GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 76-35

UPPER CRETACEOUS AND TERTIARY COAL-BEARING STRATA IN THE DRUMHELLER-ARDLEY REGION, RED DEER RIVER VALLEY, ALBERTA

D.W. GIBSON

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

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Printing and Publishing
Supply and Services Canada,
Ottawa, Canada K1A 0S9,

from the Geological Survey of Canada
601 Booth St., Ottawa, K1A 0E8

or through your bookseller.

Catalogue No. M44-76/35	Price: Canada: $3.50
ISBN - 0-660-00815-7	Other Countries: $4.20

Price subject to change without notice

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ABSTRACT

This paper provides detailed information on the character, distribution, and stratigraphic relationships of part of the Upper Cretaceous-Tertiary rock succession along a section of the Red Deer River valley area (East Coulée to Ardley) of Alberta.

The strata comprise a variable sequence of mainly nonmarine sandstone, siltstone, mudstone, claystone, shale and coal, which can be subdivided readily into five formations. These are, in ascending order, the Horseshoe Canyon, Whitemud, Battle, Scollard, and Paskapoo. The Scollard Formation, formerly designated as a member of the Paskapoo Formation, is herein elevated to formational rank, and reinterpreted as a new formation of the Edmonton Group.

Fifteen major coal seams are recognized within the rock succession in the report-area, and detailed information is provided on their thickness, distribution, and continuity.

The strata comprise part of an eastward-thinning wedge of fluvial-deltaic sediments that were transported and deposited mainly by a system of large and small braided streams along the western margin of the Bearpaw Sea.

RÉSUMÉ

Cette étude fournit des renseignements détaillés sur le caractère, la répartition et les relations stratigraphiques d'une partie d'une série rocheuse englobant le Crétacé supérieur et le début du Tertiaire, le long d'une coupe observable dans la région de la vallée de la rivière Red Deer (d'East Coulée à Ardley) en Alberta.

Les couches comprennent une série variable de grès, de siltstones, de mudstones, d'argilites de schistes argileux et de charbons, surtout non marins que l'on peut facilement diviser en cinq formations. Il s'agit, de la plus ancienne à la plus récente, les formations de Horseshoe, de Whitemud, de Battle, de Scollard et de Paskapoo. La formation de Scollard, considérée auparavant comme partie intégrante de la formation de Paskapoo, est dans cette étude élevée au rang de formation et redéfinie comme constituant une nouvelle formation du groupe d'Edmonton.

Dans la région étudiée ici, on distingue quinze couches principales de charbon dans cette série rocheuse; l'auteur donne des précisions sur leur puissance, leur répartition et leur continuité.

Les couches comprennent une partie d'un coin qui va s'amincissant vers l'est et qui est constitutté de sédiments fluviaux et deltaïques transportés et déposés principalement par un réseau de cours d'eat anastomosés, plus ou moins importants, le long de la marge occidentale de la mer Bearpaw.

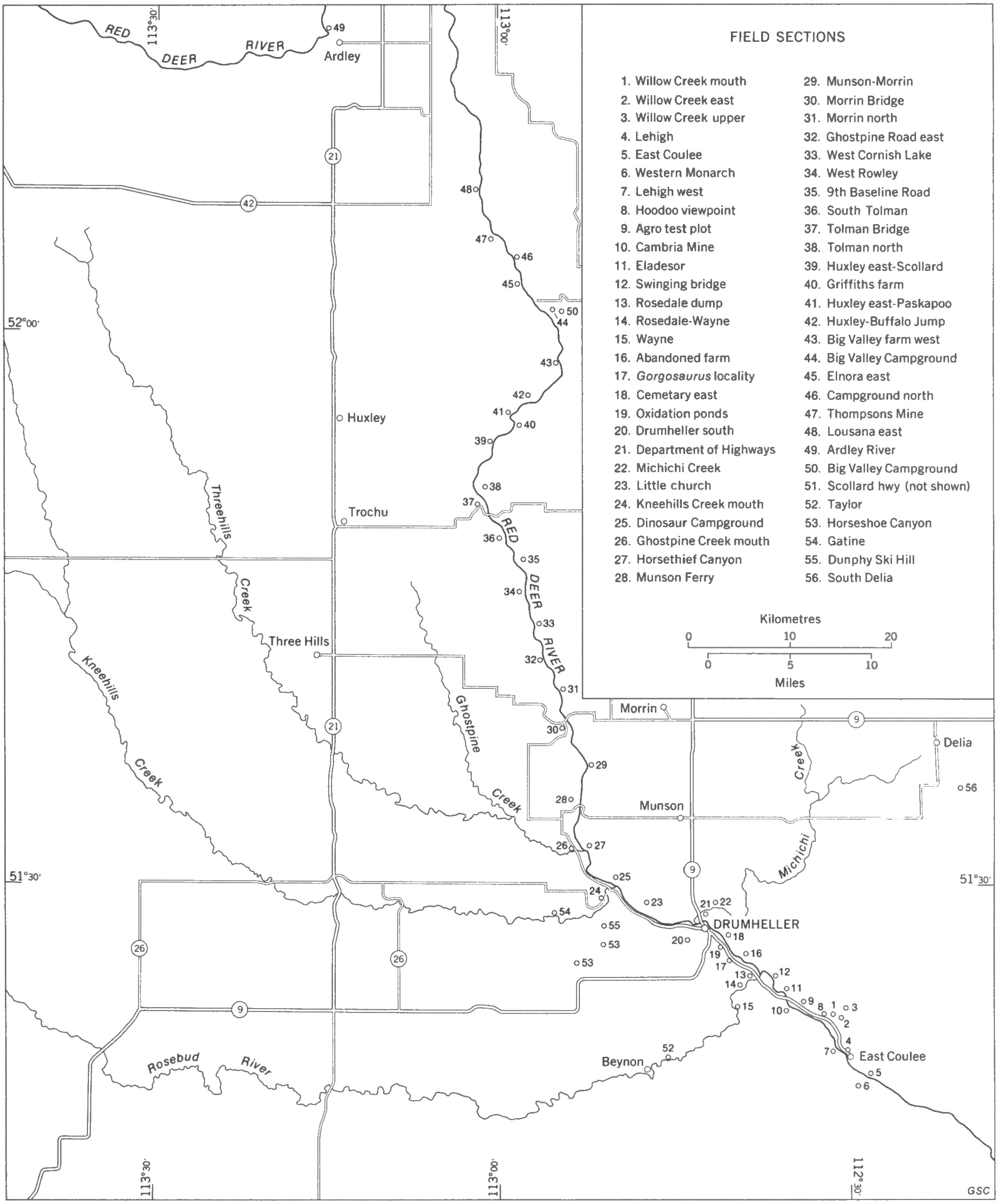

FIGURE 1. Location of measured sections, Red Deer River valley, Alberta

UPPER CRETACEOUS AND TERTIARY COAL-BEARING STRATA IN THE DRUMHELLER-ARDLEY REGION, RED DEER RIVER VALLEY, ALBERTA

INTRODUCTION

The Upper Cretaceous-Tertiary rocks of the Red Deer River area of south-central Alberta have long been of economic significance because of the intercalated coal seams, and of scientific interest to geologists and paleontologists because of their contained vertebrate faunal assemblage. In recent years, many visitors and tourists have been attracted to the Drumheller region of the report-area to view the many colours and unusual erosional characteristics of the strata (Pl. 1B). The area forms part of the northern boundary of the "Alberta Badlands".

This report is based on field work undertaken during the summer of 1973, during which time 56 field sections were measured and sampled in detail along a part of the Red Deer River valley and its major tributaries, between East Coulée on the south, and Ardley on the north (Fig. 1). In addition, stratigraphic information was obtained from 3 holes drilled by the Geological Survey of Canada in the vicinity of Trochu.

The purpose of the investigation was to update and provide detailed information on the distribution and continuity of the numerous coal seams in the area; to study in detail the major facies and facies variations, as a means of solving some of the stratigraphic and nomenclatural problems of the area; and, finally, to outline and interpret the environment and history of deposition.

ACKNOWLEDGMENTS

Able assistance was rendered in the field and laboratory by J.M. Ward, student assistant. Other laboratory support was provided by A.C. Carbone, and W.O. McEwan (thin sections). C. Singh of Alberta Research Council, Edmonton, accompanied the writer at many field localities, collecting coal and adjacent carbonaceous shale samples for palynological analyses. The results of Dr. Singh's work will be published at a later date.

PREVIOUS WORK

The Upper Cretaceous-Tertiary rocks of the Red Deer River area were described first by Tyrrell in 1886, who referred to the stratigraphic succession as the "Edmonton Series". Following Tyrrell's early work, investigations were undertaken by Brown (1914), Allan (1918, 1922), Sanderson (1931), Allan and Rutherford (1934), Rutherford (1939), Allan and Sanderson (1945), and Sternberg (1947, 1949) on the geology, coal resources, and vertebrate dinosaurian fauna of the Red Deer River region. Recent work includes papers by Elliott (1960), Ower (1960), Campbell (1962, 1967), Campbell and Almadi (1964), Clemens and Russell (1965), Srivastava (1966, 1967, 1968a, b), Russell and Chamney (1967), Irish (1967, 1970), Irish and Havard (1968), Binda and Srivastava (1968), Binda (1969), Snead (1969), Shepheard and Hills (1970), Carrigy (1970, 1971), Binda and Lerbekmo (1973) and Holter *et al.* (1975). These studies, like some of the earlier investigations, are concerned mainly with regional mapping and correlation, lithostratigraphy, biostratigraphy, sedimentary petrology, vertebrate paleontology, and palynology.

STRATIGRAPHY

NOMENCLATURE

In the Drumheller-Ardley area of the Red Deer River valley and adjacent areas of the Alberta Plains, four lithostratigraphic subdivisions and nomenclatural systems have been used or proposed in the study of Upper Cretaceous-Tertiary rocks (Fig.2). Each system has advantages and limitations over the others, depending on the specific needs and interests of the earth scientists who work or have worked in the area. Accordingly, these subdivisions and nomenclature systems either have been adopted, modified, or rejected as not applicable to a particular study. For a summary of three of the nomenclatural systems, and a discussion of the fourth system, the interested reader is referred to Irish (1970). The needs of the writer are best satisfied by the subdivisions and nomenclature proposed by Irish (1970), with modifications. The Scollard Member of the Paskapoo Formation (Irish, 1970) is herein elevated to formational rank, and reinterpreted as a new formation of the Edmonton Group. Furthermore, the upper contact and type section of the former Scollard Member (Scollard Fm. of this report) should be redefined to include additional strata, for reasons to be subsequently discussed in the text.

Edmonton Group

The Edmonton Group (this report), comprising a variable sequence of interbedded, interlensing sandstone, siltstone, mudstone, coal, and shale, is divided into four generally distinct formations which, in ascending order, are Horseshoe Canyon, Whitemud, Battle and Scollard (Fig. 2). The

Manuscript received: April 25, 1975

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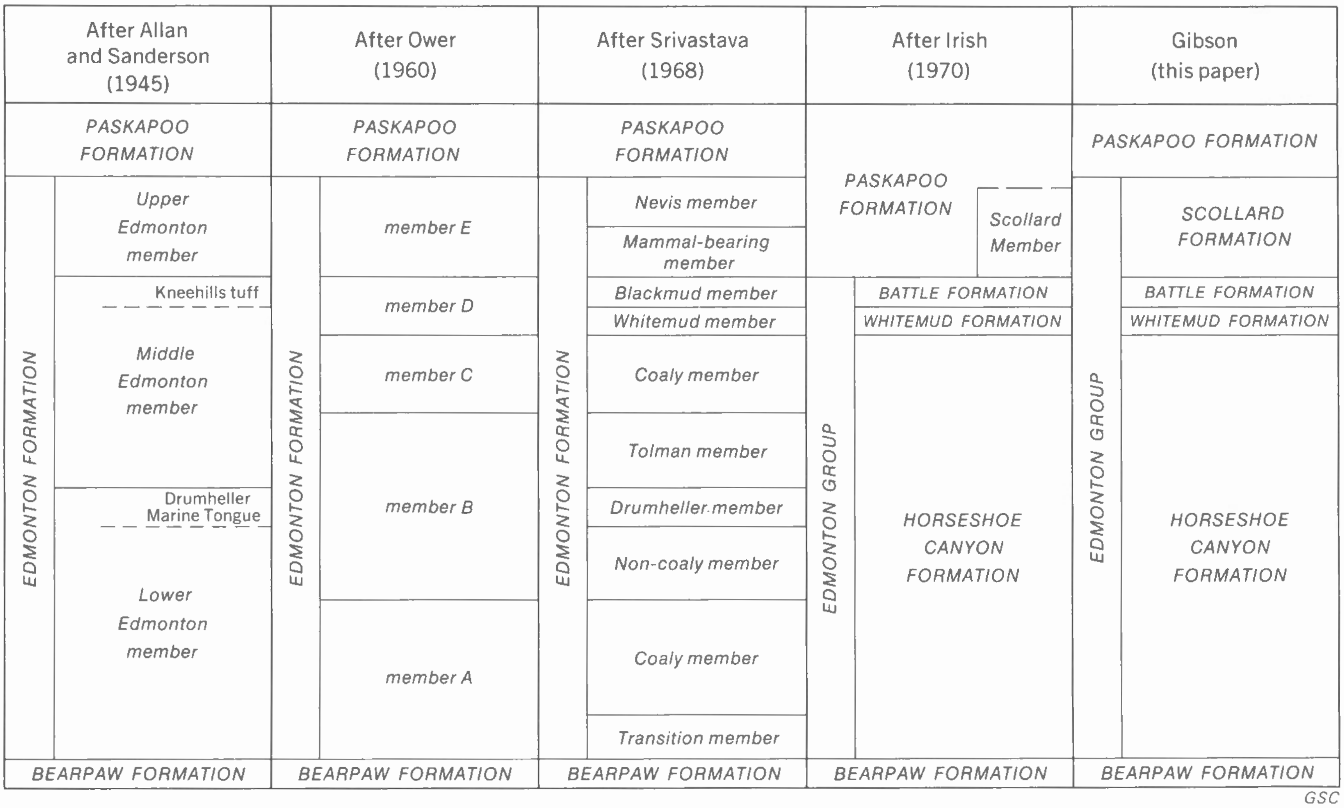

FIGURE 2. Table of Upper Cretaceous-Tertiary formations and members, Drumheller-Ardley area, Red Deer River valley, Alberta

Edmonton strata in the report-area have a maximum composite thickness of up to 398 m (1305 ft), and thin eastward. Westward, toward the Foothills, the Edmonton Group loses its colourful and distinctive character, and grades laterally into the Brazeau Formation.

In earlier investigations, there has been some confusion as to the assignment of the contact between the Edmonton and overlying Paskapoo Formation. Tyrrell (1887) originally placed the contact at an "estensive coal deposit", now called the Lower Ardley coal seam. Subsequent workers, such as Allan and Sanderson (1945), Ower (1960), Campbell (1962), and Srivastava (1968b), placed the contact at a stratigraphically higher level, at the base of a prominent cliff-forming sandstone (Pl. 2C, D, E). This sandstone is well exposed and serves as a distinctive marker lithofacies in the Tolman Bridge-Big Valley Creek-Ardley areas (Fig. 1). It has been generally accepted as the best and most reliable contact criterion between the Edmonton and Paskapoo Formations in the Red Deer River area.

However, investigations of Upper Cretaceous-Tertiary strata in the Alberta Plains by Irish (1968, 1970) and Carrigy (1970, 1971) have suggested that the prominent sandstone marker and Ardley coal zone may not be recognizable or serve as a lithologic marker facies in some areas away from the Red Deer River valley area. The Edmonton-Paskapoo contact, according to them, would be difficult to place on a regional basis at the sandstone marker horizon above the Ardley coal zone. Irish (1970), because of the apparent lack of a distinctive marker facies near the Edmonton-Paskapoo contact, redefined the Edmonton Formation elevating it to group status, and placed the upper contact of the group at the top of the Battle Formation (Fig. 2). Strata previously considered to be part of the upper Edmonton Formation were then reassigned and included in a newly defined unit called the Scollard Member, and placed by Irish (1970) into the Paskapoo Formation. Personal field observations in the report area, the general lake of major coal seams in the Paskapoo, the examination of subsurface lithological and geophysical logs from surrounding areas, the presence of a major vertebrate faunal and floral break (Lance to Paleocene) near the top of the Edmonton Group, and the observations and reports of other workers in the area (i.e. Allan and Sanderson, 1945; Sternberg, 1947, 1949; Ower, 1960; Campbell, 1962; Russell and Chamney, 1967; Srivastava, 1968b; and Holter *et al.*, 1975) suggest to the writer that the contact between the Edmonton and Paskapoo Formations is indeed recognizable throughout most of the Alberta Plains of central Alberta. The possibility of not being able to recognize the sandstone marker facies in isolated exposures or sometimes in the subsurface, or the inability to identify the upper Ardley coal seam in some parts of the Plains area, may exist, and sometimes creates difficulty in defining a consistent lithological contact between the Paskapoo and Edmonton Formations. However, this eventuality does not warrant lowering the long-established lithologic and biostratigraphic contact between the Paskapoo and Edmonton Formations to the top of the Battle Formation as suggested by Irish (1970) and Carrigy (1970, 1971). The writer does, however, recognize the strata of the Scollard Member (Irish, 1970) as a distinct and useful map-unit in the Plains area of central Alberta. It is proposed, therefore, that the Scollard Member be raised to formational status, and considered as a new formation of the Edmonton Group (Fig. 2).

The Edmonton Group conformably overlies the Bearpaw Formation.

Horseshoe Canyon Formation

The Horseshoe Canyon Formation (Irish, 1970) comprises a flat-lying, interbedded sequence of predominantly nonmarine, fluvio-deltaic sandstone, siltstone, shale, and mudstone or claystone. Variable concentrations of coal, coaly shale, bentonite, and ironstone concretions and concretionary beds are intercalated throughout parts of the succession. Marine to brackish-marine strata are interbedded close to the Bearpaw Formation contact, and again higher in the formation, in a lithofacies commonly referred to as the "Drumheller Marine Tongue" (Fig 2). In the Ardley-Drumheller region of the Red Deer River valley, the Horseshoe Canyon Formation ranges in thickness from a minimum of 227 m (745 ft) to a maximum of 267 m (876 ft) with an average thickness of 247 m (809 ft). Complete field sections are lacking at any one locality and, consequently, thickness values are obtained from composite measurements, using major coal markers.

Sandstone comprises one of the most common and conspicuous rock types of the formation, and occurs at most localities, as light to very light grey weathering lenses, and wedge- to tabular-shaped beds (Pl. 1A, B). It is poorly sorted and indurated, ranging between very fine through medium grained, to coarse grained in part, and commonly graded. The sandstone consists of sedimentary rock fragments and angular quartz grains, chert or microcrystalline quartz, and plagioclase and orthoclase feldspar. Accessory minerals include magnetite, hematite, pyrite, chlorite, muscovite, rutile, tourmaline, zircon, hornblende and, possibly, pyroxene. Scattered grains of glauconite were noted near the Bearpaw Formation contact. Matrix and cementing minerals consist of montmorillonite (bentonite), kaolinite, illite, and calcite. The montmorillonite imparts a "greasy" or "soapy" texture to the sandstone when wet. Coarsely crystalline calcite forms the predominant cement for most of the better indurated, more resistant sandstone cap rock marker facies in the area (Pl. 2F). In addition, it is the predominant cement for large ovoid concretions, some of which are as much as 1.2 m (4 ft) in diameter (Pl. 3A), tuberose concretionary bodies, and the pelecypod-bearing sandstone marker of the Drumheller Marine Tongue. The sandstone units commonly contain brown to black carbonaceous, and greenish-grey silt-shale laminations in the upper half of the individual lenses and beds. These laminations normally are parallel to lenticular, although in places they are wavy to crenulated. Sedimentary structures consist mainly of micro- to medium-scale planar and trough or festoon crossbeds (Pl. 3B, C, D), and are most common and best developed in the calcite-cemented sandstone. Other structures include oscillation ripple marks (Pl. 3E), mudcracks, and a few burrow structures.

Olive-grey to pale brown weathering siltstone forms the second most common rock type of the formation. It is very argillaceous-bentonitic, very carbonaceous, with relatively large concentration of brown to black macerated plant material, and resembles the sandstone mineralogically and texturally. Well-preserved fern and broad leaf impressions are found at some localities in the siltstone adjacent to major coal seams. The siltstone commonly interdigitates with and caps many of the light grey weathering sandstone channel facies of the formation (Pl. 1A).

Shale, mudstone and claystone (Folk, 1965, p. 127) occur in relatively high concentrations throughout much of the formation, but generally are most conspicuous between Coal Seam No. 9 and the Bearpaw Formation contact. The shale is fissile, very carbonaceous, argillaceous-bentonitic, sandy to silty in part, and invariably contains macerated or coarsely fragmented brown to black plant material, amber globules, and thin vitreous coal lenticles. Most of the shale is interbedded and interlaminated with small concentrations of coal, and commonly is classed as coaly shale. Between the basal contact with the Bearpaw Formation and Coal Seam No. 5, some of the shale is black but contains no obvious plant material. This shale is of possible marine or brackish water origin, and is characterized by yellow sulphur staining and small euhedral to subhedral crystals of selenite. The mudstone or claystone (Folk, 1965, p. 127) is silty to sandy, commonly carbonaceous and very bentonitic. The clay (montmorillonite) concentration in some units is such that it forms distinct beds of pale orange to greenish-grey bentonite up to 0.3 m (1 ft) thick. The bentonite is found most frequently adjacent to or within the coal seams, and averages 0.1 m (0.4 ft) thick.

Reddish-brown ironstone concretions and thin, lenticular concretionary beds are ubiquitous in the formation, although these are found mainly with the siltstone, mudstone, and shale in the lower half of the formation. The concentrations are as much as 0.4 m (1.3 ft) in diameter, and commonly have a core of silicified wood, dinosaurian bone fragments, or contain small vugs lined or filled with opaline silica, euhedral quartz or calcite.

For additional information on lithotypes, mineralogy, and sedimentary structures in the Horseshoe Canyon Formation, the interested reader is referred to reports by Allan and Sanderson (1945) and Shepheard and Hills (1970).

The Horseshoe Canyon Formation in the Drumheller-Ardley region of the Red Deer River valley area contains several distinct lithofacies and stratigraphic markers, some of which have been recognized and described by other workers, and used to further subdivide the formation into smaller stratigraphic units. For example, Shepheard and Hills (1970) recognized lithologic cycles between the

Bearpaw Formation contact and the No. 5 Coal Seam in the Willow Creek-East Coulée area (Fig. 1) of this report. These cycles are recognized in part of the report-area but lose their identify toward the north and cannot be extended up Red Deer River valley, beyond the mouth of Willow Creek, with any degree of reliability. In the Willow Creek area (Secs. 73-2 and 73-3, Fig. 1), a pelecypod-bearing sandstone marker, up to 38 cm (15 in) thick, occurs approximately 5.2 m (17 ft) above Coal Seam No. 1. The pelecypods consist of fragmented oyster shells that form, in places, a dense coquina. This marker has been observed only in the Willow Creek valley (Fig. 1).

Other pelecypod-bearing sandstone markers were recognized above and below Coal Seam No. 10, and are commonly referred to as the Drumheller Marine Tongue. This notable marker facies was first reported and described by Allan and Sanderson (1945) in the Horseshoe Canyon-Kneehill Creek area (Sec. 73-53, Fig. 1). They used the unit as a stratigraphic marker to separate their lower and middle members of the Edmonton Formation (Fig. 2). In the Horseshoe Canyon area (Sec. 73-53, Fig. 1), the Drumheller Marine Tongue comprises two separate, resistant, orange-brown weathering, very calcareous sandstone or siltstone beds, each about 1.1 m (3.5 ft) thick. Both beds contain an abundance of pelecypod shells of the genera *Ostrea* sp. and *Corbicula* sp. (Allan and Sanderson, 1945). These two pelecypod marker beds are 4.6 m (15 ft) apart and occur approximately 6 and 11 m (20 and 35 ft), respectively, above Coal Seam No. 10.

At Horsethief Canyon (Sec. 73-27, Fig. 1), 13.7 km (8.5 miles) north of Horseshoe Canyon, another pelecypod-bearing sandstone containing similar fossils was recognized. At this locality, however, only one of the marker beds was noted, at a level 6.1 m (20 ft) below Coal Seam No. 10. To the north, in the road cut east of Munson Ferry crossing (Fig. 1), two pelecypod-bearing sandstone markers were observed, one at a level 6.7 m (22 ft) above Coal Seam No. 10, and the other at a level 6.1 m (20 ft) below the seam. It is apparent, therefore, that the pelecypod-bearing marker beds of the Drumheller Marine Tongue occur above and below Coal Seam No. 10 and, consequently, cannot be used consistently to subdivide the Edmonton Formation, as was proposed by Allan and Sanderson (1945). Furthermore, the pelecypod-bearing sandstone markers are sporadic in occurrence, and may terminate or grade laterally into other non-fossiliferous lithofacies over short lateral distances, as can be shown in the roadcut on the west side of Red Deer River near Morrin Bridge. On the north side of the roadcut, a pelecypod-bearing sandstone marker is exposed 4.9 m (16 ft) below Coal Seam No. 10 whereas, on the opposite side of the road at the same stratigraphic level, the distinctive sandstone marker is absent.

Another conspicuous marker of the Horseshoe Canyon Formation outcrops between Munson Ferry crossing and the Big Valley Creek area (Fig. 1). This stratigraphic unit comprises three orange-brown, resistant sandstone beds, each up to 0.9 m (3 ft) thick, within a stratigraphic interval of 6.1 to 7.6 m (20-25 ft), the base of which is 12.2 to 18.3 m (40-60 ft) above Coal Seam No. 10. The sandstone is quartzose, very calcareous, and crossbedded. The strata between the three marker beds consist of less consolidated sandstone and minor amounts of siltstone. These sandstone markers, because of their well-indurated character, combine to form a prominent plateau or bench, traceable along the Red Deer River valley (Pl. 2F). Allan and Sanderson (1945) also recognized this marker facies, but only in the Munson-Morrin area, where it forms a prominent orange-weathering cliff along the rim of the valley. They interpreted these strata to be part of the Paskapoo Formation and equivalent to a superficially similar, cliff-forming sandstone sequence in the Ardley area to the north which, there, forms the base of the Paskapoo Formation. Accordingly, they suggested that the Edmonton Formation was unconformably overlain by the Paskapoo Formation in the Munson-Morrin area (Fig. 1), with the strata equivalent to the Whitemud, Battle, and Scollard Formations having been removed by erosion. Ower (1960) suggested that the prominent orange-weathering sandstone marker facies above the No. 10 Coal Seam is not equivalent to the massive cliff-forming sandstone of the basal Paskapoo Formation in the Ardley area. Field work by the writer has lead to the same conclusion. Scattered pelecypod shells and shell fragments have been observed in the middle and lower marker beds at Sections 73-34 and 73-45 (Fig. 1). These pelecypods occur in beds which lie stratigraphically higher in the formation than those of the Drumheller Marine Tongue. Another resistant sandstone marker was observed about 1.8 to 3.0 m (6-10 ft) above the No. 7 Coal Seam between Drumheller and Rosedale (Fig. 1). This unit, like that above the No. 10 Coal Seam, also forms a prominent "bench" or plateau in the area (Pl. 4B). The sandstone is up to 2.1 m (7 ft) thick, and is calcareous, well indurated, and crossbedded.

The last and probably the most obvious lithofacies of the Horseshoe Canyon Formation in the report-area is an alternating succession of greenish-grey weathering siltstone and mudstone, and light grey, fine- to very fine grained sandstone. The interval is displayed well between the Tolman Bridge river crossing and the Big Valley Creek area (Fig.1), and is developed mainly between Coal Seans Nos. 10 and 11. The lithofacies unit is typically up to 61 m (200 ft) thick, but at some localities it is considerably thicker, extending another 12.2 to 15.2 m (40-50 ft) below Coal Seam No. 10. At Section 73-31 (Fig. 1), it commences immediately above Coal Seam No. 9. This lithofacies is characterized by a noticeable reduction in brown carbonaceous laminations, brown to black plant fragments, and the absence of interbedded carbonaceous shale and coal, in comparison to other intervals of the formation (Pls. 2F, 4E).

The Horseshoe Canyon Formation conformably overlies marine mudstone, siltstone, and shale of the Bearpaw Formation (Pl. 1C, D). The contact is abrupt and readily apparent at some localities (Pl. 1C), but gradational at others. In the vicinity of East Coulée (Fig. 1), it is gradational (Pl. 1D), and the strata of the Bearpaw Formation interdigitate with the light grey weathering sandstone and siltstone of the Horseshoe Canyon Formation. The contact is placed immediately below the horizon at which the light grey weathering sandstone and siltstone of the Horseshoe Canyon Formation form the predominant lithology. In the vicinity of Willow Creek, the contact is abrupt. It is placed at the base of a thick, light grey weathering sandstone bed, which in some places contains "cap rocks" and forms local "hoodoos" in the adjacent river valley (Pl. 1C). The contact with the overlying Whitemud Formation is conformable, and is placed at a colour or compositional change between the darker grey, green and buff rocks with coal and carbonaceous-bearing strata of the Horseshoe Canyon Formation, and the very light grey weathering sandstone and lesser siltstone and mudstone of the Whitemud Formation (Pl. 2A, B). At some localities, however, the change in composition is gradational, and the contact is placed, therefore, mainly on the basis of colour change.

The flora, fauna, and correlation of the Horseshoe Canyon Formation, in the Drumheller-Ardley area of the Red Deer River valley, have been documented in varying detail by Allan and Sanderson (1945), Russell (1932), Russell and Chamney (1967), Srivastava (1968a, b), Wall *et al.* (1971), and Irish (1970), and will not be discussed here. The interested reader is referred to these reports for information and specific details.

Whitemud Formation

The Whitemud Formation (Irish and Havard, 1968) comprises a relatively thin, buff to light grey to light greenish grey weathering sequence of extremely argillaceous sandstone and mudstone with lesser amounts of siltstone and shale (Pl. 2A, B). In the Red Deer River valley area of this report, the formation ranges in thickness from a minimum of 3.4 m (11 ft) (Secs. 73-34, 73-46 and 73-53, Fig. 1), to a maximum of 7.9 m (26 ft) (Sec. 73-36, Fig. 1); the average value is based on the measurement of 16 field exposures of the formation. Irish and Havard (1968) recorded similar thickness values for the formation in the Red Deer River, Bow River, and Cypress Hills areas of central and southern Alberta. However, Binda and Lerbekmo (1973), in a detailed grain size study of the Whitemud Formation in the same area of the Red Deer River valley as described in this report, suggested a stratigraphic thickness of at least 30.4 m (100 ft) for the Whitemud Formation. It is apparent, therefore, that they have included strata which are herein considered part of the underlying Horseshoe Canyon Formation. The Whitemud Formation is recognized readily throughout most of the Drumheller-Ardley region of the Red Deer River valley, and other areas of the Alberta Plains, because of its light grey weathering colour, and contrasting lithology with the overlying Battle Formation (Pl. 2A). Where the Battle Formation cannot be seen, because of talus cover, non-deposition, or possible erosion, difficulty may be encountered in readily distinguishing the Whitemud Formation from the underlying grey-weathering siltstone and sandstone beds of the upper Horseshoe Canyon Formation. This difficulty arises because of a local similarity in colour and lithology between the two formations. Horseshoe Canyon siltstone and sandstone, however, are normally darker grey.

Buff to very light grey, very fine to coarse-grained sandstone characterizes the formation at most field locations in the report-area. The sandstone is commonly graded and moderately to poorly indurated, although it is resistant and cliff-forming at some localities. It has a detrital grain framework composed of subrounded to angular grains of quartz, orthoclase and plagioclase feldspar, and rock fragments, the latter consisting of microcrystalline quartz, chert, shale-siltstone, volcanic and possibly metamorphic grains. At Section 73-34, west of Rowley (Fig. 1), well-rounded quartzite cobbles up to 10.2 cm (4 in) in diameter were observed in a thick sandstone unit near the base of the formation. The cement and matrix consist mainly of clay, with minor amounts of calcite in some sandstone beds. The clay minerals, in order of relative abundance, are montmorillonite, kaolinite, illite and chlorite. Irish and Havard (1968, p. 17) reported clay mineral concentrations of 73 per cent montmorillonite, 16 per cent kaolinite, 6 per cent chlorite, and 5 per cent illite, in a sample of Whitemud sandstone subjected to X-ray analysis from Horseshoe Canyon (Fig. 1). The clay minerals impart the characteristic light grey weathering colour to the formation.

Subordinate thin to thick beds of light greenish grey to very light grey mudstone, siltstone, and shale are interlayered with the sandstone at most sections. At field sections 73-37 and 73-51 (Fig. 1), however, they comprise the predominant lithology, with thin sandstone beds and lenses being a minor component. The mudstone and siltstone are commonly very sandy, very argillaceous-bentonitic and, in places, contain a relatively high concentration of brown, macerated vegetal matter. At some localities (i.e. Sec. 73-46, Fig. 1), it is dark grey to brown on freshly exposed surfaces but, on exposure to the atmosphere, it changes to the light grey colour characteristic of the formation. Brown, silty, carbonaceous shale, with variable concentrations of brown to black, carbonized vegetal matter, is interbedded with or forms thin laminations in some sandstone units of the formation at many section locations.

Micro- to large-scale planar and trough cross-bedding are the dominant sedimentary structures in the formation, and these are particularly well developed in most of the calcite-cemented sandstone and siltstone. Wavy, lenticular, and parallel, silt, sand, and dark grey carbonaceous to coaly shale laminations occur throughout much of the sandstone and siltstone. At Sections 73-53, 73-37 and 73-44 (Fig. 1), unusual burrow-like structures were observed in a bentonitic mudstone adjacent to the Battle Formation. These structures, first reported by Irish and Havard (1968) from the Horseshoe Canyon area, are dark brownish grey tubes, single or branching, and up to 12.7 cm (5 in) long, and 1.3 to 1.9 cm (0.5-0.75 in) in diameter. Their origin is uncertain; however, the general shape, common vertical orientation to bedding planes, and bentonitic clay infilling suggest that these structures are of probable biogenic (possibly annelid) origin, and not a result of desiccation or root penetration as may be suggested.

The contact with the overlying Battle Formation appears to be conformable at most localities. It is placed at a prominent colour and compositional change where the light grey to greenish-grey weathering sandstone and mudstone of the Whitemud Formation change to dark grey weathering claystone characteristic of the Battle Formation (Pl. 2A, B). This contact, at most locations, is abrupt, as displayed at Big Valley Provincial Campground (Sec. 73-44), where the contact is undulatory, with a relief of up to 0.15 m (0.5 ft). At Horseshoe Canyon (Sec. 73-53, Fig. 1), however, the dark grey weathering claystone of the Battle Formation interdigitates with the light grey weathering strata of the Whitemud Formation. The contact at this location, although gradational in part, can still be placed at the major colour and compositional change between the two formations. At two sections north of Tolman Bridge river crossing (Secs. 73-38 and 73-39, Fig. 1), the Whitemud Formation is overlain by massive sandstone of the Scollard Formation. The Scollard sandstone represents a large fluvial channel facies, which eroded and removed part or all of the soft claystone of the Battle Formation.

The contact with the underlying Horseshoe Canyon Formation is abrupt and readily apparent at most localities, but gradational at some as previously discussed.

No identifiable fossils that could be used for correlation or age determinations were observed in the Whitemud Formation.

Battle Formation

The Battle Formation (Pl. 2A, B; Irish and Havard, 1968) is one of the most distinctive and easily recognized lithofacies of the Upper Cretaceous-Tertiary rock succession in the report-area. It can be traced into adjacent surface and subsurface areas because of its unusual lithology, colour and weathering characteristics; it commonly forms a characteristic "kick" on most geophysical well logs from the region (Ower, 1960; Elliott, 1960). The formation comprises a relatively thin, but areally extensive sequence of bentonitic claystone or mudstone, with volcanic tuff, ranging in measured thickness from a minimum of 3 m (10 ft) near Tolman Bridge river crossing (Sec. 73-38, Fig. 1) to a maximum of 11.3+m (37+ ft) at Horseshoe Canyon (Sec. 73-53, Fig. 1). The average thickness of the formation in the Red Deer River valley area is 5.8 m (19 ft), a value based on 13 measured field sections. Because of erosion, nondeposition, or a possible facies change, the formation is absent at some localities, as previously discussed.

The claystone is slightly silty to sandy in part, medium dark to medium olive-grey (Rock Color Chart, Goddard, 1951), and weathers to a diagnostic medium to dark purplish grey. Where silt and sand make up a conspicuous detrital component, the rock may be classed tentatively in the field as mudstone. Light grey weathering, well-indurated tuff in beds and lenses up to 0.3 m (1 ft) thick occurs at most localities (Pl. 2A). The tuff has been used in the past as a key stratigraphic marker facies for the "Kneehills Tuff Zone" (Allan and Sanderson, 1945, and others). It is not confined to any particular stratigraphic level in the formation, occurring both at the top and bottom at some localities. Up to 3 tuff beds have been observed.

The claystone is composed mainly of montmorillonite (bentonite), which is generally responsible for the recessive nature and conspicuous "cornflake texture" observed at most field sections (Pl. 2F). This texture is a result of dehydration or desiccation of the montmorillonite upon exposure to the atmosphere. Other clay minerals, occurring in lesser concentrations, include kaolinite, illite, and chlorite. The sand- to silt-size components of the claystone rarely exceed 10 per cent of the total mineralogy and consist of quartz, quartzite, feldspar, chert, and the common "heavy" minerals such as zircon, rutile, tourmaline, magnetite and pyrite. Finely macerated brown organic matter appears to be responsible for the general dark colouration of the rock. The tuff consists mainly of angular quartz and feldspar grains, and glassy volcanic shard-like fragments, with a matrix and cement composed of silica and some clay (montmorillonite). Because of the silica cement and matrix, the tuff is well indurated and, consequently, at many localities forms protruding ribs in the more recessive claystone of the formation.

The Battle Formation is overlain conformably at most localities in the report-area by olive- to greenish-grey weathering silty to sandy mudstone of the Scollard Formation (Pl. 2B). The contact generally is abrupt and readily apparent. However, at some sections (i.e. Sec. 73-45, Fig. 1), it is gradational within a thin stratigraphic interval of 1.5 m (5 ft). The contact with the underlying Whitemud Formation is gradational at some section localities and abrupt at others as previously discussed.

To date, no megafossils or useful microfossils have been collected from the Battle Formation. Sternberg (1947), however, recognized a distinct break in the dinosaurian fauna above the Battle Formation, and considered the post-Battle strata to be of Late Cretaceous (Lance) age. Similarly, Bell (1949) found a floral change in the rocks above and below the Kneehills Tuff Zone (Battle and Whitemud Fms.), although no ages were suggested by Bell. Silicified megaspores were recovered from the Battle Formation by Binda and Srivastava (1968) in the Red Deer River valley area of this report. They correlated these specimens with others collected from the Battle Formation in the Cypress Hills area of southeastern Alberta. Again no specific age was assigned to the megaspores.

Scollard Formation

The stratigraphic interval between the Battle Formation and the present land surface in much of the Red Deer River valley of this report has been the subject of recent controversy; whether it should be considered as part of the Edmonton Group, or whether it should be included as part of the Paskapoo Formation. For reasons previously discussed, the writer includes these strata as a new formation of the Edmonton Group.

The Scollard Formation (Pls. 2C, E; 4F), as recognized and defined in this report, differs slightly from the Scollard Member described by Irish (1970) because of the inclusion of younger and additional strata (Fig. 2). Irish (1970, p. 141) defined the Scollard Member as that stratigraphic interval "between the Battle Formation and the uppermost coal seam of the coaly zone (so-called Ardley coal zone)". The type section designated and described by Irish (Secs. 7, 18, twp. 34, rge. 21W4), however, is incomplete, and includes only strata up to one of the lower coal seams of the Ardley coal zone - Coal Seam No. 13 of this report. The recognition and identification of the "upper coal seam" of the Ardley coal zone is somewhat tenuous at some localities, especially those in the vicinity of Ardley. Consequently, it was deemed advisable by the writer to discard or discontinue using the "upper coal seam" as the upper contact of the Scollard Member and retain, instead, the base of the massive cliff-forming sandstone marker facies (Pl. 2C, E) or, in the subsurface, the base of the first prominent thick sandstone unit above the uppermost major coal seam of the Ardley coal zone. The cliff-forming sandstone represents a more appropriate, and more easily recognizable upper contact for the Scollard Formation. A supplemental type section of the Scollard Formation, illustrating all facies and major coal seams in the formation, may be found on the west bank of Red Deer River, at Sections 73-39 and 73-41 (Figs. 1, 3C) of this report and is included in the Appendix.

The Scollard Formation consists of an interbedded, interfingering sequence of argillaceous sandstone, siltstone, mudstone, and shale. Minor amounts of coal (Seams Nos. 13, 14), bentonite, and tuff occur in the formation. The Scollard is exposed in the report-area along Red Deer River valley between Tolman Bridge (Sec. 73-37, Fig. 1) and Ardley (Sec. 73-49, Fig. 1). Subsurface studies by Holter *et al.* (1975) on coal reserves of the Ardley coal zone indicate that strata equivalent to the formation as defined herein can be recognized and mapped at least as far northwest as the Whitecourt-Wabamun Lake area of Alberta. The Scollard Formation has a maximum composite thickness of 85.3 m (280 ft) in the Huxley-Big Valley area (Fig. 1), thinning to approximately 50.3 m (165 ft) in the Ardley area toward the north.

The sandstone resembles that of the underlying Whitemud and Horseshoe Canyon Formations both mineralogically and texturally. These beds are light grey to buff weathering, predominantly fine- to very fine grained, quartzose, bentonitic, and very calcareous in part. The sandstone units occur normally as thin to thick, lenticular beds up to 1.5 m (5 ft) thick but, in places, form individual lithofacies up to 8.5 m (28 ft) thick near the base of the formation. Medium- and micro-scale planar and festoon crossbedding are common in the thicker, better indurated, calcite-cemented sandstone. Light greenish grey weathering, bentonitic, sandy to silty mudstone and argillaceous siltstone form a conspicuous and diagnostic alternation with dark grey to dark purplish grey weathering, very bentonitic silty to sandy claystone and mudstone. The dark-weathering strata, although more sandy and silty, lithologically resemble the claystone of the underlying Battle Formation. In addition, they also display the typical bentonitic "cornflake-textured" (Pl. 3F) weathered surface. The greenish-grey weathering mudstone and siltstone commonly contain bioturbate? mottling, and thin isolated and bifurcating burrow-like structures infilled with dark grey bentonitic claystone. Similar structures, although on a slightly larger scale, were observed at the top of the Whitemud Formation. Dark grey to black, very carbonaceous to coaly shale occurs adjacent to, and commonly interbedded with, the coal seams. Relatively pure, light brown bentonite beds up to 0.1 m (0.3 ft) thick also are interbedded with the thicker coal intervals of the formation. A silicified, light grey, resistant tuff, mineralogically and texturally similar to that in the underlying Battle Formation, is found at localities in the Huxley-Trochu area, 8.8 to 14 m (29-46 ft) above the base of the formation (Pl. 4F). Because of its similarity to the underlying tuff of the Battle Formation and its association with dark to purplish-grey claystone-mudstone strata which also characterize the Battle Formation, caution must be exercised in identifying tuff beds from subsurface well cuttings. The Scollard tuff may be mistakenly identified as that of the underlying Battle Formation.

The contact of the Scollard with the overlying Paskapoo Formation is probably conformable, although Allan and Sanderson (1945) suggested that the contact was disconformable. Recent workers, including Ower (1960), Campbell (1962), and the writer, suggest that there is no convincing evidence to support the latter interpretation. The massive, cliff-forming sandstone marker probably represents a large blanket or major channel sandstone of fluvial origin, which has eroded and removed some of the underlying Scollard strata (Pl. 2C, E), thereby giving the impression or appearance of an unconformity. The contact, where exposed, is abrupt, with the greenish-grey to buff-weathering siltstone, sandstone, mudstone, shale, and coal of the upper Scollard Formation overlain by the massive, cliff-forming, crossbedded, fine- to coarse-grained, orange-brown weathering sandstone of the Paskapoo Formation. The contact with the underlying Battle and Whitemud Formations is conformable, as previously discussed.

Invertebrate fossils are scarce, and generally poorly preserved in the Scollard Formation. Unidentified gastropods and fragmented pelecypods were collected from a thin siltstone bed overlying Coal Seam No. 14 at Tolman Bridge river crossing (Sec. 73-37, Fig. 1). Mammalian and dinosaurian faunas have been reported by Clemens and Russell (1965), and Sternberg (1947, 1949) from strata of the Scollard Formation in the Red Deer River valley area. Both faunas indicate that at least part of the formation is of Lancian age. The megaflora and microflora have been described by Bell (1949), Srivastava (1966, 1967, 1968), Binda and Srivastava (1968) and Snead (1969). On the basis of the contained microfloral assemblage, Snead (1969) concluded that the Cretaceous-Tertiary boundary must occur within the Scollard stratigraphic interval.

COAL SEAMS AND THEIR LATERAL CONTINUITY

The distribution, chemical properties, and important mining statistics of the more important coal seams in the Red Deer River valley area have been described and summarized in variable detail by such workers as Allan (1943), Stansfield and Lang (1944), Allan and Sanderson (1945), Campbell (1962, 1967) and Steiner *et al.* (1972). Fifteen prominent seams or major coal-bearing intervals have been recognized in the Red Deer River valley between East Couleé and Ardley (Figs. 1, 3). These seams usually can be traced in outcrop between measured sections, until they dip or disappear beneath the present land surface. Elliott (1960), Ower (1960) and Steiner *et al.* (1972) have shown that many of these seams are continuous, and can be recognized and correlated into the surface and subsurface beyond the Red Deer River valley area of this report into other areas in the Alberta Plains.

The purpose of the following discussion is to update and provide detailed and supplementary information, not available or only briefly described during earlier investigations, on the thickness, distribution, and quality of the major exposed coal seams, and their contact relationships with overlying and underlying strata ("floor" and "roof rock"). In addition, it is hoped that the data presented here will assist others in assessing the economic potential of the coals and coal-bearing strata, particularly those of the Horseshoe Canyon Formation in the Drumheller to Big Valley region of the Red Deer River valley.

The coal nomenclature and numbering system used in this report is that proposed by Allan and Sanderson (1945). Figure 3 is a stratigraphic columnar chart illustrating 28 of the better field sections in the report-area, and shows the lithology, and suggested correlation and continuity of the 15 major coal seams or coal-bearing intervals. Table 1 is a data summary chart providing individual and cumulative thicknesses of coal seams, stratigraphic intervals between coal seams, and members or formations for the 56 field sections measured during the course of the investigation.

SEAM NO. 0

This is the lowest exposed seam in the Horseshoe Canyon Formation (Pls. 1C, D; 4A) and can be traced readily along both sides of the Red Deer River and adjacent tributary stream valleys, between East Couleé (Sec. 73-5, Fig. 1) and Eladesor (Sec. 73-11, Fig. 1). Because of a slight west to southwesterly regional dip (6 m/km; 20 ft/mile; Allan and Sanderson, 1945), the seam may be no longer exposed, or perhaps is no longer distinctive enough to be recognized up the valley beyond Eladesor. At Sections 73-9 and 73-11 (Pl. 4A), for example, it consists mainly of dark brown, very carbonaceous to coaly shale, with several thin [1.3-2.5 cm (0.5-1 in)] lenticles of coal. In the same general area, a few hundred yards along strike, the seam has been eroded, and the interval replaced by light grey weathering sandstone.

The seam is composed mainly of clean, vitreous, blocky-weathering coal, although at some locations it contains thin beds of dark grey to black, very carbonaceous shale. The coal is overlain gradationally at some sections either by carbonaceous shale or argillaceous siltstone; at other locations it is overlain abruptly by light grey weathering, fine- to medium-grained sandstone as shown at East Coulée (Sec. 73-5). The "floor-rock" consists of 0.3 to 0.6 m (1-2 ft) of brown, very carbonaceous, slightly siliceous, silty to sandy shale to shaly siltstone (Pl. 1C), characterized in part by a large concentration of black to brown, carbonized, macerated leaf and stem material. Seam No. 0 lies at a level ranging from 11.9 m (39 ft) (Sec. 73-7) to 16.2 m (53 ft) (Sec. 73-6) above the base of the Horseshoe Canyon Formation, and ranges in measured thickness from 0.2 m (0.7 ft) at Eladesor (Sec. 73-11) to 0.8 m (2.5 ft) at Willow Creek (Sec. 73-3).

Seam No. 0 is thin, and probably for this reason has never been commercially exploited.

SEAM NO. 1 (DRUMHELLER SEAM)

This seam is commonly referred to as the Drumheller Seam (Allan and Sanderson, 1945) and can be traced in outcrop between East Coulée (Sec. 73-5) and Rosedale (Sec. 73-13, Fig. 1) (Pls. 1C, D; 4A). Beyond Rosedale to the north, it is no longer exposed and disappears beneath the present land surface. In the East Coulée area to the south (Pl. 1D), the seam is, in places, difficult to identify or trace laterally because of the absence of good coal. At Section 73-5 (Fig. 1), it comprises a very carbonaceous, slightly coaly, silty to sandy shale, 0.5 m (1.5 ft) thick, whereas at Western Monarch (Sec. 73-6), 3.2 km (2 miles) to the southwest, Seam No. 1 is not present. The equivalent interval lies within a 6.1 m (20 ft) thick, light grey weathering, lenticular channel sandstone, with no obvious carbonaceous shale or coal beds. The Drumheller or No. 1 Seam is readily apparent near Willow Creek and Lehigh (Fig. 1), where it ranges in thickness from 0.9 to 1.4 m (3-4 ft). Upstream in the Red Deer River valley, beyond the mouth of Willow Creek to Rosedale, the northern limit of exposure, the seam increases in thickness and coal content, ranging from 1.2 to 3.3 m (4-10.7 ft) thick (Table 1). At Cambria (Sec. 73-10), Rosedale (Sec. 73-13), and Eladesor (Sec. 73-11), it is 2.1 m (7 ft) thick (Table 1).

The coal is vitreous, blocky to shaly weathering and contains lenses and thin, intercalated beds of dark grey to brown, carbonaceous to coaly shale in different amounts at different places. Buff-weathering bentonite, in lenticular beds up to 0.3 m (1 ft) thick, is characteristic of the seam and is most conspicuous at locations in the Red Deer River valley between the mouth of Willow Creek and Rosedale. Silicified tree stumps, as much as 0.9 m (3 ft) high and 0.5 m (1.5 ft) in diameter, and large and small blocky slabs of partially silicified wood are common also in the seam, particularly in the Willow Creek tributary valley. Other constituents of the seam include silicified accumulations of vegetal matter (referred to as "bone"), and small localized pockets of sandstone and shale. The Drumheller Seam commonly is overlain by up to 2.1 m (7 ft) of dark grey to black shale (Pl. 4A), noticeably lacking in carbonized vegetal matter although, at Rosedale (Sec. 73-13), it is overlain by interbedded carbonaceous siltstone, silty shale and sandstone. At Lehigh (Sec. 73-4), it is overlain erosionally by light grey weathering sandstone. The "floor-rock" consists of carbonaceous, brown-weathering, silty to sandy shale, ranging from 1.3 cm to 0.6 m (0.5 in to 2 ft) thick.

The No. 1 Seam occurs at a level ranging from 7.5 to 11.7 m (24.5-38.5 ft) above Seam No. 0 or, alternatively, 17.7 to 27.4 m (58-90 ft) above the base of the Horseshoe Canyon Formation. The variation in thickness between the two coal seams, and between the seams and the base of the formation at different locations within the same general area, may be in part a result of differential compaction, related to the presence or absence of sandstone interbeds or lenticular channel sandstone lithofacies.

The Drumheller Seam has been mined in the past at many localities between Drumheller and East Coulée. Now, however, only strip mining is done periodically at Cambria (Sec. 73-10), and all coal is sold and used by local residents of the Drumheller area.

SEAM NO. 2

This seam (Pl. 4A, B) is well exposed along the Red Deer River and adjacent river and creek tributary valleys between East Coulée (Sec. 73-5) and Drumheller (Sec. 73-19, Fig. 1). It ranges in measured thickness from 1.8 m (5.8 ft) at East Coulée (Sec. 73-5), to 0.2 m (0.8 ft) at Willow Creek (Sec. 73-2) and lies at a stratigraphic level ranging from 11 to 18 m (36-59 ft) above Seam No. 1 or, alternatively, at a level 28.3 to 45.7 m (93-150 ft) above the base of the Horseshoe Canyon Formation (Fig. 3, Table 1). In Willow Creek valley near the confluence of Red Deer River, and in the vicinity of, and north of Rosedale (Secs. 73-11, 73-13, 73-14 and 73-17, Fig. 1), another conspicuous carbonaceous coal-bearing seam was observed at a level ranging between 0.9 and 2.9 m (3-9.5 ft) below the main No. 2 Seam. This secondary seam may represent a split of the overlying main seam or, more likely, represents another distinct and separate seam. At Rosedale-Wayne (Sec. 73-14), for example, this secondary seam is 0.4 m (1.3 ft) thick and is composed of clean coal with very little carbonaceous shale. In contrast, the main seam at the same locality, 2.9 m (9.5 ft) higher, consists of dark grey coaly shale. One could easily, but mistakenly, interpret the 0.4 m (1.3 ft) secondary seam as the main No. 2 Seam.

The coal, like that of most other major seams in the region, is vitreous and blocky weathering. At many section locations, however, dark grey to brown, very carbonaceous to coaly shale occurs as lenses and thin interbeds. Small, partly silicified tree stumps and small blocky wood fragments were observed at West Lehigh (Sec. 73-7). However, unlike the major seam below, where such objects are common, they were observed only at West Lehigh (Fig. 1). The coal generally is overlain abruptly by argillaceous siltstone or sandstone. At Cambria (Sec. 73-10), it is overlain by a massive, light grey weathering, lenticular sandstone facies up to 4.9 m (16 ft) thick. The "floor-rock" of the seam consists of dark grey to brown, very carbonaceous shale to shaly siltstone up to 0.3 m (1 ft) thick. This unit characteristically contains a high concentration of coarse to finely macerated vegetal matter, as well as small globules of amber.

In the past, coal has been mined from the No. 2 Seam in the Willow Creek, Rosedale and East Coulée areas. Today, however, only the Atlas Mine, 2.4 km (1.5 miles) southwest of the Western Monarch locality (Sec. 73-6), is producing coal commercially from a 3.9 m (13 ft) seam, which is considered to be equivalent to the No. 2 Seam of the Red Deer River valley.

SEAM NO. 3

The No. 3 Seam (Pl. 4A, B) outcrops midway on the river escarpment at East Coulée (Sec. 73-5, Fig. 1) and can be traced visually upstream to the town of Drumheller (Sec. 73-21) where, because of a slight regional stratigraphic dip, it disappears beneath the present land surface.

The seam ranges in thickness from a minimum of 0.2 m (0.6 ft) at Willow Creek (Sec. 73-3) to a maximum of 0.7 m (2.3 ft) at Western Monarch (Sec. 73-6), although it is usually between 0.5 and 0.6 m (1.5-2 ft). The No. 3 interval occurs at a stratigraphic level ranging from 2.6 to 6.3 m (8.5-20.6 ft) above the No. 2 Seam. The latter maximum value was recorded at Cambria (Sec. 73-10), and may be due to a 4.9 m (16 ft) thick, massive, compaction-resistant, light grey weathering sandstone unit at the base of the interval.

The seam is composed of shaly- to blocky-weathering vitreous coal, with thin interbeds and lenses of dark grey carbonaceous shale. In the Rosebud River valley (Secs. 73-14, 73-15), however, it consists predominantly of coaly shale. Other notable impurities are bentonite, in a lenticular bed up to 0.1 m (0.2 ft) thick at Section 73-14, and partially silicified wood fragments. At Willow Creek (Sec. 73-1), a partially silicified tree stump, up to 0.8 (2.5 ft) in diameter, and silicified slabs and blocks of wood were observed in the coal. Both the bentonite and petrified wood are, however, uncommon constituents of the seam.

Seam No. 3 generally is overlain abruptly by very argillaceous siltstone, mudstone, and sandstone, with the latter comprising a conspicuous, light grey weathering, well-indurated sandstone facies at West Lehigh (Sec. 73-7). At some sections, the seam is overlain gradationally by dark grey to black shale, with only minor concentrations of obvious vegetal matter. Like many other major coal-bearing marker seams of the Horseshoe Canyon Formation, the No. 3 Seam is underlain by carbonaceous, silty to sandy shale to shaly siltstone, containing a large amount of carbonized vegetal matter. In the Drumheller area, seam No. 3 appears to be too thin to be of immediate commercial interest.

SEAM NO. 4

Seam No. 4 can be traced visually along both sides of the Red Deer River valley between East Coulée (Sec. 73-5) and Drumheller (Sec. 73-21), at a level ranging from 2.5 m (8.3 ft) (Sec. 73-4) to 5.2 m (17 ft) above Seam No. 3. The No. 4 Seam varies in thickness from a minimum of 0.2 m (0.8 ft) at Sections 73-1 and 73-17 (Fig. 3, Table 1), to a maximum of 0.5 m (1.8 ft) at Western Monarch (Sec. 73-6), while averaging 0.3 m (1 ft) throughout most of the area. At Hoodoo Viewpoint (Sec. 73-8), however, the seam is not present, having been eroded and replaced by an overlying fluvial sandstone.

The coal has a vitreous to dull lustre (fresh surface), and is blocky weathering. A few lenses of dark grey carbonaceous shale are interbedded with the coal at some sections. At Section 73-17 near Rosedale, however, Seam No. 4 is only 0.2 m (0.8 ft) thick, and is made up mainly of coaly shale, with subordinate lenticles and thin bands of coal. Partially silicified wood as blocks and small fragments up to 0.2 m (0.8 ft) long were observed in the coal near Drumheller (Secs. 73-18, 73-19). In addition, small, euhedral selenite crystals were noted in the seam at East Coulée.

Between East Coulée and the Cambria area (Secs. 73-5, 73-9), Seam No. 4 is overlain gradationally by dark grey carbonaceous shale, in places up to 3 m (10 ft) thick. At Willow Creek (Sec. 73-2), this shale contains very little conspicuous plant matter. Dark grey shale also overlies the seam between Rosedale and Drumheller. In this region, however, it is more carbonaceous with a greater concentration of brown to black carbonized vegetal matter. In addition, silt and sand form a relatively high and conspicuous component of the shale. At other localities not overlain by the shale, the "roof-rock" consists either of buff- to brown-weathering, slightly carbonaceous, argillaceous siltstone to sandstone or, most noticeably, light grey weathering sandstone, up to 2.7 m (9 ft) thick (Sec. 73-10). Like most other seams of the formation, the No. 4 Seam is underlain by carbonaceous shale to shaly siltstone, with a large concentration of carbonized vegetal matter. This "seat rock" usually ranges in thickness from a few inches up to 1 foot.

Seam No. 4 (Pl. 4A, B), although an excellent stratigraphic and correlation marker in the Horseshoe Canyon Formation, does not appear to contain coal of sufficient quality and thickness to be of potential economic value.

SEAM NO. 5 (NEWCASTLE SEAM)

This seam (Pl. 4A, B), sometimes referred to as the Newcastle Seam, forms the uppermost of the major coal seams exposed along the Red Deer River valley between East Coulée and Cambria (Secs. 73-5, 73-10, Fig. 1). At East Coulée (Sec. 73-5), however, it is not exposed, having been removed by Pleistocene or more recent erosion. Upstream from Cambria, it occurs at a level midway between the top and bottom of the river valley escarpment, whereas near Drumheller it is found at the base of the escarpment in the highway roadcut, near Section 73-21 on the east side of the Red Deer River bridge crossing at Drumheller. Additional exposures can be found north of the highway roadcut, along the east side of the river valley; however, slumping and talus or ground vegetation cover can make recognition and identification of the seam difficult and in places uncertain.

The No. 5 or Newcastle Seam ranges in thickness from a minimum of 0.3 m (1 ft) at Lehigh (Sec. 73-4, Fig. 1), to a maximum of 1.6 m (5.3 ft) at Eladesor (Sec. 73-11). It lies at a level which varies between 4 and 7 m (13-23 ft) above Seam No. 4. The coal is vitreous to dull in lustre, and weathers blocky but occasionally shaly. Dark grey, very carbonaceous to coaly shale interfingers with the seam as lenses and thin beds at some sections, whereas at others it forms the predominant lithology. At Eladesor (Sec. 73-11), for example, Seam No. 5 is composed of 1.6 m (5.3 ft) of very coaly, carbonaceous shale and minor amounts of bentonite; at Wayne (Sec. 73-15) in the Rosebud River valley (Fig. 1), it consists of dark grey to brown coaly shale. Downstream toward Rosedale, however, the seam increases in thickness and coal content, such that, at Rosedale (Sec. 73-13), it comprises a vitreous coal 1 m (3.3 ft) thick with no obvious shale. The bentonite at Eladesor is buff, forming a lenticular bed between 0.1 and 0.2 m (0.5-0.8 ft) thick. Silicified and "charcoalized" wood fragments were observed in the seam at Wayne (Sec. 73-15).

Like many of the major seams in the Horseshoe Canyon Formation, the No. 5 Seam is overlain either gradationally by carbonaceous shale, mudstone or siltstone, or erosionally by light grey weathering sandstone, similar in appearance to that in Plate 4C. The seam normally is underlain by up to 0.9 m (3 ft) of brown, very carbonaceous silty shale to shaly siltstone.

The interval between Seams No. 4 and 5 contains other carbonaceous to coaly shale and coal beds which, in adjacent areas of the subsurface, may develop into thick seams. If these secondary seams become more conspicuous and better developed in the subsurface, at the expense of either Seams No. 4 or No. 5, miscorrelation of the No. 5 or perhaps the No. 4 could result. In and north of Rosedale (Secs. 73-13, 73-17, Fig. 1), a distinctive coal and coaly shale unit up to 0.1 m (0.5 ft) thick, was observed 1.8 and 2.1 m (6 and 7 ft), respectively, below the No. 5 Seam. Another conspicuous coaly shale unit was noted 3 m (10 ft) above Seam No. 4 at Rosedale-Wayne (Sec. 73-14) in the Rosebud River valley. Intercalated beds of coal and coaly shale were not observed between the two seams north of Section 73-16 (Fig. 1).

Although actively mined in the early 1920's in the Drumheller and upper Willow Creek areas (Allan and Sanderson, 1945), no coal has been produced commercially from the seam since that time.

SEAM NO. 6

Seam No. 6 (Pl. 4B, C) is best exposed along both sides of Red Deer River valley between Rosedale at the mouth of Rosebud River, and the Drumheller Golf and Country Club, 9.6 km (6 miles) north of Drumheller. It is exposed also at Western Monarch (Sec. 73-6), and in part of the Rosebud River valley, at least as far as Taylor (Sec. 73-52, Fig. 1). At Taylor, the seam is exposed on the north side of the river at the base of the escarpment adjacent to the railway tracks, where it consists of 0.2 m (0.6 ft) of interbedded coal and coaly shale. Downstream from Taylor, the No. 6 Seam thickens and becomes increasingly more coaly so that, at Rosedale (Sec. 73-13), it consists of 0.5 m (1.6 ft) of clean coal, with only a few thin lenses and laminations of carbonaceous shale. Between Rosedale and Drumheller, it crops out near the top of the river valley escarpment, then progressively descends the section upstream to the Little Church locality (Sec. 73-22, Fig. 1), where it is found at the level of the road and cannot be traced laterally in outcrop with any degree of reliability farther to the north. Isolated exposures of the seam, however, may occur between the Little Church locality and the Red Deer River (Fig. 1).

The coal has a vitreous to dull lustre, characteristically fracturing into small angular blocks. However, it commonly forms only a subordinate component in the seam. For example, between Rosedale and Drumheller in the Red Deer River valley, the No. 6 Seam (Pl. 4B) consists of carbonaceous to coaly shale, with the coal forming sparse, thin beds and lenticles, less than 2.5 cm (1 in) thick. Small "charcoalized" wood slabs and partially silicified wood fragments are common in the seam at some sections. The seam ranges in thickness from a minimum of 0.2 m (0.7 ft) near Rosedale (Sec. 73-17) to a maximum of 1.3 m (4.4 ft) at Drumheller (Sec. 73-21). Seam No. 6 is overlain gradationally by silty to sandy shale and argillaceous siltstone (i.e. Western Monarch, Sec. 73-6), or erosionally by light grey weathering sandstone, as shown at the West Lehigh and Swinging Bridge localities (Secs. 73-7, 73-12). The seam is underlain by brown, carbonaceous, silty to sandy shale or siltstone up to 0.3 m (1 ft) thick.

Seam No. 6 lies at a level which ranges from 13.9 m to 22.2 m (45.5-72.8 ft) above the No. 5 Seam. The intervening strata contain several beds of coal and carbonaceous coaly shale in places forming units up to 1.2 m (4 ft) thick. These carbonaceous-coaly beds, if present near the main marker seam, can be mistaken for the No. 6 Seam. However, in most cases, the relatively constant stratigraphic thickness between Seam No. 6 and the overlying Seam No. 7 is a good enough criterion to identify and separate Seam No. 6 from any of the nearby underlying secondary seams.

Seam No. 6, like Seam No. 4, although an excellent stratigraphic and correlation marker in the Horseshoe Canyon Formation, does not appear to be of potential economic value.

SEAM NO. 7 (DALY SEAM)

The No. 7 or Daly Seam (Pl. 4B, C) is a distinctive and useful correlation marker in part of the report-area, since it is well exposed and readily traceable in the vicinity of and between Drumheller and the mouth of Kneehills Creek (Fig. 1). It is exposed also between Drumheller and Rosedale, and from there westward up the tributary Rosebud River valley as far as Taylor (Sec. 73-52, Fig. 1).

In the main river valley south of Drumheller, the seam is thin and consists mainly of carbonaceous to coaly shale with several thin bands and lenticles of vitreous coal. In the vicinity of, and north of Drumheller, however, the seam thickens and consists predominantly of blocky-weathering, vitreous coal, in beds up to 0.8 m (2.5 ft) thick. At Michichi Creek (Sec. 73-22, Fig. 1), it is up to 3.3 m (10.7 ft) thick, but contains only two beds of vitreous coal, 0.5 and 0.4 m (1.8 and 1.4 ft) thick, separated by 0.7 m (2.3 ft) of carbonaceous to coaly shale. The Daly Seam ranges from the minimum of 0.1 m (0.3 ft) near Rosedale (Secs. 73-13, 73-17), to a maximum of 3.3 m (10.7 ft) on Michichi Creek (Sec. 73-22). At Drumheller (Sec. 73-21), the seam contains two slightly carbonaceous, very bentonitic shale interbeds, up to 0.3 m (1 ft) thick, in addition to small, partly silicified tree stumps, and small "charcoalized" wood fragments and slabs.

Seam No. 7 lies at a level ranging from 6.2 to 9.5 m (20.2-31.3 ft) above Seam No. 6, but is usually between 6.1 and 7.6 m (20 and 25 ft) at most locations. The interval between Seams No. 6 and 7, like that between other major coal seams of the Horseshoe Canyon Formation, includes some thin carbonaceous shale and coal beds which commonly occur near No. 7 Seam. For example, on the east side of Red Deer River valley, south of Drumheller (Secs. 73-16, 73-18, 73-21), a distinctive carbonaceous to coaly shale and coal unit, up to 0.2 m (0.8 ft) thick, can be traced at a level 0.9 to 1.5 m (3-5 ft) below No. 7 Seam. Because of the proximity of this and other less important marker seams to the main seam, caution must be exercised in identifying and correlating No. 7 Seam, so as not to jump to a lower or different secondary seam in the area. Carbonaceous shale and coaly interbeds were not observed in the interval north of Drumheller, nor upstream in the Rosebud River valley between Wayne and Taylor (Fig. 1).

The Daly Seam is overlain gradationally by argillaceous, bentonitic siltstone, sandstone, and shale, the latter commonly being carbonaceous. At the Drumheller (Sec. 73-21), Michichi Creek (Sec. 73-22), and Little Church (73-23) localities, the seam is overlain abruptly either by pale green to brown bentonite and bentonitic shale, or by light grey weathering sandstone, the latter up to 2.7 m (9 ft) thick (Pl. 4C). The "floor-rock" of the seam is composed of light to dark brown, sandy, carbonaceous shale to shaly siltstone, containing a large amount of brown to black, carbonized vegetal material.

Except at Michichi Creek, Seam No. 7 does not appear to contain coal of sufficient thickness and quality to warrant mining in the Drumheller area. The No. 7 Seam was mined in this area in 1921; however, all commercial coal production has ceased since that time.

SEAM NO. 8

This distinctive coal marker (Pl. 4D) is readily apparent in the Red Deer River valley at Drumheller (Sec. 73-20), midway in the river valley escarpment on the west side of town, and can be traced from there upstream to an area immediately north of Morrin Bridge river crossing (Sec. 73-31). Beyond this locality, the seam dips beneath the present land surface. The seam also is exposed south of Drumheller in Rosebud River valley (Fig. 1), at least as far as Wayne (Sec. 73-15). Upstream at Taylor (Sec. 73-52, Fig. 1), it is not exposed, although a 0.3 m (1 ft) carbonaceous shale unit was recorded 3.4 m (11 ft) below the top of the measured section (Fig. 3). This shale possibly may represent a split of the No. 8 Seam.

Seam No. 8 ranges in measured thickness from a minimum of 0.1 m (0.3 ft) at Munson Ferry crossing (Sec. 73-28), to a maximum of 2 m (6.7 ft) north of Wayne (Sec. 73-14). The No. 8 Seam splits into two units of variable thickness at many locations in the report-area. The two seams commonly are separated by carbonaceous to coaly shale, which is well illustrated at the mouth of Kneehills Creek (Sec. 73-24). There, the seam is divided into two beds, separated by 1.1 m (3.5 ft) of carbonaceous to coaly shale. Vitreous coal forms only a small proportion of the seam in the region (i.e. Secs. 73-15, 73.25, 73.26, 73-28), occurring mainly as thin lenticular beds and isolated lenticles, 0.03 to 0.06 m (0.1-0.2 ft) thick in the shale. At a few sections, however, blocky-weathering, vitreous coal, in beds up to 0.8 m (2.5 ft) thick, was observed (Sec. 73-31). In addition to coal and shale, the seam also contains thin, buff, bentonite lenses in the Kneehills Creek valley (Sec. 73-55), and scattered partially silicified wood fragments at Horsethief Canyon (Sec. 73-28). The seam commonly is overlain by carbonaceous siltstone to mudstone to silty shale although, at Gatiné (Sec. 73-54), it is overlain by a 0.1 m (0.3 ft) thick bed of buff-weathering bentonite. At Sections 73-24, 73-25, 73-27 and 73-28, the "roof-rock" of the seam comprises typical light grey weathering, bentonitic sandstone, similar to that described above other lower major marker seams. The seam is underlain by brown, sandy, carbonaceous shale to siltstone although, at some sections where coal is absent or in relatively small amounts in the seam, the "floor-rock" consists of argillaceous siltstone to sandstone.

Seam No. 8 lies at a level ranging from 35 to 40 m (114.8-131.3 ft) above the No. 7 or Daly Seam. The rocks between those two markers contain secondary carbonaceous to coaly shale and coal beds which, at some sections in the area, are developed within a few feet of both major seams. For example, secondary coal to coaly shale, in units up to 0.4 m (1.3 ft) thick, was observed at four locations (Secs. 73-54, 73-55, 73-27, 73-31), ranging from 4 to 4.6 m (13-15 ft) below the No. 8 Seam. With the exception of the above example, most of the intercalated carbonaceous to coaly shale and coal beds between Seams No. 7 and No. 8 cannot be traced laterally between adjacent sections.

Seam No. 8 does not appear to contain coal of sufficient quality and thickness to be of potential economic interest.

SEAM NO. 9

This seam (Pl. 4D), like No. 8, is recognized easily at Drumheller (Sec. 73-20) and, similarly, can be traced in outcrops northward along the Red Deer River valley escarpment to an area approximately 6.4 km (4 miles) north of Morrin Bridge river crossing (Sec. 73-32). The seam also is exposed in the valleys of Kneehills Creek and Ghostpine River, two major tributaries of the Red Deer River. Seam No. 9 has not been recognized in outcrop south of Drumheller, although Allan and Sanderson (1945) report that coal was mined from a seam 3.2 km (2 miles) north of Beynon (Fig. 1), which may be equivalent to the No. 9 of the Red Deer River valley.

The seam has a thickness varying from a minimum of 0.1 m (0.4 ft) at the mouth of Ghostpine River (Sec. 73-26), to a maximum of 0.7 m (2.4 ft) at Gatiné (Sec. 73-54). Near the mouth of Kneehills Creek (Sec. 73-24), however, it is absent, having been erosionally truncated and replaced by a light grey weathering channel sandstone although, upstream at Dunphy and Gatiné (Secs. 73-54, 73-55), it is well exposed and contains good coal. The seam is made up mainly of interbedded and interlaminated coal, and carbonaceous to coaly shale, with the latter dominating at most localities. Vitreous, blocky-weathering coal, in beds up to 0.6 m (2 ft) thick, was observed at Gatiné although, at most other localities in the area, individual coal beds rarely exceed 0.2 m (0.6 ft). At three sections (73-23, 73-25, 73-27) on the east side of Red Deer River valley, buff to light brown bentonite occurs within the seam in beds up to 0.03 m (0.1 ft) thick. "Charcoalized" and partially silicified wood fragments were noted at Sections 73-54, 73-28, 73-30 and 73-31 (Fig. 1).

The stratigraphic interval between Seams No. 8 and No. 9 varies between 13 and 20.5 m (42.5-67.2 ft) and, like most of the other intervals between major coal units, contains several coaly to carbonaceous shale and thin coal seams. At the Morrin north locality (Sec. 73-31, Fig. 1), for example, a prominent coal to coaly shale unit, 0.7 m (2.2 ft) thick, is exposed 5.8 m (19 ft) below the No. 9 marker. This carbonaceous unit may extend into the subsurface; it could develop into a vitreous coal seam and, accordingly, be misinterpreted as Seam No. 9.

Because of the generally small amount of coal in the seam, mining activity has not occurred in the report-region, with the possible exception of the area near Beynon.

SEAM NO. 10 (MARKER SEAM)

The No. 10 or Marker Seam of Allan and Sanderson (1945) (Pl. 4E) is exposed near the top of the river escarpment above the "Drumheller Marine Tongue" at Horsethief Canyon (Sec. 73-27). It can be traced in outcrop upstream along the Red Deer River valley to the mouth of Big Valley Creek (Sec. 73-40), at which point it begins to lose its distinctive brown colour, and becomes difficult to separate from adjacent strata. Furthermore, in this region, the seam lies close to the present river floodplain, and at many places dips beneath the land surface. The seam also is exposed west of Drumheller near Horseshoe Canyon (Sec. 73-53, Fig. 1) and Dunphy Ski Hill (Sec. 73-55, Fig. 1)

The No. 10 marker, although low in coal, is generally the most conspicuous, and most easily recognized major marker seam in the Horseshoe Canyon Formation. It comprises a single dark to medium brown weathering unit, within a thick sequence of alternating light green and light grey, argillaceous mudstone, siltstone, and sandstone, conspicuously lacking other carbonaceous interbeds. Seam No. 10

consists of carbonaceous to coaly shale, with rare thin beds and lenticles of vitreous coal. The latter were noted only at Horseshoe Canyon (Sec. 73-53) and Dunphy Ski Hill (Sec. 73-55), where the seam occurs as thin beds up to 0.03 m (0.1 ft) thick. At most other localities, the coal forms thin vitreous laminations and lenticles, rarely exceeding 0.01 m (0.05 ft). The Marker Seam becomes progressively less carbonaceous and coaly, and increasingly more silty and sandy toward the north up Red Deer River valley, so that, at Section 73-40 near the mouth of Big Valley Creek, it consists of light brown argillaceous sandstone to siltstone, with minor scattered fragments of brown carbonized vegetal matter. Across Red Deer River valley at Section 73-39 (Figs. 1, 3), the seam cannot be recognized. The level at which it should be exposed consists of light grey to greenish-grey argillaceous siltstone and mudstone.

Seam No. 10 lies at a level ranging from 37.5 to 40.5 m (123-133 ft) above Seam No. 9, and rarely exceeds a thickness variation between sections of more than 1.5 m (5 ft). Consequently, the seam may be used as an excellent datum or stratigraphic reference marker in the Red Deer River region. The strata between Seams No. 9 and No. 10 contain very few conspicuous carbonaceous or coaly shale interbeds. Those that do occur (rarely more than 3) are found close to Seam No. 9.

Seam No. 10 does not contain coal of sufficient quality and thickness in the report-area to be of economic interest.

SEAM NO. 11 (CARBON SEAM)

This seam, commonly referred to as the Carbon Seam, is well exposed along Red Deer River valley between Section 73-32, north of Morrin Bridge river crossing, and the river valley escarpment east of Lousana (Sec. 73-48, Fig. 1). Upstream, beyond the latter locality, it is commonly covered with talus and trees, and difficult to trace and identify. Excellent exposures also occur at Horseshoe Canyon (Sec. 73-53), 14.5 km (9 miles) west of Drumheller.

Seam No. 11 comprises an interbedded, interlaminated sequence of dark grey to black carbonaceous to coaly shale, shaly siltstone, and coal, ranging in measured thickness from a minimum of 0.2 m (0.8 ft) northwest of Rowley (Sec. 73-35), to a maximum of 1.6 m (5.3 ft) at Horseshoe Canyon (Sec. 73-53). The coal displays a vitreous to dull lustre, is blocky weathering, and forms individual beds up to 0.8 m (2.5 ft) thick (i.e. Secs. 73-37, 73-43) although, at most sections, beds rarely exceed 0.3 m (1 ft). The coaly to carbonaceous shale not only forms a significant constituent of the seam but, at some localities, is a notable rock type above and below the seam. At Sections 73-35 (Fig. 1) northwest of Rowley, for example, clean vitreous coal constitutes the entire seam, while the "roof" and "floor" rock consist of carbonaceous to slightly coaly shale, up to 0.8 m (2.5 ft) thick. In contrast, at Horseshoe Canyon (Sec. 73-53, Fig. 1), the seam is made up mainly of coaly to carbonaceous shale, with coal present as a secondary or minor component. Light brown to buff bentonite, in lenticular beds up to 0.2 m (0.7 ft) thick, is common at many sections in the area. "Charcoalized" and partially silicified wood fragments also were found in the seam at Horseshoe Canyon (Sec. 73-53) and northeast of Rowley (Sec. 73-35, Fig. 1).

The No. 11 Seam is overlain either by dark grey, carbonaceous shale or by shaly siltstone, as shown at Sections 73-54, 73-32 and 73-35, or by the typical light grey weathering, argillaceous-bentonitic sandstone, similar to that described above and overlying other lower major seams in the formation. Seam No. 11 is underlain by carbonaceous siltstone to silty shale, containing a large amount of vegetal matter. At some section locations, however, the vegetal material does not form a conspicuous component.

The Carbon Seam occurs at a level ranging between 53.5 and 61.6 m (175.5 and 202 ft) above the Marker Seam (No. 10). This interval, like many others between major coal seams, is characterized by secondary carbonaceous to coaly shale interbeds although, between Seams No. 10 and No. 11, they are limited to a zone generally within 7.6 m (25 ft) of the No. 11 Seam. At Section 73-39 (Fig. 1), for example, a secondary seam was encountered 3.5 m (11.5 ft) below the Carbon Seam, which consists of 0.4 m (1.3 ft) of clean vitreous coal. At Section 73-35, northwest of Rowley, another secondary seam, 0.4 m (1.3 ft) thick, was observed 7.9 m (26 ft) below Seam No. 11 although, at this locality, it consists mainly of coaly to carbonaceous shale with only one interbed of coal 0.2 m (0.5 ft) thick. The remaining stratigraphic interval to Seam No. 10 consists of alternating light grey to greenish-grey weathering mudstone, siltstone and sandstone.

In former years, coal was produced from the Carbon Seam at widely separated areas in the region (Allan and Sanderson, 1945) but, today, coal is not being mined from the seam. However, under favourable economic conditions, the seam again may be worthy of development because of the relatively large coal content at many localities.

SEAM NO. 12 (THOMPSON SEAM)

The No. 12 or Thompson Seam (Pls. 2B; 4E) is the highest of the major coal-bearing markers in the Horseshoe Canyon Formation. It is exposed in Red Deer River valley between the area east of Lousana (Sec. 73-48) and the area north of Morrin Bridge river crossing (Sec. 73-32). Additional, although generally poor, exposures of the seam occur along Red Deer River valley north of Section 73-48 to the Nevis Bridge area, the northern limit of this report. The seam also is exposed at Horseshoe Canyon (Sec. 73-53), 14.5 km (9 miles) west of Drumheller, where it forms a distinctive correlation marker unit beneath the light grey weathering sandstone and siltstone of the Whitemud Formation. Precise identification of the seam is, in places, difficult in the Huxley-Trochu area of the river valley, because the interval above the below No. 12 Seam contains carbonaceous to coaly shale and coal units within a few feet of it.

The Thompson Seam consists of an interbedded sequence of coal and dark grey to black, very carbonaceous to coaly shale, similar in appearance and composition to that of other major marker seams in the Horseshoe Canyon Formation. The coal is vitreous and blocky weathering, and commonly occurs as thin beds and lenticles, in approximately equal concentration to the carbonaceous and coaly shale. In the Huxley-Trochu area, however, it forms distinctive vitreous beds up to 0.9 m (3 ft) thick (i.e. Sec. 73-39). Thin lenticular beds and stringers of buff to light brown bentonite, up to 0.1 m (0.3 ft) thick, also are interbedded with the coal and shale at many localities. The No. 12 Seam varies in thickness from a minimum of 0.1 m (0.4 ft) near Tolman Bridge (Sec. 73-42) to a maximum of 1.5 m (5 ft) southeast of Huxley (Sec. 73-39). At Big Valley Provincial Campground (Sec. 73-44), however, the seam is overlain and underlain by carbonaceous shale 1.4 and 0.5 m (4.5 and 1.5 ft) thick, respectively, which, if combined with the coal and shale of the main seam, would make a carbonaceous-coal unit in excess of 2.4 m (8 ft) thick. The average range in thickness of the seam is 0.5 to 0.6 m (1.5-2 ft).

Seam No. 12 crops out at a level ranging between 6.9 and 15.9 m (22.5 and 52 ft) above the Carbon or No. 11 Seam (Fig. 3, Table 1). The unusually high maximum value was recorded at Section 73-46 (Fig. 1) and may be a result of locally reduced compaction due to numerous thin and thick, lenticular channel sandstone beds, up to 2.7 m (9 ft) thick in places, which are less common at other nearby localities. The strata between the two seams contain up to two carbonaceous to coaly shale or coal beds. At Big Valley Provincial Campground (Sec. 73-44), for example, vitreous coal forms two separate beds each 0.3 m (1 ft) thick, 9 and 10.7 m (29.5 and 35 ft), respectively, above Seam No. 11. These secondary carbonaceous shale and coal interbeds were observed only north of Tolman Bridge river crossing.

The interval between Seam No. 12 and the top of the Horseshoe Canyon Formation progressively thickens upstream beyond the Morrin Bridge river crossing. At Section 73-32 east of Three Hills (Fig. 1), the overlying Whitemud Formation rests directly on Seam No. 12 whereas, east of Lousana (Sec. 73-48), 18.3 m (60 ft) of strata are exposed between Seam No. 12 and the Whitemud Formation. Secondary carbonaceous to coaly shale and coal beds characterize part of the interval in the Big Valley Creek area and, in some areas, make it difficult to identify and laterally trace Seam No. 12 between adjacent sections. An example of these secondary seams occurs at a section east of Goosequill Lake (Sec. 73-46, Fig. 1), where 1.3 m (4.3 ft) of coal and coaly shale are exposed 3.5 m (11.5 ft) above the No. 12 Seam. Five kilometres (3 miles) upstream at Section 73-48, however, the strata between the Whitemud Formation and Seam No. 12 contain no obvious carbonaceous shale beds.

The Thompson Seam is overlain abruptly and erosionally at most section locations by light grey weathering, argillaceous sandstone up to 3.4 m (11 ft) thick (Sec. 73-38). At two sections (Secs. 73-32, 73-53), however, the overlying sandstone belongs to the lower Whitemud Formation. At other sections (i.e. Secs. 73-34, 73-35, 73-40, 73-44, 73-46, 73-48) in the area, the seam is overlain gradationally by carbonaceous, locally bentonitic shale, mudstone or siltstone. At most places the seam is underlain by the typical carbonaceous, silty to sandy shale but, in some areas, it is underlain by argillaceous, slightly carbonaceous sandstone, as shown by a 9.4 m (32 ft) thick unit at the mouth of Big Valley Creek (Sec. 73-43).

The Thompson Seam has been mined at Section 73-47 (Fig. 1), although nowhere is coal now being produced. However, like the underlying Carbon Seam, it has good secondary carbonaceous shale, siltstone and coal beds a few feet above, below and adjacent to the main marker seam. These secondary units may develop into thick seams of good coal along strike in the subsurface.

SEAM NO. 13 (NEVIS SEAM)

The No. 13 or Nevis Seam (Lower Ardley "A", Holter *et al.*, 1975) (Pl. 4F) lies at a stratigraphic level ranging between 36.4 and 46.6 m (119.5 and 153 ft) above the base of the Scollard Formation. The seam is exposed and easily recognized in the Huxley-Trochu area of the Red Deer River valley, at Sections 73-39 and 73-40 (Fig. 1), and at the supplemental type section location of the Scollard Formation (this report - *see* Appendix). Beyond this area toward the north, recognition and correlation of the seam is difficult because of poor and laterally discontinuous exposures with consequent lack of measurable sections. At Big Valley Provincial Campground (Sec. 73-50, Fig. 1), the river valley escarpment on the east side of the valley is capped by a thick coal, coaly shale, and bentonite lithofacies, which is herein interpreted to be equivalent to Seam No. 13. The stratigraphic thickness (46.6 m, 153 ft) between the capping coal-bearing facies and the base of the Scollard Formation is such that, when compared to thickness values between Seam No. 13 and the base of the member at Sections 73-40 and 73-39 downstream, it is more likely to be equivalent to Seam No. 13 than to Seam No. 14. The relatively thick carbonaceous and coal-bearing seam at the top of the escarpment of the Thompson's Mine locality (Sec. 73-47, Fig. 1) for similar reasons also is considered to be equivalent to Seam No. 13. At this section, it occurs 37.5 m (123 ft) above the base of the Scollard Formation. At Ardley, 25.7 km (16 miles) northwest of Thompson's Mine (Fig. 1), a major, thick, coal-bearing seam is exposed near river level (Sec. 73-49), and has been named the Ardley or Big Seam (Allan and Sanderson, 1945; Ower, 1960; Campbell, 1967). Ower (1960, p. 323) reported the seam at a level approximately 19.8 m (65 ft) above the contact of the Kneehills Tuff member of the Edmonton Formation (Battle Fm. of this report), and referred to it as the "Lower Ardley Seam". Campbell (1967), in his investigations of the Ardley coal zone of the central Red Deer River area, recorded approximately 22.9 to 24.4 m (75-80 ft) of strata between the Kneehills Member and the Ardley Seam in the Ardley area. The thickness of strata recorded between this seam and the contact with the Kneehills Member (Battle Fm.) is such that the Lower Ardley Seam may be equivalent to Seam No. 13 of the Huxley-Trochu area to the south, and not Seam No. 14 as may be suggested. The stratigraphic interval between Seam No. 13 and the base of the Scollard Formation decreases from 46.6 m (153 ft) at the Huxley East locality (Sec. 73-39) to 37.5 m (123 ft) at Thompson's Mine (Sec. 73-47). If this thickness trend continues upstream into the Ardley area, then the

Ardley Seam at Ardley (Sec. 73-49) likely would correlate with the No. 13 or Nevis Seam of the Huxley-Trochu area. Alternatively, if the thickness trend does not continue, and indeed the Ardley Seam does occur at a level 19.8 to 24.4 m (65-80 ft) above the base of the member as reported by Ower (1960) and Campbell (1967), then it may not correlate with either Seam No. 13 or Seam No. 14, and thus would represent a new and perhaps older seam at the base of the Scollard Formation.

Seam No. 13 consists of an interbedded, interlaminated unit of very carbonaceous to coaly shale and coal, with the latter forming conspicuous vitreous beds up to 1.4 m (4.5 ft) thick (Sec. 73-50). Lenticular beds of buff- to orange-weathering bentonite, up to 0.3 m (0.9 ft) thick, also occur in the coal seam at Big Valley Campground (Sec. 73-50), Thompson's Mine (Sec. 73-47), and Ardley (Sec. 73-49). The seam ranges in measured thickness from a minimum of 0.3 m (1.1 ft) west of Scollard (Sec. 73-40) to a maximum of 3 m (9.8 ft) at Ardley (Sec. 73-49). At Big Valley Campground, it is 2.4 m (7.3 ft) thick.

Carbonaceous or coal-bearing beds are not common between the seam and the base of the Scollard Formation, thus making it very conspicuous when first encountered in the river valley. However, at Big Valley Provincial Campground (Sec. 73-50), 3 prominent carbonaceous shale and coal units occur 29.9, 31.1 and 35.2 m (98, 102 and 115.5 ft), respectively, above the base of the formation. All 3 secondary seams contain clean vitreous coal, in beds up to 0.5 m (1.5 ft) thick. The two lower seams possibly could be considered equivalent to Seam No. 13 downstream, although the thickness of strata between Seam No. 13 and the base of the member, as previously mentioned, does not support this interpretation for the Big Valley Campground region.

The Nevis Seam is overlain gradationally by carbonaceous shale or shaly siltstone. However, at Sections 73-50 and 73-47, it is overlain by Pleistocene till or forms the exposed surface of the river escarpment. The seam is underlain by dark brown, very carbonaceous siltstone to silty shale or sandstone, containing a large amount of carbonized vegetal matter.

Because of the increase in both thickness and coal content upstream beyond the Huxley-Trochu area, the seam may be of interest as a potential producer in the area. At Sections 73-50 and 73-47, the seam is close to or at the level of the present land surface and, accordingly, may be amenable to surface strip mining. The Lower Ardley Seam to the north has been mined in the past, and today is strip mined near Heatberg.

SEAM NO. 14 (ARDLEY SEAM)

This seam (Lower Ardley "B", Holter *et al.*, 1975) is the uppermost of the coal-bearing markers in the Scollard Formation in the report-area, and is well exposed and readily identified along the top of the river valley escarpment east of Huxley and Trochu (Pl. 2C) in the Red Deer River valley (Fig. 1). It has been identified by many workers, and is considered equivalent to the coal-producing Ardley or Big Seam of the Ardley area to the north. Accordingly, the No. 14 Seam is commonly referred to as the Ardley Seam in the Huxley-Trochu area. However, as noted previously, Ower (1960) and Campbell (1967) recorded the thick seam at Ardley at a stratigraphic level much lower in the Scollard Formation than the level at which Seam No. 14 is found in the Huxley-Trochu area of this report. Ower (1960) further suggested that Seam No. 14 be designated as the "Upper Ardley" Seam, and that the major seam exposed at Ardley (Sec. 73-49) be called the main or "Lower Ardley" Seam. Campbell (1967) combined all of the major coal-bearing seams above the Kneehills Marker Horizon (Battle Fm. of this report) into the Ardley Coal Zone, although he suggested correlation of the thick seam at Ardley with the Upper Ardley or No. 14 Seam of the Huxley-Trochu area. The writer, however, as previously discussed, correlates the major seam at Ardley with the No. 13 Seam of the Huxley-Trochu and Big Valley Campground areas. In the Hand Hills south of Delia (Sec. 73-56, Fig. 1), a thick (3.5 m; 11.4 ft) coal-bearing seam is exposed, which may be equivalent to Seam No. 14. Unfortunately, this section does not contain a contact with the Battle Formation and, consequently, one is not sure whether this seam is equivalent to No. 13 or No. 14, or in fact whether it may be an entirely different seam.

Seam No. 14 consists of interbedded, interlaminated coal, coaly to carbonaceous shale, and bentonite, ranging in measured thickness from a minimum of 2.2 m (7.1 ft) (Sec. 73-40) east of Huxley to a maximum of 3.2 m (10.4 ft) in the road-cut exposure west of Tolman Bridge river crossing (Fig. 1). The coal is clean, with a vitreous to dull lustre, and forms individual beds up to 1.8 m (6 ft) thick. The shale is extremely carbonaceous, coaly in part, and is characterized by a large amount of black to brown, macerated, carbonized vegetal fragments. Buff to light brown bentonite is a common constituent of the seam, and forms lenticular beds up to 0.15 m (0.5 ft) thick.

The Upper Ardley or No. 14 Seam occurs at a level ranging between 15.2 and 17.8 m (49.8-58.5 ft) above the Nevis or No. 13 Seam or, alternatively, 57.6 to 64.6 m (189-212 ft) above the base of the Scollard Formation. The strata between the two seams contain a few secondary carbonaceous to coaly shale and coal facies up to 0.3 m (1 ft) thick, with seams at two sections containing vitreous coal up to 0.1 m (0.3 ft) thick. The stratigraphic interval between Seam No. 14 and the top of the Scollard Formation, about 14.9 m (49 ft) (Sec. 73-41), contains similar secondary carbonaceous to coaly shale and coal beds although, at this level, they are up to 0.5 m (1.5 ft) thick and contain individual beds of coal up to 0.2 m (0.5 ft) thick. Many of these secondary marker beds are characterized by yellow sulphur staining, and contain scattered euhedral selenite crystals. East of Huxley (Sec. 73-41), the Scollard Formation, immediately below its contact with the overlying, cliff-forming, massive sandstone facies of the Paskapoo Formation, is characterized by a very distinct sulphurous coaly to carbonaceous shale bed, up to 0.5 m (1.5 ft) thick.

Seam No. 14 was mined formerly in the Huxley-Trochu and possibly other areas of the central Alberta

Plains. The seam is thick where exposed, commonly contains clean vitreous coal and, under suitable conditions, may be considered as a good commercial prospect. For a more detailed résumé and discussion of the Ardley coal zone, including Seam No. 14 of this report, in the central Alberta Plains of the Red Deer River valley, the interested reader is referred to reports by Campbell (1967) and Holter *et al.* (1975).

DEPOSITIONAL HISTORY

INTRODUCTION

The depositional history of the Upper Cretaceous-Tertiary rock succession in the Red Deer River valley of the central Alberta Plains has been described in varying detail by such workers as Allan and Sanderson (1945), Ritchie (1960), Elliott (1960), Russell and Chamney (1967), Irish and Havard (1968), Binda (1969), Irish (1970), Shepheard and Hills (1970), Carrigy (1971), Wall *et al.* (1971), and Binda and Lerbekmo (1973). Many of these descriptions and interpretations are brief, and concern only specific intervals or facies of the rock succession. However, in spite of additional stratigraphical and sedimentological information obtained by the writer during this field study in the Ardley-Drumheller area of the Alberta Plains, the basic interpretations of the above workers remain valid. An attempt is made, based on the following discussion, to summarize the major depositional events in the report-area for the stratigraphic interval between the Bearpaw Formation, and the cliff-forming lithofacies of the Paskapoo Formation. The more important observations and interpretations of other workers will be incorporated into the discussion.

Horseshoe Canyon Formation

Strata of the Horseshoe Canyon Formation comprise part of an eastward-thinning wedge of fluvial-deltaic sediments, deposited along the western margin of the Late Cretaceous Bearpaw Sea. The lower 61 to 73.2 m (200-240 ft) of the formation, between the Bearpaw contact and the approximate level of Coal Seam No. 6 (Fig. 3), contain sedimentary and faunal characteristics that are found commonly in recent Lower Delta Plain depositional environments. Shepheard and Hills (1970) recognized several deltaic lithofacies in the lower 54.9 to 61 m (180-200 ft) of the Horseshoe Canyon Formation in the Willow Creek-East Coulée area of this report (Fig. 1), which they interpreted as being similar to recent major distributary, marginal swamp, levee, backswamp, interdistributary bay, open and partially restricted bay, and point bar deltaic subenvironments. For example, they interpret the relatively thick and laterally extensive, light grey weathering sandstone at the base of the Horseshoe Canyon Formation in the Willow Creek area (i.e. Sec. 73-3, Fig. 1) as a major distributary channel. The sandstone contains thin pebble beds and well-developed large- and small-scale trough crossbedding. The thinner and areally less extensive, light grey weathering sandstones higher in the stratigraphic interval are interpreted as beach, barrier complex, or point bar deposits. The interbedded dark grey shale and mudstone units are considered to be analogous to recent backswamp or mudflat deposits, while the coal and the carbonaceous to coaly shale are interpreted by them to represent former marsh or swamp deposits. Russell and Chamney (1967) have identified Foraminifera, including *Bathysiphon* sp., *Haplophragmoides* sp., *Hippocrepina* sp., and *?Miliammina* sp. from an interval ranging between 15.2 and 61 m (50 and 200 ft) above the base of the Horseshoe Canyon Formation. Foraminifera also have been identified by Wall *et al.* (1971) in subsurface shale samples collected from an interval near the base of the Horseshoe Canyon Formation. Some of these microfossils are considered to have lived in a brackish water or salt marsh depositional environment.

The writer agrees in general with the deltaic model proposed by the above workers but would suggest, however, the possibility of an alternative fluvial distributary system within the Delta Plain to account for the sedimentary facies, facies relationships and sedimentary structures in the Horseshoe Canyon Formation of the report-area. The lenticular, isolated, and blanket-like character of many of the sandstones (Pl. 4), the rapid vertical and lateral facies changes, and the frequency and configuration of the crossbedding in the lower Horseshoe Canyon Formation may be interpreted as being indicative of sediment transport and deposition by a series of large and small braided streams flowing across a rapidly prograding delta. For example, the relatively thick and laterally extensive sandstone facies at the base of the formation (Pl. 1C, D) may have been deposited by numerous laterally migrating braided stream channels, in contrast to one or two large meandering stream channels. The lower Brahmaputra River of Bangladesh, a classic example of a major braided river system developed in a delta plain environment, may serve as a recent example with which to compare and explain some of the postulated depositional environments of the lower Horseshoe Canyon Formation. The Brahmaputra River contains braided stream channels in the deltaic plain displaying lateral migration rates of up to 853 m (2800 ft) per year (Coleman, 1969). The effect of a migrating braided channel system ultimately would be to form extensive "blanket sand bodies" with considerable lateral continuity (Coleman, *ibid.*). Such a system of migrating stream channels may have been operative in the Drumheller area, resulting in the deposition of the light grey weathering sandstone near and at the base of the Horseshoe Canyon Formation. The thinner, and areally less extensive lenticular sandstone units, 30.5 to 61 m (100-200 ft) above the base of the formation, probably represent smaller braided channel sands or, in some exposures, possible small transverse or longitudinal bars, a depositional feature common to braided stream environments (Ore, 1964, 1965; Smith, 1970; Coleman, 1969). The interfingering of and lateral gradation between fine-grained sandstone, siltstone, mudstone, claystone, and shale is characteristic of recent crevasse splay, interdistributary bay or flood basin environments. These finer grained sediments have been deposited mainly from suspension during and after falling flood stages. Annual flooding is common to many recent braided and meandering river and stream systems of the world and may, therefore, result in the interfingering and vertical and lateral gradation of the finer grained silts, clays and muds in the lower Horseshoe Canyon Formation. However, some of the finer grained sandstones and siltstones of the formation may represent crevasse sheet-like splays. The Foraminifera- and oyster-bearing black shale and sandstone units of the Horseshoe Canyon Formation represent strata deposited during periods of marine inundation or, alternatively, in shallow-marine to brackish water lagoons, bays, or salt marshes connected to the Bearpaw Sea.

Sedimentary structures, such as medium- to large-scale festoon and planar crossbedding (Pl. 3B), micro-scale trough crossbedding (Pl. 3C, D), and lenticular and regular parallel laminations, are common to many of the sandstone and siltstone beds or lenses of the Horseshoe Canyon Formation. Similar structures are found in recent braided stream environments (Ore, 1964, 1965; Coleman, 1969; Smith, 1970; McGowan, 1970; and others), particularly in many recent large and small transverse channel bars. In addition, many recent transverse sandbars are capped by micro- or small-scale festoon crossbedding. The microscale trough and most of the medium-scale planar and trough crossbedding in the sandstone beds and lenses of the report-area are cemented with calcite, and often stained or permeated by reddish-brown iron oxide. Allan and Sanderson (1945) consider these calcite-cemented sandstone units as evidence of subareal exposure with cementation having formed as a result of evaporation, a phenomenon one might expect to develop in subareally exposed transverse bars.

Progradation of the delta continued following deposition of the strata between the Bearpaw Formation contact and the approximate level of Coal Seam No. 6, such that the Drumheller-Red Deer region, once adjacent to and periodically inundated by the Bearpaw Sea, now lay farther inland away from marine influence. The sedimentary character of much of the remaining strata in the formation indicates a depositional mechanism similar to that postulated for the lower 61 m (200 ft) of the formation. However, the increase in number of the sandstone beds, coupled with more numerous lateral and vertical lithofacies variations (Pl. 1A), suggests that these strata were deposited by generally smaller and perhaps more numerous braided streams, mainly within the Upper Delta Plain subenvironment. The light grey weathering sandstone units are more lenticular, areally less extensive, and generally much thinner than those beneath Coal Seam No. 6. The sandstones are thin to medium bedded, finely laminated in part, and commonly contain microscale trough crossbedding in the upper few centimetres of each bed. Medium- to large-scale crossbedding, although present in some of the thicker sandstone beds, is less common in comparison to that found near the base of the formation. Lateral and vertical facies changes and grain size variations are noticeably more numerous in the upper half of the Horseshoe Canyon Formation, so that individual stratigraphic units are difficult to trace even between closely spaced locations. For example, many locally distinctive lithofacies, with the exception of the carbonaceous to coaly shale, cannot be extended or traced laterally more than 91 to 183 m (100-200 yds). In the braided Brahmaputra River delta plain, peat accumulates in the flood basin or interchannel areas, in thicknesses of up to 3.7 m (12 ft) (Coleman, 1969). In a delta plain environment characterized by numerous small braided streams, thin layers or beds of carbonaceous shale or vegetal matter may develop or accumulate in the flood basin marsh or swamp areas. As a result of the rapid shifting of channels and variation in sedimentation rates, a feature common to braided stream environments, peat and potential coal accumulating areas would tend to be ephemeral, and to result in the formation of generally thin and lenticular coal or carbonaceous seams, a feature common to some of the coal seams and carbonaceous shale units of the Horseshoe Canyon Formation. In areas where coal seams are thick and laterally extensive, vegetal accumulation took place over a much longer time interval, possibly during a period of low clastic sediment input, or at a time when the major river channels were less numerous or flowing elsewhere in the area, thus permitting subsidence and luxuriant growth and accumulation of vegetal matter in the flood basin or swamp areas.

The occurrence of *Ostrea* sp. in two calcareous sandstone beds of the "Drumheller Marine Tongue" indicates a brackish-water depositional environment (Allan and Sanderson, 1945; Irish, 1970). This fossiliferous lithofacies, however, is difficult to explain in view of the Upper Delta Plain environment postulated for much of the strata in the Horseshoe Canyon Formation. One might suggest, however, an influx of salt water due to catastrophic storms, resulting in extensive flooding inland beyond the upper limit of the Lower Delta Plain environment. Alternatively, marine inundation also may occur during a period of rapid subsidence in the delta, permitting marine transgression and the temporary development of small oyster "reefs" in low-lying flood basin or lagoonal areas.

Following deposition of the oyster-bearing sandstone of the Drumheller Marine Tongue, environmental and depositional conditions changed in the area. The strata between Coal Seams No. 10 and No. 11 (Fig. 3) are characterized by a distinctive alternation of light grey weathering, fine-grained sandstone with well-developed microscale crossbedding, and greenish-grey weathering mudstone to siltstone. Carbonaceous and coal-bearing interbeds are conspicuously rare within the interval, reflecting perhaps a period of relatively low rainfall in the delta area. Little or no vegetation would grow or accumulate in the area. The sedimentary character of the interbedded, interlaminated and laterally interfingering siltstone, sandstone and claystone is again typical of a shallow-water braided stream-deltaic depositional environment. Microscale trough crossbedding (Pl. 3C, D) and poor sorting characterize the sandstone of the interval.

Climatic and environmental conditions again may have changed during deposition of the sandstone, siltstone, mudstone, shale and coal between Seam No. 11 and the top of the formation. The region appears to have been subjected to periods of increased rainfall, high clastic sediment input, and a luxuriant growth of vegetation in the flood basin or swamp areas. Coal seams (Nos. 11 and 12) are relatively thick and laterally extensive in the region. The sandstone units of the interval are thick, poorly sorted, commonly crossbedded and, at some localities, are coarse grained, and contain well-rounded pebbles and cobbles up to 7.6 cm (3 in) in diameter, suggesting increased and relatively strong current activity in many of the major distributary stream channels.

Montmorillonite is a common cement and matrix component of most strata in the Horseshoe Canyon and younger formations in the area. In addition, it forms thin beds of buff- to orange-weathering bentonite. Montmorillonite and bentonite generally represent diagenetically altered wind- or water-borne volcanic ash (Ritchie, 1960; Irish and Havard, 1968; Binda, 1969; and others) and, therefore, indicate periods of explosive activity during Late Cretaceous time. The source of the volcanic material transported and deposited during Horseshoe Canyon time, however, is uncertain and remains speculative. Studies by Ritchie (1960), Irish and Havard (1968), Binda (1969), and Carrigy (1971) on bentonitic claystones, bentonites, and tuff interbeds in the overlying Battle and lower Paskapoo Formations (Fig. 2) suggest a southern or western source area for the volcanic material and volcanic activity.

Whitemud Formation

The light grey to white-weathering bentonitic sandstone, siltstone, and claystone of the Whitemud Formation (Pl. 3A, B) were deposited in a fluvial-deltaic environment, under conditions similar to those postulated for much of the underlying Horseshoe Canyon Formation. The sandstone is fine to coarse grained and commonly displays medium- to microscale festoon crossbedding. The sandstone concentration and grain size decrease from the base to the top of the formation in the report-area so that the upper few feet of the Whitemud Formation at many localities consist of very bentonitic claystone to mudstone. The vertical decrease in sand content suggests that the clastic sediment input, and the transporting capacity of the distributary stream channels decreased progressively during the latter stages of Whitemud time, reflecting a possible change in climate and depositional environment in the Red Deer River area and the detrital sediment source area to the west. With a decrease in clastic sediment to the delta, subsidence may have become a dominant factor, resulting in the formation of extensive shallow-water interdistributary basinal areas during the latter stages of Whitemud time.

Explosive volcanic activity in the source area increased during Whitemud time, as shown by the increase in concentration of montmorillonite and bentonite from the base to the top of the formation. Irish and Havard (1968) analyzed samples of the Whitemud Formation from different areas of the Alberta Plains, Cypress Hills and southwestern Saskatchewan. They discovered that the montmorillonite concentration decreased from 90 per cent of the clay minerals in the western region of the southern Alberta Plains to 27 per cent of the clay minerals in the Cypress Hills area to the east. In southwestern Saskatchewan, the montmorillonite concentration showed a further decrease, compared to other clay minerals of the formation. As a result of these analyses, Irish and Havard (1968) postulated a western source area for the diagenetically altered volcanic ash.

Battle Formation

During the deposition of Battle strata, explosive volcanic activity appears to have been at a maximum in the source area. The strata consist mainly of dark grey bentonitic claystone, with about three, light grey to white-weathering beds of well-indurated silicified volcanic tuff (Kneehills Tuff, Pl. 2A). In the report-area the claystone consists mainly of montmorillonite which is thought to have formed by the diagenetic alteration of volcanic ash in an aqueous environment (Irish and Havard, 1968). Following deposition of the Whitemud strata, subsidence in the delta appears to have been at a maximum, resulting in the formation of a series of large shallow-water lakes, bays, or interconnected flood basins, with the region probably close to sea level. As a result of the postulated reduction in rainfall and resultant dry climate, the transporting capacity of most rivers and streams would be greatly reduced, with little or no terrigenous clastic sediment carried to the delta. Conclusive evidence has not yet been found to indicate whether the Battle Formation claystone was deposited under marine or nonmarine conditions, Irish and Havard (1968) concluded that the basinal area comprised an interconnected series of fresh-water lakes. Elliott (1960) and Russell and Chamney (1967), however, considered the formation to be part of a marine succession.

The interbedded Kneehills Tuff has been analyzed and described in detail by Ritchie (1960), Irish and Havard (1968), and Binda (1969). All agree that the tuff is a diagenetically altered, wind-blown volcanic ash, deposited in a subaqueous, fresh-water, basinal environment. Heavy mineral and maximal grain-size studies by Ritchie (1960) and Binda (1969) have led to the suggestion of a southern source area for the volcanic ash, possibly related to the effusive stage of the Boulder batholith in Montana (Ritchie, 1960).

Scollard Formation

Medium- to microscale trough crossbedding, rapid lateral and vertical lithofacies changes, and thick coal and carbonaceous to coaly shale in the upper part of the Scollard Formation suggest that the Red Deer River region of this report gradually returned to an environment similar to that postulated for the deposition of the Horseshoe Canyon and Whitemud Formations. Subsidence in the delta appears to have decreased following deposition of the Battle Formation. The region was again subjected to increased detrital sediment input and progradation by an extensive system of braided rivers and streams, during which time thin- to thick-bedded, light grey weathering bentonitic sandstone and siltstone, and bentonitic mudstone and claystone were deposited. Shallow-water basins or lakes remained in part of the area during the initial stages of Scollard deposition, as shown by the presence of beds of purplish-grey weathering, Battle-like claystone, and light greenish-grey mudstone. Thin to thick coal seams and carbonaceous to coaly shales in the upper half of the member suggest a return to periods of heavy or increased rainfall, resulting in the rapid and luxuriant grown of vegetation in the flood basin or low-lying swamp areas.

Volcanic activity continued in the western source-area throughout deposition of the Scollard strata. Volcanic rock fragments, montmorillonite clays, and minor siliceous tuffs occur in the strata. Orange- to buff-weathering bentonite forms thin, laterally persistent beds within and adjacent to Coal Seams No. 13 and No. 14. Carrigy (1971) suggests that the source for the volcanic matter in the Scollard and Paskapoo Formations is from the breakdown of effusive rocks in the interior of British Columbia.

Following deposition of the Scollard Formation, the Trochu-Ardley and adjacent areas of this report (Fig. 2) became the site of a major distributary channel, during which time a coarse-grained, cross-bedded, laterally extensive sandstone facies was deposited (Pl. 2C). This sandstone forms the base of the Paskapoo Formation and represents the uppermost rock exposure in most of the Red Deer River valley of this report.

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APPENDIX

SUPPLEMENTAL REFERENCE SECTION, SCOLLARD FORMATION

Lithology of formation represented by composite measurement of field Sections 73-39 and 73-41 (Fig. 1). Base of unit of Section 73-41 is equivalent to base of Unit 91 of Section 73-39 (Fig. 1)

Section 73-41. Located at Huxley East, Paskapoo locality. Section measured high on cliff-forming escarpment, west side of Red Deer River, 2.9 km (1.8 miles) upstream from Section 73-39, L.S.D. SE3-34-22W4. All measurements are in metres (feet).

Unit	Lithology	Thickness	Height Above Base
	PASKAPOO FORMATION		
24	Sandstone, slightly argillaceous, fine- to medium-grained, yellowish-grey to dusky yellow, and weathering orange-grey; large-scale trough crossbedding; fine to coarse, dark grey carbonaceous laminations in part; scattered siltstone and sandstone pebbles up to 2.5 cm (1 in) in diameter near base; moderate induration; unit forms abrupt contact with underlying shale; resistant and cliff-forming	6.1 (20.0)	23.6 (77.6)
	SCOLLARD FORMATION		
23	Shale, very coaly and carbonaceous, with lenticles of claystone; appears silty in part; greyish-black, and weathers dark brown; small, brown plant fragments in claystone lenticles; unit of variable thickness along strike; recessive	0.2 (0.7)	17.5 (57.6)
22	Mudstone, silty, may be classed in part as silty claystone; medium to medium dark grey, and weathering light bluish grey; unit replete with brown to black carbonized vegetal fragments; recessive	0.2 (0.7)	17.3 (56.9)
21	Shale, coaly, very carbonaceous with large concentrations of brown to black plant matter; greyish-black, and weathering same to dark brown; yellow sulphur staining throughout; scattered selenite crystals; resistant	0.1 (0.4)	17.1 (56.2)
20	Siltstone to very fine grained sandstone, very argillaceous, medium grey, with slight olive tint, and weathering bluish grey; sandstone occurs as thin, finely laminated, 5 cm (2 in) thick interbeds; brown plant fragments throughout; slightly recessive to resistant	2.8 (9.2)	17.0 (55.8)
19	Sandstone, very calcareous, argillaceous, fine-grained, yellowish-grey, and weathering same; microscale trough crossbedding; brown plant stem and broad leaf fragments throughout; dark grey, carbonaceous ripple laminations in part; moderate induration; resistant	0.2 (0.6)	14.2 (46.6)
18	Mudstone, may be classed in part as claystone, very silty in part, light olive-grey to medium grey, and weathering buff to bluish grey; weathers very flaky; recessive	0.6 (2.1)	14.0 (46.0)
17	Siltstone to mudstone, very argillaceous, light olive-grey to yellowish-grey, and weathering buff; no plant fragments; weathers flaky; slightly recessive	0.4 (1.2)	13.4 (43.9)
16	Mudstone, may be classed in part as silty claystone, medium grey with slight olive tint, and weathering bluish grey; few thin, fine-grained sand lenses; plant fragments throughout including fern and broad leaf impressions; very wavy bedding surfaces; slightly recessive	0.5 (1.5)	13.0 (42.7)
15	Coal, sulphurous, with yellow weathered coating; scattered small selenite crystals on parting surfaces; thin, 1.2 cm (0.5 in) thick, buff bentonite bed at top; unit very fissile to flaky; coal displays prominent vitreous lustre; recessive	0.1 (0.3)	12.5 (41.2)

Unit	Lithology	Thickness	Height Above Base
14	Claystone, slightly silty in part, light olive-grey to greenish-grey, and weathering bluish to greenish grey; thin, buff bentonite seam near base, 1.2 to 2.5 cm (0.5-1 in) thick; unit displays orange-brown ferruginous staining; slightly recessive	0.6 (2.0)	12.4 (40.9)
13	Coal, and coaly shale, very sulphurous and limonitic in part; black, and weathering same with orange ferruginous and yellow sulphur staining throughout; coal very vitreous, forming chunky, 7.6 to 15 cm (3-6 in) thick, bands at top and bottom; colourless selenite crystals throughout; very fissile and flaky in part; recessive	0.4 (1.4)	11.8 (38.9)
12	Mudstone, very silty, light to medium olive-grey, and weathering same; few small plant fragments; slightly recessive	1.6 (5.2)	11.4 (37.5)
11	Sandstone, argillaceous, fine-grained, yellowish-grey with slight olive tint, and weathering greenish grey to buff; few plant rootlets vertical to stratification; poorly indurated; resistant	0.6 (2.0)	9.8 (32.3)
10	Coal, shaly in part, sulphurous and ferruginous with yellow and orange staining throughout; 5 to 7.6 cm (2-3 in) thick, buff bentonite bed at base; scattered ironstone nodules and nodular bands; selenite crystals throughout; weathers shaly; recessive	0.4 (1.2)	9.2 (30.3)
9	Sandstone, very argillaceous, fine- rained, greenish-grey, and weathering same; scattered plant fragments - some vertical to stratification; few coaly fragments; poorly indurated; slightly recessive to resistant	1.0 (3.3)	8.8 (29.1)
8	Siltstone, very argillaceous, light grey to light olive-grey, and weathering same; mottled sand pockets in part; scattered black carbonized plant fragments; few 2.5 cm (1 in) thick, wavy ironstone bands; recessive	0.5 (1.7)	7.8 (25.8)
7	Sandstone and minor shale; sandstone very calcareous, argillaceous, and fine-grained; shale carbonaceous, slightly sandy; unit yellowish grey to dark olive-grey, and weathering same; shale occurs as fissile-weathering interbeds; microscale trough crossbedding in part; well-preserved broad leaf impressions in some sandstone; thin ironstone bands in part; wavy carbonaceous laminations in sandstone; small worm? burrows vertical to stratification in some sandstone; resistant	0.5 (1.6)	7.3 (24.1)
6	Mudstone, very argillaceous and may be classed in part as claystone, medium light grey to light olive-grey, and weathering same to dark grey; ironstone bands up to 5 cm (2 in) thick in part; black carbonized plant fragments throughout; recessive	1.6 (5.3)	6.8 (22.5)
5	Sandstone and minor siltstone; latter forms dense, calcareous, well-indurated, 15 to 30.1 cm (6-12 in) thick bed at top; sandstone very argillaceous, slightly carbonaceous, and is fine to very fine grained; sand contains small vitreous grains and fragments of coal throughout; unit olive-grey, and weathering same to buff; slightly recessive	2.4 (8.0)	5.2 (17.2)
4	Shale, very coaly with black vitreous coal laminae and bands throughout; 10.2 cm (4 in) thick buff bentonite band in part; recessive	0.6 (1.9)	2.8 (9.2)
	<u>Coal Seam No. 14 (Units 3-1)</u>		
3	Coal and minor coaly shale; latter occurs as thin lenses in upper 15 cm (6 in); coal vitreous and chunky; slightly recessive	1.9 (6.2)	2.2 (7.3)

Unit	Lithology	Thickness	Height Above Base
2	Bentonite, buff to light grey, and weathering same; unit forms distinct marker band in area; recessive	0.1 (0.3)	0.3 (1.1)
1	Coal, vitreous, chunky; base of unit covered; recessive	0.2 (0.8+)	0.2 (0.8+)

Section 73-39. Located at Huxley East, Scollard locality. Section measured up steep ridge on west side of Red Deer River, L.S.D. E7-11-34-22W4. All measurements are in metres (feet).

SCOLLARD FORMATION

91	Covered interval; unit underlain by sporadic patches of coal representing probable base of Seam No. 14; very recessive	1.2 (4.0)	151.3 (497.8)
90	Sandstone and siltstone, interbedded; very fine to fine-grained, yellowish-grey and weathering grey-brown; argillaceous; fine wavy to lenticular laminations; 7.6 cm (3 in) carbonaceous black coaly band near centre; fern-like leaf impressions throughout siltstone; upper 1.5 m (5 ft) shaly weathering; slightly recessive to recessive	3.4 (11.3)	150.1 (493.8)
89	Sandstone, slightly argillaceous, calcareous in upper 0.3 m (1 ft), ferruginous banding in part; fine-grained, yellowish-grey to very light grey with prominent yellow-orange banding in part, and weathering orange-grey; upper 0.3 m (1 ft) microscale trough crossbedded; resistant to slightly recessive	2.7 (9.0)	146.7 (482.5)
88	Shale, medium dark grey and weathering same; very fissile; recessive	0.5 (1.8)	144.0 (473.5)
87	Siltstone to silty shale and minor fine-grained sandstone; argillaceous, ferruginous in part; yellowish to dark grey in part, and weathering olive-grey; thin, lenticular ironstone nodular bands in part up to 1.3 cm (0.5 in) thick; sandstone occupies upper 0.6 m (2 ft); slightly recessive	2.5 (8.3)	143.5 (471.7)
86	Siltstone and shale and minor fine-grained calcareous sandstone; unit argillaceous and ferruginous; yellowish-grey to dusky yellow, and weathering buff to orange-brown; sandstone microscale trough crossbedded, forming upper 7.6 cm (3 in); resistant	0.4 (1.3)	141.0 (463.4)
85	Siltstone to silty shale and minor sandstone; latter forms thin, calcareous, fine-grained bed at top; unit very argillaceous; light olive-grey, and weathering greyish brown; fine, regular to wavy carbonaceous laminations; orange-weathering, ferruginous bands and ironstone concretions up to 7.6 cm (3 in) in diameter in part; very carbonaceous, shaly siltstone band with fragmented plant material 0.6 m (2 ft) above base; slightly recessive	1.4 (4.7)	140.6 (462.1)
84	Claystone and minor shale; latter forms upper 5 cm (2 in) and is very carbonaceous, containing fragmented plant material; claystone, sandy in part, dusky yellow to light olive-brown with medium dark grey bioturbate? mottling throughout; shale dark grey and weathering same; claystone weathers dull grey with orange tint; recessive	1.1 (3.6)	139.2 (457.4)
83	Claystone and minor shale, similar to unit 84, but does not display bioturbate mottling; very micaceous; yellowish-grey to light olive-grey, and weathering medium grey with slight green tint; very sandy in part; finely laminated; may be micro-cross-laminated in part; recessive	1.2 (3.9)	138.1 (453.8)
82	Shale, very coaly and may in part be classed as shaly coal; greyish-black, and weathering same; recessive and serves as marker horizon in area	0.1 (0.4)	136.9 (449.9)

Unit	Lithology	Thickness		Height Above Base	
81	Sandstone, very argillaceous, fine-grained, yellowish-grey, and weathering same; unit becomes finer grained toward top; upper 0.3 m (1 ft) contains plant fragments; slightly recessive	1.3	(4.3)	136.8	(449.5)
80	Sandstone, argillaceous, with black, coaly, carbonaceous, wavy laminations in part; medium- to fine-grained, yellowish-grey to very light grey, and weathering light grey; black plant fragments scattered throughout; resistant	1.4	(4.5)	135.5	(445.2)
79	Shale and shaly siltstone, carbonaceous, very bentonitic in part with good "cornflake" weathered surface; dark grey to light olive-grey, and weathering same; siltstone occurs as thin interbeds and laminations; slightly recessive to recessive	0.5	(1.5)	134.1	(440.7)
	<u>Coal Seam No. 13 (Unit 78 only)</u>				
78	Coal and coaly shale, dark grey to greyish-black, and weathering same; coal occurs as thin lenses and interbeds in shale and displays dull vitreous lustre; recessive	0.4	(1.3)	133.6	(439.2)
77	Sandstone, very argillaceous and carbonaceous, containing abundance of plant fragments; very fine grained, brownish-grey, and weathering same with yellowish-orange, ferruginous mottling; unit forms base of coal interval; may be classed in part as sandy shale; recessive	0.1	(0.3)	133.2	(437.9)
76	Sandstone, slightly argillaceous near top, fine- to medium-grained, becoming finer toward top, yellowish-grey, and weathering light grey; resistant to slightly recessive	1.8	(5.8)	133.1	(437.6)
75	Claystone to siltstone, very bentonitic in upper 0.9 m (3 ft), slightly calcareous, light olive-grey, and weathering same; finely laminated in upper half; olive-black burrow? structures perpendicular and parallel to bedding in claystone facies; upper 0.9 m (3 ft) have well-developed "cornflake" weathered surface; scattered ironstone lenticular concretionary bands up to 2.5 cm (1 in) thick	0.4	(1.3)	131.3	(431.8)
74	Sandstone and shale; sandstone very argillaceous, very fine to fine-grained, yellowish-grey, and weathering same with olive tint; shale carbonaceous, dark grey, and weathering same and forms 0.3 m (1 ft) thick bands at base, 1.2 m (4 ft) above base and top of unit; upper shale contains scattered plant fragments; slightly recessive	1.9	(6.3)	130.9	(430.5)
73	Siltstone to sandstone; latter very calcareous, fine grained and forms lower 0.3 m (1 ft) containing microscale trough crossbedding; siltstone very argillaceous and may be classed in part as silty claystone; unit yellowish grey with slight olive tint, and weathering greyish green; sandstone well indurated; resistant	1.2	(3.9)	129.0	(424.2)
72	Shale, very bentonitic, light olive-grey, and weathering same; very fissile in part; recessive	1.0	(3.3)	127.8	(420.3)
71	Claystone and minor fine-grained sandstone; latter occurs as thin band in centre of unit; claystone very silty in part and contains olive-grey bioturbate? mottling and burrows? in upper 0.9 m (3 ft); unit pale olive to greenish grey, and weathering same; unit very bentonitic; slightly recessive to recessive	2.1	(7.0)	126.8	(417.0)
70	Siltstone to silty shale, very argillaceous, olive-grey and weathering same; slightly recessive	1.0	(3.3)	124.7	(410.0)

Unit	Lithology	Thickness	Height Above Base
69	Claystone and minor fine-grained sandstone; latter very argillaceous-bentonitic; claystone very silty and sandy in part; yellowish-grey with orange and green tinting, and weathering green; sandstone occurs as 0.3 m (1 ft) thick bed, 0.5 m (1.5 ft) above base; slightly recessive to recessive	2.1 (7.0)	123.7 (406.7)
68	Shale, very bentonitic, slightly silty; may in part be classed as shaly claystone; light olive-grey to olive-grey when damp or wet, and weathering medium dark grey; good "cornflake" weathered surface; recessive	0.6 (2.1)	121.6 (399.7)
67	Sandstone and minor shale; latter forms lower 25.4 cm (10 in); sandstone very argillaceous, slightly calcareous, fine- to very fine grained; unit yellowish grey with olive tint, and weathering same; shale may in part be classed as silty claystone; scattered vegetal fragments; minor olive-grey bioturbate? mottling and/or vertical worm? burrows in upper 0.6 m (2 ft); slightly recessive to resistant	1.2 (3.9)	121.0 (397.6)
66	Siltstone to silty shale, and minor sandstone; latter occurs as thin, fine-grained, calcareous facies of variable thickness, up to 0.9 m (1.5 ft) thick, 0.6 m (2 ft) and 1.5 m (5 ft) above base - unit part of sand channel facies along strike; siltstone to silty shale may be classed in part as silty claystone; *Azolla?*-like leaf impressions near base; yellowish-grey to light olive-grey, and weathering same; facies very bentonitic; unit finely laminated in lower 0.3 to 0.6 m (1-2 ft); slightly recessive	3.0 (10.0)	119.8 (393.7)
65	Shale, very silty to sandy in part; scattered plant fragments; very bentonitic with good "cornflake" weathered surface; olive-grey, and weathering dark grey; slightly recessive	0.6 (2.0)	116.8 (383.7)
64	Sandstone and siltstone, interbedded and interlaminated; very argillaceous and may be classed in part as mudstone or claystone; sandstone very fine to fine-grained, light olive-grey, and weathering same; laminations wavy to lenticular; scattered plant fragments; slightly recessive to resistant	1.6 (5.3)	116.2 (381.7)
63	Shale, very silty, and may be classed in part as very argillaceous shaly siltstone; olive-grey, and weathering same to dark grey; scattered plant fragments; recessive	0.2 (0.8)	114.6 (376.4)
62	Sandstone and siltstone to mudstone, latter forming lower 0.3 m (1 ft); sandstone very argillaceous, very fine grained, light olive-grey, and weathering same; slightly recessive to resistant	1.1 (3.6)	114.4 (375.6)
61	Mudstone, very silty in part and may be classed as very argillaceous siltstone; very bentonitic; light olive-grey to olive-grey, and weathering dark grey; dark olive-grey bentonite-filled bioturbate? burrows and/or plant rootlets; recessive	1.3 (4.3)	113.3 (372.0)
60	Sandstone and minor mudstone, latter forming lower half; sandstone very argillaceous, and very fine grained, dusky yellow to yellowish grey, and weathering same; sandstone contains well-developed dark olive-grey bentonite-filled burrows? and/or replaced plant rootlets; mudstone well-indurated; slightly recessive to resistant	0.9 (2.8)	112.0 (367.7)
59	Shale, very bentonitic, silty in part, light olive-grey to olive-grey, and weathering dark grey; weathers with good "cornflake" surface; recessive	0.3 (1.1)	111.1 (364.9)
58	Sandstone, siltstone and mudstone; unit forming graded sequence from base to top; sandstone very calcareous, and fine grained, forming lower half of unit; sandstone contains microscale trough cross-bedding; siltstone and mudstone contain dark olive-grey bentonite-		

Unit	Lithology	Thickness	Height Above Base
	filled burrows? and/or replaced plant rootlets; unit yellowish-grey with slight olive tint, and weathering same; orange, ferruginous banding in part; slightly recessive to resistant	1.2 (4.0)	110.9 (363.8)
57	Shale and minor siltstone, latter forming prominent resistant argillaceous band in centre; shale very silty and bentonitic; unit olive-grey to light olive-grey, and weathering same; shale displays only moderate fissility; recessive	0.7 (2.3)	109.6 (350.8)
56	Siltstone to mudstone, very argillaceous, unit very sandy near base; unit pale olive, and weathering same; dark olive-grey, bentonitic mottling near base; recessive	1.7 (5.5)	108.9 (357.5)
55	Sandstone, argillaceous, medium-grained, yellowish-grey, and weathering buff; unit has well-developed trough crossbedding; dark grey regular to wavy carbonaceous laminations near top; scattered bone fragments near base; unit grades laterally along strike to shale and siltstone; resistant	2.7 (8.7)	107.2 (352.0)
54	Siltstone to mudstone, very argillaceous, bentonitic, pale olive to olive-grey, latter occurring as two bands at base and 0.6 m (2 ft) above base; unit becomes slightly sandy near top; slightly recessive	1.6 (5.1)	104.5 (343.3)
53	Tuff, very sandy to silty, with well-rounded fine grains of quartz and feldspar, light to very light grey, and weathering same; small vugs up to 1.9 cm (0.75 in) in diameter; unit dense and well indurated and forms prominent marker horizon in area; resistant	0.1 (0.3)	102.9 (338.2)
52	Mudstone, bentonitic, very sandy and silty in part and may be classed as shaly siltstone; detrital well-rounded sand grains of all sizes scattered throughout; olive-grey to light olive-grey, and weathering dull grey with mauve tint; recessive	0.5 (1.5)	102.8 (337.9)
51	Sandstone, very argillaceous, becoming increasingly more argillaceous toward top, fine- to medium-grained; upper 0.3 m (1 ft) may be classed as very sandy to silty mudstone; pale olive, and weathering same; bioturbate? bentonitic mottling and/or plant rootlet replacement in upper 0.3 m (1 ft) - could be mudcrack infilling by pure clay; slightly recessive	0.9 (3.0)	102.3 (336.4)
50	Sandstone, calcareous, argillaceous, fine-grained, yellowish-grey to dark yellowish-orange, and weathering brownish-orange; moderate to well-indurated; resistant	0.5 (1.7)	101.4 (333.4)
49	Sandstone, argillaceous, slightly calcareous and ferruginous in part, fine- to medium-grained; becoming finer grained toward top, yellowish-grey to pale brown, and weathering same; trough crossbedding; ferruginous facies near top; resistant	8.5 (28.0)	100.9 (331.7)
48	Mudstone, very silty to sandy in upper 0.9 to 1.2 m (3-4 ft), and may be classed as very argillaceous siltstone to very fine grained sandstone; light olive-grey, and weathering same; olive-black bioturbate? bentonitic filled burrows and/or plant rootlets; unit forms base of Scollard Formation	3.7 (12.0)	92.4 (303.7)
	BATTLE FORMATION		
47	Shale, very carbonaceous, coaly, greyish-black; and weathering same to dark grey; very fissile; recessive	0.2 (0.5)	88.7 (291.7)

Unit	Lithology	Thickness		Height Above Base	
46	Shale, very argillaceous-bentonitic, olive-grey, and weathering same with slight mauve tint; well-developed "cornflake"-textured weathered surface; thin 2.5 cm (1 in) thick lenticular sandy to silty tuff bed in centre; unit slightly recessive to recessive	0.8	(2.6)	88.5	(291.2)
45	Tuff, slightly silty, light olive grey, and weathering light grey; small empty vugs up to 1.3 cm (0.5 in) in diameter; dense and well-indurated; unit of variable thickness in area; resistant	0.1	(0.3)	87.7	(288.6)
44	Claystone, very bentonitic, olive-black, and weathering same with slight mauve tint; weathers with prominent "popcorn" or "cornflake" weathered surface; lithology same as that filling burrows? or replacing rootlets in overlying siltstones, sandstones and mudstones of Scollard Formation; unit of variable thickness in area, grading laterally in places to facies of Whitemud Formation; recessive	2.8	(9.3)	87.6	(228.3)
	WHITEMUD FORMATION				
43	Sandstone, and minor silty shale; sandstone argillaceous, and medium- to fine-grained; thin silty shale bands near base; very carbonaceous black laminations near base; unit displays in part alternation of fine- and medium-grained laminations and thin bands; unit light grey to pale yellowish brown, and weathering same to light grey near top; coarse, black coaly lenses and carbonized plant fragments in lower half; unit becomes finer grained toward top; very tuffaceous, fine-grained nodular sandstone band, 0.5 m (1.5 ft) below top; unit forms sharp and abrupt contact with overlying Battle Formation; resistant	4.9	(16.1)	84.8	(279.0)
42	Shale, slightly silty and carbonaceous; brownish-grey, and weathering same; small black plant and leaf fragments throughout; moderate fissility; well-indurated in part; recessive	0.2	(0.8)	79.9	(262.9)
41	Sandstone, argillaceous, slightly calcareous in part; very fine to fine-grained, yellowish-grey to light olive-gray, and weathering light grey; unit becomes finer grained toward top; fine, regular to lenticular dark grey carbonaceous laminations; slightly recessive; unit forms probable base of formation	0.9	(2.8)	79.7	(262.1)
	HORSESHOE CANYON FORMATION				
40	Sandstone, siltstone, and minor shale, very argillaceous; sandstone very fine to fine-grained displaying fine regular to lenticular light and dark or grey laminations, latter very argillaceous; micro-scale trough cross-laminations in calcareous sandstone near base; shale silty in part and forms prominent 7.5 cm (3 in) carbonaceous lenticular bed, 1.2 m (4 ft) above base; unit yellowish grey to light olive-grey; shale contains abundant plant fragments; orange-weathering, ferruginous sandstone-siltstone bands scattered throughout; ironstone concretionary bed, 7.6 cm (3 in) thick, 0.3 m (1 ft) above base; slightly recessive to recessive	2.5	(8.1)	78.8	(259.3)
39	Siltstone to shale, carbonaceous, very bentonitic, small, carbonized, black vegetal fragments throughout; dark grey to pale yellowish-brown; slightly recessive	0.2	(0.8)	76.3	(251.2)
38	Siltstone to very fine grained sandstone, with minor fine- to medium-grained sandstone interlaminated near base; argillaceous, light olive-grey to olive-grey, and weathering same with brownish tint; sandstone replete with carbonized plant fragments; fine wavy to lenticular sand laminations in part; irregularly shaped ironstone concretions up to 27.9 cm (11 in) in diameter near base; resistant	3.7	(12.2)	76.1	(250.4)

Unit	Lithology	Thickness	Height Above Base
	Coal Seam No. 12 (Units 37-35 only)		
37	Coal and minor coaly shale; coal dull to vitreous lustre, blocky in part; shale greyish black with thin lenticles of shiny coal; shale forms upper 2.5 to 5 cm (1-2 in); small grains amber; coal mainly shaly to flaggy weathering; recessive	0.2 (0.7)	72.4 (238.2)
36	Shale, very carbonaceous, slightly silty, dark grey, and weathering same; minor small plant flecks and fragments; weathers earthy; recessive	0.4 (1.3)	72.2 (237.5)
35	Coal, black, vitreous to dull lustre; 2.5 cm (1 in) thin carbonaceous sandstone band at base; 7.6 cm (3 in) thick light brown bentonite seam, 0.6 m (2 ft) above base; few thin, black carbonaceous shale lenses in coal; recessive	0.9 (3.0)	71.8 (236.2)
34	Shale, coaly, very silty to sandy, brownish-black, and weathering brown; small pockets amber; coal occurs as thin, wavy, vitreous lenses; resistant	0.1 (0.3)	70.9 (233.2)
33	Sandstone, argillaceous, very fine to fine-grained, light olive-grey to pale yellowish-brown, and weathering light grey; scattered black plant fragments; resistant to slightly recessive	0.9 (3.0)	70.8 (232.9)
32	Shale, very silty in part, carbonaceous; scattered plant fragments throughout; moderate to good fissility; dark yellowish-brown, and weathering same; recessive	0.3 (1.0)	69.9 (229.0)
31	Siltstone to silty shale, very argillaceous; may be classed in part as silty claystone; medium to light olive-grey, and weathering light grey; few black plant fragments; very finely laminated in part; 5 cm (2 in) thick, very ferruginous sandstone band at base; slightly recessive	1.2 (4.0)	69.6 (228.9)
30	Sandstone, and minor carbonaceous shale, latter occurring as thin interbeds in lower half; sandstone very fine to medium grained, becoming finer grained toward top; calcareous in part, argillaceous; medium- to large-scale festoon crossbedding in lower 3.7 m (12 ft); very ferruginous bands in upper half; shale contains abundance of plant fragments; unit light grey to yellowish grey, and weathering same; dark brown, ferruginous-carbonaceous laminations throughout; resistant	6.9 (22.8)	68.4 (224.9)
29	Siltstone, very argillaceous, may be classed in part as silty shale; light olive-grey, and weathering same; slightly recessive to recessive	0.4 (1.2)	61.5 (202.1)
28	Shale, carbonaceous, greyish-black, and weathering brown; orange, ironstone concretionary band at base, no conspicuous plant fragments; recessive	0.1 (0.3)	61.1 (200.9)
	Coal Seam No. 11 (Unit 27 only)		
27	Coal, vitreous, and blocky; thin buff, 5 cm (2 in) bentonite seam, 0.5 m (1.5 ft) above base; recessive	1.1 (3.5)	61.0 (200.6)
26	Shale and minor very argillaceous siltstone, latter occurring as thin interbeds; shale very silty in part and replete with black, carbonized plant fragments; good fissility in part, but mainly flaky; olive-grey to pale olive, and weathering same; recessive	1.8 (5.8)	59.9 (197.1)
25	Siltstone, and minor fine-grained calcareous sandstone; siltstone very argillaceous, and very sandy in part; unit light olive-grey,		

Unit	Lithology	Thickness	Height Above Base
	and weathering same to greyish green; plant fragments throughout upper 0.5 m (1.5 ft); thin, orange-brown ironstone concretionary bands, 0.5 m (1.5 ft) below top; slightly recessive	1.5 (5.0)	58.1 (191.3)
24	Shale, carbonaceous, very coaly in part; high concentration carbonized plant fragments; silty to sandy in part; lenticular ironstone concretionary band at top to 15 cm (6 in) thick; recessive	0.2 (0.8)	56.6 (186.3)
23	Coal, blocky, with dull to vitreous lustre; seam is of variable thickness in area; no obvious shale interbeds; forms prominent marker seam within region; recessive	0.4 (1.3)	56.4 (185.5)
22	Shale, carbonaceous, silty to sandy, very coaly in upper 15 cm (6 in) with abundant carbonized plant fragments; olive-grey with slight brown tint, and weathering same; slightly recessive to resistant	0.3 (0.9)	56.0 (184.2)
21	Siltstone, very argillaceous and may be classed in part as silty shale; pale yellowish-brown to light olive-grey, and weathering dull to dark grey; slightly recessive	0.4 (1.4)	55.7 (183.3)
20	Sandstone, argillaceous, fine- to very fine grained toward top, yellowish grey, and weathering light grey; moderate induration; unit grades laterally to siltstone; resistant	0.7 (2.2)	55.3 (181.9)
19	Siltstone to very fine grained sandstone, argillaceous, slightly calcareous in part, yellowish-grey to light olive-grey, and weathering same; fine, wavy to lenticular, more argillaceous laminations throughout; scattered plant fragments near top; slightly recessive	1.4 (4.6)	54.6 (179.7)
18	Sandstone, argillaceous, slightly calcareous, fine-grained, light grey to yellowish-grey, and weathering same; moderate to well-indurated; resistant	0.2 (0.8)	53.2 (175.1)
17	Siltstone, argillaceous, very sandy in part, latter consisting of fine, wavy to lenticular laminations, light olive-grey, and weathering light grey; moderate to well-indurated; slightly recessive	1.0 (3.3)	53.0 (174.3)
16	Sandstone, argillaceous, calcareous, slightly ferruginous in part, fine- to medium-grained, yellowish-grey to light grey, and weathering same, except for upper 15 cm (6 in) which are orange-brown; microscale trough crossbedded; scattered plant fragments near base; moderate to good induration; resistant	0.8 (2.6)	52.0 (171.0)
15	Siltstone and minor fine- to very fine grained sandstone, very argillaceous; sandstone calcareous, siltstone may be classed in part as silty shale; unit light olive-grey to yellowish grey, and weathering same; sandstone micro-trough crossbedded; scattered ironstone concretions in upper 1.5 m (5 ft); unit in part displays sand mottling and lenticular laminations in siltstone facies; slightly recessive to resistant	6.0 (19.8)	51.2 (168.4)
14	Sandstone, calcareous, medium- to fine-grained, yellowish-grey, and weathering brownish-grey; microscale trough crossbedded; carbonaceous laminations outlining crossbed foresets; well-indurated; resistant	0.4 (1.4)	45.2 (148.6)
13	Sandstone, argillaceous, medium- to fine-grained, yellowish-grey with slight olive tint, and weathering same to buff; coarse, regular laminations in part; large brown to black leaf and plant fragments; slightly recessive	2.1 (6.8)	44.8 (147.2)
12	Sandstone, calcareous, argillaceous, fine-grained, light grey to yellowish-grey, and weathering same; microscale trough crossbedding throughout; moderate to good induration; resistant	0.4 (1.3)	42.7 (140.4)

Unit	Lithology	Thickness	Height Above Base
11	Sandstone, and minor siltstone and silty shale, very argillaceous; sandstone very fine to fine grained, and slightly calcareous in part; unit olive-grey to yellowish grey, and weathering same; fine to coarse, wavy and lenticular, very argillaceous siltstone laminations in part; two 7.6 cm (3 in) thick concretionary ironstone bands near base; slightly recessive	5.4 (17.8)	42.3 (139.1)
10	Sandstone, argillaceous, calcareous in part, fine-grained, yellowish-grey, and weathering same to light grey; good microscale trough crossbedding in centre of unit; fine to coarse silt laminations in part; resistant	1.3 (4.4)	36.9 (121.3)
9	Sandstone and siltstone; sandstone argillaceous, and calcareous in part; very fine to fine-grained; siltstone very argillaceous and slightly sandy; facies interbedded in approximately 0.6 m (2 ft) thick intervals; unit pale olive to yellowish-grey, and weathering olive-grey; sandstone microscale trough crossbedded in part; siltstone finely to coarsely laminated; large, 0.6 m (2 ft) diameter, concretionary siltstone band in centre; scattered plant fragments in sandstone; slightly recessive	5.2 (17.2)	35.6 (116.9)
8	Sandstone, argillaceous, fine- to medium-grained, yellowish-grey, and weathering buff; calcareous, microscale trough cross-laminated bed at top; scattered, angular, olive-grey siltstone clasts up to 5 cm (2 in) in diameter; scattered brown to black, small plant fragments; coarse, wavy brown to black, carbonaceous laminations in part; resistant	1.3 (4.2)	30.4 (99.7)
7	Sandstone, argillaceous, calcareous and ferruginous in part, medium- to fine-grained, yellowish-grey to light olive-grey, and weathering same with orange-brown banding in part; upper 1.2 m (4 ft) contain large- to medium-scale trough crossbedding; scattered well-rounded pebbles and shale clasts in crossbedded sandstone; few large black dome-shaped seed cases up to 1.9 cm (0.75 in) in diameter; resistant	4.1 (13.3)	29.1 (95.5)
6	Sandstone and minor siltstone, argillaceous, calcareous and slightly ferruginous in part; sandstone fine to medium grained, and contains microscale trough crossbedding in upper 15 cm (6 in); unit yellowish grey to greenish grey, and weathering same to orange-brown; siltstone occurs as well-indurated, orange-brown weathering interbeds near base; sparse, black plant fragments throughout; resistant	3.1 (10.3)	25.0 (82.2)
5	Sandstone, calcareous, argillaceous, slightly ferruginous, fine-grained, yellowish-grey, and weathering same to dull orange-brown; microscale trough crossbedded in part; unit forms prominent cap marker facies in region; very well indurated; resistant	0.4 (1.2)	21.9 (71.9)
4	Sandstone, argillaceous, slightly calcareous and ferruginous in part, fine-grained, yellowish-grey to greyish-orange, and weathering buff; orange-brown, ferruginous banding in part; well-developed microscale trough crossbedding in well-indurated, calcareous sandstone at top; resistant	1.4 (4.7)	21.5 (70.7)
3	Siltstone to very fine grained sandstone; argillaceous, very calcareous, dark yellowish-grey to light olive-grey, and weathering bright yellowish-orange; unit dense and well indurated; resistant	1.2 (4.0)	20.1 (66.0)
2	Sandstone, argillaceous, very calcareous in part, fine- to very fine grained with grain size forming alternating beds; coarser grained sandstone displays microscale trough crossbedding; dinosaur bone fragments near top of unit; fine to coarse, regular to wavy lenticular, black, carbonaceous laminations in part	3.7 (12.0)	18.9 (62.0)

Unit	Lithology	Thickness	Height Above Base
1	Siltstone to mudstone, and minor fine-grained sandstone; unit very argillaceous and appears to be bentonitic in part; light olive-grey, and weathering same; few scattered plant fragments; sand occurs as more resistant interbeds; 15 cm (6 in) thick, brown, very carbonaceous band, 6.1 m (20 ft) above base; unit partly talus covered; unit resistant and cliff-forming, and represents last of outcrop to river level	15.2 (50.0)	15.2 (50.0)

PLATES

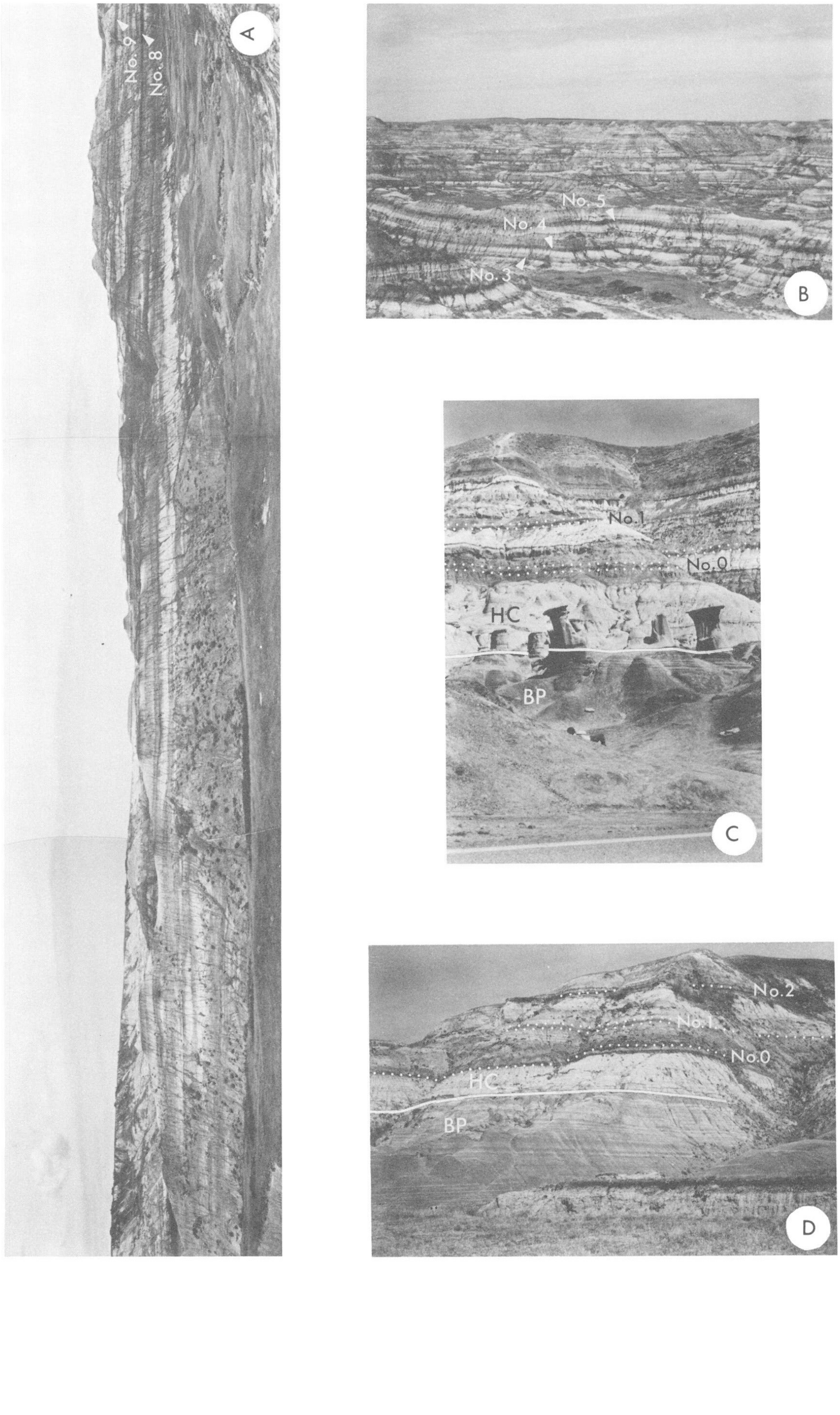
PLATE 1

A. Horseshoe Canyon Formation; illustrating lenticular, light grey weathering sandstone lithofacies at Horsethief Canyon (Sec. 73-27). Note interfingering of light and dark weathering strata, and Coal Seams No. 8 and No. 9. ISPG 532-54, 55, 53.

B. Typical flat-lying, light and dark grey weathering strata of the Horseshoe Canyon Formation, west side of Red Deer River between Rosedale and Drumheller. Note tabular to wedge-shaped character of light grey to white-weathering sandstone. Coal Seams Nos. 3, 4 and 5 well exposed in foreground. ISPG 532-52.

C. Colour and lithologic contrast between Bearpaw and Horseshoe Canyon Formations, Hoodoo Viewpoint. Note abrupt contact between the two formations. Coal Seams Nos. 0 and 1 well exposed in centre of photo. Bearpaw Formation (BP), Horseshoe Canyon Formation (HC). ISPG 532-32.

D. Colour and lithologic contrast between Bearpaw and Horseshoe Canyon Formations, south of East Coulée. Note gradational contact between the two formations in this area. Coal Seams Nos. 0, 1 and 2 well exposed in section. Bearpaw Formation (BP), Horseshoe Canyon Formation (HC). ISPG 532-33.


A
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No.8
No.5
No.4
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B
No.1
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HC
BP
C
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No.0
HC
BP
D

PLATE 2

A. Contact and lithologic relationships between Horseshoe Canyon, Whitemud and Battle Formations, at Elnora East locality (Sec. 73-45). Note light grey weathering Kneehills Tuff in the Battle Formation. Horseshoe Canyon Formation (HC), Whitemud Formation (WM), Battle Formation (BT), Kneehills Tuff (KT). ISPG 532-48.

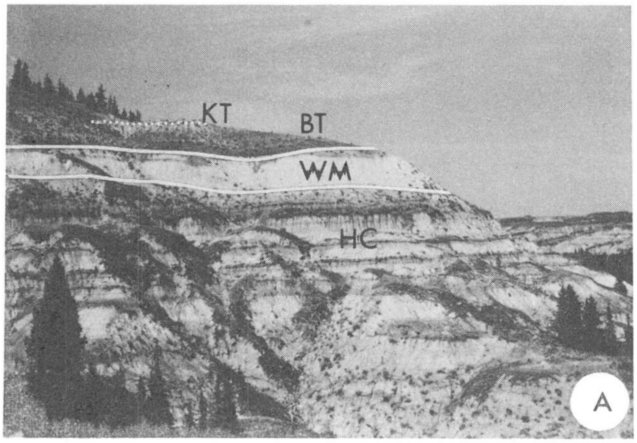
B. Contact and lithologic relationships between Horseshoe Canyon, Whitemud, Battle, and Scollard Formations of the Edmonton Group at Tolman north locality (Sec. 73-38). Coal Seams Nos. 11 and 12 poorly exposed near top of Horseshoe Canyon Formation. Note calcareous, well-indurated sandstone "cap rocks" in Whitemud and Scollard Formations. Horseshoe Canyon Formation (HC), Whitemud Formation (WM), Battle Formation (BT), Scollard Formation (SC). ISPG 532-41.

C. Contact and lithologic relationships between Scollard Formation and the cliff-forming sandstone of the basal Paskapoo Formation, at Huxley East Paskapoo locality (Sec. 73-41). Note abrupt nature of contact and position of Coal Seam No. 14. Scollard Formation (SC), Paskapoo Formation (PK). ISPG 532-51.

D. Close-up view of contact between Scollard Formation and cliff-forming sandstone of the basal Paskapoo Formation, at Huxley East Paskapoo locality (Sec. 73-41). Note the thinly bedded and carbonaceous nature of the Scollard strata near the contact. Scollard Formation (SC), Paskapoo Formation (PK). ISPG 532-49.

E. Contact between Scollard Formation and the cliff-forming sandstone of the Paskapoo Formation, at Ardley River locality (Sec. 73-49). Note recessive, shaly weathering nature of the upper Scollard Formation at this locality. Scollard Formation (SC), Paskapoo Formation (PK). ISPG 532-45.

F. Horseshoe Canyon Formation illustrating alternating light grey and darker greenish grey strata between Coal Seams Nos. 10 and 11. Note conspicuous bench forming "cap rock" marker sandstone lithofacies forming centre of escarpment. Coal Seams Nos. 11 and 12, and light grey weathering Whitemud Formation exposed near top of escarpment. Dark grey weathering carbonaceous shale and coal interbeds are conspicuously absent in the escarpment. ISPG 532-3.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BT
WM
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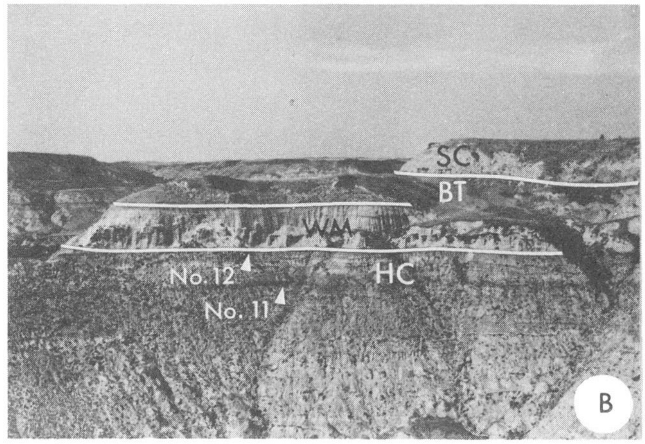
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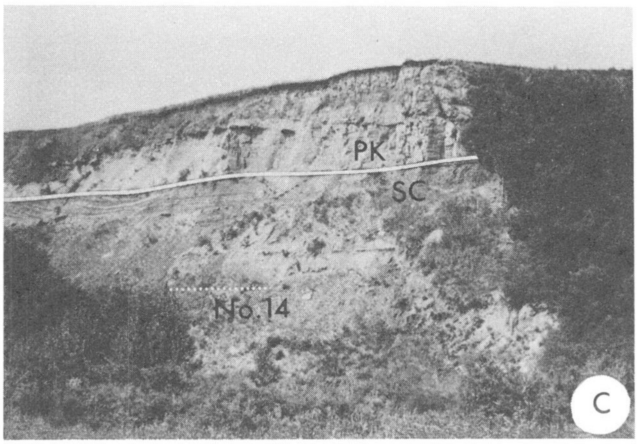
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SC
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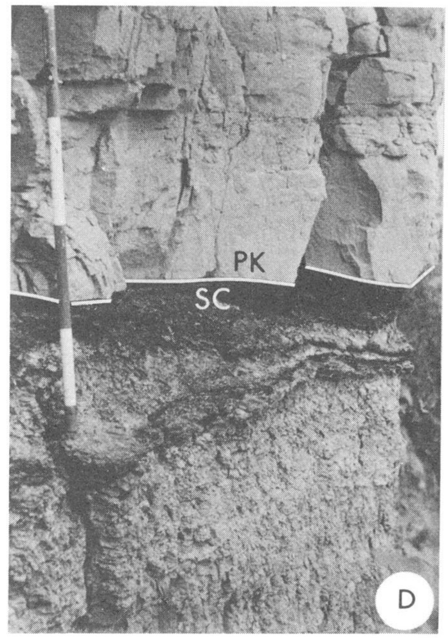
C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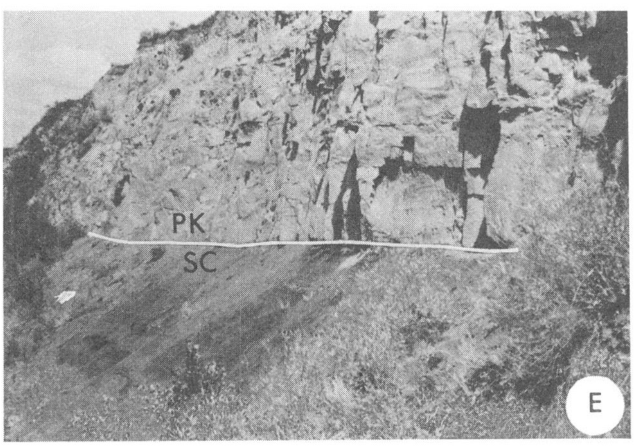
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E

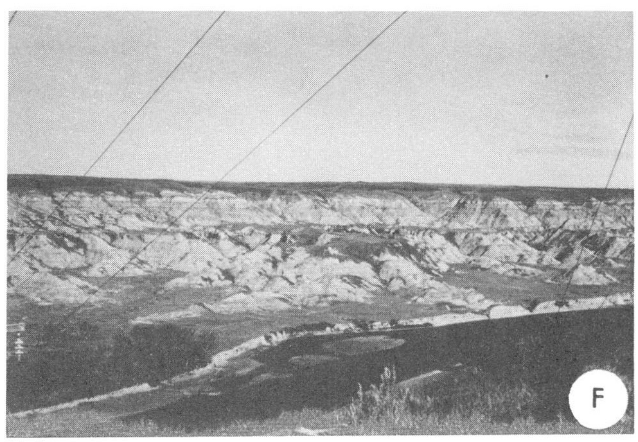
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PLATE 3

A. Sandstone "concretions" in basal sandstone of Horseshoe Canyon Formation. ISPG 532-26.

B. Medium-scale trough crossbedding, basal sandstone of Horseshoe Canyon Formation. ISPG 532-7.

C. Side view of microscale trough crossbedding in calcareous sandstone of the Horseshoe Canyon Formation. ISPG 532-14.

D. Front view of microscale trough crossbedding in calcareous sandstone of the Horseshoe Canyon Formation. ISPG 532-15.

E. Oscillation ripple marks in calcareous, slightly ferruginous sandstone of Horseshoe Canyon Formation. ISPG 532-64.

F. "Cornflake texture" common to claystone of the Battle Formation and many bentonitic mudstone, siltstone and sandstone units of the Horseshoe Canyon Formation. ISPG 532-34.

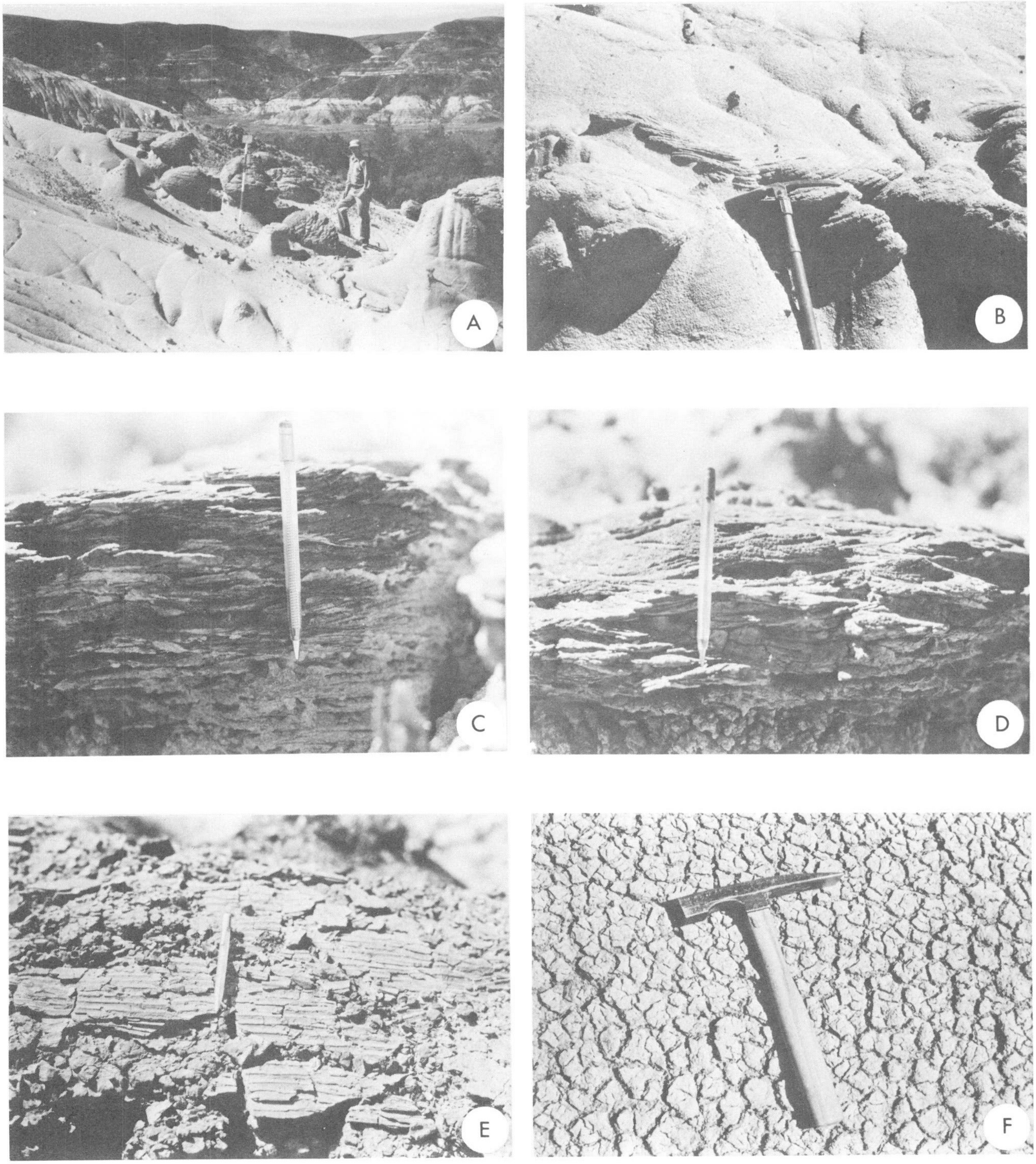
A
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PLATE 4

A. Coal Seams No. 0 to No. 5 at Eladesor (Sec. 73-11). Note "cap rock" sandstone lithofacies at base of section. ISPG 532-21.

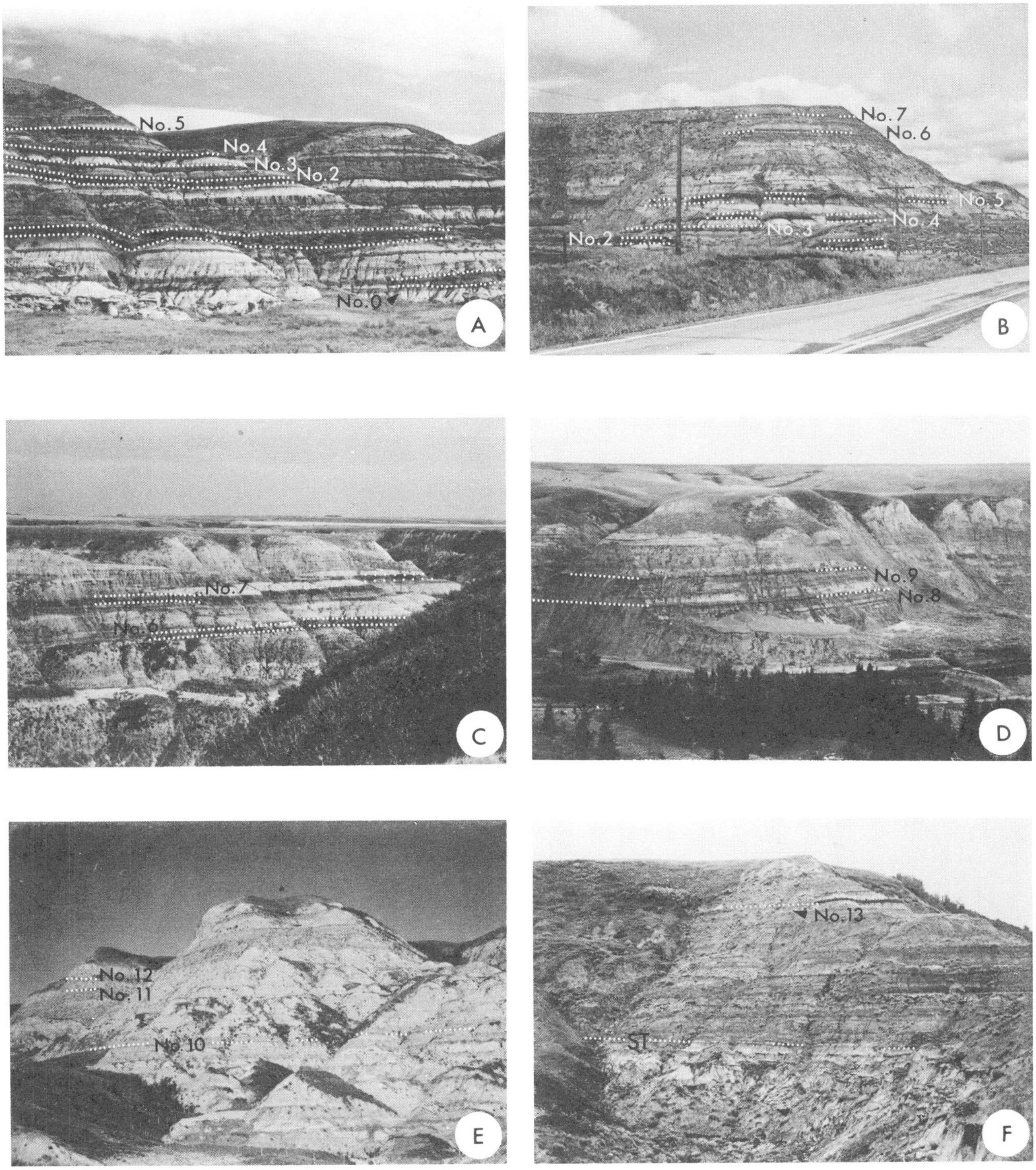
B. Coal Seams No. 2 to No. 7, Drumheller oxidation ponds (Sec. 73-19). ISPG 532-57.

C. Coal Seams Nos. 6 and 7, at Drumheller east road cut. Note prominent light grey weathering sandstone channel lithofacies in centre of photo. ISPG 523-39.

D. Coal Seams Nos. 8 and 9 at Gatiné, Kneehills Creek (Sec. 73-54). ISPG 532-35.

E. Coal Seams Nos. 10, 11, and 12, at West Rowley (Sec. 73-34). Note general absence of dark grey carbonaceous shale or coal interbeds in the vicinity of Seam No. 10. ISPG 532-58.

F. Coal Seam No. 13 at Huxley East Scollard locality (Sec. 73-39). Note light grey to white-weathering tuff near base of exposure. Scollard Tuff (ST). ISPG 532-2.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D
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ST
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