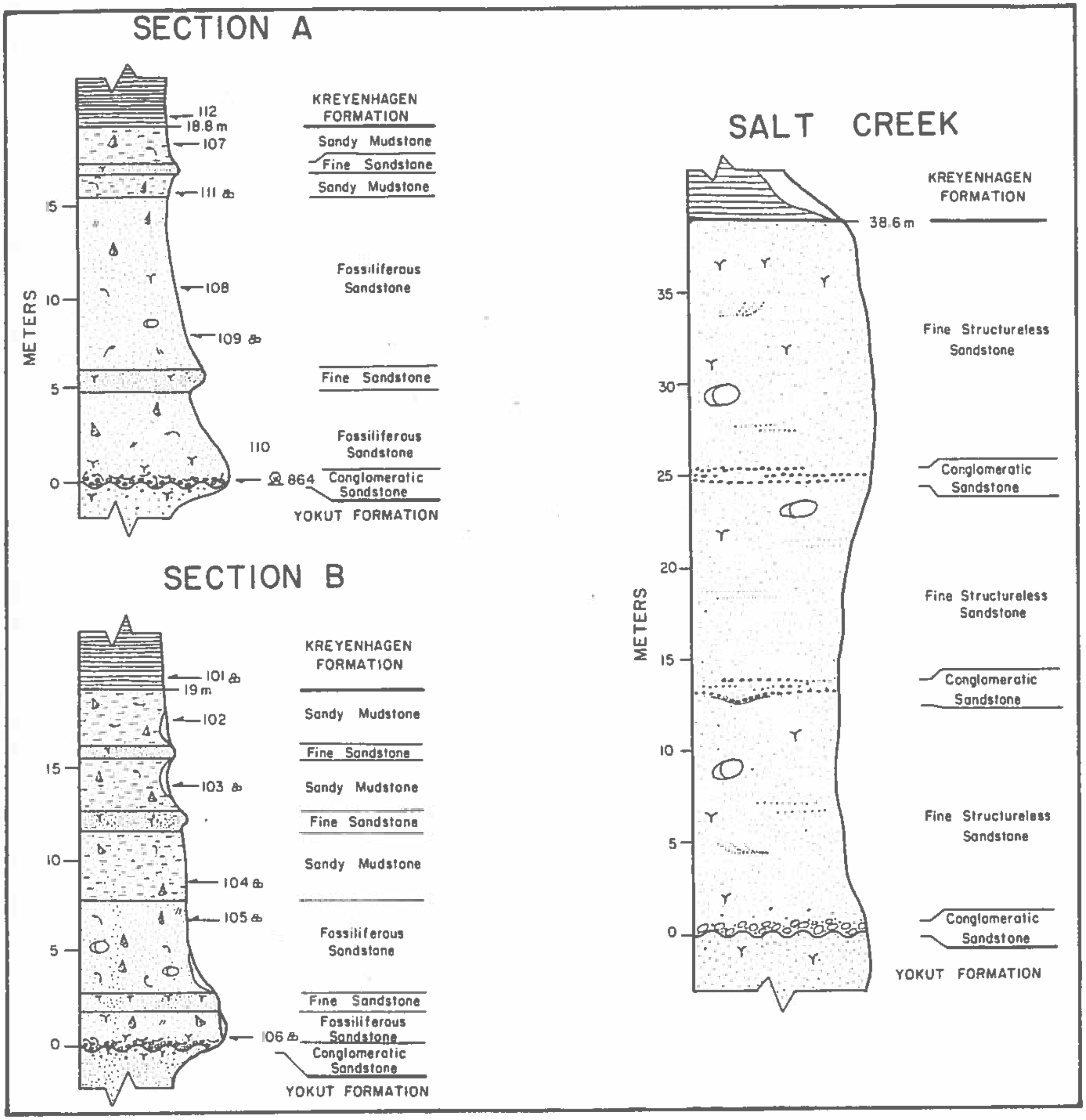

FIGURE 5 Stratigraphic columns for Section A, Section B, and the Salt Creek sections.

sedimentary structures such as parallel and wavy laminations, and low angle cross bedding. Carbonaceous material occurs along many of the parallel and wavy laminations as well as scattered throughout the sandstone. Carbonized wood fragments reach lengths of 3 cm and widths of 1 cm. Burrow traces and *Ophiomorpha* burrows occur near the top of the unit.

The characteristic feature of the lithosome is the presence of fossiliferous lenses. These lenses contain *Ostrea idriaensis*, *Solena* sp., and other molluscs (Table 1). The majority of oysters are disarticulated and well preserved. However, a few articulated *Ostrea* and *Solena* were found.

The fossiliferous lenses generally occur directly over coal seams and are 10 to 15 cm thick. The contacts of these lenses are gradational and no erosional surfaces are present. The lenses lie parallel to bedding in many areas, but one observed lens cuts across bedding at an angle of approximately 25 degrees.

At the very top of the lithosome there is a coarse sandstone bed which is tabular in shape and weathers to form a cliff. It contains grains ranging in size from very fine sand to granule. It has an average grain size of coarse sand and is poorly sorted. It contains fossiliferous lenses consisting of internal molds of bivalves such as *Spisula* sp., as well as the body fossils of gastropods such as *Crommium andersoni* and *Odostomia grisuoldensis*. The bivalve molds are the most abundant fossil and comprise approximately 20% of these lenses. All the fossils are abraided and poorly preserved.

TABLE 1 MACROFOSSIL FAUNAL LIST

MACROFOSSILS	C.S.U.N LOCALITIES: DC			**	SA	*	CMC			*		OC	
	040	041	042	043	044	045	046	047	048	069	070	071	072
SCAPHOPODA													
Dentalium sp.			x								x		
GASTROPODA													
Calyptraea diegoana (Conrad)				x				x					
Crepidula sp.								x					
Crommium andersoni (Dickerson)									x				
Ficopsis remondii crescentensis Weaver and Palmer	x												
?Fusinus sp.			x										
Neverita sp.									x				
Odostomia griswoldensis Vokes									x				
Turritella andersoni lawsoni Dickerson			x										
Turritella bulwaldana Dickerson			x										
Turritella uvasana aedificata Merriam		x	x										x
Turritella uvasana aedificata? Merriam				x		x							
Turritella uvasana subsp.					x								
Turritella sp.			x										
cerithiid						x							
unidentified gastropods			x										
unidentified gastropod n. sp.?				x									
BIVALVIA													
Barbatia (Obliquarca) morsei? Gabb								x					
Crassatella uvasana? Conrad								x					
Glycymeris (Glycymerita) sagittata Gabb				x		x							
Glycymeris sp.		x											
Macrocallista (Costacallista) domenginica? Vokes				x						x			
Nemocardium linteum (Conrad, 1855)			x										
?Nemocardium sp.			x										
Ostrea idriaensis Gabb				x			x	x	x	x			
Pitar (Calpitaria) campi Vokes						x						x	
Pitar sp.			x				x	x					
Solena sp.			x					x					
Spisula sp.				x					x				
Venericardia (Glyptoactis) domenginica Vokes			x	x		x				x			
Venericardia (Pacificor) hornii calafia? Stewart			x										
pitarid								x					
unidentified bivalves	x	x	x					x	x			x	
ECHINODERMATA													
Schizaster diabloensis Kew		x											

Key: DC = Domengine Creek, SA = Section A, CMC = Coalmine Canyon, OC = Oil City, * = between section B and Oil City, ** = between Domengine Creek and Section B.

Interpretation: The *Ostrea*-bearing sandstone lithosome was deposited on the sandy beach of the interdistributary bay. Interdistributary bay deposits are commonly found interbedded with marsh and swamp deposits (Reineck and Singh, 1975). These bays contain brackish to marine water and rarely exceed 1 to 8 m in depth, averaging 4 m (Coleman and Prior, 1982).

The margins of the bay are commonly lined with sandy beaches. These beaches contain oyster fragments, small scale cross bedding, organic debris, and clay laminations (Kolb and Van Lopik, 1966; Coleman, 1982). They typically consist of well sorted, fine- to very-fine-grained sandstone (Kolb and Van Lopik, 1966). These beaches form on a low energy coastline and may contain the sedimentary structures associated with typical foreshore and shoreface deposits (Reineck and Singh, 1975). The *Ostrea*-bearing sandstone lithosome contains some of these structures although they are relatively rare beacause of the low-energy environment.

Therefore, the *Ostrea*-bearing sandstone lithosome was deposited along the shore of an interdistributary bay. The region may have subsided continuously, however, the area was occasionally built up enough by the influx of sediment to allow the formation of a heavily vegetated swamp. This formed the alternating sequence of coal and the *Ostrea*-bearing sandstone. The lenses of *Ostrea* were periodically deposited on the beach, possibly during moderate storm activity. These shells collected on the backshore, up against the marsh areas, forming the *Ostrea* lenses which directly overlie the coal seams. Such concentrated areas of shell material are commonly found on the backshore (Kolb and Van Lopik, 1966; Reineck and Singh, 1975; Reading, 1975).

The coarse sandstone bed at the top of the lithosome is a storm lag which was possibly deposited on the shoreface of the sand beach along the interdistributary bay. The marine fossils have undergone significant transport and the coarse grain size indicates deposition during heightened energy levels. The poor sorting and structureless nature of the unit is indicative of rapid deposition (Reineck and Singh, 1975). The bed may be deposits that were held in suspension by storm induced currents. "Storm lags" characteristically contain a high concentration of shell material and have a larger average grain size the the surrounding units (Brenner and Davies, 1973; Kumar and Sanders, 1976).

Low Energy Shoreline

Lower Shoreface (Fossiliferous Sandstone)

Description: The fossiliferous sandstone lithosome outcrops in all sections except Coalmine Canyon and Salt Creek (Fig. 3 and 4). It consists of muddy sandstone (96%), fossiliferous material (3%), and organic material (1%). It is predominantly structureless (90 to 100% bioturbated) however individual burrows can be found. It also contains rounded, oxidized wood fragments which are scattered throughout the unit (Fig. 4 and 5).

The lithosome consists of muddy sandstone. It has a median grain size of medium to coarse silt and is moderately to poorly sorted. The lithosome contains

TABLE 2 MICROFOSSIL FAUNAL LIST

MICROFOSSILS	LOCALITIES SB					SA		DC			OC
	101	103	104	105	106	109	111	113	118	119	126
FORAMINIFERA											
? Amphistegina sp.											x
Anomalina coalingensis Cushman and Hanna		x		x	x	x	x	x			x
A. cf. A. coalingensis Cushman and Hanna		x		x	x	x	x	x			x
A. keenae Martin		x		x	x	x	x	x			x
A. cf. A. keenae Martin		x									
A. welleri (Plummer)				x							
Anomalina sp.		x			x	x		x			
Bathysiphon eocenica Cushman and Hanna											x
Bathysiphon sp.		x									
Bolivina cf. B. thomsoni											x
Bulimina cf. B. pupoides d'Orbigny					x						
B. pupoides d'Orbigny		x									
Bulimina sp.					x						
Cibicides eoonidiformis (Martin)						x		x			
C. pachyderma (Rzehak)		x			x	x	x	x			x
C. sandiegensis Cushman and Hanna						x					
C. cf. C. sandiegensis Cushman and Hanna						x	x				x
C. whitei var. Martin								x			x
Cibicides sp.		x				x					
Cibicidoides venezuelanus? (Nuttall)											x
Cyclammina coalingensis (Cushman and Hanna)											x
C. cf. C. simiensis Cushman and McMasters											x
Dentalina cf. D. approximata Reuss		x									
Dentalina sp.				x			x				x
Discorbis coalingensis (Cushman and Hanna)		x				x	x	x			
Ellipsonodosaria cocoaensis (Cushman)		x									
Elphidium hanni var.				x	x						
E. smithi Cushman and Dusenbury				x							
Eponides lodoensis Martin		x		x	x	x	x				x
E. mexicana (Cushman)		x		x	x	x	x				x
E. cf. E. primus Martin						x					
Eponides sp.					x	x					
Gaudryina cf. G. jacksonensis Cushman				x							
Gaudryina sp.				x	x			x			x
Globigerina bakeri Cole						x	x				
G. bulloides d'Orbigny		x				x	x	x			x
G. triloculinoides Plummer											x
Globorotalia aragonensis Nuttall		x				x	x				
G. crassata (Cushman)		x									x
G. cf. G. crassata (Cushman)		x				x	x				
G. nicoli Martin											x
G. cf. G. nicoli Martin						x	x				
Globorotalia sp.					x						
Gumbelina globulosa					x						
Gyroidina danvillensis											x
G. orbicularis d'Orbigny					x						x
G. soldanii var.								x			
Gyroidina sp.											x
Lagena cf. L. substriata Williamson											x
Lagena sp.								x			x
Lenticulina sp.											x
Marginulina cf. M. bullata Reuss					x						
M. subbullata Hantken		x		x							
M. cf. M. subbullata Hantken					x						
Nodogenerina cf. N. consobrina		x			x						
N. kressenbergensis (Gumbel)											x
N. cf. N. kressenbergensis (Gumbel)						x					
Nodosaria arundinea Schwager					x						
N. conspurcata				x							
N. latejugata Gumbel		x		x	x		x				x
Nodosaria sp.				x	x	x		x			
Nodosaria chamber		x									
Nonion plantum Cushman and Thomas											x
Nonionella sp.				x							
Pseudoglandulina cf. P. ovata (Cushman & Applin)		x						x			
Pseudoglandulina sp.					x						
Pullenia? quinqueloba (Reuss)											x
P. salsburyi Stewart and Stewart		x		x	x						x
Robulus pseudomamiligera var.							x				
R. cf. R. pseudomamiligera		x				x					
R. cf. R. terryi Coryell and Embich		x									
R. cf. R. welchi var.		x									
Robulus sp.		x		x	x	x	x	x			x
Saracenaria sp.		x									
Siphonina umbilicatulus											x
S. wilcoxensis Cushman and Garrett						x	x				x
Textularia mississippiensis Cushman								x			x
Tritaxia sp.		x		x	x	x	x	x			x
Uvigerina sp.											x
Vaginulinopsis cf. V. nudicostata		x		x	x		x	x			x
V. saundersi (Hanna and Hanna)		x			x						
V. cf. V. vacavillensis (G. Hanna)											x
Vaginulinopsis sp.		x			x						x
OTHER FAUNAL MATERIAL											
Fish Teeth					x			x			
Ostracods (smooth)				x				x			x
Ostracods (ornamented)		x				x	x	x			x
Radiolaria				x	x			x	x	x	
Recrystalized Foraminifera	x										
Poorly Preserved Foraminifera		x									

Key: SA = Section A, SB = Section B, OC = Oil City, DC = Domengine Creek.

local accumulations of glauconite. The relative abundance of this mineral ranges from 0 to 5% and varies throughout the unit due to mottling. At the top of the Domengine Creek section, however, the upper 5 m is charcterized by a very high percentage (10 to 25%) of glauconite. In this portion of the section, fossils are rare.

The unit contains a wide assortment of fossiliferous material including fish scales, plant fragments, foraminifera, gastropods, scaphopods, and echinoderms (Table 1). These fossils occur predominantly within concretionary lenses and are moderately preserved. Articulated bivalves were found in the Domengine Creek section (locality 862, Table 1). A growth series of *Turritella andersoni lawsoni* was also found in this lithosome.

The lithosome contains over 20 species of foraminifera (Table 2). The most common genera include *Anomalina*, *Cibicides*, *Elphidium*, *Nodogenerina*, *Robulus*, and *Tritaxia*. Planktonic foraminifera represent less than 10% of the fossil assemblage.

Interpretation: The fossiliferous sandstone lithosome was deposited on the lower shoreface of a low-energy coastline. This interpretation is based upon the fossils, the grain size, and the high degree of bioturbation present in the unit. Shoreface deposits usually contain many sedimentary structures, but a majority of these structures are subsequently destroyed by biogenic activity, as in the case of the fossiliferous sandstone lithosome. Low-energy coastlines allow the large population of bioturbating organisms to homogenize the sediment thus forming deposits consisting of poorly sorted, structureless, fine-grained sandstone (Howard and Reineck, 1972; Reineck and Singh, 1975; Reading, 1978). With such a high degree of bioturbation, there are few individual burrows remaining (Howard and Reineck, 1972).

Lower shoreface deposits can be muddy if silt and clay are available (Howard and Reineck, 1972; Howard, 1971). They can contain shell layers and a high percentage of organic detritus (Howard, 1971; Howard and Reineck, 1972; Reineck and Singh, 1975), much like the fossiliferous sandstone lithosome.

The high concentration of glauconite at the top of the Domengine Creek section indicates that the sedimentation rate had slowed significantly following the deposition of the underlying lithosomes. Increasing reducing conditions hampered the accumulation of a large fossil community like that of the rest of the lithosome. The amount of bioturbation was uneffected.

The macrofossils and microfossils found within the lithosome are indicative of shallow marine conditions. The majority of macrofossils appear to have been transported only short distances.

Middle Shoreface (Fine Structureless Sandstone)

Description: The fine structureless sandstone lithosome occurs in the Salt Creek section interbedded with the conglomeratic sandstone lithosome. It comprises 95% of this section (Fig. 5). Bedding is present in some areas and averages approximately 40 cm in thickness. The lithosome, however, is predominantly structureless and 70 to 90% bioturbated. It is locally parallel laminated and cross bedded. Bioturbation was recognized by a mottled appearance and the presence of patches of medium- and coarse-grained sandstone within the unit.

The lithosome consists of moderately sorted, fine-grained sandstone. It is in gradational contact (within 20 to 40 cm) with the conglomeratic sandstone lithosome.

Interpretation: The fine structureless sandstone lithosome is interpreted to have formed in a middle shoreface environment. The amount of bioturbation decreases and the sediment grain size increases landward along the shoreface. The fine structureless sandstone lithosome is slightly coarser grained, contains more sedimentary structures, and is slightly less bioturbated than the lower shoreface deposits of the fossiliferous sandstone lithosome. Therefore, this lithosome was formed landward of the lower shoreface deposits of the fossiliferous sandstone lithosome.

Ophiomorpha traces are a common feature on the shoreface (Howard, 1971; Howard and Reineck, 1972). Parallel laminations, like those found in the fine structureless sandstone lithosome, are the most common sedimentary structure found on the middle shoreface. Cross bedding does occur but is rare (Reading, 1978).

Transgressive Lag (Conglomeratic Sandstone)

Description: The conglomeratic sandstone lithosome is traceable in outcrop from 3 km north of Los Gatos Creek to the northern portion of the study area. It lies at the base of the formation, unconformably overlying the Yokut Formation. The unit consists of 65% sandstone matrix, 35% clasts, and 5% fossils.

The lithosome is predominantly structureless but burrows occur at the upper gradational contact with the overlying lithosome. In the Salt Creek section, the lithosome also occurs within the middle of the Domengine in the fine structureless sandstone lithosome. These exposures show excellent bedding and in some areas consist of a single parallel bedded layer of pebbles. In one location, the unit has an erosional base and forms a channel.

The lithosome is very well indurated and forms a distinctive ridge. The basal contact is erosional south of Domengine Creek. At Domengine Creek the contact is diffuse, and northward the contact becomes more gradational.

The fossils found within the lithosome are listed on Table 1. The bivalves are poorly preserved, broken, abraided, and disarticulated.

Interpretation: The conglomeratic sandstone lithosome is a transgressive lag. Transgressive lags are formed by the shoreline advance along an actively subsiding basin (Swift, 1968, 1975). Clifton (1981) described such deposits as laterally continuous conglomerates consisting of pebbles, granules, and fossil material (Swift, 1968, 1975). The lags typically lie upon planar erosion surfaces and are less than 30 cm thick (Clifton, 1981), similar to those seen in the Domengine Formation.

The occurrences of the conglomeratic sandstone higher in the Salt Creek section were formed by storm activity on the middle shoreface. During a storm, the high-energy river water brings coarser material to the beach region. The coarse material rolls around on the shoreface during the maximum storm intensity, and as the energy level decreases, it is deposited. Pebbles deposited by waves occur along laterally continuous discrete beds (Clifton, 1973), similar to the outcrops in the Salt Creek area.

Storm Deposits (Fine Sandstone)

Description: The fine sandstone lithosome is found in all sections except Salt Creek. The unit is tabular in shape, 5 to 50 cm in thickness, and laterally continuous. It is predominantly structureless, however burrows (including *Ophiomorpha*) do occur near the top of the unit. It consists of fine sandstone: calcitic mature arkose. In Domengine Creek the unit contains floating granules and small pebbles of the same composition as the conglomeratic sandstone lithosome. The basal contact of the lithosome is sharp and irregular.

Interpretation: The fine sandstone lithosome was deposited during storm activity on the lower shoreface and within the transition zone. Storm deposits occur on shelves, as well as the shoreface. The sand beds are interbedded with silt and clay of the shelf and are very common within transition zone deposits (like those of the sandy mudstone lithosome). These deposits pass upward into amalgamated layers of the parallel laminated and structureless beds of the upper shoreface (Reineck and Singh, 1975; Kumar and Sanders, 1976).

According to Goldring and Bridges (1973), storm deposits are formed by storm waves, tsunamis, and ebb tidal currents. The presence of floating clasts is indicative of quick deposition. Their description of these storm deposits closely matches that of the fine sandstone lithosome.

Transition Zone (Sandy Mudstone)

Description: The sandy mudstone lithosome occurs in the upper portion of all the sections except Salt Creek. It is structureless (90 to 100% bioturbated) and individual burrows are very rare. The unit is in gradational basal contact with the fossiliferous sandstone lithosome. The lithosome consists of sandy mudstone: immature chlorite-, foraminiferal-, and glauconite-bearing arkose. It is well to very well sorted and contains plant and wood fragments, fish scales, foraminifera, and casts of macrofossils. The macrofossils are too poorly preserved to be identified. The most common microfossils include *Anomalina, Cibicides, Discorbis, Elphidium, Eponides, Globoratalia, Robulus*, and *Tritaxia* (Table 2).

Interpretation: The sandy mudstone lithosome is similar to the transition zone deposits described by Reineck and Singh (1975). The unit is finer grained than the underlying lower shoreface deposits, but coarser than the overlying shelf and bathyal shales of the Kreyenhagen Formation. This gradation in grain size is the primary charcateristic of this depositional environment. Primary sedimentary structures in the transition zone can be totally destroyed by the high degree of bioturbation. These burrowing organisms create a structureless deposit consisting of a homogenous sediment mixture (Howard, 1971; Reineck and Singh, 1975), much like that of the sandy mudstone lithosome.

The transition zone is also characterized by a wide variety of species. The microfossils present in this lithosome are very similar to those found in the fossiliferous sandstone lithosome. The low percentage of planktonic forams also indicates a shelf environment. The genera most abundant in this lithosome are most commonly found in normal marine waters of the inner shelf at depths of 0 to 50 m (Murray, 1973).

PROVENANCE

The Domengine Formation consists predominantly of submature arkose. Folk (1974) states that a submature arkose is indicative of a mild tectonic setting during sedimentation. The formation of an arkose requires quick erosion of the source material and relatively rapid deposition in order to preserve the unstable grains (Folk, 1974).

The heavy mineral studies, petrographic analysis, and conglomerate clast analysis of the Domengine Formation reveal that the source terrain consisted predominantly of sedimentary and granitic rocks, as well as some high rank metamorphic rocks. Because the Domengine unconformably overlies the Panoche, Moreno, Lodo, and Yokut Formations, it is possible that these formations were eroding within the Domengine source area.

The conglomerate clasts and heavy minerals of the Panoche and Yokut Formations are very similar to the Domengine. The Panoche Sandstone is arkosic, and contains subangular to angular grains and fresh feldspar and quartz fragments. A sedimentary source is suggested by the roundness of the heavy minerals and conglomerate clasts. A sedimentary source is also suggested by the presence of sandstone, chert, quartzite, jasper, and shale clasts.

The distributary channel environment deposits in Coalmine Canyon contain a large percentage of sedimentary rock fragments. Many of these clasts are derived from the underlying Panoche Formation. The rock composition of the Domengine in Coalmine Canyon varies slightly from that of the other sections. This variation is possibly due to further reworking and transport of these sediments prior to deposition of the delta.

The Domengine contains forams which are believed to be reworked from a sedimentary rock source. These forams represent a bathyal environment (Ingle, 1980) and are common in deep marine deposits such as the Lodo and Moreno Formations.

The Franciscan complex is believed to be a major source for the Domengine Formation in the Vallecitos area (Nilsen and Clarke, 1975). The Franciscan Formation was also eroding within the source terrain of the Domengine Formation in the study area. This source is indicated by the presence of glaucophane and red chert clasts which are characteristic of the Franciscan complex (White, 1940; Bailey, 1966; Nilsen, 1981).

PALEOGEOGRAPHY

The Domengine Formation in the Alcalde Hills rests unconformably on the Cretaceous age deposits of the Panoche Formation. This hiatus is not present north of Oil City. In this region there is a fairly continuous sequence of Cretaceous through early Eocene deposits beneath the Domengine. A paleo high is therefore inferred to have been present in the Alcalde Hills area at some time between the Cretaceous and late early Eocene which resulted in the erosion or nondeposition of the Paleocene and early Eocene deposits. A depositional basin was present, however in the northern half of the study area. This depositional basin was filled with the sandstones and shales of the Lodo and Yokut Formations.

The study area subsided in the late early Eocene. This regional subsidence resulted in a westward marine transgression and the deposition of the Domengine Formation. The coastline was relatively low energy. In the northern portion of the study area, deposition occured along this low-energy shoreline. The lack of transitional environments such as foreshore and backshore deposits could indicate that a rocky coastline was present which prevented their deposition. The Domengine Formation, however, lacks the fauna which is characteristically found along a rocky shoreline (Squires, personal communication). Another more plausible explanation is that the region underwent rapid subsidence so that these transitional environments were not preserved. More evidence is needed in order to determine which explanation is correct.

In the southern portion of the study area, a river brought sediment to the low-energy coastline and formed a prograding river-dominated delta. This delta extended down to the Reef Ridge area (Fig. 6) and is also evident in the rocks of the Avenal Formation. The rocks of Coalmine Canyon were deposited predominantly along the margin of an active distributary channel, near the interdistributary bay. The occurrence of coal seams within the Alcalde Hills indicates that swamps were present throughout an area at least 2.5 km wide (Fig. 1).

The depositional environments distinguishable within the Avenal Formation are very much like those of the Domengine Formation. The tidal-dominated delta deposits of the Avenal described by Kappeler (1984) are probably part of the same deltaic complex which formed the Domengine Formation in the Alcalde Hills. The presence of tidal-dominated and fluvial-dominated lobes on the same deltaic complex occurs on the Mississippi delta. Individual lobes of the Mississippi are known to prograde, become abandoned, and then transgress. During the transgressive phase, tidal processes play a major role in reshaping the depositional environments found on the lobe. The tidal channels occupy abandoned distributary channels and with increased exposure to even small tidal currents, the sediments become progessively coarser (Howard, 1982). This depositional relationship occurs in the Domengine-Avenal deltaic complex.

The lack of transitional environments in the Coalmine Canyon, Domengine Creek, and Salt Creek sections may indicate that there was quick subsidence within the study area that preceeded the deposition of the Canoas Siltstone member of the Kreyenhagen Formation. The "missing" transitional environments in the Coalmine Canyon section are possibly represented by a 1-m-thick interbedded sandstone and siltstone bed at the base of the Kreyenhagen Formation (Fig. 3)(Al Almgren, personal communication). This deposit has a different character than the rest of the Domengine and Kreyenhagen Formations and may have resulted from quick sub-

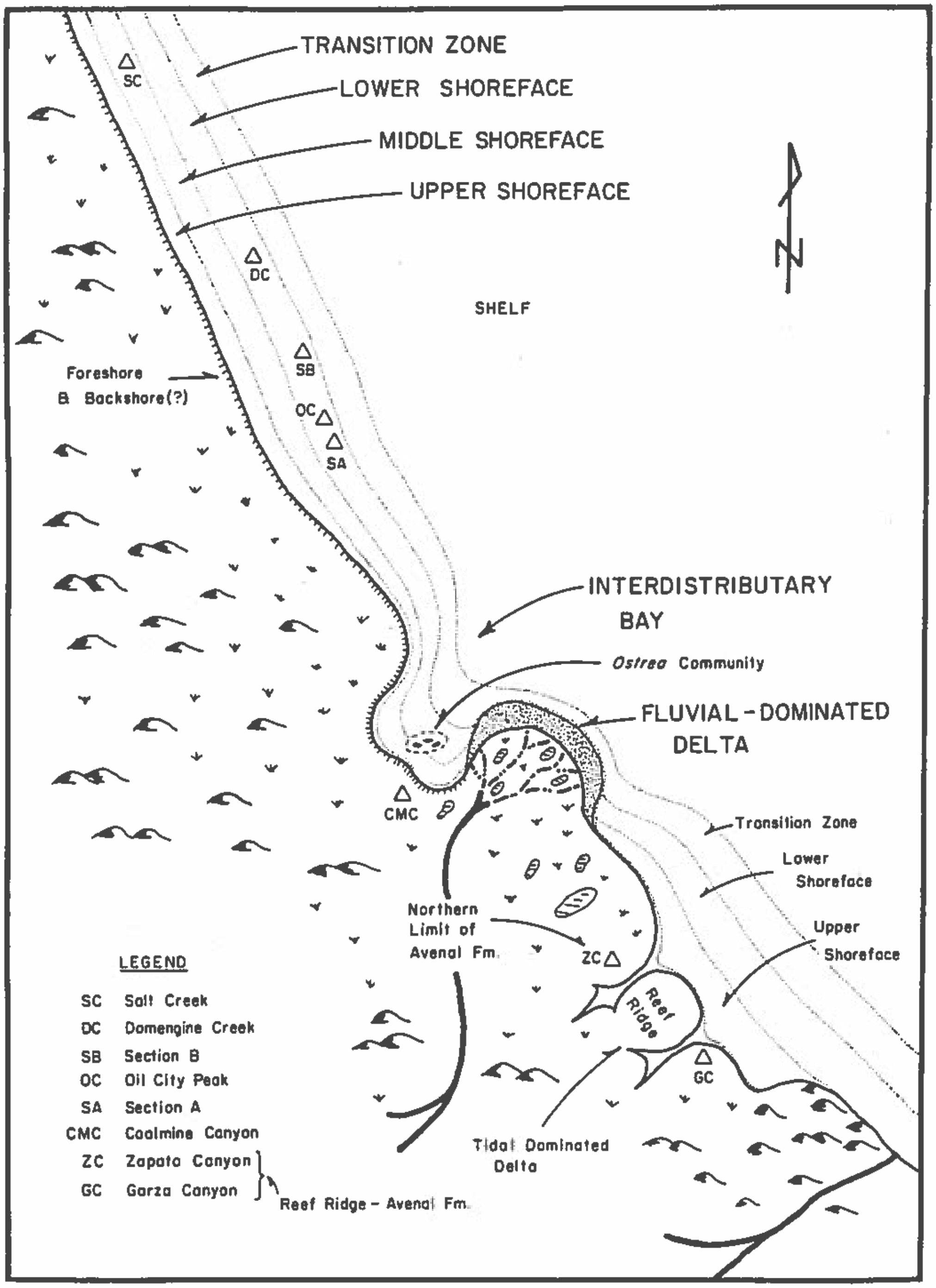

FIGURE 6 Paleogeography of the Big Blue Hills, Alcalde Hills, and Reef Ridge during the late early through early medial Eocene.

sidence in which the rate of subsidence exceeded the rate of sedimentation. The evidence for this however, is inconclusive.

REFERENCES

Anderson, F.M., 1905, A stratigraphic study in the Mount Diablo Range of California: California Academy of Sciences Proceedings, 3d. series, v. 2, p. 155-248.

Bailey, E.H., 1966, Geology of northern Calfiornia: California Division of Mines and Geology Bulletin 190, 507 p.

Brenner, R.L., and Davies, D.K., 1973, Storm-generated coquinoid sandstone: genesis of high-energy marine sediments from the Upper Jurassic of Wyoming and Montana: Geological Society of America Bulletin, v.84, p. 1685-1698.

Clark, B.L., 1926, The Domengine horizon, middle Eocene of California: University of California Publications Bulletin, v.16, p.99-118.

Clifton, H.E., 1973, Pebble segregation and bed lenticularity in wave-worked versus alluvial gravel: Sedimentology, v.20, p.173-187.

---- 1981, Progradational sequences in Miocene shoreline deposits, southeastern Caliente Range, California: Journal of Sedimentary Petrology, v. 51, no. 1, p. 165-184.

Coleman, J.M., 1982, Deltas, processes of deposition and models for exploration: Boston, International Human Resources Development Corporation, second edition, 124 p.

Coleman, J.M., Gagliano, S.M., and Webb, J.E., 1964, Minor sedimentary structures in a prograding distributary: Marine Geology, v. 1., no. 3, p. 240-258.

Coleman, J.M., and Prior, D.B., 1982, Deltaic environments of deposition, in Scholle, P.A., and Spearing, D., eds., Sandstone depositional environments: American Association of Petroleum Geologists Memoir 31, p. 139-178.

Davis, R.A., Jr., 1978, Beach and nearshore zone, in Davis, R.A., Jr., ed., Coastal sedimentary environments: New York, Springer-Verlag, p. 101-169.

Dibblee, T.W., Jr., 1971a, Geologic map, Joaquin Rocks quadrangle, California: United States Geological Survey Open-File Report.

Dibblee, T.W., Jr., 1971b, Geologic map, Coalinga quadrangle, California: United States Geological Survey Open-File Report.

Elliott, T., 1974, Interdistributary bay sequences and their genesis: Sedimentology, v. 21, p.611-622.

Fisk, H.N., and McFarlan, E. Jr., etc., 1954, Sedimentary framework of the modern Mississippi delta: Journal of Sedimentary Petrology, v.24, p. 76-99.

Folk, R.L., 1974, Petrology of sedimentary rocks: Austin, Hemphill Publishing, 182 p.

Goldring, R., and Bridges, P., 1973, Sublittoral sheet sandstones: Journal of Sedimentary Petrology, v. 43, p. 736-747.

Harun, H., 1984, Distribution and deposition of lower to middle Eocene strata in central San Joaquin Valley, California: Stanford University unpublished Masters thesis, 100 p.

Howard, J.D., 1971, Comparison of the beach-to-offshore sequence in modern and ancient sediments, in Howard, J.D., Valentine, J.W., and Warme, J. E., eds., Recent advances in paleoecology and echnology: American Geological Institute Short Course Lecture Notes, p. 148-183.

Howard, P.C., 1982, Tidal deposits of Quatre Bayou Pass, Louisiana, in Nummedal, D., ed., Deltaic sedimentation on the Lousiana coast: Gulf Coast Section Society of Economic Paleontologists and Minerologists Spring Field Trip Guidebook, p. 92-100.

Howard, J.D., and Reineck, H.E., 1972, Georgia coastal region, Sapelo Island, U.S.A.: sedimentology and biology. IV. Physical and biogenic sedimentary structures of the nearshore shelf: Senckenbergiana Maritima, v. 4, p. 81-123.

Ingle, J.C., Jr., 1980, Cenozoic paleobathymetry and depositonal history of selected sequences within the southern Calfiornia continental borderland: Cushman Foundation for Foraminiferal Research, Special Publication, No. 19, p. 163-195.

Kappeler, K.A., 1984, Depositional environments of the Avenal Sandstone of Reef Ridge, central California: California State University, Northridge unpublished Masters thesis, 86 p.

Kolb, C.R., and Van Lopik, J.R., 1966, Depositional environments of the Mississippi River deltaic plain - southeastern Louisiana, in Shirley, M.L., and Ragsdale, J.A., eds., Deltas in their geologic framework: Houston Geological Society Special Publication, p. 17-60.

Kumar, N., and Sanders, J.E., 1976, Characteristics of shoreface storm deposits: Modern and ancient examples: Journal of Sedimentary Petrology, v. 46, no. 1, p. 145-162.

Milam, R.W., 1984, Late early to late middle Eocene planktonic foraminiferal zonations in California, in Blueford, J.R., ed., Kreyenhagen and related rocks: Society of Economic Paleontologists and Minerologists Special Publication, p. 51-66.

Murray, J.W., 1973, Distribution and Ecology of living benthonic foraminiferids: New York, New York, Crane, Russak and Company, Inc., 274 p.

Nilsen, T.H., 1981, Early Cenozoic stratigraphy, tectonics and sedimentation of the central Diablo Range between Hollister and New Idria, in Frizzell, V., ed., Geology of the central and northern Diablo Range, California: Society of Economic Paleontologists and Minerologists Special Publication, p. 21-34.

Powers, M.C., 1953, A new roundness scale for sedimentary particles: Journal of Sedimentary Petrology, v. 23, p. 117-119.

Reading, H.G., 1978, Sedimentary environments and facies: New York, Elsevier Publications, 569 p.

Reineck, H.E., and Singh, I.B., 1975, Depositional sedimentary environments: New York, Springer Verlag Publishers, 439 p.

Roush, K.A., 1986, Depositional environments of the Eocene Domengine Formation near Coalinga, Fresno County, California: California State University, Northridge unpublished Masters thesis, 99 p.

Selley, R.C., 1982, An introduction to sedimentology: London, Academic Press, 417 p.

Swift, D.J.P., 1968, Coastal erosion and transgressive stratigraphy: Journal of Geology, v. 76, p. 444-456.

---- 1975, Barrier-island genesis: evidence from the central Atlantic shelf, eastern U.S.A.: Sedimentary Geology, v.14, p. 1-14.

Van Heerden, I.L., 1982, Deltaic sedimentation in Atchafalya Bay (South-central Louisiana), in Nummedal, D., ed., Deltaic sedimentation of the Louisiana coast: Gulf Coast Section of Economic Paleontologists and Min-erologists Special Publication, p. 40-61.

White, R.T., 1940, Eocene Yokut Sandstone north of Coalinga, California: American Association of Petroleum Geologists, Bulletin, v. 24, no. 10, p. 1722-1751.

Zingg, T., 1935, Beitrage zur Scholtteranalyse: Min. Petrog. Mitt Schweiz., v. 15, p. 39-140.