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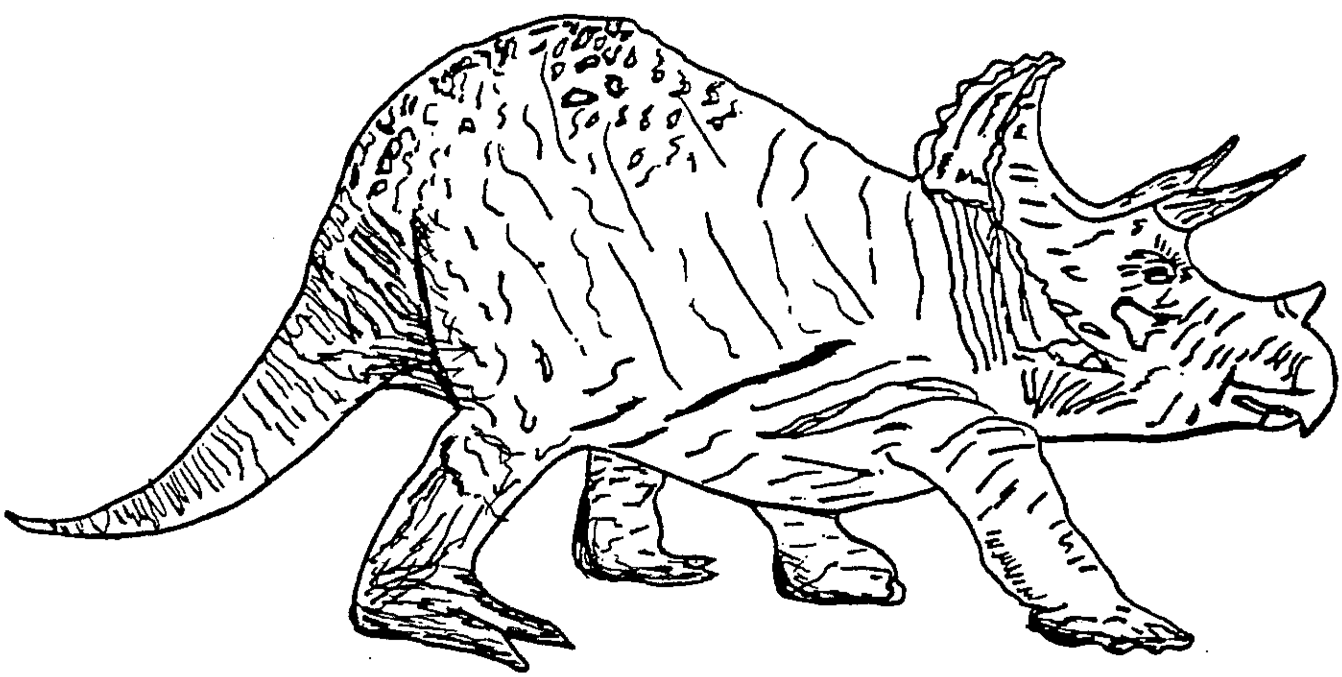
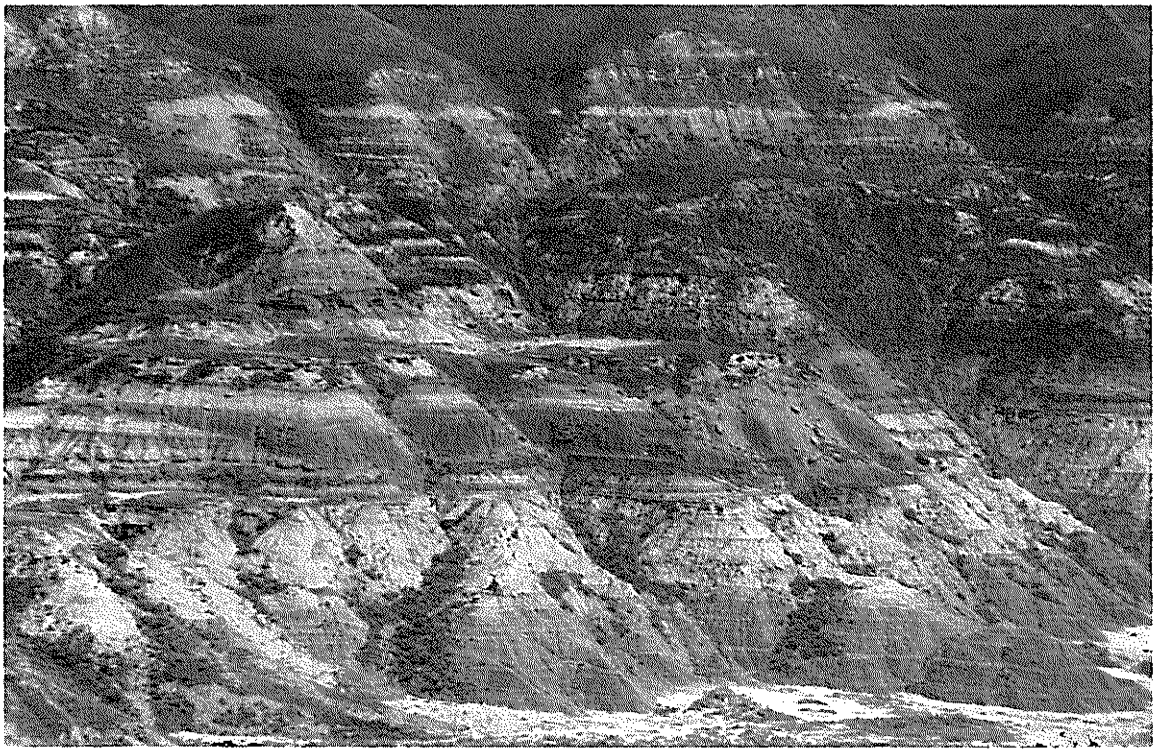


FIELD CONFERENCE

GUIDE BOOK



FRONTISPIECE

Horseshoe Canyon Formation: Abandoned Mud-Filled Tidal Channel near East Coulee, Alberta.

FACIES RELATIONSHIPS AND PALEOENVIRONMENTS OF A LATE CRETACEOUS TIDE-DOMINATED DELTA, DRUMHELLER, ALBERTA. A FIELD GUIDE

by

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INTRODUCTION

Along most of its 200 km stretch between the city of Red Deer and town of Dorothy (Fig. 1), the Red Deer River valley of central Alberta plains, displays spectacular badland terrain, therefore providing the geologist with a superbly exposed and almost continuous section of Upper Cretaceous and Paleogene clastic rocks. This, in addition to the fact that strata are almost flat lying renders this area among the very few localities in North America where lateral facies relationships can be examined in considerable detail. The main Red Deer River valley and its many tributary gullies combine to offer a three dimensional view of lithofacies.

For the purpose of this fieldtrip, a 13 km stretch of valley wall, 12 km southeast of Drumheller (Figs 1, 2 and 3) is chosen to examine the facies relationships of a prograding delta sequence and attempt to interpret their depositional environments. This valley segment exposes slightly over 100 metres of the transitional zone between the Bearpaw and Horseshoe Canyon Formations. The sequence has been studied by the present author as part of a regional investigation of the coal-bearing Cretaceous and Tertiary rocks of Alberta by members of the Sedimentary Geology Section of the Alberta Geological Survey. Shepheard and Hills (1970) were the first to conduct a detailed stratigraphic and sedimentologic study of this sequence.

This fieldguide has a fairly generalized format in terms of description and interpretation, leaving more detailed lithological description and interpretation of specific lithofacies for discussion during the fieldtrip.

STRATIGRAPHIC SETTING

The sequence to be examined comprises the upper 20-30 metres of the marine Bearpaw Formation (mostly shale) and the lower 70-80 metres of the overlying shallow marine and continental Horseshoe Canyon Formation

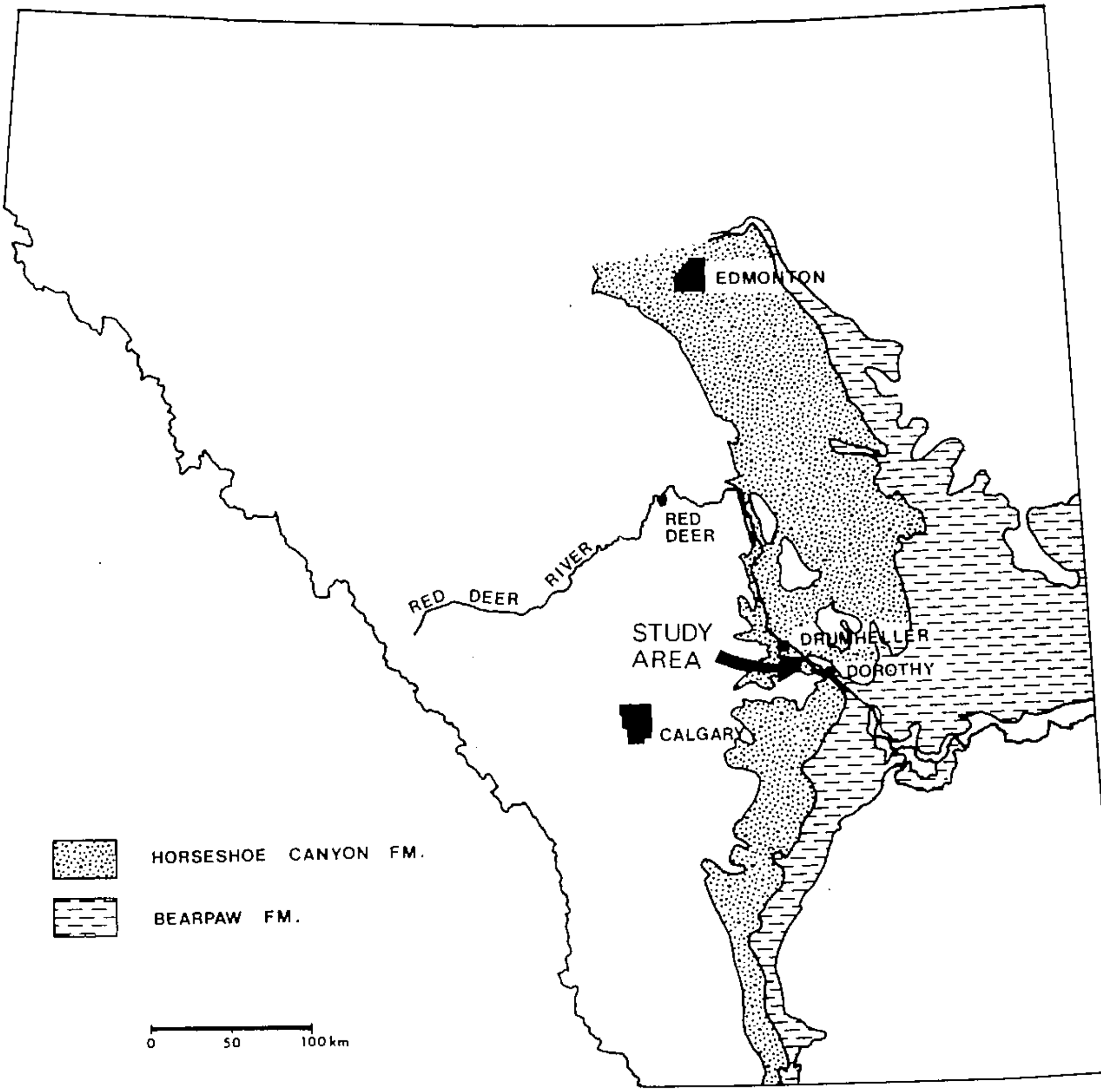

Fig. 1: Location of field trip area.

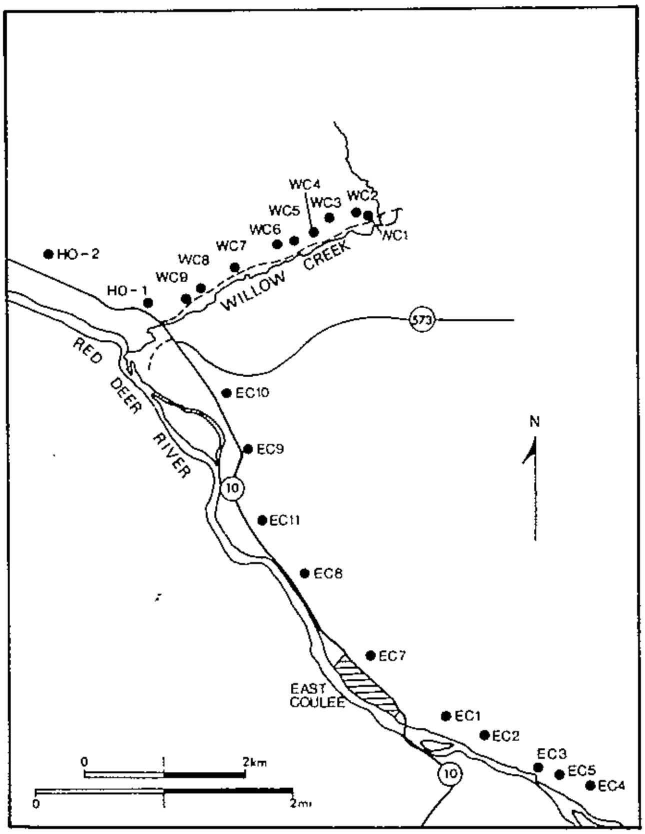

Fig. 2: Location of measured sections.

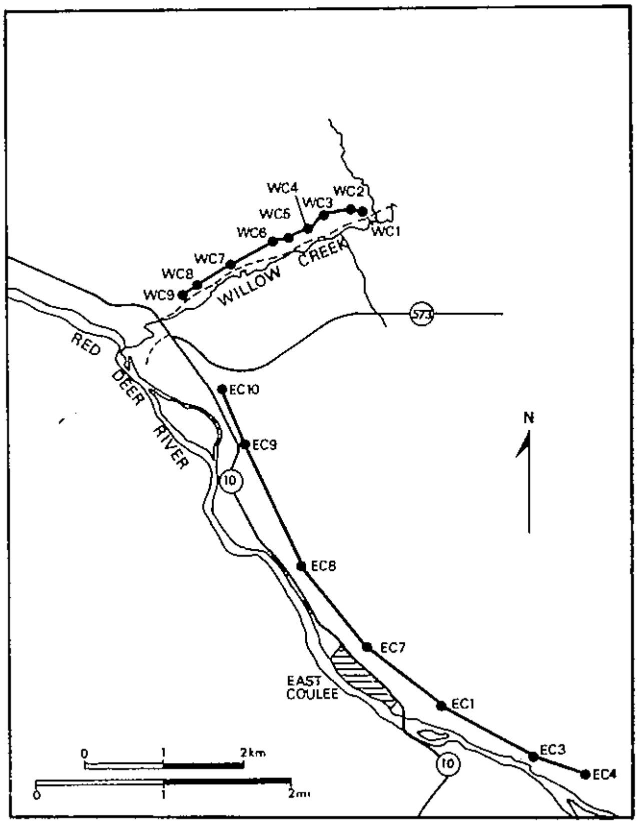

Fig. 3: Location of fence diagrams of Figs. 6 and 7.

(mostly coarser clastics) (Fig. 4) of Campanian to Maastrichtian age. This is an eastward prograding sequence typical of Mesozoic Rocky Mountain molasse deposited at the western shoreline of the epicontinental seas of the Western Interior (Fig. 5). Moreover, it forms part of one of the most classic and widely studied clastic wedges in North American stratigraphy.

For paleogeographic orientation, and based on various lines of evidence discussed in a later section, the ancient shoreline probably had an average orientation of west-southwest to east-northeast, with the sea being to the southside.

The present author has found it convenient to adopt Shepheard and Hills' (1970) scheme of units (Figs. 6 and 7) as a stratigraphic framework for his detailed section logs, with the exception of the boundary between units E4 and E5 which has been raised to coincide with Coal No. 2. This seam, although poorly developed in the Willow Creek area, is relatively thick and well exposed in the East Coulee area (Figs. 6 and 7), thereby serving as a valuable marker bed. The scheme of units is sufficiently entrenched among Alberta geologists that erection of a new scheme would likely create considerable confusion. Otherwise, Shepheard and Hills' (1970) scheme is most useful in the Willow Creek area.

GROSS DEPOSITIONAL SETTING

The basic depositional framework of the Bearpaw-Horseshoe Canyon transition zone around Drumheller was established by Shepheard and Hills (1970) as that of a sequence deposited in an easterly prograding deltaic complex fed by river(s) draining the Cordillera and debouching their load into the shallow, warm epicontinental Bearpaw Sea. The present author agrees with this general interpretation of Shepheard and Hills. Shepheard and Hills (1970, 1979), in their search for an analogous modern deltaic model, concluded that "...The sequence described resembles most closely that of the Mississippi Delta more than any other deltaic complex." The present author, however, considers that the Mississippi Delta model does not adequately account for many features exhibited by the Bearpaw-

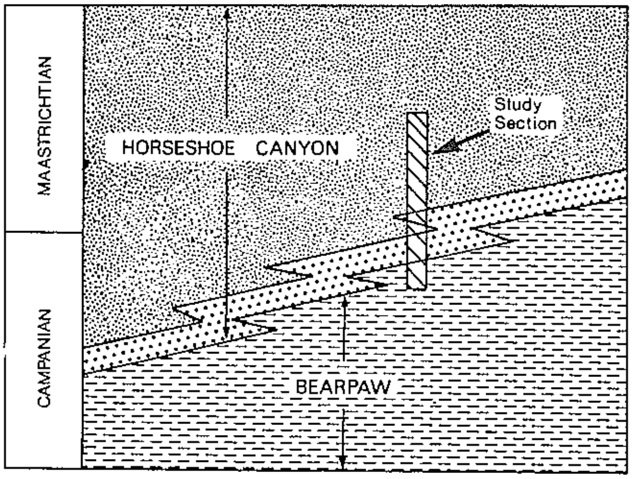

Fig. 4: Schematic diagram of the Bearpaw-Horseshoe Canyon Formations transition.

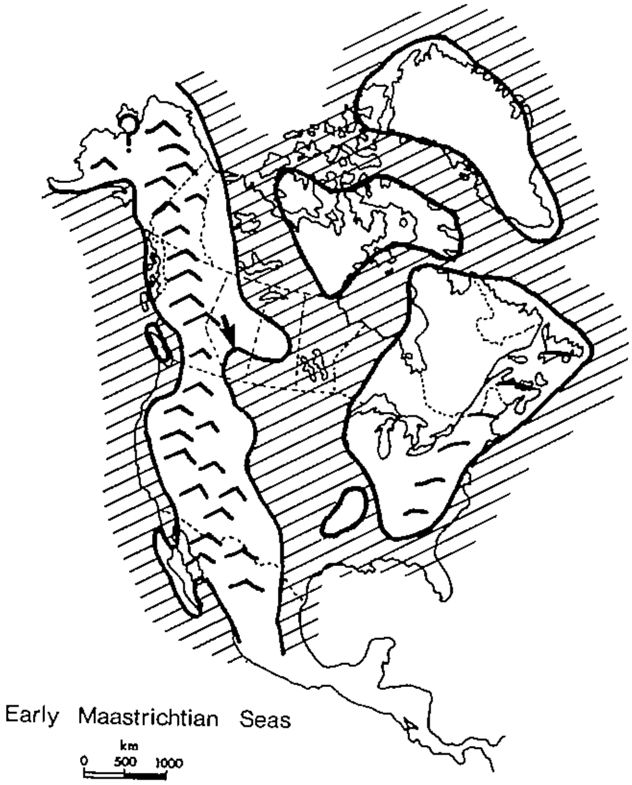

Fig. 5: Early Maastrichtian paleogeographic map (after Williams and Stelck, 1975). Arrow points to location of study.

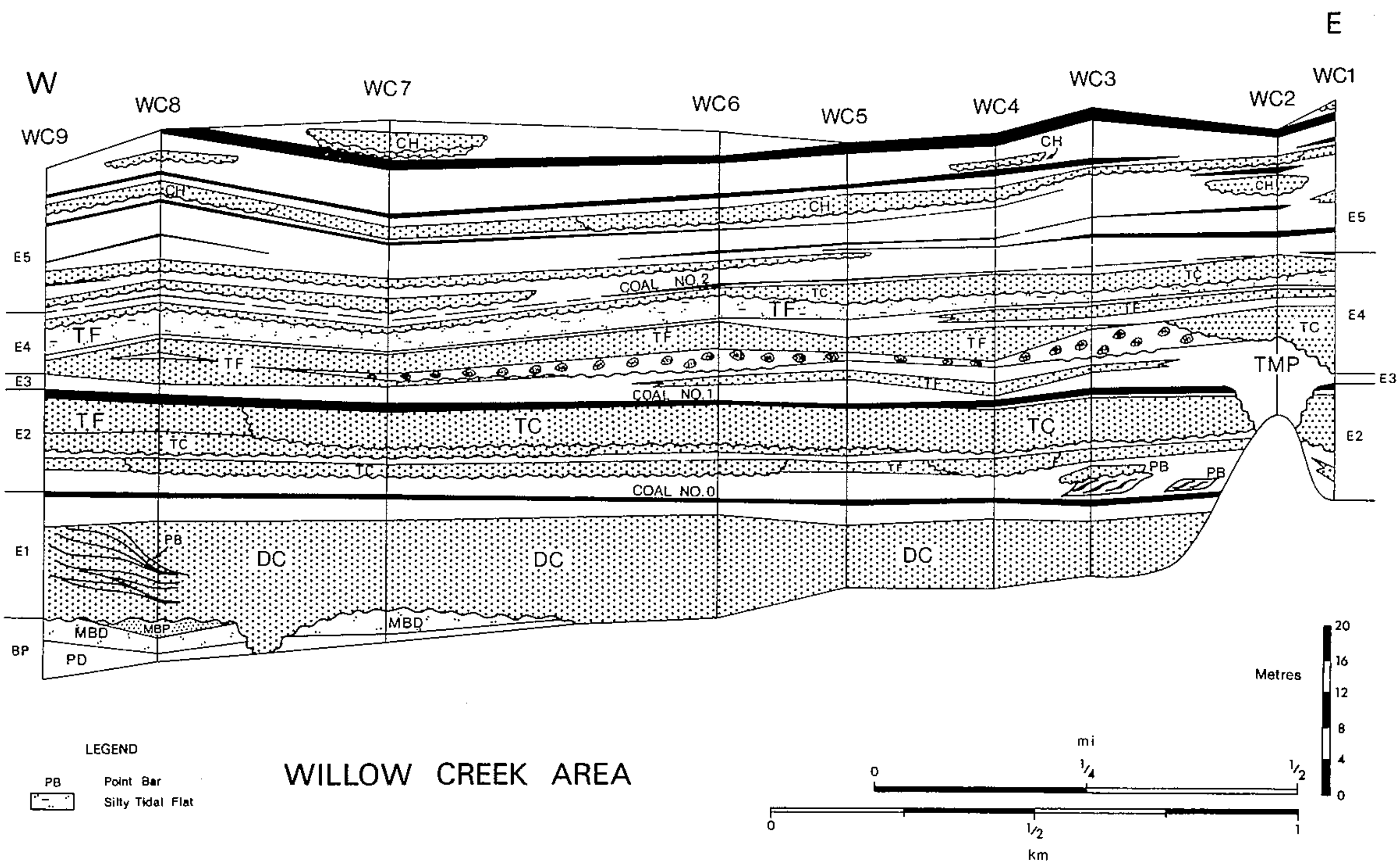

Fig. 6: Fence diagram showing units and facies in the Willow Creek area. See Fig. 7 for legend.

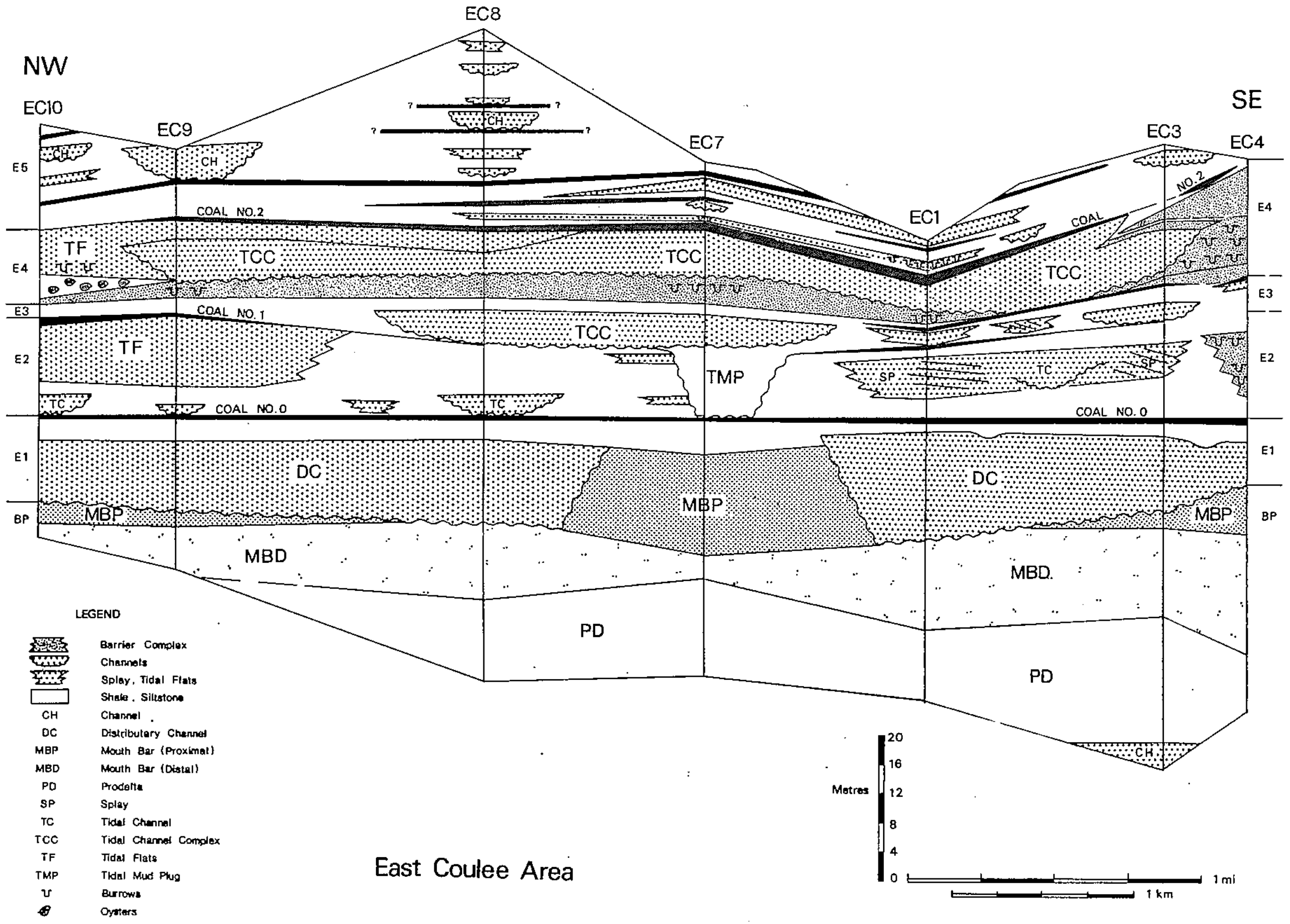

Fig. 7: Fence diagram showing units and facies in the East Coulee area.

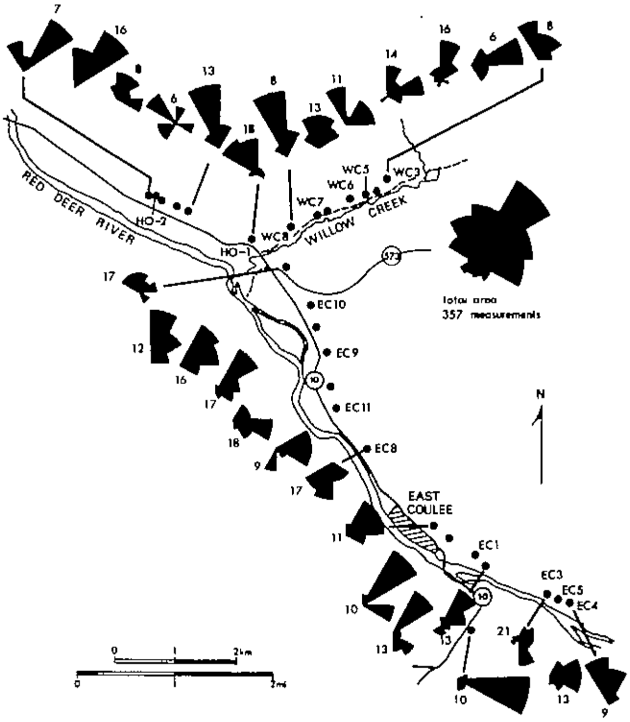

Fig. 8: Paleocurrent map based on large scale trough cross-stratification of the distributary channel of unit E1.

Horseshoe Canyon transition zone. The present author interprets most of the Bearpaw-Horseshoe Canyon transitional sequence as the deposits of a prograding delta complex in an embayment where tidal influences dominated over wave and river processes.

Paleocurrent patterns of the basal Horseshoe Canyon sandstone (Unit El; Fig. 8), combined with the nature of vertical and lateral facies ralationships (Figs. 6 and 7) favour an analogy with such delta systems as those of the Ord River of western Australia and the Klang River of Malaysia (Coleman, 1976) (Figs. 9 and 10), and the Ogeechee River-Ossabaw Sound of the coast of Georgia, U.S.A. (Greer, 1975; Dörjes and Howard, 1975; and Howard, et al., 1975).

STRATIGRAPHY AND FACIES RELATIONSHIPS

Units labelled BP, El, E2, E3, E4 and E5 in figures 6 and 7 are as defined by Shepheard and Hills (1970), apart from the earlier-noted change in elevation of the E4-E5 unit boundary to coincide with the top of Coal No. 2. Unit BP refers to that part of the section that falls within the Bearpaw Formation. The overlying units El to E5 fall within the Horseshoe Canyon Formation of the Edmonton Group. Figures 6 and 7 were constructed from measured outcrop sections and the extensive utilization of photo-mosaics of the valley walls, some of which will be shown during the field-trip. In the following description of the units, numbering and coding of facies was only attempted for units BP and El.

Unit BP

Unit BP consists mostly of shale, and siltstone with minor amounts of sandstone in an overall upward coarsening sequence, and is subdivided into the following facies: (1) CH, an upward fining channel sandstone at the base of section EC3; (2) PD, the prodelta facies basically comprised of shale and siltstone; (3) MBD, the distal mouth bar consisting of alternating shale, siltstone and sandstone; and (4) MBP, the proximal mouth bar differing from the underlying MBD facies by an increase in number, thickness and grain size of the sandstone beds. The latter two facies (MBD and MBP) locally

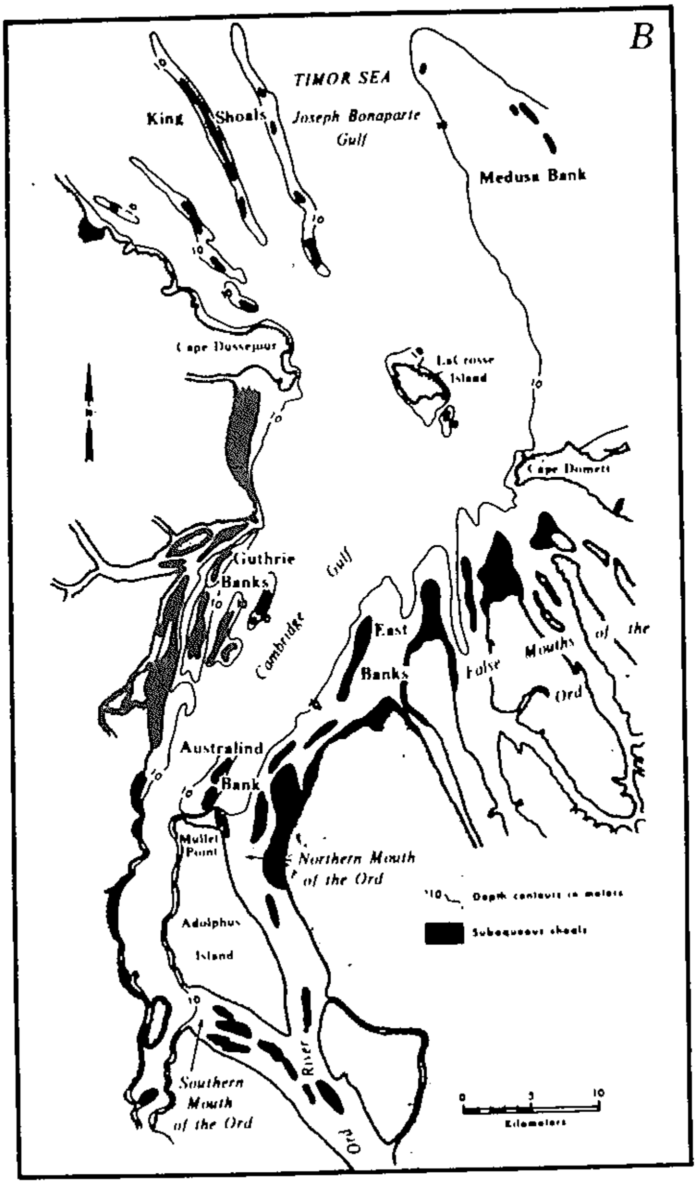

Fig. 9: Map of Ord River Delta (after Coleman, 1976).

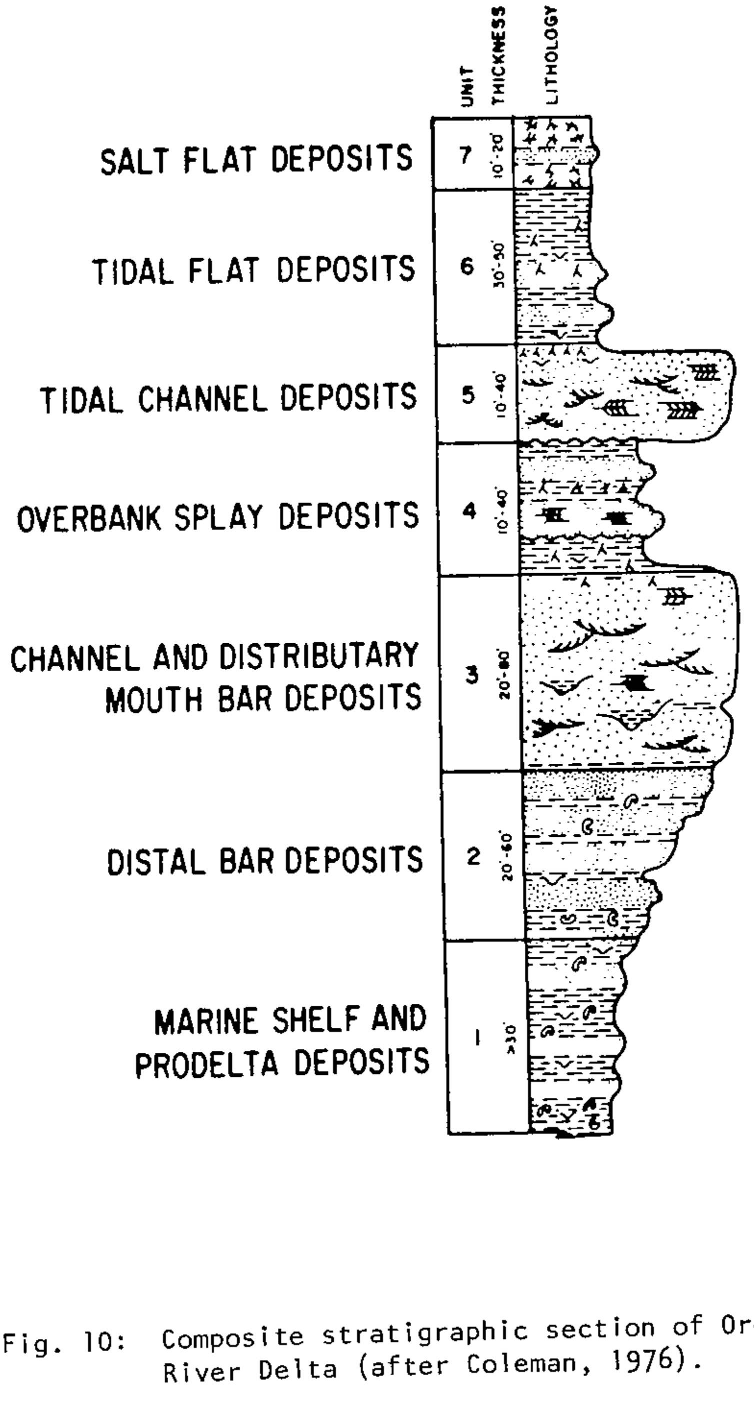

Fig. 10: Composite stratigraphic section of Ord River Delta (after Coleman, 1976).

exhibit soft sediment deformation. A four metre thick sandstone bed which forms the base of section EC3 (Fig. 7), consists of a lower trough cross bedded portion overlain by a finer grained portion with hummocky and ripple cross lamination. The complete spectrum of facies in the BP unit are best exposed southeastwards of section EC9 (Fig. 7). Only a very thin upper part of the unit BP is exposed in the Willow Creek area (Fig. 6). Unit BP has a maximum exposed thickness of 35 metres at section EC3 (Fig. 7).

Unit E1

Unit E1 is the basal unit of the Horseshoe Canyon Formation. In all locations except section EC7, it lies with an erosional contact over unit BP. E1 consists mostly of sandstone and is capped by a coal seam almost 1 m thick. This unit can be subdivided into the following facies: (1) DC, distributary channel facies comprised of coarse to fine-grained sandstone and characterised by erosional basal contact with overlying mud pebble lag, large-scale trough and tabular cross-stratification and occasional point bar accretionary bedding; (2) MBP, proximal distributary mouth bar, as in unit BP, best exemplified in section EC7 (Fig. 7) and composed of thin beds of fine sandstone with gently dipping cross-stratification; (3) fine-grained overbank facies overlying DC and MBP facies; and (4) peat swamp facies represented by the Coal No. 0. Paleocurrent directions (Fig. 8), obtained from trough and tabular cross-bedding, show considerable variation in sediment transport. A few of the locations show poly- and bi-modal distributions. Unit E1 has an average thickness of 15 metres.

Unit E2

This unit is capped by Coal No. 1 (Figs. 6 and 7) and is comprised of sub-equal amounts of sandstone and finer clastics. Characteristic sedimentary structures of this unit, especially in the Willow Creek and the northwestern parts of East Coulee areas, are flaser, wavy, lenticular and herringbone bedding and trough and tabular cross bedding. Lateral accretionary bedding can also be seen in the Willow Creek area (Fig. 6). This unit represents tidal channel, point bar, mud and sand flat facies. In the most southeasterly section (section EC4, Fig. 7) this unit is represented by an 8.5 metre thick barrier island complex sandstone. This barrier sandstone consists of five facies which are, in ascending order, 1.5 metres of thin bedded sandstone with minor shale, a two metre thick homogeneous sandstone with abundant Ophiomorpha burrows, a four metre thick flat bedded sandstone, a 0.7 metre thick wavy bedded sandstone with some plant and wood remains, and a 0.3 metre thick sandstone bed that caps this sandy unit containing abundant feeding burrows of Teichichnus and Rhizocorallium. The base of this barrier complex is an erosional surface over coal and highly carbonaceous shale. This transgressive surface can be traced northwestward to section EC5 (Fig. 2). In the Willow Creek area this unit exhibits a high degree of lateral continuity and lithological consistency. Maximum variation occurs in the southeastern half of the East Coulee area (Figs. 6 and 7). Paleocurrent directions, obtained from trough and tabular cross-bedding, show a polymodal distribution with a dominant flow towards the northeast (Fig. 11). Unit E2 has an average thickness of 12 metres.

Unit E3

Unit E3 is the thinnest unit recognized in this area, averaging about five metres. In the western portion of the Willow Creek area it is only two metres thick (Fig. 6). Shale, which is typically black colored near the top of the unit, predominates, but to the east and southeast, the unit becomes increasingly more arenaceous. Sandstones of these areas are considered to represent tidal channels and sand flats. In two places (section WC 2 of Fig. 6 and section EC7 of Fig. 7) this unit is abnormally thick, due to underlying scour of E2 unit (facies TMP of Figs. 6 and 7), forming mud-filled channels up to 8 metres deep and over 60 metres wide. In section EC7 (Fig. 7) the base of the channel fill is comprised of a 2 metre thick sandstone sequence.

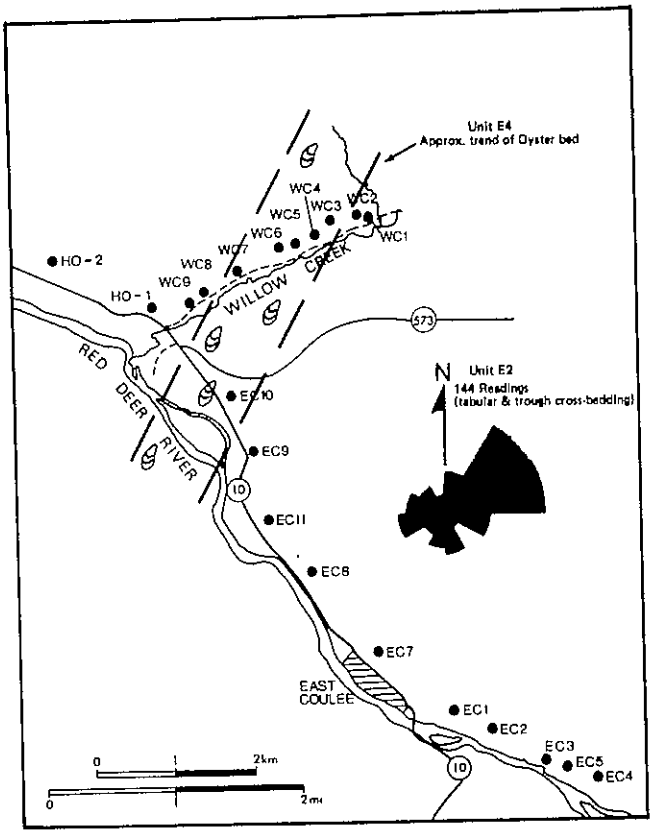

Fig. 11: Paleocurrents of Unit E2 and distribution of oyster bed of Unit E4.

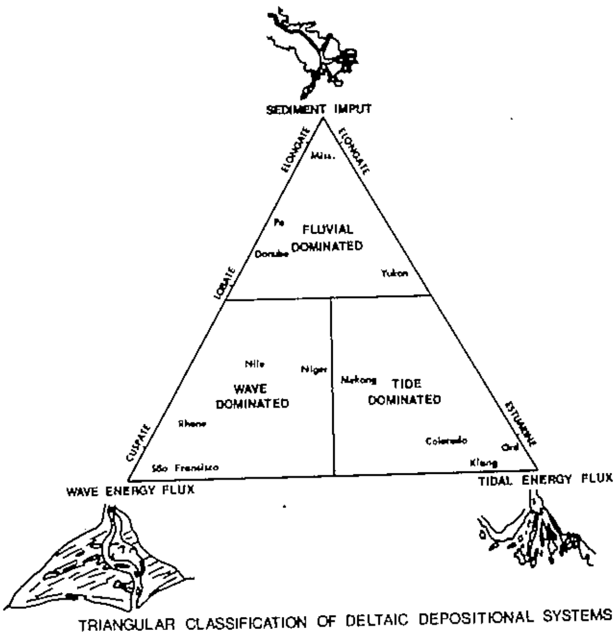

Fig. 12: Threefold division of deltas (modified after Galloway, 1975).

Unit E4

Sandstone is the predominant lithology on unit E4, especially in the East Coulee area (Fig. 7). Coal No. 2 which caps this unit attains a maximum measured thickness of 1.5 metres at section EC1, and is better developed in the East Coulee than in the Willow Creek area (Fig. 6 and 7). In the Willow Creek area this unit is comprised of sandy, silty, muddy tidal flats and channels with trough and tabular cross bedding, flaser, wavy and lenticular bedding. A prominant oyster bed up to 4 m maximum thickness, occurs within this unit in the Willow Creek area and pinches out one kilometre to the southeast of the mouth of Willow Creek (Fig. 6 and 7). In the easternmost portion of the Willow Creek area a sandy channel scours through the oyster bed and the underlying shale of unit E3 (Fig. 6) Glauconite is abundant in the oyster bed and underlying sandstones of this unit. Figure 11 portrays the outcrop configuration of the oyster bed. In the East Coulee area this unit consists of tidal channels, tidal flats and a barrier island complex. As can be seen in figure 7, tidal flat facies give way southeastward to tidal channels which in turn scour into and laterally (southeastward) interfinger with the barrier island complex. Coal No. 2 overlies the tidal flat and channel complex, and between EC3 and EC4 It rides over the landward portion of the barrier island complex (Fig. 7). Sandstone of the barrier island complex in section EC4 is trough and tabular cross bedded in its lower half and wavy to flat bedded in the upper half. The thin remnants of the barrier complex northwestward of EC4 (Fig. 7) are normally ripple cross laminated and occasionally contain herringbone cross lamination. The barrier complex sandstone exhibits, in its various parts, an abundant trace fossil assemblage of well-repserved burrows such as Ophiomorpha and various large sized (up to 40 cm in length and 15 cm in width) v-shaped and other burrows attributed to escaping and feeding activities of sea anemones. Within this barrier complex there exists at least one erosional transgressive surface represented by a burrowed beach sandstone resting abruptly on coal and/or highly carbonaceous shale. One such surface can be traced throughout the entire East Coulee area from section EC4 to EC10 (Fig. 7). Unit E4 average 12 metres in thickness.

Unit E5

Unit E5 forms the topmost unit in the study area, and it marks increased frequency of coal occurrence. Coal seams occur as part of the familiar cyclic channel-overbank-swamp (coal) succession, which tends to be dominated by inter-channel fine clastics. Point bar accretionary bedding is common in the sandstone of this unit. Marine palynomorphs and trace fossils are present at least in the lower 6 metres of this unit in the southeastern portion of East Coulee area (Fig. 7). Two shale samples from this unit, in section WC6 of Willow Creek area (Fig. 6) were found to contain continental palynomorphs. However, S.A.J. Pocock (personal comm., 1980) recovered significant quantities of microplankton (marine palynomorphs) from this unit in the Willow Creek area. Maximum thickness measured for this unit is 26 metres (section EC8, Fig. 7). In the Willow Creek area, the highest coal of this unit reaches a maximum thickness of 1.3 metres and averages around 85 cm.

DEPOSITIONAL ENVIRONMENTS

It was mentioned above that the author favors a tidally dominated delta model for the deposition of the Bearpaw-Horseshoe Canyon transitional sequence of the Drumheller area (Fig. 12). Evidence for this model stems primarily from the overall facies relationship, the tidal sedimentary structures and tidally interpreted paleocurrent system of units E1, E2 and E4 (Fig. 6, 7, 8 and 11). Unit E1 was probably deposited as channel fill and point bars of a meso- to macro-tidal estuary in an embayed coastline. Units E2 and E4 are considered to have been deposited in a mesotidal barrier island system, thus probably suggesting an upward decrease in tidal range overall from macro- to a mesotidal system. Such vertical evolution from macrotidal to a mesotidal regime can result from lateral migration of a mesotidal shoreline system over a macrotidal shoreline system in an embayed, regional shoreline. The head (apex) of the embayment shows tide-dominant features in contrast to the embayment outlet which is characterized by wave-dominant features (Hayes, 1979) (Fig. 13). There is no apparent reason why such an embayed shoreline could not have occurred in the study area

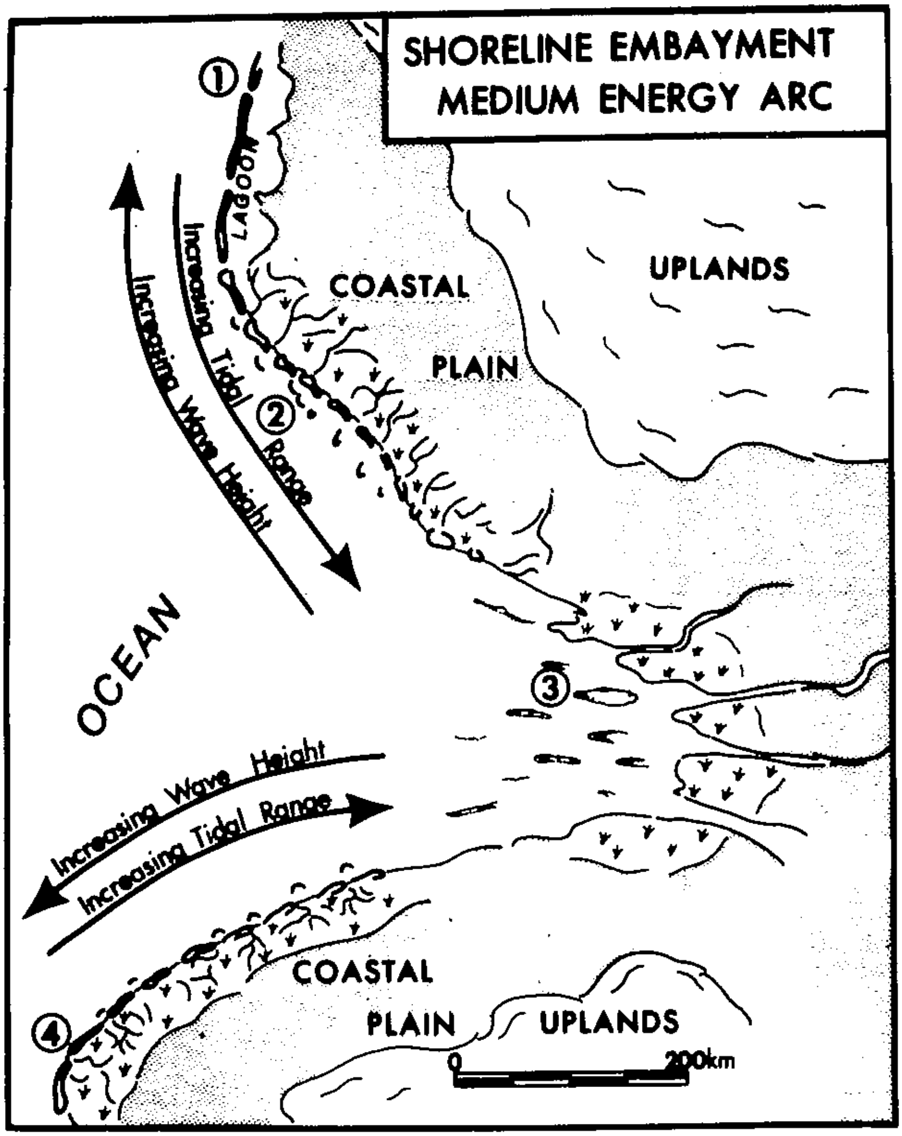

Fig. 13: Variation of shoreline morphology along an embayment in a hypothetical coastal plain shoreline with medium wave energy (after Hayes, 1979).

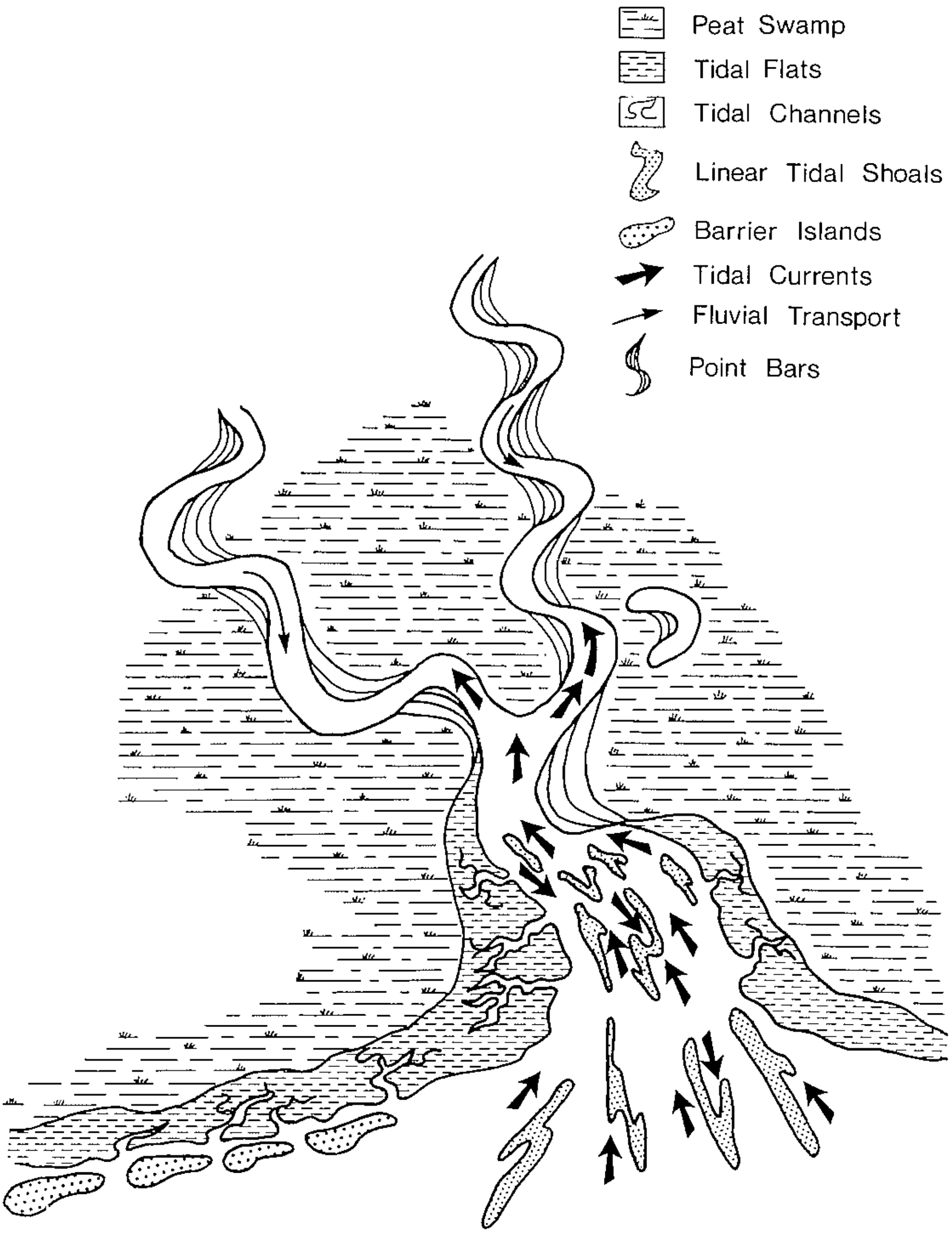

Fig. 14: Depositional paleoenvironments of the Bearpaw-Horseshoe Canyon transition. Drumheller, Alberta.

during the time of the Bearpaw-Horseshoe Canyon transition. The paleogeographic map of early Maastrichtian time suggests the presence of such an embayment in southern Alberta (Fig. 5).

Figures 9 and 10 are map and composite stratigraphic sections, respectively, of the Ord River Delta of western Australia, studied by Coleman (1976). Tidal range in this river estuary is 5.8 metres (i.e. macrotidal). According to Galloway's scheme (Fig. 12), this delta therefore is classified as a tidally dominated delta. The composite stratigraphic section bears a striking resemblance to BP-E1-E2 units of the fieldtrip section. Units 1 and 2 of the Ord River Delta (Fig. 10) can be matched, in type, with unit BP of the study area; units 3 and 4 match unit E1 and units 5 and 6 match unit E2. Due to the fact that the climate is arid in the area of the Ord River, salt flat deposits form in place of peat swamps (coal).

Figure 14 is a depositional model reconstructed from the facies relationships of the Bearpaw-Horseshoe transition of this study area. It depicts the various depositional settings of a tide-dominated delta and inter-deltaic mesotidal barrier system that is thought to have occurred during Campanian-Maastrichtian time in the Drumheller area. The basic elements of this model are a meandering distributary channel system entering a tidally dominated, embayed coastline and building up a delta sequence. The mouth of the main distributary channel is a funnel-shaped estuary outlined by wide expanses of tidal flats and channels and occupied and floored by migrating sandy bedforms (dunes and sandwaves perpendicular to shoreline and occasionally exposed as tidal shoals). Marginal to the estuarine mouth, the coastline was outlined by a mesotidal barrier island complex of beaches, backbeach tidal channels, flats and salt marshes, and tidal inlets. Peat-forming swamps were common in the lowlands surrounding the river-estuary system. Upstream of the estuarine mouth the distributary channels were meandering and bounded by point bars, levees and abandoned meanders (ox-bow). The following is a brief and somewhat tentative interpretation of depositional environment for each unit.

Unit BP

This unit, except for the sandstone at the base of section EC3, represents the marine portion of typical upward coarsening delta. Prodelta shale (PD) gradually gives way upward to distal mouth bar (MBD) shale, siltstone and very fine sandstone and then to the fine sandstone, siltstone and shale of the proximal mouth bar (MBP). In section WC8, and other locations, the mouth bar (delta front) exhibits downslope gravity and fluid escape deformational features so common in many delta front facies. The channel sandstone at the base of section EC3 possibly represents the shoreface facies of an offshore bar.

Unit E1

The basal sandstone of this unit (DC) represents sand deposited in a distributary channel-estuarine complex of tidally dominated delta (Fig. 14). The paleocurrent pattern (Fig. 8) suggests that its northern portion was deposited in the most landward reaches of a flood-dominated meandering distributary tidal channel. Central and southern poritions of the sandstone may have been deposited near the mouth of the distributary tidal channel, as suggested by its complex paleocurrent pattern. A lateral shift of the distributary channel system and/or seaward progradation of the delta was followed by the expansion of peat-forming swamps that deposited Coal No. 0.

Unit E2

Throughout most of the study area this unit was deposited as tidal flats and channels in belts oriented east-northeast to west-southwest as suggested by geometry, facies relationshps and paleocurrent directions (Fig. 11). These tidal flats and channels in turn give way south to southeastward to barrier island environments (Fig. 14) of shoreface to beach and back-beach facies. The occurrence of these sediments above a coal seam (No. 0) suggest a transgression of the sea over the peat-swamps terminating peat formation. Such a transgression could have been formed by the foundering of the deltaic sediments underneath the swamps caused by the compaction of the fine-grained sediments. Coal seam No. 1 indicates that a peat-forming swamp prograded southeastward over the tidal and back-barrier environments. The paleocurrent pattern (Fig. 11) obtained from this unit suggests that the tidal channels flowed in an east-northeast to west-southwest direction, with the former being the dominant tidal current behind the barrier islands. Such a facies geometry is very similar to that found in mesotidal barrier island systems of South Carolina (Hayes and Kana, 1976).

Unit E3

This unit represents deposition of shale in a bay/lagoon setting flanked by sandy and muddy tidal flats and minor sandy channels. This situation is also reminiscent of a mesotidal shoreline setting. The eight metres deep, essentially mud-filled channels could have been the product of the abandonment of large tidal channels that represent the landward extension of tidal inlets. Dimensions, depths, and nature of fill of Unit E3 mud-filled channels are similar to modern abandoned inlet fills described by Tye (1981) from the barrier island system of South Carolina. The barrier facies, predicted from the interpretation, does not outcrop in the area. Deposition of the shoreline unit immediately above Coal No. 1 suggest another stage of landward transgression of sea water over peat-forming swamps.

Unit E 4

As with E2, this unit comprises facies relationships which resemble those of modern mesotidal barrier island complexes. Barrier island sediments (as in sections EC4 and EC3) grade landwards, that is northwestwards, into tidal channel and flat sediments, all of which are abruptly underlain by swamp and marsh sediments throughout most of the East Coulee area. In turn, these interfinger further landwards with oyster beds which suggests passage from barrier islands to back-barrier tidal and open bay/lagoonal environments. Abundant glauconite in this unit further supports its marine origin. Facies relationships of this unit in the East Coulee area (Fig. 7) suggest that an initial rapid northwestward transgression of the sea was followed by southeastward progradation of the tidal flats and channels over the barrier island complex, partly by seaward migration of back-barrier tidal channels in a manner similar to that portrayed by Land

(1972, Figs. 33 and 34). Similar seaward progradation of peat swamps was responsible for Coal No. 2 at the top of this unit. The fact that this seam is, in some places, poorly developed to absent, attests to the discontinuity of peat swamps behind the barrier-bay complex.

Unit E5

Interpretation of this unit awaits further paleontological analysis. Tentatively, however, the author is inclined to believe that in the northern part of the study area this unit was deposited in the upper to lower delta plain, with meandering fluvial channels responsible for the observed cyclicity of channel-levee-coal swamp environments. Southeastwards, this unit contains marine beds in its lowermost 6 metres, indicating a prevalence of marine conditions in the southeast.

GUIDE TO FIELDTRIP STOPS

Introduction

Figure 2 shows locations of measured stratigraphic sections in the fieldtrip area. Locations of only those sections used to construct the fence diagrams of the Willow Creek and East Coulee areas (Figs. 6 and 7) are shown in figure 3.

During the first day of the fieldtrip we will examine four or five of the East Coulee sections. On the second day we will make six stops to examine sections in the Willow Creek area. Other, shorter stops will also be made to look at some isolated features of interest.

In the East Coulee area, discrete stops will be made at selected sections (sections prefixed EC) and no attempt will be made at walking between sections for reasons of highway safety. Access to the Willow Creek area is provided by a single-lane dirt road travelled only by local farmers. There will, therefore, be an ample opportunity to walk along most if not all, of the road (approximately 3 km) and observe the correlation of extremely well exposed rocks.

The following descriptions of stops are kept brief and are not intended to be an exhaustive description of each bed in each section. Only those features critical to the interpretation of the various facies are outlined.

A few features are common to most of the stops and their facies and will not be discussed in each stop description. These are: (1) carbonaceous hash and carbonized plant remains which seem to occur throughout most facies, except for the beach complex; (2) plant roots which are prevalent in lithologies underlying coal beds; and (3) ironstone concretions and iron-cemented (mostly sideritic) beds present throughout the section, but especially so in fine-grained, coal-bearing zones.

East Coulee Area

Eight kilometres of continuous valley wall exposures will be examined in this area in five stops (Figs. 2, 3 & 7). Features to be studied in each stop are outlined below.

Stop 1 (Section EC4)

a. Unit BP exhibits a typical upward coarsening delta sequence, from prodelta muds (PD) up through distal and proximal distributary mouth bar deposits (MBD, MBP) of the delta front (Figs. 7 and 15). Amount and grain size of the sandstone increases upwards. Note small grazing and feeding burrows, as well as thin zones of abundant comminuted, carbonized plant debris.

b. Five to six metres of distributary channel sandstone (DC) of unit E1 (Fig. 7). It overlies the proximal mouth bar (MBP) and exhibits trough cross stratification. The coal seam that caps unit E1 is approximately 70 cm thick.

c. The basal three metres of unit E2 are mostly shale and silty shale with abundant plant remains and a few very thin coal and argillaceous coal beds which originated in a marsh to lagoonal environment. Overlying this argillaceous interval, and with sharp contact (transgressive surface), is a 8.5 m thick fine- to medium-grained sandstone (Fig. 7). This sandstone is thinly to medium bedded in its lower part (lower shoreface) grading upward to a structureless 1.5 m thick interval with abundant Ophiomorpha burrows (middle shoreface) (Figs. 16 and 17). The upper 4 metres of this sandstone exhibit flat, thin stratification (upper shoreface and foreshore) throughout most of its thickness. It contains some leaf imprints and abundant sprieten-bearing burrows (e.g. Teichichnus) in the uppermost 1 metre (protected back-beach). Overlying the sandstone is a marine dark gray shale (open bay/lagoon) interval that together with the overlying unit E3 forms, in this section, one continuous argillaceous sequence. The sharp, and perhaps erosional, contact between the argillaceous/coaly deposits and the overlying prograding beach complex sandstone near the base of unit E2 suggests an erosional unconformity caused by transgression of marine deposits over marginal marsh environments Fig. 7). This erosional, transgressive surface can be traced northwestward to section EC5 (Fig. 2).

d. Unit E3 is 5 m thick, consists of dark gray shale at its base and rooted, fine-grained sandstone above, capped with a 10 cm coal seam. This sequence indicates shallowing from the previous beach-bay to marsh/swamp environment.

e. Unit E4 overlies E3 with a sharp, erosional (transgressive) contact. This transgression can be traced northwestward to section EC10 (Fig. 7). It also exhibits features of a prograding barrier beach complex. Its lower 2 m are characterized by fine-grained, thinly bedded, fine-grained sandstone (lower shoreface) followed by an 8 m interval of cross-stratified, fine to medium grained sandstone containing Ophiomorpha burrows (middle and upper shoreface, Figs. 18 and 19). The top 6 m of unit E4 consists of fine-grained sandstone exhibiting flat and wavey stratification as well as isolated scour surfaces and ripples (foreshore; Fig. 20).

Stop 2 (Section EC3)

a. At the base of unit BP is a 4 m fining upward sandstone showing trough cross stratification and hummocky stratification. This is interpreted as a submerged offshore bar.

b. The distributary channel (DC) of unit E1, comprised of medium-grained sandstone, displays well preserved cross stratification with clay pebble conglomerate (Fig. 21).

c. The back-barrier facies of unit E2 comprises shale of lagoonal environment overlain by interbedded sandstone and shale with scoured surfaces, small scale tabular cross-lamination, ripple lamination and clay pebble lag. This sandy portion shows a gently southeastward dipping depositional surface as viewed from across the valley. It could represent a splay deposit advancing from the land onto the lagoon.

d. Unit E3 consists of tidal channel sandstone overlain by shale, siltstone and thin coal of marsh and swamp environments.

e. Unit E4 in this section consists of interfingering barrier beach and back barrier tidal channels. As in section EC4, the base of unit E4 is sharp (erosional?) overlying a back-barrier environment. This arrangement of facies indicates a local transgression.

Coal bed No. 2 is not well developed in this section. Instead it is replaced by a few very thin beds of highly argillaceous coal.

Stop 3 (Section EC1, Fig. 22).

a. The angular, discordant, relationship between the distal mouth bar (MBD) of unit BP and the overlying distributary channel (DC) of unit E1 is well exposed in this stop (Fig. 23).

b. Coal No. 0 contains thin discontinuous streaks of bentonite. Note the rooting in underlying brown to grayish brown shale.

c. Unit E4 starts at the base with a thin remnant of barrier beach deposits with Ophiomorpha and is overlain by a tidal channel/flat complex.

d. Coal No. 2 is nearly 1.5 m thick. Note rooting in underlying lithologies also.

e. Near the base of unit E4 there is a 1.2 m thick, upward coarsening, heavily burrowed sandstone bed. It represents transgression of a beach over back-beach swamps.

Coal seams No. 0, 1 and 2 were mined in this area on the southwest side of the Red Deer River. An abandoned mine can be seen across the valley from this stop.

Stop 4 (Section EC7). The main features of this section are:

a. Unit E1 is represented by the proximal mouth bar facies (MBP). The absence of distributary channel facies (DC) points to this area being remote from active distributary channels.

b. An abandoned tidal inlet mud plug (TMP) is conspicuous in this area. Note the thin active fill at its base represented by medium to coarse sandstone containing traces of glauconite and fragments of flat coal chips. The remainder of the fill is mainly light brown shale. This channel fill is synchronous with the deposition of unit E3. The channel completely scours through unit E2 and rests sharply over Coal No. 0 (Fig. 24).

c. The barrier beach of unit E4 contains abundant *Ophiomorpha* burrows on the northwest side of the stop, but gradually gives way southeastward to very large (40 cm long), vertical V-shaped burrows and other traces that are believed to have been formed by sea anemones. This burrowed bed is overlain by a tidal channel showing typical upward fining, and at its top, Coal No. 2 is 1 m thick. An in situ silicified tree trunk and stump can be seen embedded in the coal seam.

Stop 5 (Section EC9). Three features will be looked at in this stop.

a. The distributary channel (DC) of unit E1 contains very well-preserved large-scale trough cross-bedding. Also note the scoured surface between DC and underlying proximal mouth bar (MBP).

b. The tidal deposits of unit E2. Flaser, lenticular, wavey bedding and herringbone cross-stratification (Fig. 25) are present.

c. The barrier beach facies of unit E4 contains the best preserved and most abundant concentration of *Ophiomorpha* of this area. The *Ophiomorpha* bed is underlain by a 25 cm thick sandstone bed with abundant millimetre size, bedding plane burrows, probably *Palaeophycus*.

Willow Creek Area

We will walk this nearly 3 km long valley wall of continuous exposures and make several stops to examine various features (Figs. 2, 3 and 6). The valley is oriented approximately parallel to the ancient shoreline, therefore the facies here show remarkable lateral continuity when compared to their discontinuous nature in the East Coulee area (Figs. 6 and 7).

The following stops' descriptions are kept brief due to the fact that almost all the facies have already been described in the East Coulee area stops.

Stop 1 (Sections WC1 and WC2). These are very closely spaced sections, the lower part of which contain multiple channel scouring. In sections WC1 and WC2 we will examine the following:

a. The tidal channel of unit E2. It comprises fine-grained sandstone with trough and tabular cross-stratification. It also contains wavey, lenticular and flaser bedding.

b. Channel cross-stratification in unit E4 which forms concave layers parallel to the channel bottom. The channel bed is scoured below the usual base of unit E4 and pinches out westward of section WC2 (Fig. 6).

c. The abandoned tidal inlet mud plug (TMP) at base of section WC2. This fill is mainly argillaceous, interbedded with thin beds of siltstone and very fine-grained sandstone.

Stop 2 (Section WC3). The following facies will be closely examined:

a. Unit E2 tidal point bar, channels and flats.

b. Silicified, in-place tree stumps associated with Coal No. 1 (Fig. 26).

c. Unit E3 black shale and associated sediments.

d. Unit E4 oyster bed and associated glauconitic sediments.

e. The mostly fine grained, and coaly lower to upper delta plain sediments of unit E5.

<u>Stop 3 (Section WC4).</u>

a. Several types of tidal bedding structures in unit E2 (Fig. 27).

b. Bentonite bed in black shale of unit E3 (Fig. 28).

c. Broken oysters forming a channel lag at base of unit E4 (Fig. 29).

<u>Stop 4 (Section WC8).</u>

a. Soft sediment deformation in delta front (mouth bar) sediments of unit BP (Fig. 30).

b. Burrowing in the delta front (mouth bar) sediments of unit BP.

c. Bedding types and structures of a tidal channel point bar of Unit E1.

d. Point bar bedding of thin fluvial channels and overlying coal of unit E5 (Fig. 31).

<u>Stop 5 (Section WC9).</u>

a. Feeding burrows in the delta front sediments of unit BP.

b. Excellent exposures of tidal channel point bar, showing accretion bedding, multiple scour and pieces of overbank slump blocks (Fig. 32) in unit E1.

Stop 6 (Section HO-2). At this stop a mud-filled channel (Fig. 33) is scoured into and interfingering with channel sandstone of unit El. This mud-filled channel is believed to have formed by the same channelling episode that formed the point bar of WC8 and WC9.

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REFERENCES

Coleman, J.M. (1976): Deltas, processes of deposition and models for exploration; Continuing Education Publication Company, Inc., Champaign, IL, 102 p.

Dörjes, J. and Howard, J.D. (1975): Fluvial-marine transition indicators in an estuarine environment, Ogeechee River-Ossabaw Sound; Senckenbergiana Maritima, Vol. 7, p. 137-179

Galloway, W.E. (1975): Process framework for describing the morphologic and stratigraphic evolution of deltaic depositional systems; in Deltas, models for exploration, M.L. Broussard, ed., Houston Geological Society, p. 87-98.

Greer, S.A. (1975): Sandbody geometry and sedimentary facies at the estuary-marine transition zone, Ossabaw Sound, Georgia: a stratigraphic model; Senckenbergiana Maritima, Vol. 7, p. 105-136

Hayes, M.O. (1979): Barrier island morphology as a function of tidal and wave regime; in Barrier islands, S.P. Leatherman, ed , Academic Press, p. 1-27.

Hayes, M.O. and Kana, T.W., eds. (1976): Terrigenous clastic depositional environments; Technical Report No. 11-CRD, Coastal Research Division, Department of Geology, University of South Carolina, Columbia, S.C., 302 p.

Howard, J.D., Elders, C.A. and Heinbokel, J.F. (1975): Animal-sediment relationships in estuarine point bar deposits, Ogeechee River-Ossabaw Sound, Georgia; Senckenbergiana Maritima, Vol. 7, p. 181-203.

Land, C.B. Jr. (1972): Stratigraphy of Fox Hills sandstone and associated formations, Rock Springs Uplift and Wamsutter Arch area, Sweetwater County, Wyoming: A shoreline-estuary sandstone model for the Late Cretaceous; Quarterly of the Colorado School of Mines, Vol. 67, No. 2, 69 p.

Shepheard, W.W. and Hills, L.V. (1970): Depositional environments, Bearpaw-Horseshoe Canyon (Upper Cretaceous) transition zone, Drumheller "Badlands", Alberta; Bulletin Canadian Petroleum Geology, Vol. 18, no. 2, p. 166-215.

Shepheard, W.W. and Hills, L.V. (1979): Upper Cretaceous: Drumheller "Badlands", Alberta; C.S.P.G. Field Trip Guide, May 26, 1979, 4 text pages + 6 figures.

Tye, R.S. (1981): Geomorphic evolution and stratigraphic framework of Price and Capers Inlets, South Carolina. Unpubl. M.Sc. thesis, University of South Carolina, 144 p.

Williams, G.D., and Stelck, C.R. (1975): Speculations on the Cretaceous paleogeography of North America; in The Cretaceous System in the Western Interior of North America, W.G.E. Caldwell, ed.; The Geological Association of Canada, Spec. Paper no. 13, p. 1-20.

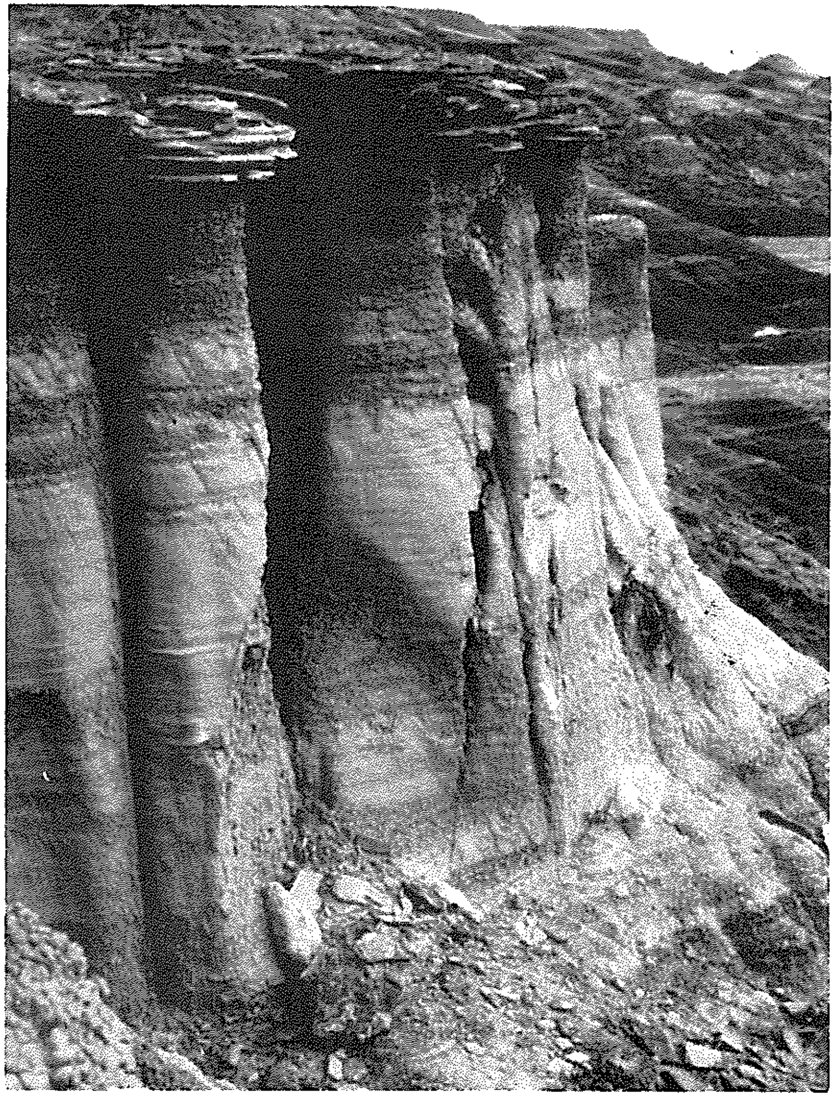


Fig. 15: Flat bedded, fine to medium grained sandstone of the proximal distributary mouth bar facies (MBP). Section EC4. Total exposed section is 3 metres thick.

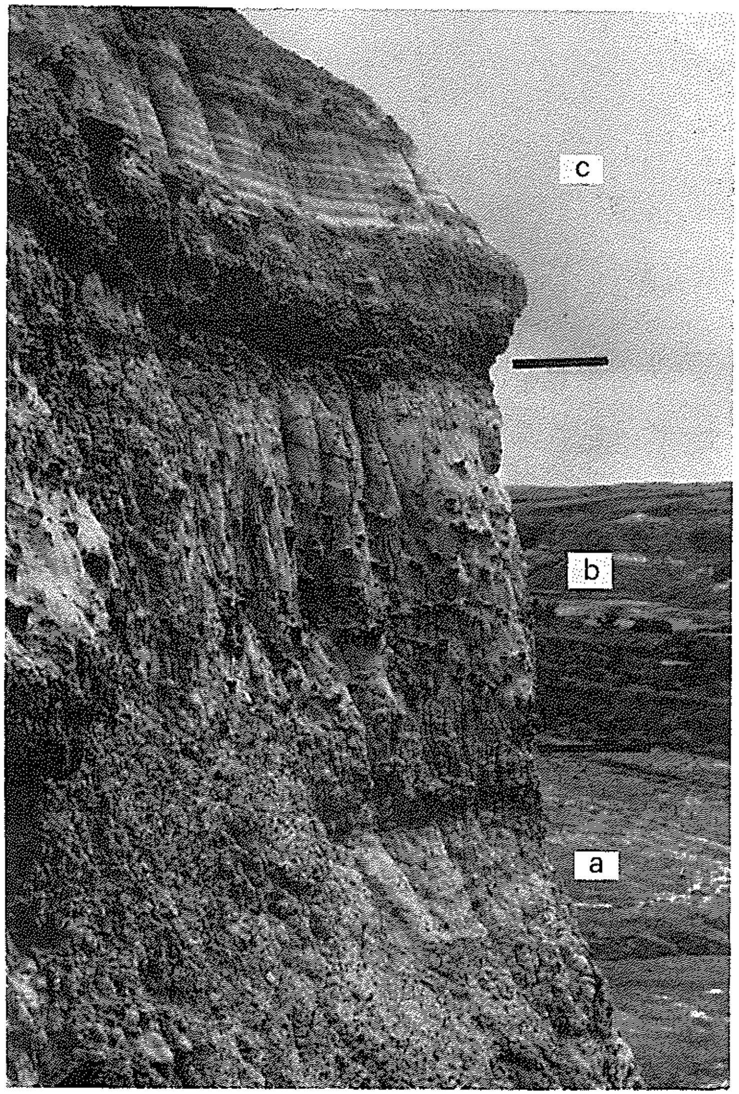


Fig. 16: Prograding barrier beach of unit E2, section EC4. (a) lower shoreface, (b) middle shoreface with Ophiomorpha burrows, and (c) upper shoreface and foreshore. For scale, interval b is 1.5 metre thick.

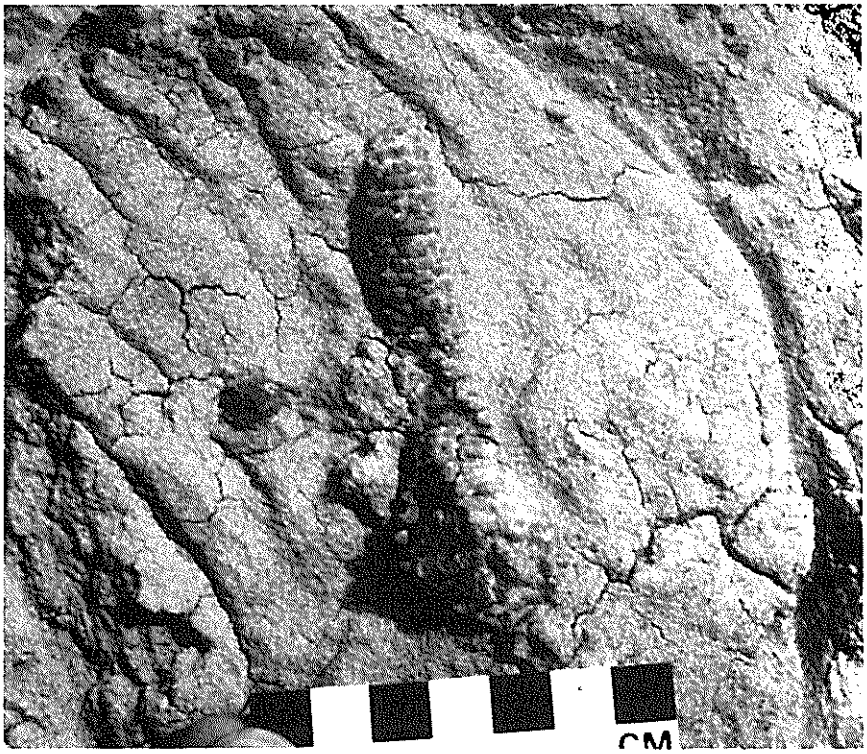


Fig. 17: Close-up of an Ophiomorpha burrow from middle shoreface of Fig. 16.

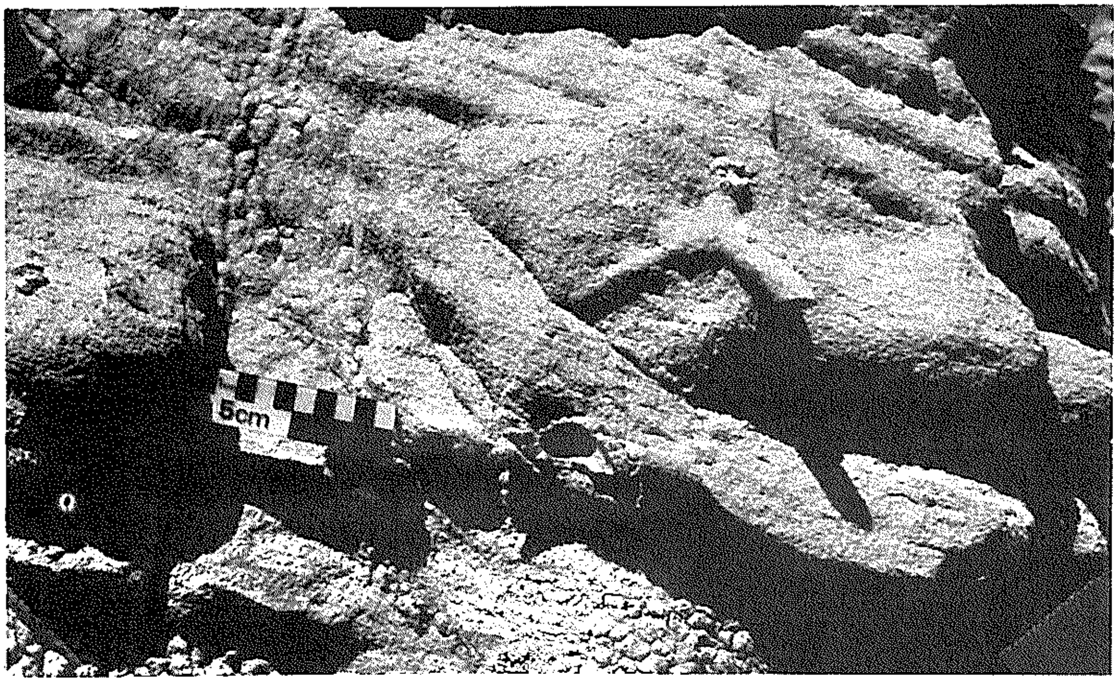


Fig. 18: Branching Ophiomorpha burrow in tabular cross-stratified middle to upper shoreface sandstone. Unit E4, section EC4.

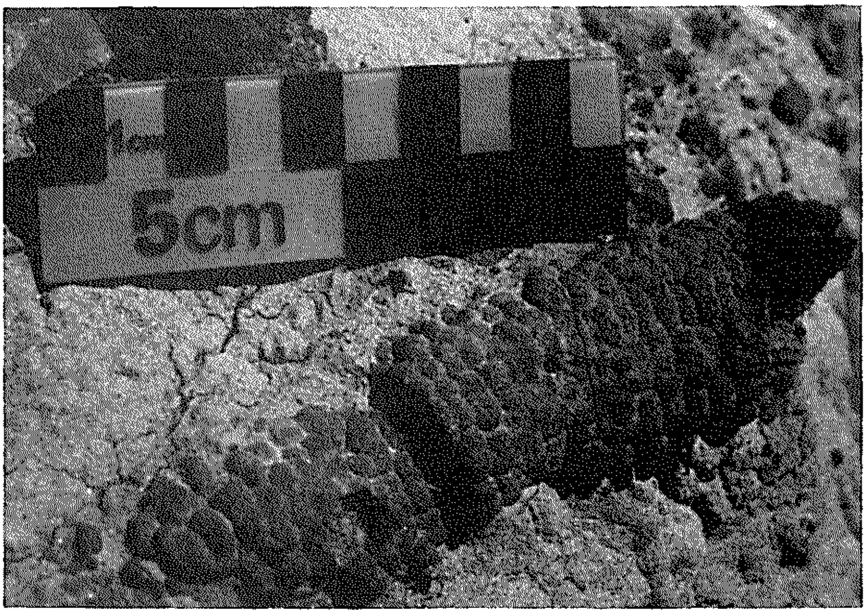


Fig. 19: A close-up of a corn-cob shaped Ophiomorpha burrow of middle to upper shoreface sandstone. Unit E4, section EC4.

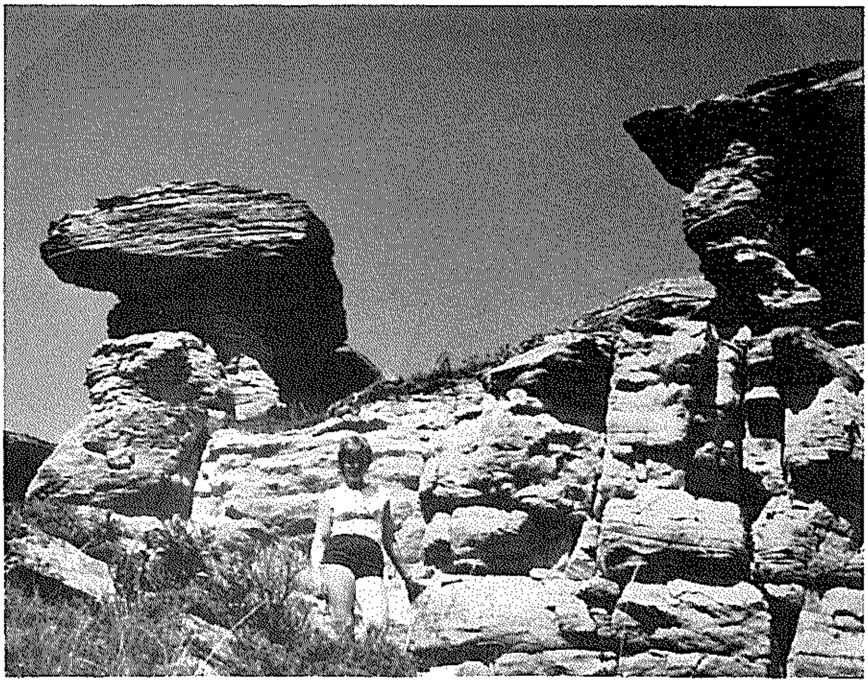


Fig. 20: Sandstone of the foreshore facies. Top of unit E4, section EC4.

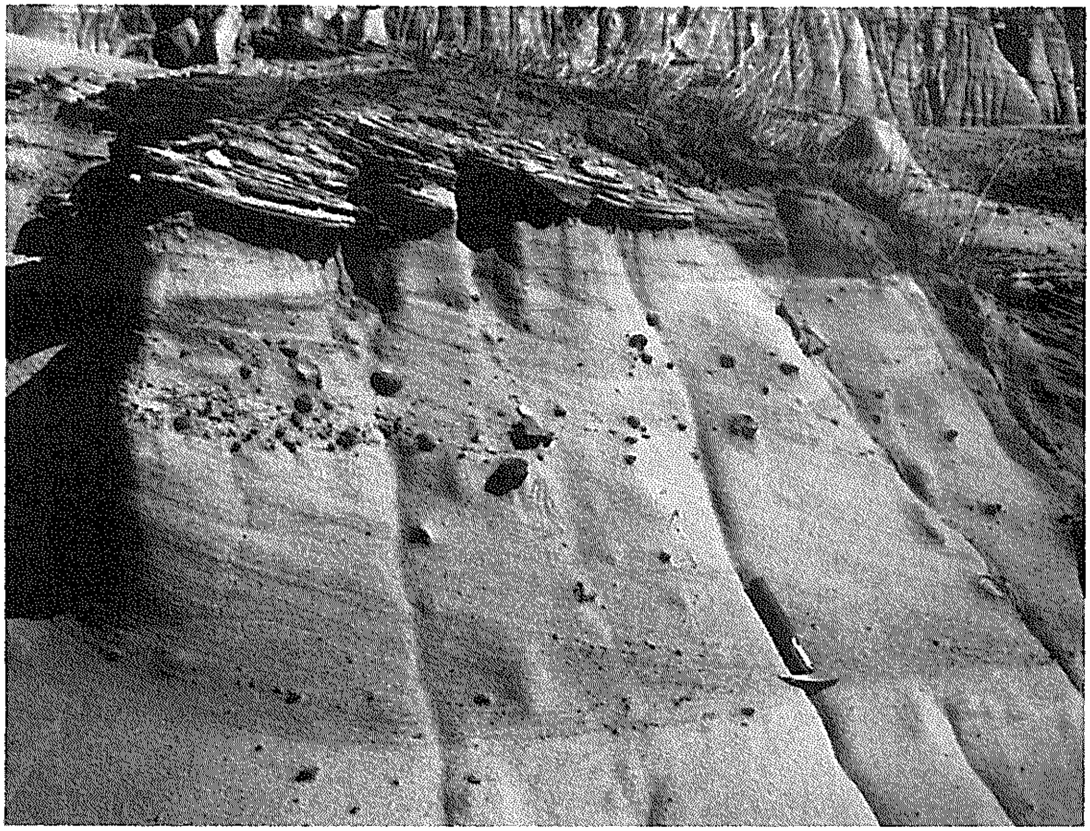
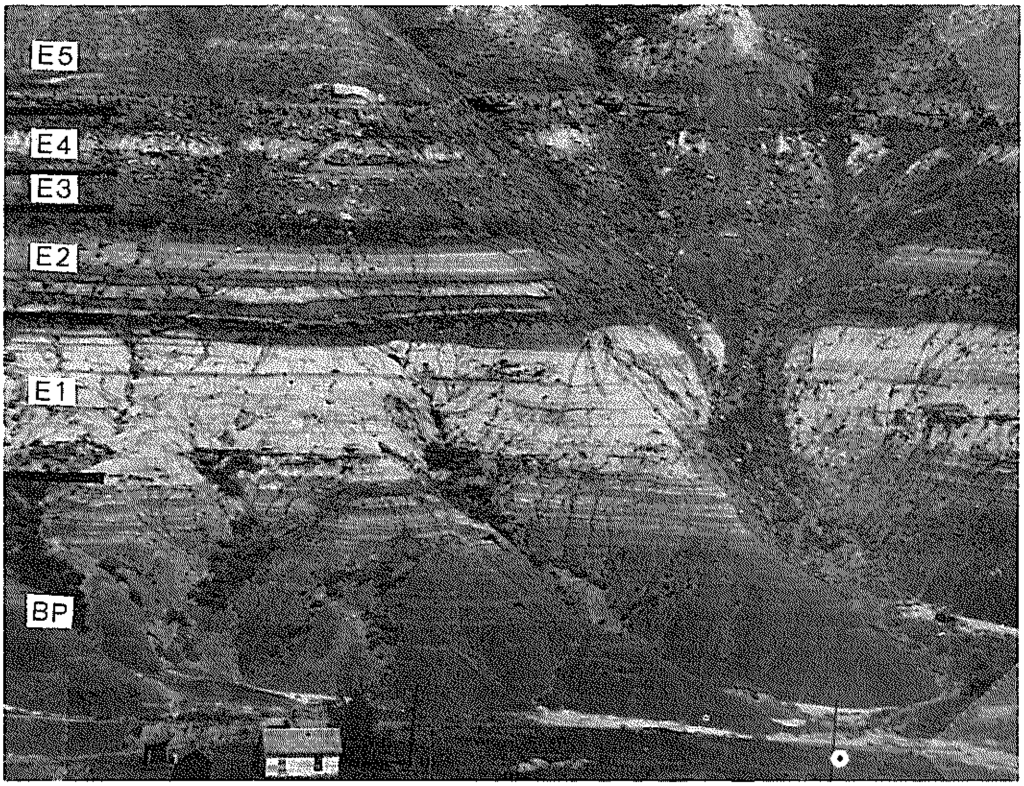


Fig. 21: Trough cross-stratification with clay pebble conglomerate of the distributary channel. Unit E1, section EC8.



22: General view of section EC1 (Stop 3), showing the 6 units.

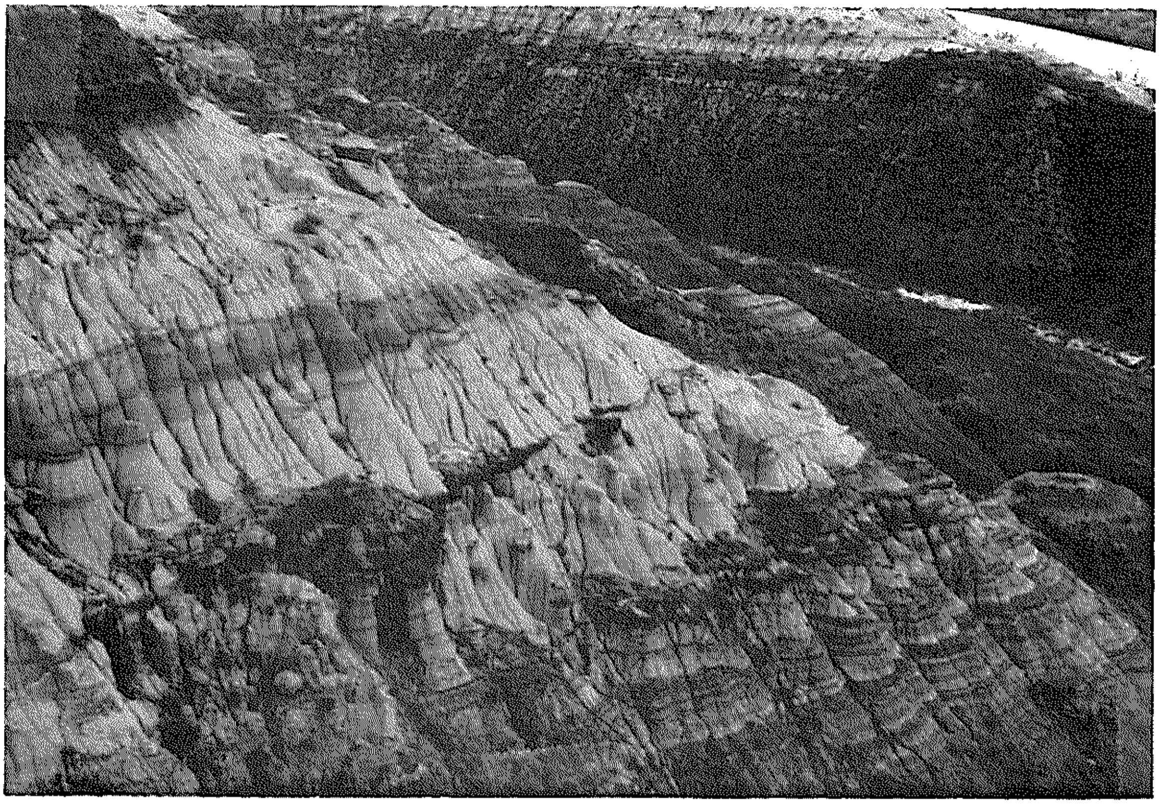


Fig. 23: Distributary channel sandstone (DC) erosionally and discordantly overlying rhythmically stratified distal mouth bar sediments (MBD). Units BP and E1, section EC1.

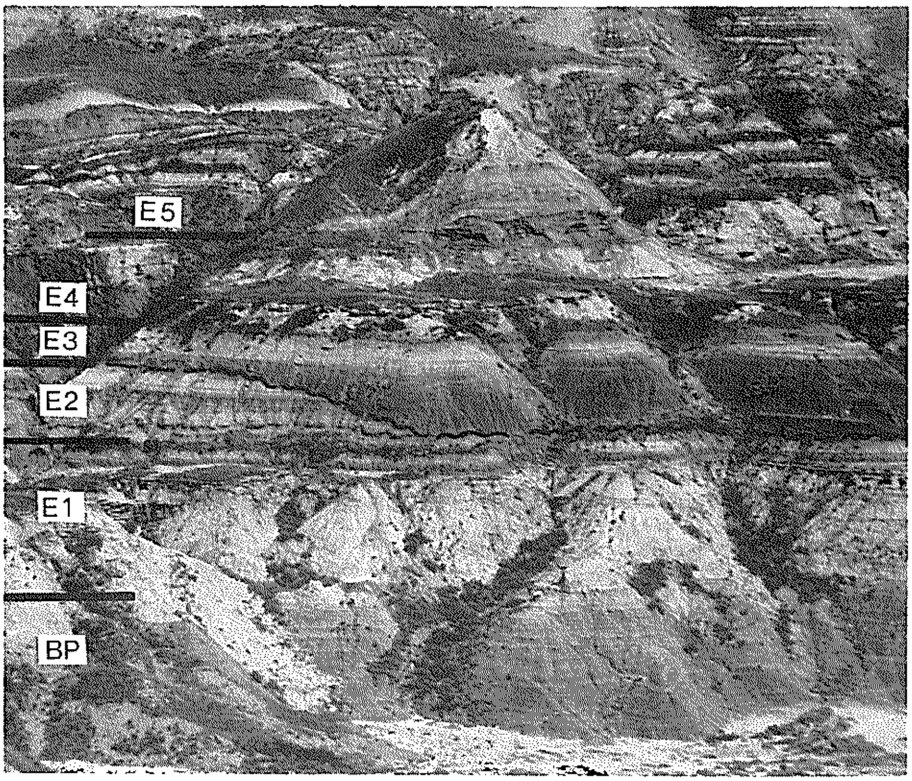


Fig. 24: Tidal mud-filled channel (TMP) of unit E3 eroding down through unit E2. Section EC7.

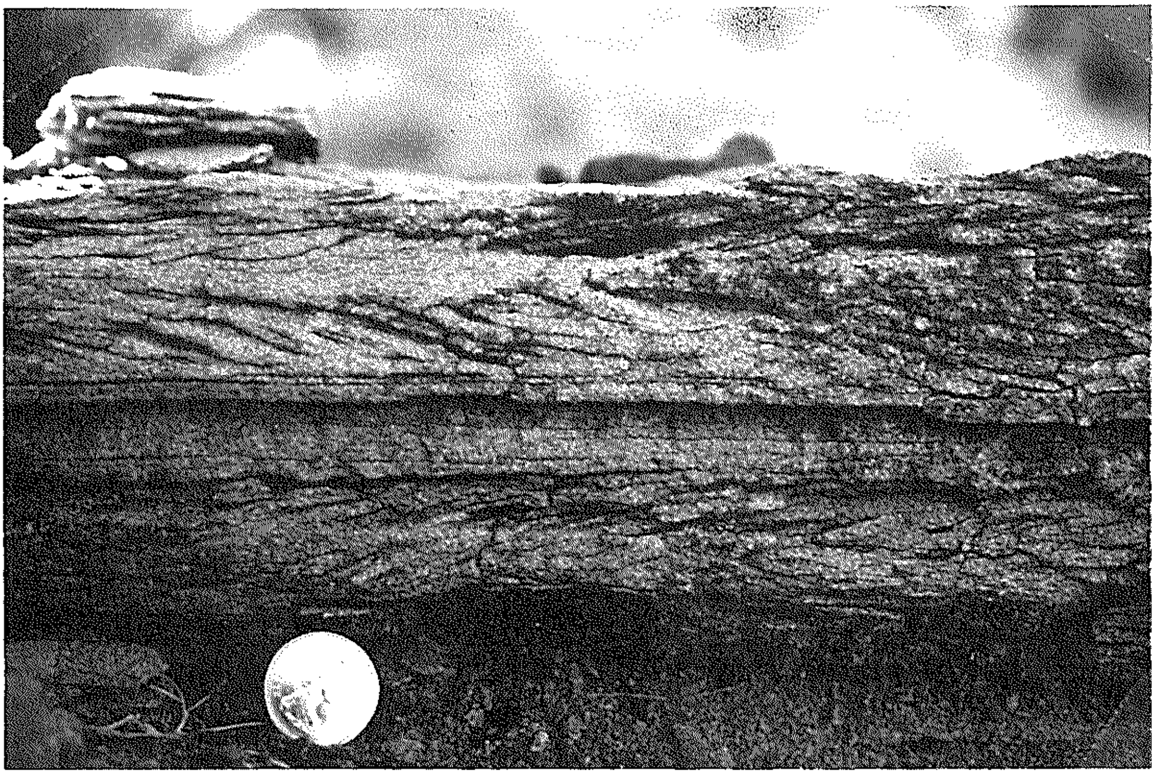


Fig. 25: Herringbone cross-lamination in tidal deposits of unit E2, section EC9.

Fig. 26: In situ silicified tree stump resting on top of Coal No. 1, section WC3.

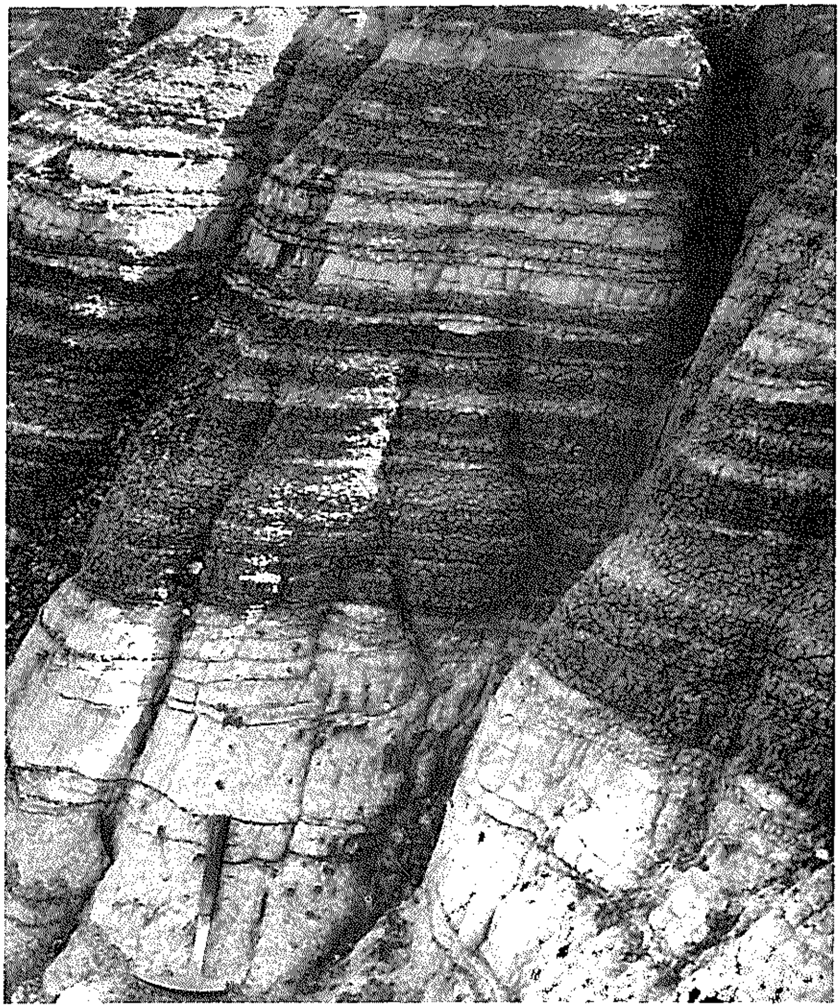


Fig. 27: Tidal bedding. Unit E2, section WC4.

Fig. 28: Bentonite bed enclosed by black shale. Unit E3, section WC4.

Fig. 29: Broken and whole oyster shells in glauconitic sandstone (unit E4) resting with a sharp erosional contact over black shale (unit E3).

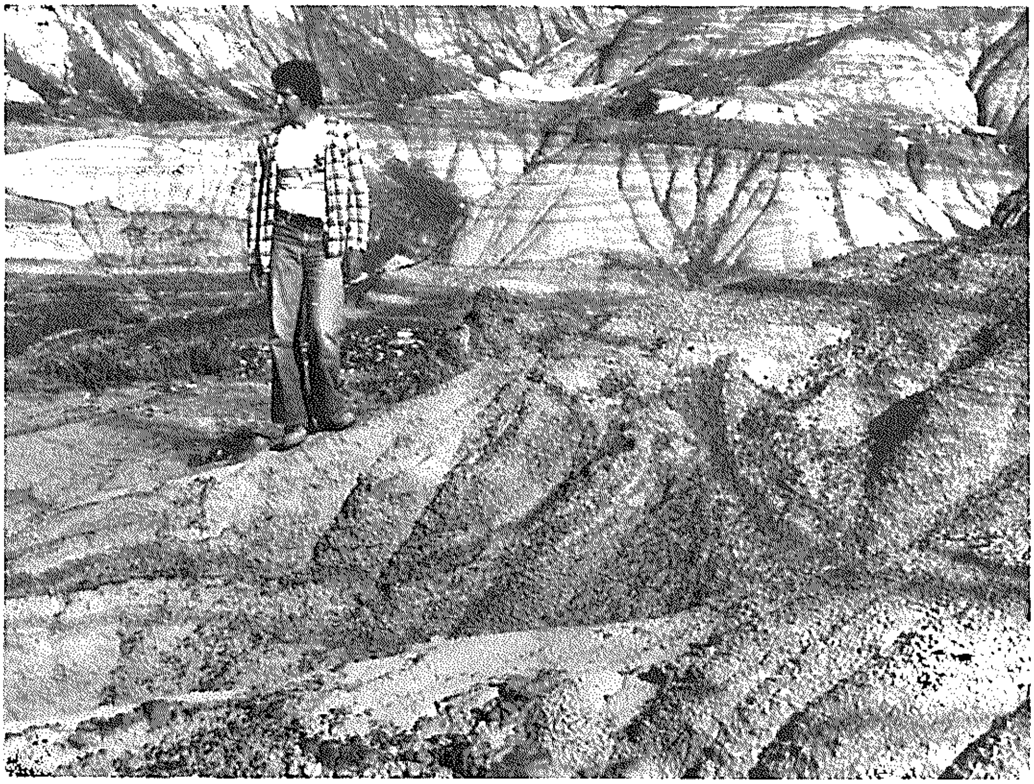


Fig. 30: Distributary mouth bar (delta front) sediments showing deformational structures (foreground) and inclined bedding (background). Unit BP, section WC8.

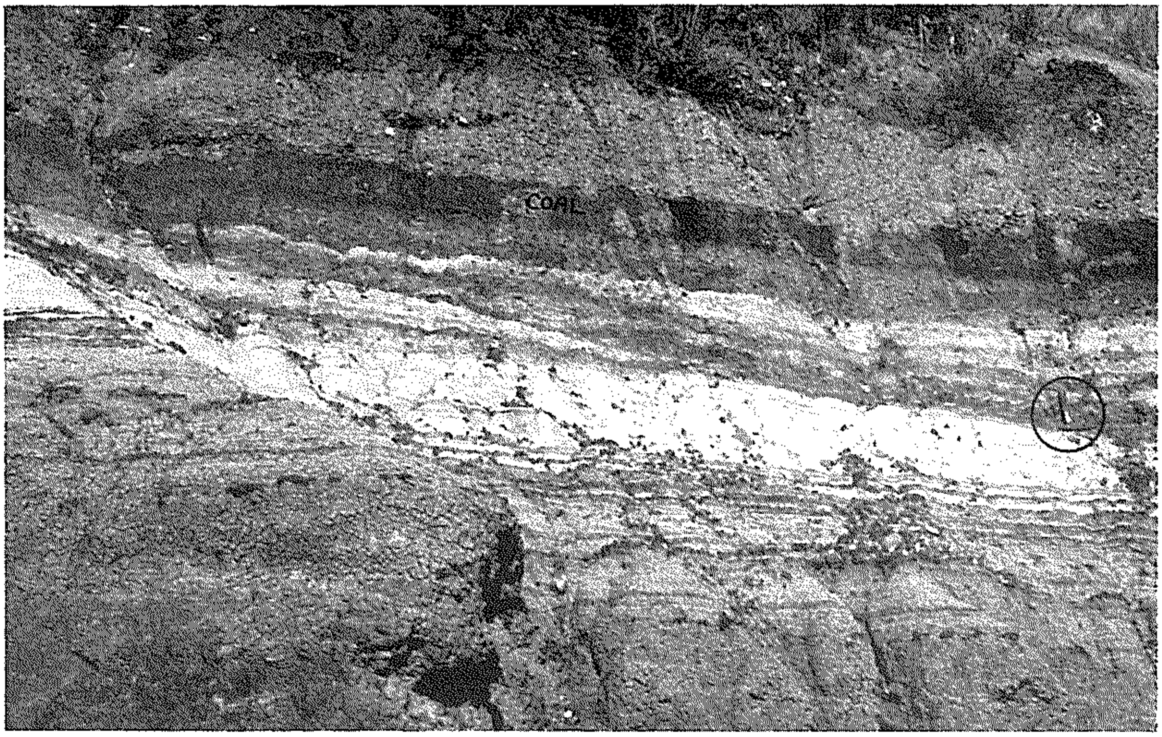


Fig. 31: Point bar sandstone (white) with accretion bedding showing undercutting (accretion towards the right side) and overlain by a coal bed. Circled hammer for a scale. Unit E5, section WC8.

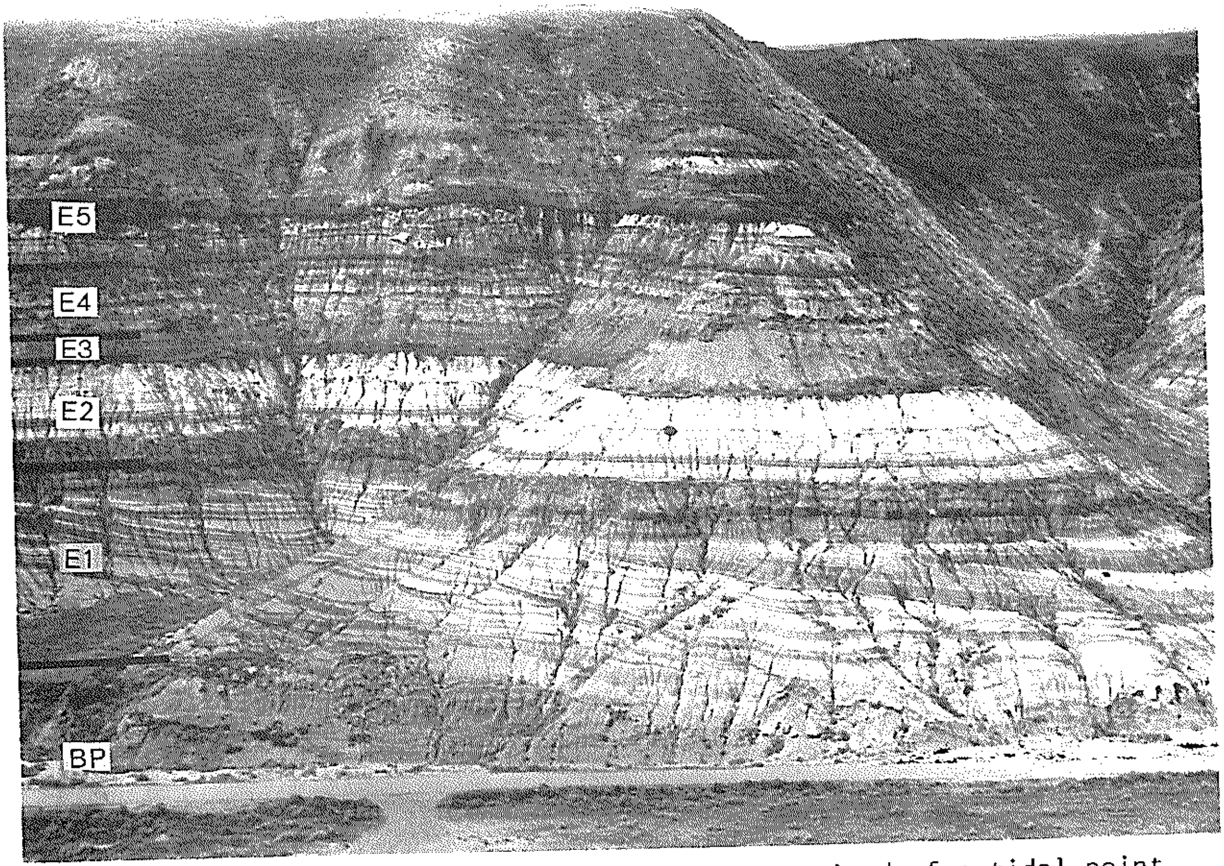


Fig. 32: General view of section WC9. Unit E1 comprised of a tidal point bar with accretion bedding migrating towards the right side and showing multiple scouring. Compare with Fig. 6 for scale.

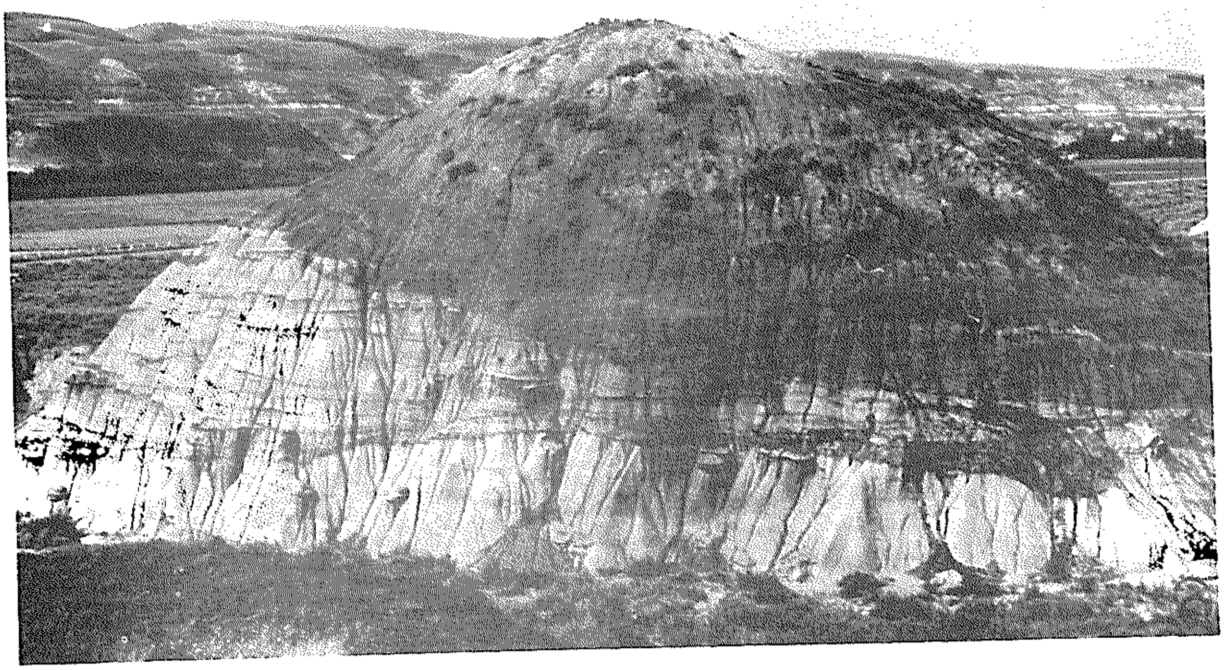


Fig. 33: Mud filled channel scoured in trough cross-stratified channel sandstone of unit E1. The knoll is approximately 7 metres high.