Paleoshorelines in the Upper Cretaceous Point Lookout Sandstone, Southern San Juan Basin, New Mexico

Robert S. Zech
U.S. Geological Survey
Denver, CO

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Table of Contents

Illustrations

ABSTRACT

LANDSAT images and aerial photography reveal several parallel linear features as much as 17 km long and 0.7 km wide. Detailed cross sections normal to a linear feature show it to be an exhumed paleoshoreline containing several overlapping sandstone units. Each unit tends to pinchout into the shales of the overlying Menefee Formation, showing a range of depositional environments including upper shoreface, foreshore, washover and eolian. Paleogeomorphic elements, predominately beach ridges and interridge swales, shape the upper surface of the sandstone and produce a relief as great as 4.2 m. The various components found in the paleoshoreline create a trellis-like drainage pattern that contrasts with the regional dendritic drainage pattern; the resulting linear feature is easily discernible on aerial photography and LANDSAT images. The rapid lithologic and thickness changes of the sandstone bodies in these linear features provide excellent potential as stratigraphic trap for hydrocarbons. Paleoshoreline facies are likely to be preserved in areas of thickest marginal marine regressive sand accumulation and similar paleoshoreline systems may be preserved at depth in the Point Lookout (Sandstone) or other Cretaceous sandstones.

INTRODUCTION

Field investigation of a prominent linear feature first identified on Landsat imagery and aerial photography (Zech and Knepper, 1979) has led to the recognition of a paleoshoreline as reflected by modern geomorphology. Landsat image E-1425-17193 shows this feature to be approximately 17 km in length and 0.7 km in width. The linear feature is best exposed in the study area 32 km northeast of Gallup, New Mex. (fig. 1). At this locality the overlying Menefee Formation is present and its relationship with the Point Lookout may easily be seen. The linear feature is the result of variations in lithology and thickness, and by paleogeomorphic and depositional features preserved in the upper part of the Point Lookout Sandstone. These elements are reflected in modern topography and are the result of Cretaceous coastal processes which formed the Point Lookout Sandstone.

Field work on the paleoshorelines of the Point Lookout Sandstone was done during the summer of 1980. Methods of study included the following: interpretation of LANDSAT images and aerial photographs, fracture and fault analysis, construction of detailed measured sections and cross sections, Abney level surveys, and investigation along the length of the feature to determine continuity of form and internal structures. Previous work in this area includes the geologic mapping of the Oak Springs and Hard Ground Flats Quadrangles (Kirk and Zech, 1976a, 1976b).

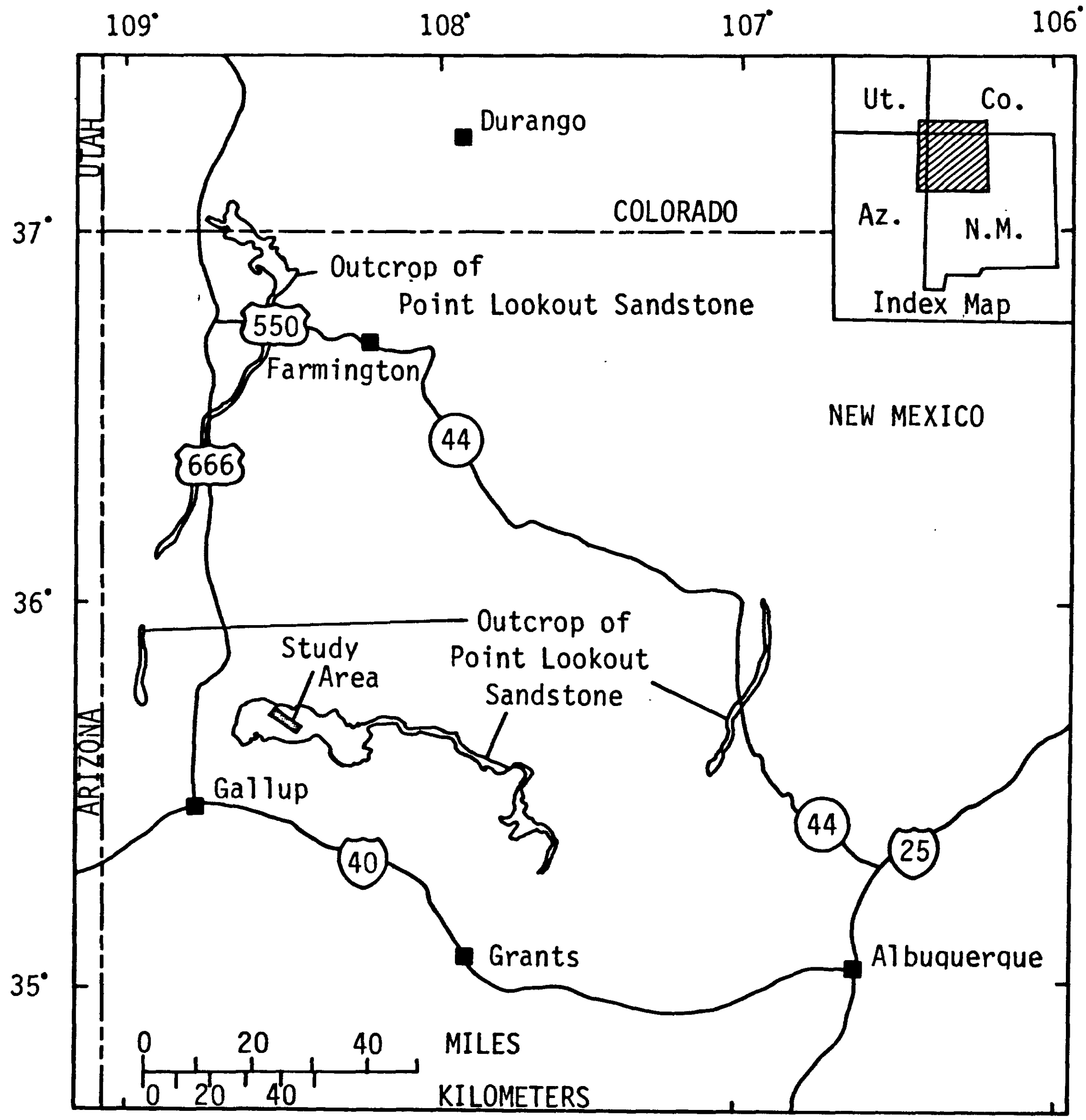

Figure 1.--Index map showing study area and Point Lookout Sandstone outcrop in the San Juan Basin, New Mexico.

GEOLOGIC SETTING

Within the study area (fig. 2), three Upper Cretaceous rock units are exposed; the Gibson Coal Member of the Crevasse Canyon Formation, the Point Lookout Sandstone, and the Cleary Coal member of the Menefee Formation. Structurally, the study area may be characterized as a homocline gently dipping 3^{o} to the north-northeast. Inspection and analysis of fractures and faults did not reveal any significant trend praralle1 to the linear feature. However, a regional fracture pattern trending N. 25^{o} E. is well developed in the Point Lookout Sandstone and strongly influences the modern-day drainage pattern. Except for minor intraformational faults in the Cleary Coal Member, the area generally lacks any surface expression of faulting.

The Gibson Coal Member of the Crevasse Canyon Formation represents sediment accumulation in a lower coastal-plain environment. It is composed of a variable, interbedded sequence of light- to dark-gray shale and siltstone, lenticular very fine to medium-grained crossbedded sandstone, minor dark-gray carbonaceous shale and lenticular, subbituminous coals (Kirk and Zech, 1977). The thickness of the Gibson Coal Member in the study area is 30-45 m.

The Point Lookout Sandstone is a regressive marginal marine coastal barrier sandstone which separates the open marine facies from the restricted or nonmarine facies. The Point Lookout is approximately 49 m thick in the study area. It is generally a yellowish gray (5Y 7/2) to a pale-grayish-orange (10YR 7/4), very fine- to fine-grained, well-sorted, subrounded to subangular, calcareous sandstone. The Point Lookout Sandstone overlies the Gibson Coal Member of the Crevasse Canyon Formation, and the contact is generally sharp and well defined to the north-northeast (Kirk and Zech, 1976b). Five kilometers north of the study area, the Point Lookout Sandstone is split into two units by the Satan Tongue of the Mancos Shale. The lower

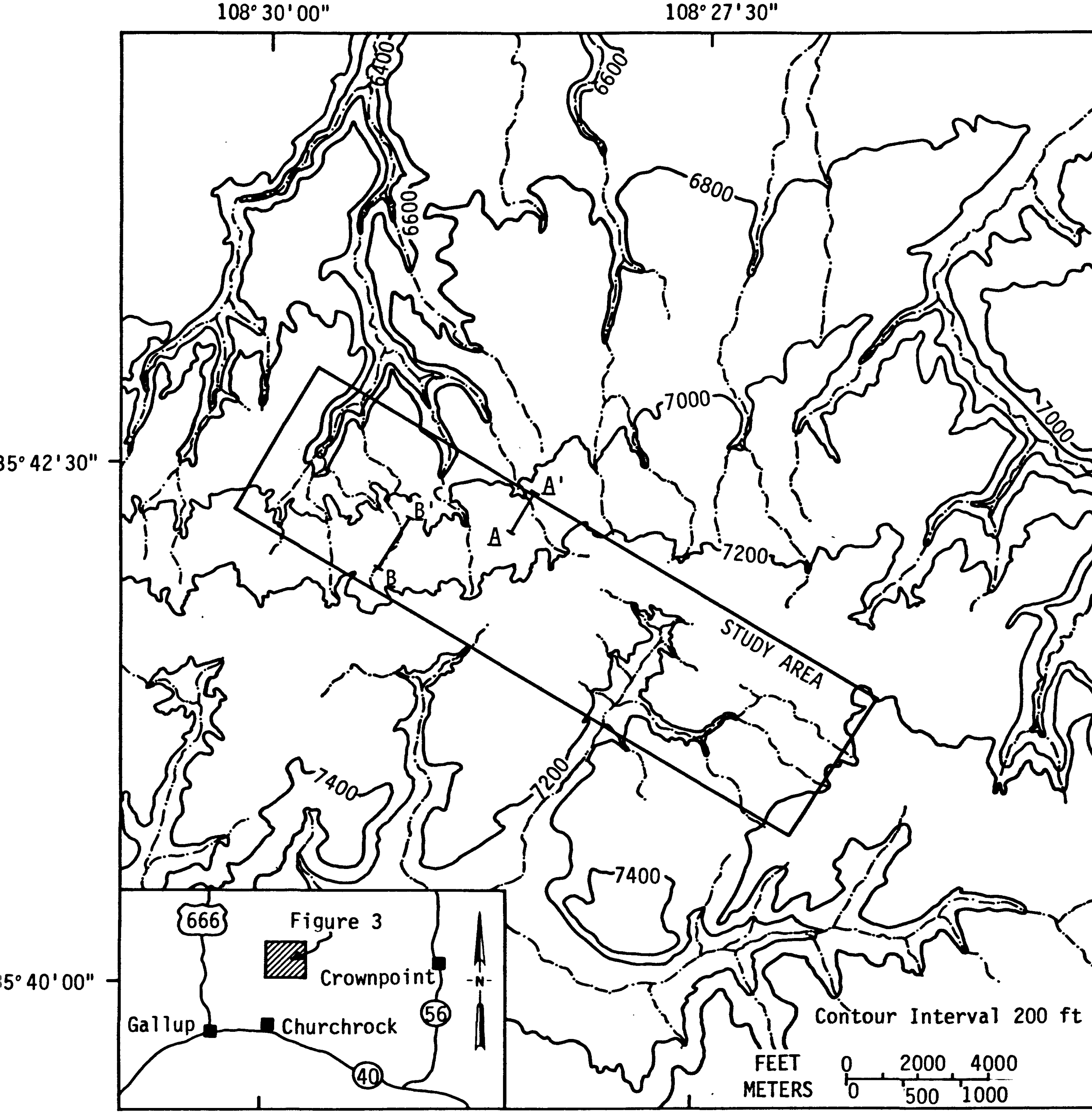

Figure 2.-- Topographic map showing location of study area and cross sections A-A' and B-B'.

regressive unit of the Point Lookout Sandstone is called the Hosta Tongue. Rocks equivalent to the Hosta Tongue interval may make up the lower half of the Point Lookout in the study area but are not differentiated due to the absence of the Satan Tongue. The Point Lookout Sandstone changes character and thins to the west and south of the study area reflecting the transition from marine to fluvial facies (fig. 3) (Kirk and Zech, 1976b). Seven kilometers south of the linear feature the Point Lookout pinches out between the continental beds of the overlying Cleary Coal Member of the Menefee Formation and the Gibson Coal Member of the Crevasse Canyon Formation. Sedimentary structures and bedding in the Point Lookout Sandstone include gently dipping parallel beds, small- and medium-scale low- to high-angle trough-crossbedded, wavy-nonparallel beds, and contorted beds. These structures will be discussed in more detail in the following section.

The Cleary Coal Member of the Menefee Formation represents sediment accumulation in a lower coastal-plain environment which prograded to the northeast parallel to and landward of the regressive Point Lookout coastline. The Cleary Coal Member is composed of a variable interbedded sequence of light- to dark-gray shale and siltstone, lenticular very fine to medium-grained, white to tan fluvial sandstone, minor dark-gray cabonaceous shale, and lenticular subbituminous coal beds. The contact with the underlying Point Lookout Sandstone is generally sharp but interfingered, particularly to the south and west toward the depositional pinchout of the Point Lookout Sandstone (Kirk and Zech, 1976b). The thickness of the Cleary Member is approximately 62 m. A few intraformational faults with displacements of 0.5 m or less are present in the Cleary Coal Member and are probably the result of differential compaction beneath the channel sandstones (Cavaroc and Flores, 1980).

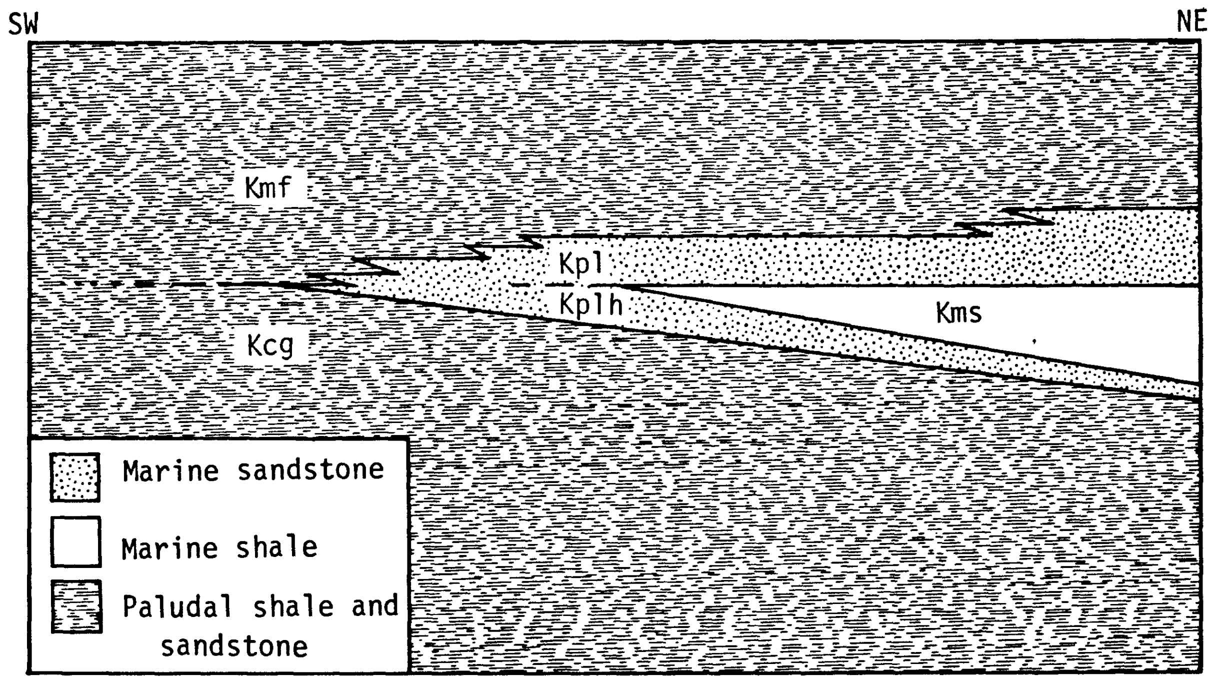

Figure 3.--Schematic diagram showing stratigraphic relationships and major depositional facies of rock units in the study area. Kmf, Menefee Formation; Kpl, Point Lookout Sandstone; Kplh, Hosta Tongue of the Point Lookout Sandstone; Kms, Satan Tongue of the Mancos Shale; and Kcg, Gibson Coal Member of the Crevasse Canyon Formation.

DEPOSITIONAL ENVIRONMENTS

Eleven detailed measured sections and the construction of two cross sections (fig. 2) perpendicular to the linear feature shows an orderly sequence of coastal sedimentation from shoreface to lower coastal-plain environments. Most of the data for the cross sections were collected along the lines of section, however some details were projected along the depositional strike of the Point Lookout Sandstone in order to complete the section and aid in interpretation.

Upper Shoreface

The northern third of cross section A-A' (fig. 4) and the northern part of unit I of section B'-B' (fig. 5) show the upper part of the Point Lookout Sandstone to be predominately composed of medium- to small-scale low-angle trough crossbeds oriented in a northwest-southeast direction. These trough crossbeds are thought to be produced by longshore currents which develop within the breaker zone by wave action and run parallel to the shoreline a few tens of meters distant (Reineck and Singh, 1975; Molenaar, 1973). The plunge of the trough axes indicate the dominant sediment transport direction was to the northwest. These troughs range in width from 0.4 to 1.5 m and from 0.1 to 0.45 m in height. The few troughs found oriented at right angles to the shoreline may be products of rip currents draining excess water from the swash zone and backshore runnels (fig. 6). The sandstone in this environment is moderately well sorted, lower medium grained (1.5 Ø), and subrounded, with little interstitial clay. A few sandstone pebbles may be found at the base of the larger troughs. These pebbles may represent a local early cementation of the unconsolidated Point Lookout Sandstone which was then transported, rounded, and redeposited by longshore currents. The upper shoreface

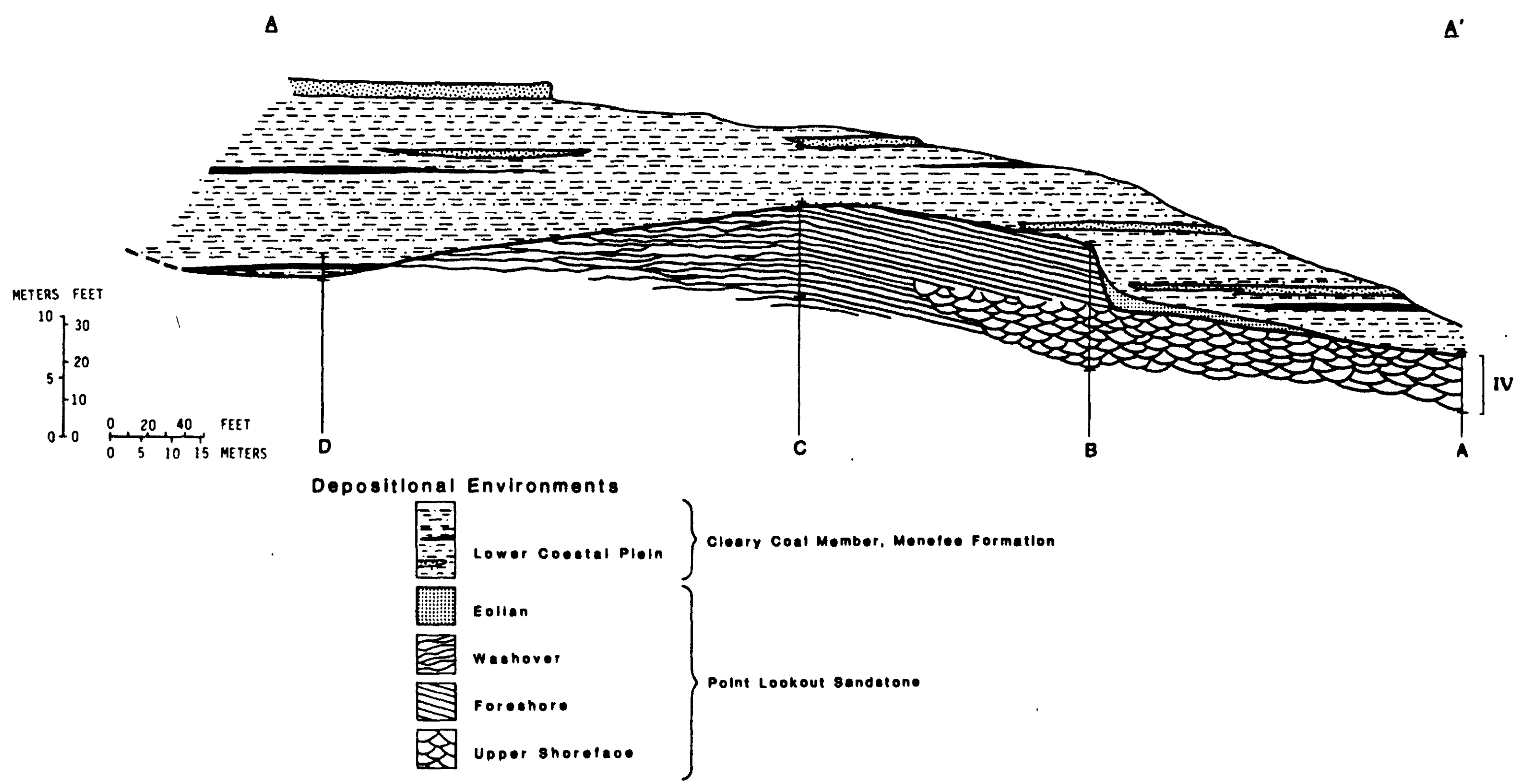

Figure 4.--Cross section A-A' showing sedimentary structures, measured sections A-D, and sedimentary sequence IV.

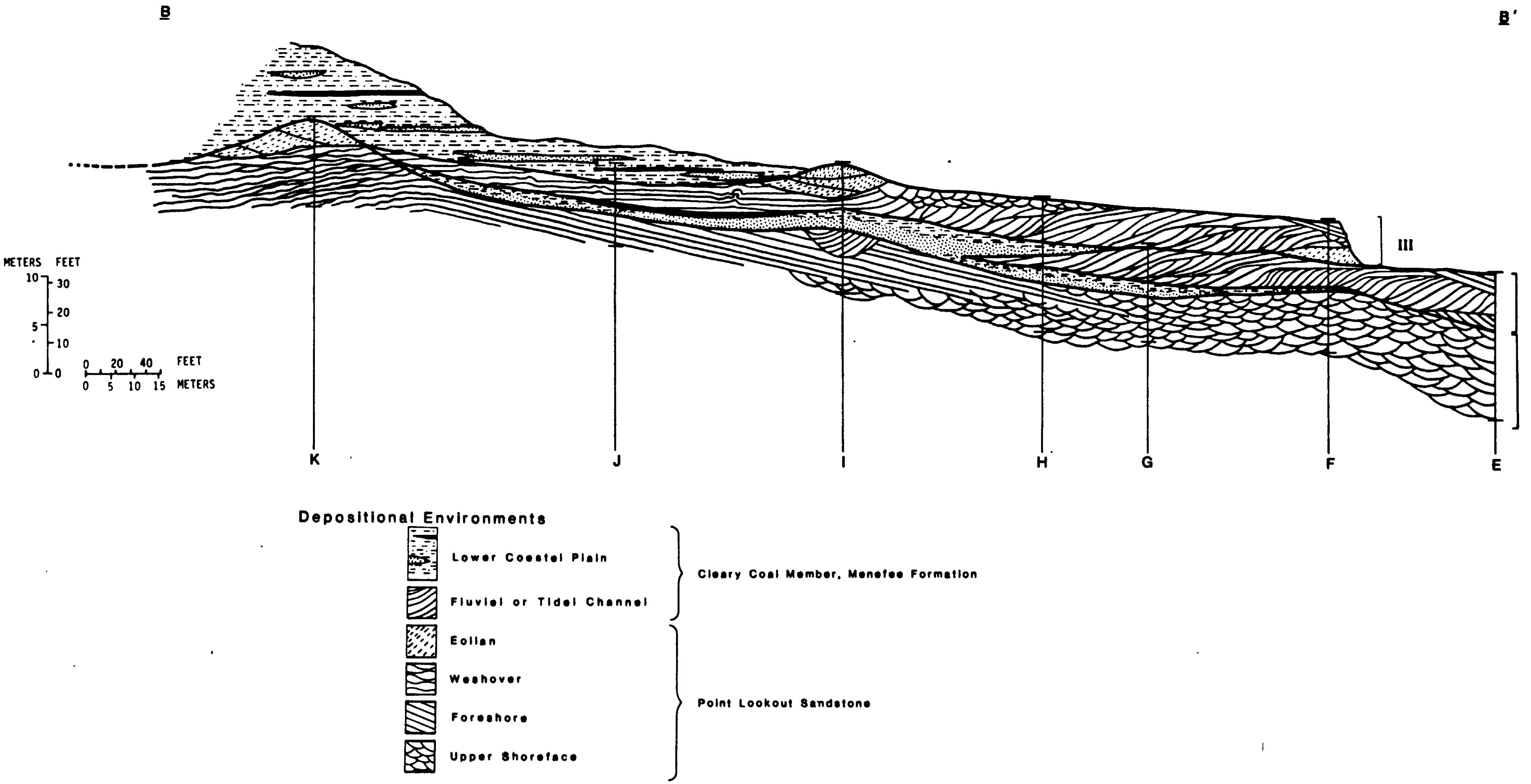

Figure 5.--Cross section B-B' showing sedimentary structures, measured sections E-K, and sedimentary sequences I-III.

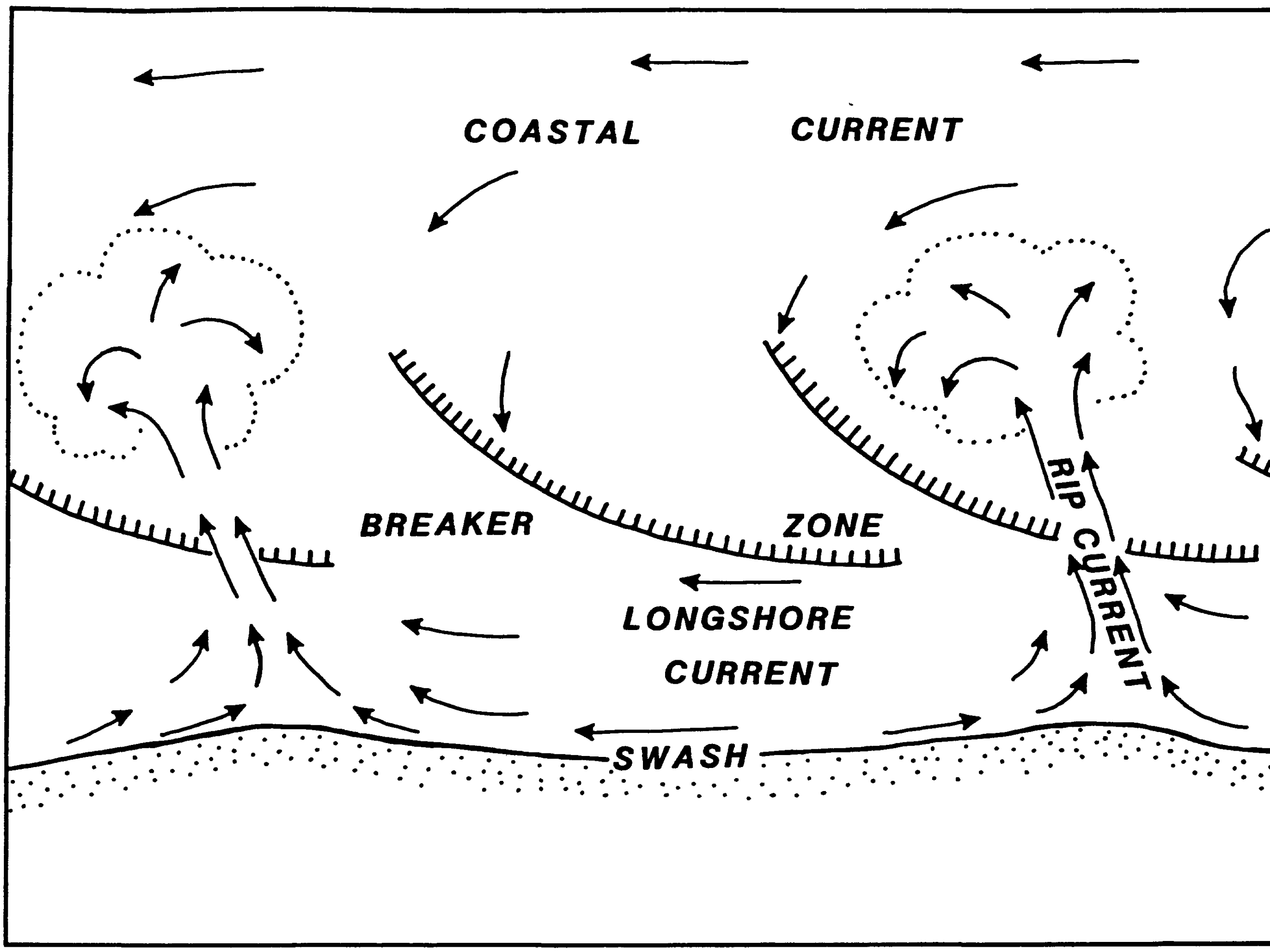

Figure 6.--Plan view diagram showing nearshore currents. (Modified from Reineck and Singh, 1975.)

environment is also present in part of the measured sections A, B, (fig. 4), and measured sections E through I (fig. 5).

Foreshore

Within the study area the foreshore facies may reach a thickness of 6 m and is thought to represent deposition in the swash zone or beach. The foreshore beds are typically 7.5-20 cm thick, parallel, and inclined at a low angle in a seaward direction (northeast). Individual beds may be followed as much as 19 m parallel to and as much as 12 m normal to the shoreline. Where the unit is overlain by the finer grained sediments of the lower coastal plain environment, the bedding is partially to totally obscured by burrowing and root tubes(?); this bioturbation may reach a depth of 1 m or more. The sandstone in this environment is very fine grained (2.0 Ø), well sorted, subrounded to rounded and contains little interstitial clay. Slight angular differences between beds or groups of beds may indicate this unit was not deposited during one event, but built up over several events. This facies frequently shows evidences of subaerial erosion such as fluvial or tidal channels (fig. 5, section I) and storm scarps. The foreshore facies is present in measured sections B, H, I, and J (figs. 4 and 5).

Beach Ridge and Washover

The beach ridge and washover deposits are discussed together due to the incomplete development of a beach ridge facies and the merging without apparent discontinuity of the foreshore and washover facies.

The poorly developed beach ridge facies are located in the transition zone between foreshore and washover facies. The beach ridge facies are characterized by forset stratification composed of beds 5-20 cm thick dipping

2^o-9^o landward to the southwest. The forset stratification ranges from 0.25 m to 1.0 m in height and from 1.1 m to 2.2 m in length. The foreset beds become wavy, irregular, and non-parallel, merging with the washover deposits. The beach ridge may be overlain by subsequent washover deposits.

The washover deposits in the study area were deposited in the upper part of the beach immediately landward of the foreshore or beach ridge. This is produced by the overwash that carries over the foreshore without flowing directly back to the sea. The area of the coast where washover deposition occurs is normally dry except during high-water periods such as storm surges when the area is flooded by overwash and receives most of its sediment. This environment typically serves as a major sand source for back beach dunes during interstorm periods and may show deflation features or eolian ripples. The bedding preserved in this unit are subhorizontal wavy discontinuous to continuous nonparallel beds 5-15 cm thick. The dip of the beds is generally at a low angle in the landward direction. Small trough crossbeds are preserved in the medial and distal parts of the washover deposit and probably represent the beginning of channelized flow of the overwash. Delta-foreset strata may be present in washover deposits and are produced when the washover sediment is transported into a standing body of water. The landward-dipping delta foresets show a dip as much as 26^o and may show forset slump structures. A schematic cross section of washover deposits is shown in figure 7.

Sand composing both the beach ridge and washover deposits in the study area ranges from lower to upper fine grained (2.5-2.0 Ø) moderately sorted, and subangular. Sedimentary structures of both environments may be obscured by burrowing or root tubes(?). Washover deposits are shown in measured sections C, F, G, H, and K (figs. 4, 5).

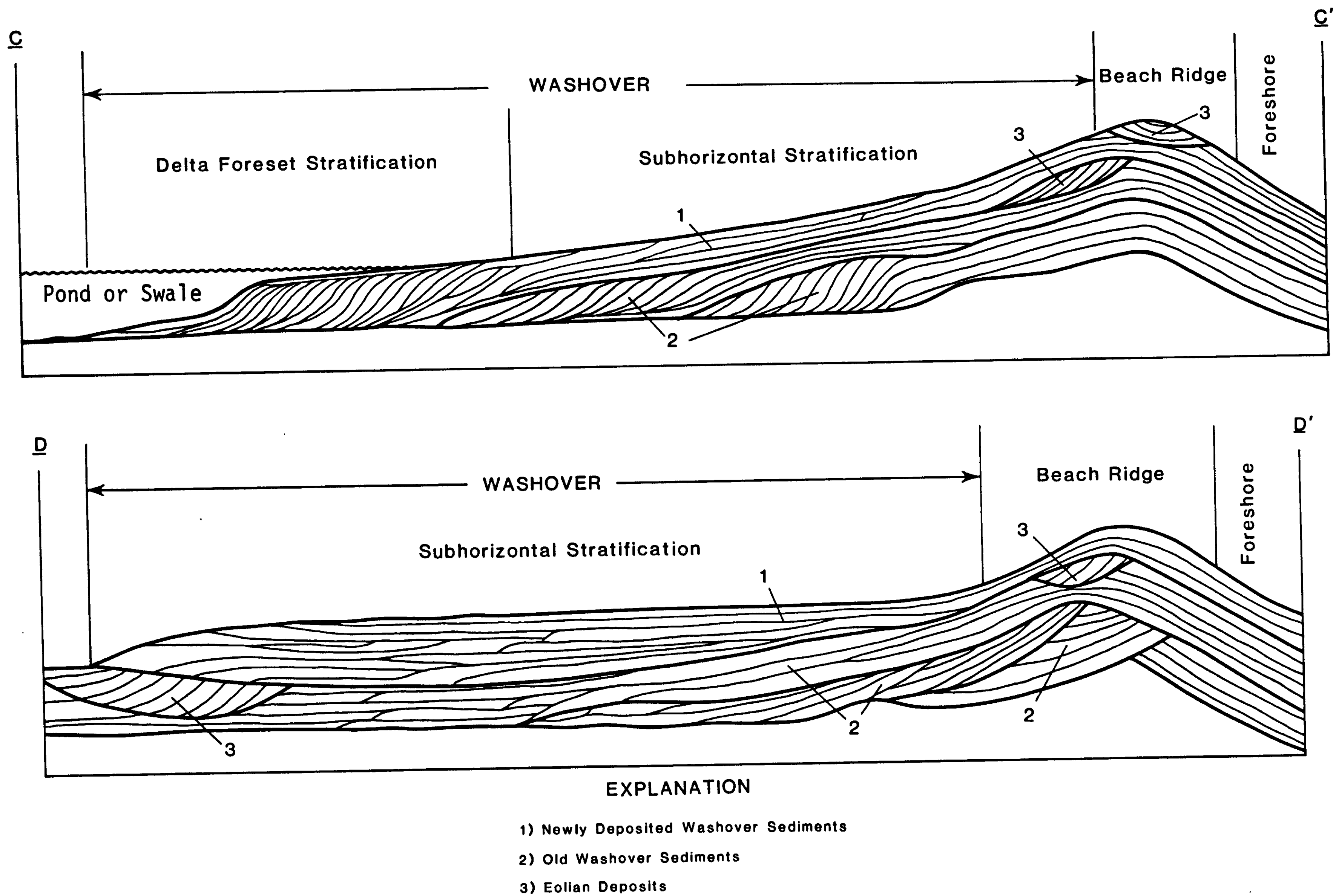

Figure 7.--Schematic cross section showing the upper few meters of two washover deposits. Section C-C' shows sequences of sedimentary structures and beds resulting from flow across a subaerial surface into a body of standing water. Section D-D' shows a sequence of sedimentary structures resulting from flow across a subaerial surface. Eolian processes may bury or modify washover deposits. (Modified from Schwartz 1975)

Eolian

The sand deposited along the seashore is exposed to wind activity and may be reworked into dunes. The eolian facies is the least likely of all the coastal facies to be preserved, because they are commonly reworked by prograding fluvial facies. However in measured sections I and K (fig. 5) the rather steep foreset laminae of eolian beds have eroded into the washover facies and are preserved. Sand composing this facies is slightly finer grained (2.5 Ø) and better sorted than the sand of the water-laid sediments discussed above. A fine-grained, friable, and structureless sandstone unit is present north of measured section B (fig. 4). This unit may represent an eolian deposit which accumulated in the lee of a storm or high-tide erosional scarp.

DEPOSITIONAL SEQUENCE

The sedimentary structures exposed in the upper part of the Point Lookout Sandstone in the study area are alined parallel to a linear Cretaceous shoreline and clearly show several overlapping events of regressive coastal sedimentation. Stratigraphic unit I shows the first sedimentary sequence deposited (fig. 5). Tracing this unit lateraly from northeast to southwest reveals sedimentary structures indicative of upper shoreface, foreshore, beach ridge(?), washover, and eolian environments. The regressive sequence is completed by the prograding back-barrier deposits of the Cleary Coal Member which directly overlies unit I from measured sections K to F.

The middle stratigraphic unit (II) shows medial and distal washover sediments deposited on the eroded unit I (measured section E) and into the carbonaceous shaly sands of the prograding lower coastal plain environment of the Cleary Coal Member (measured sections F, G, and H). A series of landward-dipping (southwest) delta foresets indicate deposition during several events into a standing body of water. Progradation of the back-barrier coastal-plain sediments continues and overlies the washover deposit (measured section H).

A sequence of delta foresets similar to unit II make up the bulk of unit III and indicate this part of the unit was also deposited in a washover environment (measured sections F, G, H, fig. 5). A reworking of these sediments by eolian dunes which cut out the washover sequence can be seen in measured section I. These large scale eolian beds form a linear ridge parallel to the paleoshoreline. The eolian sediments thin landward becoming a unit (measured section J) consisting of generally horizontal beds which are bioturbated, contorted, and locally contain a few trough crossbeds. This probably indicates the landward thinning and intertonguing of eolian deposts into the coastal-plain environment. Dewatering of the fine-grained coastal-plain sediments may have formed the contorted beds.

Exposures did not permit a detailed correlation of the northern cross section (A-A' fig. 3) with the southern cross section (B-B' fig. 4). Projected along strike, the facies exposed in cross section A-A' appear to be younger and stratigraphicly higher than those of cross section B-B'. The upper shoreface, foreshore, beach ridge, and washover facies exposed in this cross section represent another regressive event similar to unit I in figure 4.

INTERPRETATION OF PALEOGEOMORPHIC FEATURES

In addition to the various coastal sedimentary facies, the Point Lookout paleoshoreline contains several recognizable paleogeomorphic features. The northern edge of this linear paleoshoreline is marked by a scarp 2.2 m in height and approximately 900 m in length (measured section B, fig. 4). This feature is very similar to scarps found on modern beaches which are produced by the erosive action of storm waves (Ruzyla, 1973). Behind the scarp a ridge and swale system is preserved on the upper surface of the Point Lookout Sandstone. The ridge lithology and structure has already been described, however it should be noted that the ridge is a positive paleogeomorphic feature with a present measured maximum relief of 2.1 m. The maximum length noted of a single ridge is 1200 m. Landward from the beach ridge, a parallel interridge swale is carved into the underlying washover deposits. The swales are approximately 30 m wide and as deep as 2 m. Ridge and swale features of similar dimensions are found in the modern coastal environment and have been reported by several authors (Bernard and others, 1970, Davis and others 1972, Reineck and Singh, 1975). The swales are negative paleogeomorphic features and were filled in with the finer grained carbonaceous shales, sandstones, and silty coals of the Cleary Coal Member. A few lenticular trough crossbedded sandstones are present in this fill with trough axes parallel to the beach. Swales are distinguished from beach runnels by their position behind the beach ridge and the predominance of fine-gained fill. The paleogeomorphic features noted in the area of study are shown in figure 8.

The thickening of the resistant Point Lookout Sandstone in the washover deposits and ridges and its thinning in the swales which were filled with the less-resistant Cleary Coal Member has influenced present-day topography and drainage. Regionally major streams flow down the structural dip to the north toward the center of the San Juan Basin and are controlled in part by the northeast-trending regional fracture pattern. Tributaries to the main streams commonly exhibit a dendritic pattern except locally where they are altered to a trellis-like pattern along the Point Lookout paleoshoreline. This change in the drainage pattern is controlled by the presence of easily eroded Cleary sediments deposited as fill in the paleoswales. Upon further topographic dissection, ridges are formed by the thicker and more resistant beach ridge and washover facies. The effects of paleotopographic and paleogeomorphic features on modern topography can be seen by noting the changes in stream courses in figure 8.

On a regional scale, a linear feature resulting from the paleoshoreline system can easily be seen. The feature is enhanced on aerial photographs and Landsat images by the absence of vegetation on the paleoridges and the presence of vegetation in the paleoswales or present-day drainages.

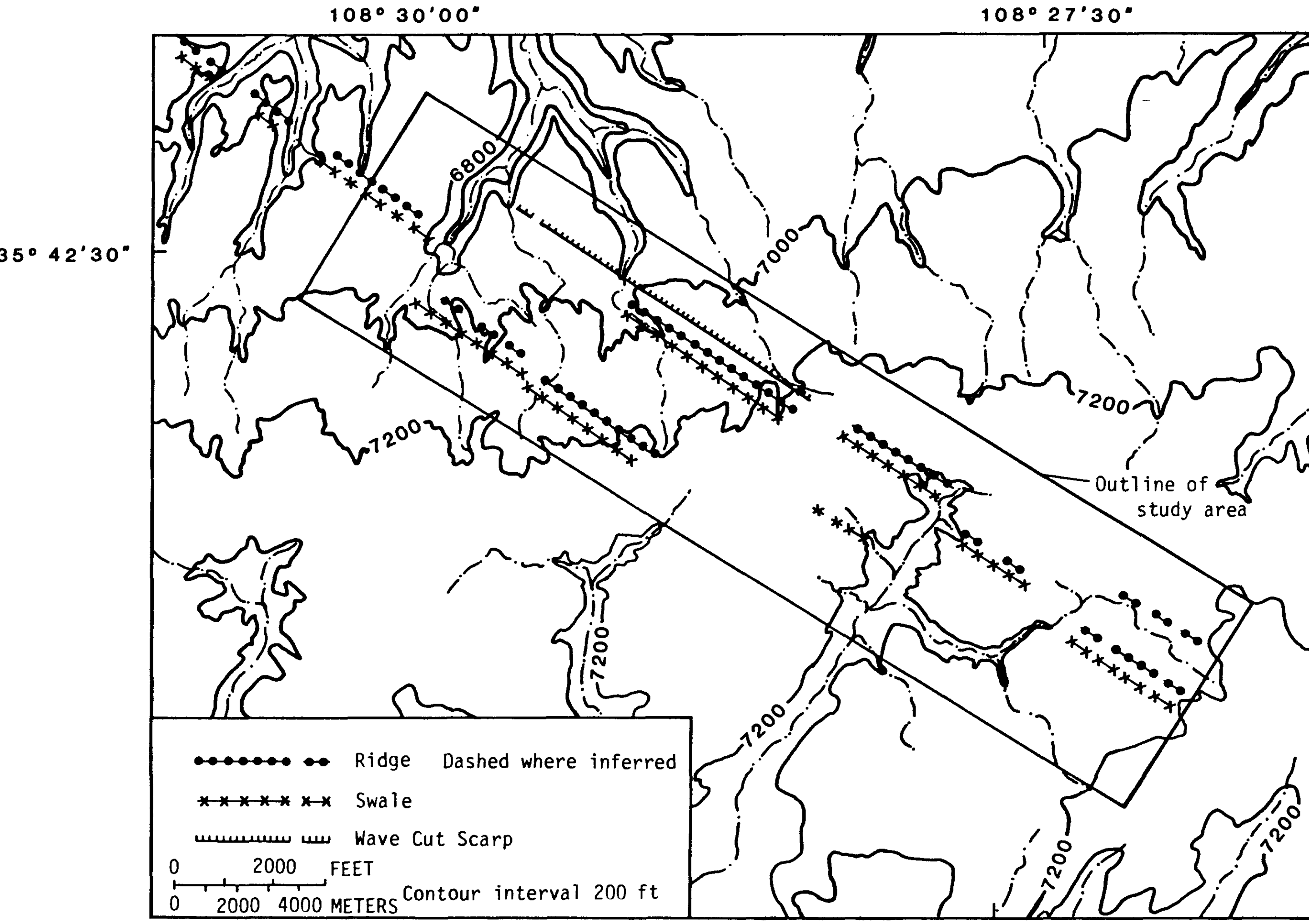

Figure 8.--Topographic map showing distribution of paleogeomorphic features in the Point Lookout Sandstone.

ECONOMIC SIGNIFICANCE

The paleoshoreline exposed in the Point Lookout Sandstone serves as an exhumed example of a potential stratigraphic trap. An effective trap may be formed by the paleotopography on the upper surface of the Point Lookout Sandstone. A paleoshoreline system may contain many ridge and swale sets, each with a relief as great as 4.2 m. The length of each of these features may be as much as 1200 m. Another potential trap is the rapid thinning and pinching out of marginal-marine and washover deposits. These wedge-shaped sandstone bodies may have a thickness of as much as 5 m and a length equal to or greater than the associated ridges. In both of the above examples the sandstones are overlain or intertongue with the relatively impermeable lower coastal-plain deposits of the Menefee Formation.

It should be noted that these facies overlap seaward and this imbrication increases the thickness of a potential stratigraphic trap. Also, the length of the paleoshoreline is limited by its surface exposure. It would be reasonable to assume the exposed paleoshoreline continues for some distance in the subsurface.

Similar paleoshoreline features may be present deeper in the San Juan Basin in the Point Lookout Sandstone and in other Cretaceous marginal-marine sandstones. Hollenshead and Pritchard (1973) observed that "the regressive Point Lookout *** shoreline did not move uniformly, depositing a blanket of sand of constant thickness. Instead, it moved very rapidly across some areas, whereas in other areas it remained stationary, within a narrow belt. In areas where the shoreline remained stationary, thick well-sorted sand bodies are present." Foreshore, washover and eolian facies would not be as well developed or preserved in areas of rapid shoreline movement. The facies which have potential as stratigraphic traps are more likely to be found in areas where the shoreline remained stationary for relatively long periods of time. Likewise the landward lower coastal-plain deposits would remain stationary, have a greater overall thickness and thicker coal beds.

SUMMARY

A northwest trending linear feature originally identified from aerial photography and LANDSAT images of the southern San Juan Basin is the result of differential erosion along a paleoshoreline complex in the Upper Cretaceous Point Lookout Sandstone. The paleoshoreline is 17.0 km long and 0.7 km wide and is made up of a number of shorter linear sedimentary deposits and paleotopographic features such as beach ridges, eolian dunes, swales and coalesced washover sediments. The geometry of the various elements which make up the paleoshoreline complex holds significant potential as a stratigraphic trap for hydrocarbons. These deposits may form during a particular style of regressive deposition where the shoreline was stationary for relatively long periods of time. Additional paleoshoreline systems may be found at depth in the Point Lookout or in other Cretaceous regressive marine sandstones such as the Gallup Sandstone or Dalton Sandstone Member of the Crevasse Canyon Formation.

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