SASKATCHEWAN RESEARCH COUNCIL
GEOLOGY DIVISION

REPORT No.8

THE LATE CRETACEOUS BEARPAW FORMATION IN THE SOUTH SASKATCHEWAN RIVER VALLEY

by
W. G. E. CALDWELL

1968

FOREWORD

The following report presents the results of a stratigraphic study of the Cretaceous Bearpaw Formation in the Lake Diefenbaker area of the South Saskatchewan River valley. The Bearpaw Formation is one of the most widespread formations at the bedrock surface in the inhabited portion of the Province and its sand members are important groundwater aquifers. Therefore, this report provides both a basic contribution to understanding of the Cretaceous stratigraphy of southwestern Saskatchewan and a regional geologic framework for studies in groundwater hydrology and other fields of geotechnology.

R. G. ARNOLD,
Head, Geology Division
Saskatchewan Research Council

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W. G. E. Caldwell

Department of Geological Sciences,
University of Saskatchewan, Saskatoon
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ABSTRACT

The Upper Cretaceous Bearpaw Formation in the South Saskatchewan River valley forms the thick eastern end of a westward-thinning wedge of marine clays and sands deposited during the final transgression and regression of the Late Cretaceous sea. The underlying Oldman Formation and overlying Eastend and Whitemud Formations form parts of complementary eastward-thinning wedges of non-marine sands, silts, and clays deposited mainly during the penultimate and ultimate regressions of that sea. Both the transgression and regression of the sea were gradual, so that the lower and upper interformational contacts are diachronous and facies changes are common throughout most of the sequence.

In the South Saskatchewan River valley, the 1,150-foot Bearpaw Formation is divisible into eleven members, six of silty clay alternating with five of silty sand. The lowest clay member, known only from the subsurface and lacking a suitable type section, is unnamed, but the succeeding clay members are named Broderick, Sherrard, Beechy, Snakebite, and Aquadell. The sand members, generally thinner than the clays, are named in upward sequence Outlook, Matador, Demaine, Ardkenneth, and Cruikshank. All members can be traced through the subsurface for more than 100 miles from their type localities. Characteristics of the sediments and fossils suggest that epineritic conditions prevailed over the Bearpaw sea bed in the area of the South Saskatchewan River valley, and the water depth probably never exceeded 150 feet.

Two broad faunal assemblages are recognizable in the Bearpaw Formation of the South Saskatchewan River valley: a *Baculites-Placenticeras* assemblage, containing a number of boreal elements, in the lower half, and a *Scaphites (Hoploscaphites)* assemblage in the upper. The numerous baculites permit biostratigraphical analysis in terms of the zonal scheme established in the Western Interior of the United States. In all probability, the Bearpaw Formation in the South Saskatchewan River valley ranges from the Zone of *Didymoceras stevensoni* (Whitfield) to that of *Baculites grandis* (Hall and Meek) — a range comparable to that in east-central Montana — although the lowest and highest zones positively identified are those of *Exiteloceras jenneyi* (Whitfield) and *Baculites baculus* Meek and Hayden.

A Late Campanian-Early Maestrichtian relative age span for the Bearpaw Formation in the South Saskatchewan River valley is indicated by the ammonites. By relating the ammonite zones to radiometric dates, calculated from bentonites using the potassium-argon method, it can be estimated that the formation accumulated between 74.5 and 70 million years ago.

ACKNOWLEDGMENTS

Investigation of the Bearpaw Formation in the South Saskatchewan River valley was sponsored by the Saskatchewan Research Council, and I am indebted to the Council for its support. Drs. E. A. Christiansen, J. R. Smith, and S. H. Whitaker of the Geology Division of the Council have shown interest in all aspects of the study and have given generously of their time to assist me. In particular, Dr. S. H. Whitaker spent much time in editorial work. Mr. C. G. Elias and Mr. W. E. Taylor contributed to the design and preparation of the illustrations.

Exposures of the formation between Swiftcurrent Creek and Snakebite Creek were studied by Dr. J. K. Evans as a graduate student at the University of Saskatchewan, and his results were presented in a thesis for the M.A. degree. Dr. Evan's work, emended and revised, forms the basis of two sections of this report, and these bear due acknowledgment to him. I record my indebtedness to colleagues in the Department of Geological Sciences of the University of Saskatchewan for their contributions to the study both in the field and laboratory — in particular to the late Professor F. H. Edmunds, who permitted me to draw freely upon his extensive knowledge of the Cretaceous System in Saskatchewan. Drs. W. O. Kupsch and N. C. Wardlaw prepared detailed criticisms of the manuscript, Professor T. E. W. Nind, now of Trent University, guided me in the use of mechanical and radiation logs in making subsurface correlations, Dr. M. W. Steeves commented on the morphology of the plant remains, and Mr. J. R. McLean, currently studying the Oldman and Foremost Formations of southwestern Saskatchewan, has been helpful in dealing with the boundary beds of common interest.

The co-operation of the Geological Survey of Canada in drilling the G.S.C. 61-1 bore hole to serve partly as a stratigraphical test of the newly established sequence in the river valley is gratefully acknowledged, as is the assistance of a number of its officers, including Dr. J. A. Jeletzky, who advised me on many palaeontological problems, Mr. L. Price, who supervised the drilling of the above bore hole and furnished a complete lithological log of the section, and Dr. R. T. D. Wickenden, who sent me records of some older bore holes.

Dr. W. A. Cobban of the United States Geological Survey identified most of the ammonites recovered, and he and Dr. J. R. Gill have been extremely generous in furnishing me with information (published and unpublished) on other Bearpaw and equivalent sections in the Western Interior of the continent.

Subsurface study of the Bearpaw Formation was facilitated by the kindness of numerous officials of the Province of Saskatchewan Department of Mineral Resources in Regina, who on several occasions, placed cores, lithological and electric logs, and maps at my disposal. I record my gratefulness particularly to Mr. D. R. Francis, Dr. J. E. Brindle, and Mr. H. Sawatzky (now of Francana Oil and Gas Ltd.).

The Canada Agriculture Prairie Farm Rehabilitation Administration generously donated core from a bore hole at the site of the Gardiner Dam and stratigraphical information from others, provided maps of the entire reservoir area, and permitted me to visit the dam site and use information gathered during excavation and construction. I wish to thank, especially, Dr. R. Peterson, Chief Soil Mechanics and Materials Engineer, and Mr. D. H. Pollock (engineer) and Mr. E. H. Frison (formerly geologist) at the dam site.

Mr. B. McCorquodale, formerly curator of the Museum of Natural History in Regina, kindly provided me with information on the distribution of vertebrate fossils in the region under investigation, and Dr. E. H. Colbert of the American Museum of Natural History commented on the unusual occurrence of the hadrosaur skeleton.

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During Late Cretaceous time, North America was divided by a vast seaway, which extended from the present-day Gulf of Mexico to the Arctic Ocean and lay to the east of tectonically restless mountains, now forming part of the Cordillera, and to the west of a peneplaned cratonic hinterland. The Western Interior of the continent was the site of a fluctuating epicontinental sea in which there accumulated sediments supplied by the western mountainous landmass and its associated volcanic centres. Recurrent pulsatory uplift of the highlands to the west and subsidence of the sea-covered lowlands to the east, with attendant changes in the quantity of detritus being supplied, caused variations in the position of the shoreline within the Western Interior region. Repeatedly, broad alluvial flats encroached eastward under a generous supply of terrigenous clastic detritus, until subsidence of the region caused inundation of the flats by a shallow sea, which spilled westward, again to make a shoreline near the foothills of the western mountains.

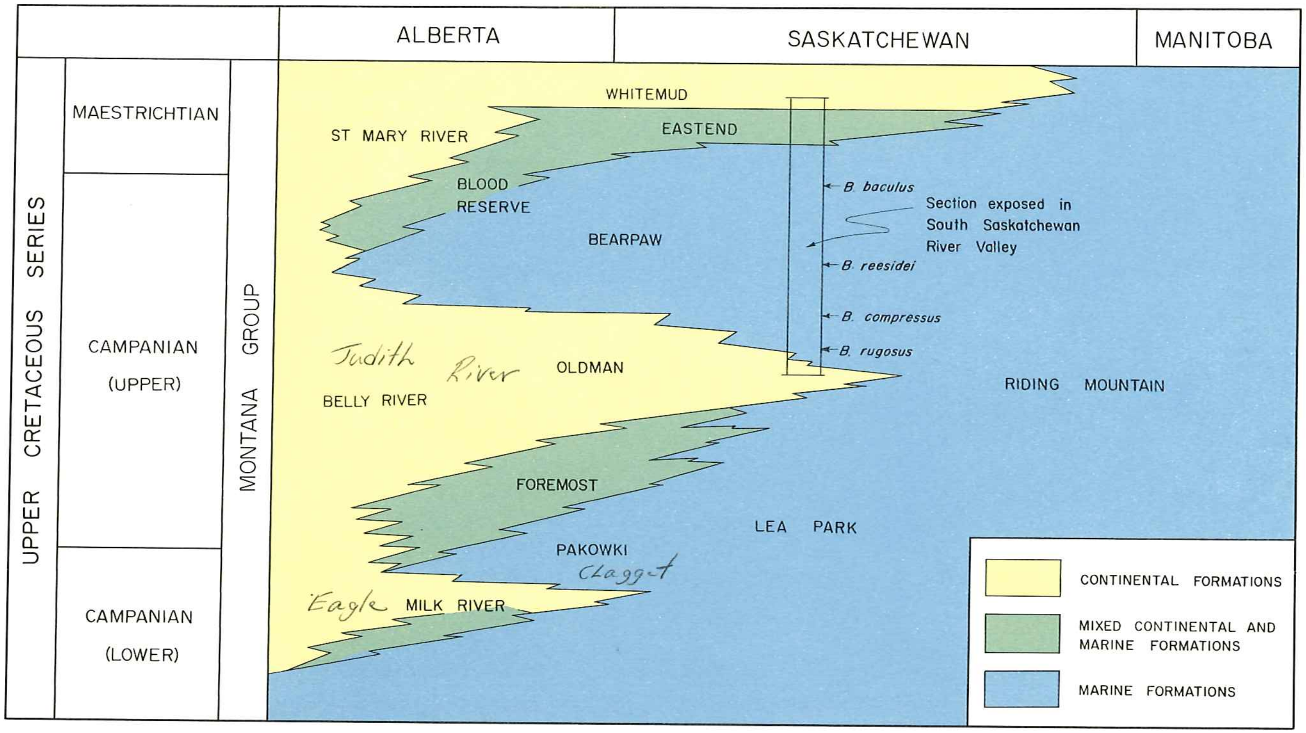
Within the northern part of the Western Interior region, there lay much of what is now the plains of Alberta and Saskatchewan, and at least three times during the Late Cretaceous Epoch, this area underwent extensive transgression followed by progressively more extensive and more gradual regression, until the sea finally withdrew completely near the end of the epoch. The movements of land and sea are recorded in the sedimentary sequence, which, broadly, between the Rocky Mountain foothills of Alberta and the plains of eastern Saskatchewan and Manitoba, is cyclic and composed of marine, brackish-water, and fresh-water clays, silts, and sands.

In Early Campanian time, subsidence within the seaway dispatched the Lea Park-Pakowki sea westward to drown the vast Milk River delta, a bilobate wedge of non-marine sands, silts, and clays that had developed over parts of Alberta and Montana. No sooner had the sea attained its most westerly limits, which in southern Alberta probably approached the position of the present Rocky Mountain front, than it began a gradual recession that lasted throughout mid-Campanian time. Broadening alluvial plains, initially fringing the Cordilleran highlands from which they derived their detritus, gradually pushed the shoreline eastward, until ultimately it lay well within southwestern Saskatchewan (McLearn *in* Fraser *et al.,* 1935, p. 116-118). This temporary retreat of the sea was the most extensive of the Late Cretaceous Epoch (text-fig. 2) and led to the deposition of the sands, silts, and clays of the Foremost and Oldman Formations, which form a wedge that thickens westward and passes into the Belly River Formation in the foothills and front range of the Rocky Mountains in Alberta. Deposition of these formations brought to an end a cycle of sedimentation and set the stage for another — that which records the last fundamental geographical changes to affect the area now occupied by the southern Canadian plains during the Cretaceous Period.

In Late Campanian time, subsidence initiated advance of the Bearpaw sea, the shallow waters of which, at maximum westward extent, reached the present Rocky Mountain front (text-fig. 3). Thus clays of the Bearpaw Formation overlie Oldman beds and, in the extreme west, rest on Belly River sands (text-fig. 1). Relative to the advance, withdrawal of the Bearpaw sea was more gradual. Russell (1939, p. 92-93) has pointed out that it began first in central Alberta, then spread to southwestern Alberta. In the latter region, Bearpaw clays are overlain by sands and silts of the Blood Reserve and St. Mary River Formations, which complete the Cretaceous sequence. The Bearpaw sea retreated last from southeastern Alberta and Saskatchewan, where the thinned equivalents of parts of the Blood Reserve and St. Mary River Formations are the Eastend and Whitemud Formations. The Eastend-Whitemud sequence, recording gradual change from marine to continental conditions, is an approximate and condensed repetition of that of the Foremost and Oldman Formations, and points to broad duplication of sequential depositional environments. Since the equivalent of only the uppermost beds of the relatively thick Eastend Formation in southeastern Alberta conformably overlie the Bearpaw Formation in southwestern Saskatchewan, it can be concluded that retreat of the Bearpaw sea took place considerably earlier in the west: but persistence of the Whitemud Formation from southeastern Alberta across much of southern Saskatchewan suggested to Russell (*op. cit.*, p. 92) a measure of contemporaneity in the final emergence of these adjacent areas in Maestrichtian time.

Absence or thinness of transitional deposits between the non-marine sands, marking regressions of the Late Cretaceous seas, and the marine clays, marking transgressions, together with persistence of lithological and faunal marker beds at comparable footages above the bases of the clay formations, indicates that the advances of the seas were rapid — so rapid in fact that over certain areas, such as most of the southern plains of Alberta, the contacts are held to be essentially isochronous (Russell, *op. cit.*, p. 98). In contrast, marker beds toward the top of the clay formations are much less persistent, but suffice to indicate that facies changes between clays and sands are rife, and these changes are a product of gradual oscillatory retreats of the seas. As a consequence of such retreats, the formations of the offlap sequences are grossly diachronous (text-fig. 1). But although the transgressions undoubtedly were accomplished more rapidly than the regressions, the concept of near-isochronous surfaces of transgression opposed to markedly diachronous surfaces of regression (see for example, Russell, *op. cit.*, fig. 8; Nauss, 1945, fig. 5; Lines, 1963, figs. 2, 3; Caldwell and North, 1964, fig. 1) probably is invalid. At least so far as Bearpaw events are concerned, it is demonstrable, using ammonite range zones and foraminiferal local range zones, that the transgression began in southwestern Saskatchewan well before it reached southeastern Alberta, and it is entirely possible that, for considerably more than a million years, oscillatory movements of the sea, resulting in a weak westward encroachment, took place only to the east of the interprovincial boundary. Apparently, when the Bearpaw sea did encroach upon the Alberta plains, it advanced quickly to a position near the foothills of the present-day Rocky Mountains, then again was delayed briefly before establishing its most westerly shoreline at a position now located farther into the mountain belt (Wall, 1967, p. 192-193 and compare Caldwell and North, 1964, p. 148-150). As a result, in regional context, the record of the Bearpaw transgression and regression is not a rhythm of sedimentation (to be expected from extremely rapid advance and gradual retreat) but an asymmetrical wedge-like cycle of sedimentation — one that should be subject to the kind of analysis to which Weimer (1960, p. 1-20) and Kauffman (1967, p. 71-90) have subjected the Cretaceous sedimentary cycles of the Western Interior of the United States.

The sedimentary pattern of intertonguing continental and marine deposits is in keeping with that described from other parts of the North American Western Interior, and the fact that similar tongues have been correlated along the Rocky Mountain front for hundreds of miles demonstrates that the orogenic and epeirogenic movements of the western uplands and adjacent eastern lowlands were regional crustal movements — premonitory rumblings of the Rocky Mountain revolution — affecting sizeable segments of the interior province. Recently, Gill and Cobban (1966, p. A45) have challenged the long-held view that the Upper Cretaceous sediments of the Western Interior are to be interpreted as the result of widespread transgression and regression due to regional movements and have sought to explain the sedimentary record in terms of local uplift, subsidence, and variation in the rate of sediment delivery. Some ambiguity surrounds the terms *local* and *regional,* but it is difficult to see how the distribution of the Bearpaw and contiguous formations in northern Montana, southern Alberta, and southern Saskatchewan, for example, can be explained other than within a framework of movements affecting the entire region of the international borderland.



Text-figure 1: Reconstructed, simplified cross-section through the southern Canadian Great Plains to show the intertongued relationship of the Late Cretaceous non-marine and brackish-water sands and silts, diagnostic of the "western facies belt" of the continental Western Interior region, and the marine silty clays, developed in uninterrupted sequence in the "central facies belt." The cross-section has been built on a time-stratigraphical frame to show facies relationships and put a relative measure on diachronism. The span of the section encountered in the South Saskatchewan River valley is shown, as in the position of several of the baculite indices important in placing the river-valley section in its regional context.

The sequence of formations resulting from the last two advances and retreats of the Western Interior sea are included in the Montana Group (Eldridge, 1889, p. 313-321). The term *Montana Group* is convenient, but in the southern Canadian plains it denotes a somewhat unnatural division, since the group spans formations formed during two complete cycles of sedimentation and part of a third. As Jeletzky (1968, p. 55-56) has pointed out, the use of *Montanan* as a local stage name should be discontinued.

Stratigraphical sequence: the Bearpaw and associated formations

From the comments on regional palaeogeography, it will be apparent that investigation of the complete Bearpaw Formation in any region demands consideration not only of the contact relationships with the overlying and underlying formations but also, to some extent, of these formations themselves. Such consideration is equally a requirement for the restricted area of study in the South Saskatchewan River valley (text-fig. 4), where, to place the Bearpaw Formation in its regional stratigraphical context, it is necessary to gain some appreciation of the mainly non-marine Oldman Formation (in the past regarded as part of the Belly River Formation) below and the mainly non-marine Eastend and Whitemud Formations above.

The offlap sequence of the Lea Park-Pakowki sea is divisible into a group of brown and grey sands, silts, and shales with the remains of marine and brackish-water invertebrates and with numerous interbedded coal seams — the Foremost Formation — and an overlying group of comparatively pale-coloured sands, sandstones, silts, and clays with the remains of land snails and terrestrial vertebrates — the Oldman Formation. These formations have been described in their type area of the southern plains of Alberta by a number of geologists, including Dowling (1916, p. 107, map; 1917, p. 32-40, 51 ff.), who proposed the name *Foremost,* Russell (*in* Russell and Landes, 1940, p. 45-72), who proposed the name *Oldman,* and Crockford (1949, p. 500-510), who used subsurface information to demonstrate the regional distribution of the formations in an eastward-thinning wedge. Together, the Foremost and Oldman Formations constitute the Belly River Formation of Williams and Dyer (1930, p. 16-18) but not the Belly River Series of Dawson (1884, p. 36C ff.) or Dowling (1917, p. 32-33).

It has been shown that, to the west, the Foremost and Oldman Formations pass into sands, silts, and clays, wholly continental in origin, and to the south, they are continuous with similar sediments, but of non-marine, brackish-water, and marine origin, forming the Judith River Formation of Montana. To the north, in east-central Alberta, they are represented by intertongued sands and sandstones, named Brosseau, Victoria, Ribstone Creek, Birch Lake, and Oldman, and silty clays, named Shandro, Vanesti, Grizzly Bear, and Mulga, and to the east, they change in facies to become marine silty clays of the upper Lea Park and lower Bearpaw Formations.

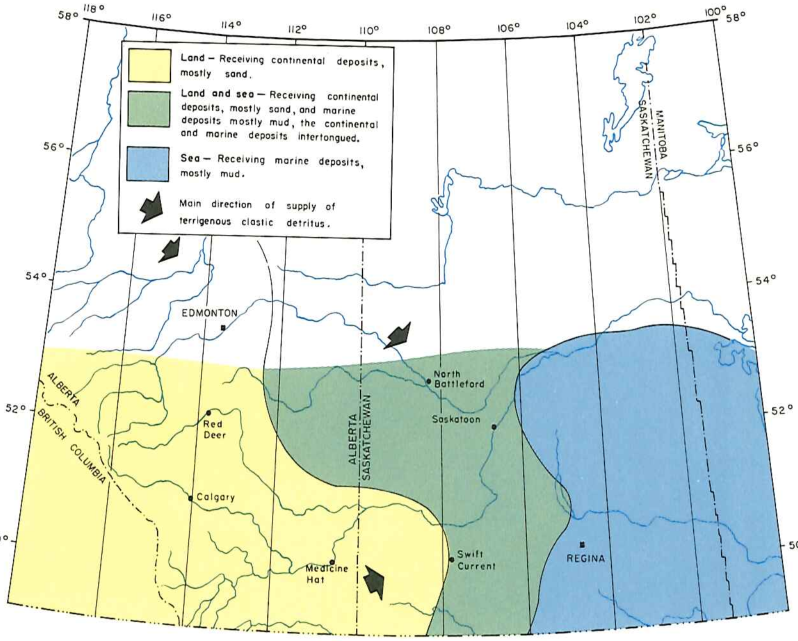
Sections spanning the complete Foremost and Oldman Formations have been described by Furnival (1946, p. 29-38, 144-148) from two creeks and from two bore holes on the flanks of the Cypress Hills. As Furnival pointed out, distinction of the two formations, particularly in the Cypress Hills, is not easy, and, due to structural complications, the thicknesses of the sections are unreliable. Regional cross sections, compiled largely from subsurface data in the Alberta-Saskatchewan borderland, indicate that the Foremost Formation does not extend for any distance east of the border (*fide* Dr. S. H. Whitaker) and, in southwestern Saskatchewan, it is represented by interbedded marine silty clays and non-marine to brackish-water sands that can be identified partly in terms of the sequence established in east-central Alberta and west-central Saskatchewan (Slipper, 1919, p. 8C; Allan, 1919, p. 11C-13C; Hume, 1933, p. 188-195; 1937, p. 135-140; Hume and Hage, 1941, p. 20-32; Nauss, 1945, p. 1619-1627; Shaw and Harding, 1949, p. 490-498; and Christiansen, 1965, p. 14, fig. 4; 1967).

Beds belonging (or equivalent) to the Foremost and Oldman Formations are known to form part of the bedrock surface north and east of the Cypress Hills, but they are exposed, through a thick blanket of drift, only at a few isolated localities and to a thickness of only a few tens of feet. Although some geophysical data (unfortunately seldom cores) from exploratory bore holes also are available, configuration of the formational outcrops and delineation of the eastern limit of the subcrops (where the beds pass mainly into the Lea Park clays and silts) are vague; and information regarding the nature and sequence of the beds is scanty.

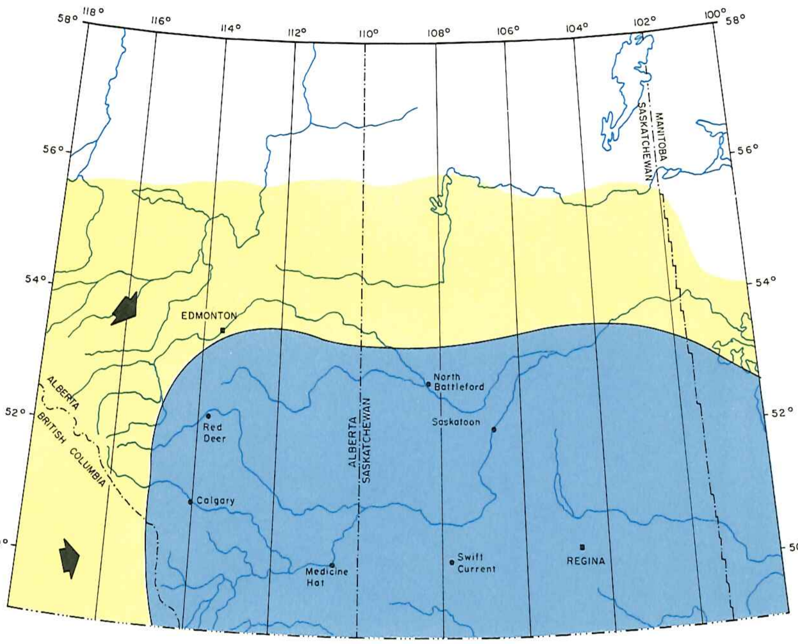
The beds immediately underlying the Bearpaw Formation in the South Saskatchewan River valley and its environs have been referred to the Belly River Formation (Warren *in* Fraser *et al.,* 1935, p. 9, 18-21) on the grounds that they are a thinned continuation of Williams and Dyer's Belly River Formation of Alberta. But the term *Belly River* has had an unfortunate history and the distinct ambiguity surrounding it has been noted already by Russell (*in* Russell and Landes, *op. cit.,* p. 45). The bulk of the beds are closely similar to those of the Oldman Formation and can be regarded satisfactorily as belonging to that formation. Most exposures include some grey- to white-weathering sands, silts, and clays, indistinguishable superficially from those in the nearest undisputed Oldman beds, which crop out in the Irvine badlands near the Alberta-Saskatchewan border. Thin coal seams, interbedded with the terrigenous beds, enhance the similarity, and indicate that at least some of the beds, like those of the Oldman Formation farther west, originated under non-marine conditions. In the studied segment of the river valley, however, the highest beds of the Oldman Formation pass eastward by facies change into the lowest beds of the Bearpaw Formation, initially by some Oldman beds passing directly into marine silty clays of Bearpaw facies so producing an intertongued sequence, ultimately by the more persistent tongues of non-marine, pale-coloured silts and sands passing into buff-weathering sands containing a varied, marine, molluscan fauna. Where the sequence is present in mixed lithology, the question of position of the Oldman-Bearpaw boundary (and thus of accommodation of the intermediate beds) arises. Throughout most of the transitional zone, the thickness of the marine clays exceeds that of the non-marine sands so that the boundary is most satisfactorily placed at the base of the lowest tongue of marine clay above the main body of the Oldman Formation.

The intimate association of marine and non-marine beds in the South Saskatchewan River valley and farther north and west readily can be explained. It seems probable that, for some time prior to the main phase of the Bearpaw transgression, the western shores of the sea were confined to a zone that straddled part of the present valley (text-fig. 2). Within this zone, the shorelines underwent fluctuations of varying magnitude, no doubt in response to weak earth movements heralding the imminent subsidence responsible for the main westward incursion. As a result, continental and marine deposits are complexly interfingered, locally on a small scale that can be appreciated in individual outcrops and regionally on a scale that permits the establishment of lithostratigraphical divisions and their correlation to those of adjacent areas.

The Bearpaw Formation, named from the Bearpaw Mountains of north-central Montana by Stanton and Hatcher (1903, p. 211-212; 1905, p. 13-14), forms the bedrock surface over the greater part of southwestern Saskatchewan. Most of the silty clays and subordinate sands of which it is composed originated under shallow-water, marine conditions. They form a wedge that thins to the west and northwest by facies change of all but the middle beds into the non-marine sands of the Oldman, Eastend, Blood Reserve, St. Mary River, and Edmonton Formations, and thickens to the east to become a non-distinct part of the Riding Mountain Formation of southeastern Saskatchewan (text-fig. 1). To the north, Bearpaw beds are truncated by the pre-Pleistocene erosion surface, so that their former northward extent is a matter of conjecture, and to the south, in the central part of the



Text-figure 2: Generalized sketch map, showing the approximate distribution of land and sea during the early stages of development of the Bearpaw sea (?*Didymoceras stevensoni* through *Exiteloceras jenneyi* time). Reconstruction based upon the lithology of biostratigraphically correlative deposits.



Text-figure 3: Generalized sketch map, showing the approximate distribution of land and sea at maximum extent of the Bearpaw sea (*Baculites reesidei* time). Reconstruction based upon the lithology of biostratigraphically correlative deposits. Legend as for text-figure 2. Some information in both text-figures 2 and 3 drawn from Russell (1939, figs. 4 and 5).

Western Interior basin, they pass into the upper part of the thick sequence of mixed marine beds forming the Pierre Formation.

Some uncertainty regarding the precise interval occupied by the Bearpaw Formation followed its initial definition (Furnival, 1946, p. 38), but in Canada, invariably it is accepted now to be that between the top of the Oldman Formation and the base of the Eastend Formation.

In Saskatchewan, the Bearpaw Formation is best known from the flanks of the Cypress Hills, where a series of exposures span its complete interval. Remarks on the general Bearpaw sequence and its distribution in the Cypress Hills area are to be found in the accounts of Furnival (1946, p. 38 ff.) and Russell (1948, p. 10-22), both of which also include numerous measured sections documented in detail. Both these authors found that the Bearpaw Formation in the Cypress Hills area contains prominent sand or sandstone markers, particularly in the upper part, and explicitly and implicitly emphasized the importance of these in regional correlation.

The exposures of the Bearpaw Formation in the South Saskatchewan River valley combine to form one of the densest belts of outcrop of Cretaceous rocks in the province. Near Cabri and Pennant and north of Outlook, Bearpaw clays and sands rest on sands and silts of the Oldman Formation (compare Allan, 1919, p. 10C, who thought the clays and sands underlay the Belly River [Oldman] Formation and belonged to the lower Pierre [Lea Park] Formation). In the intermediate ground, almost the entire Bearpaw Formation is exposed, and locally, as for example near Herbert Ferry and in the Vermilion Hills, remnant caps of the Eastend and Whitemud Formations rest on a Bearpaw foundation (text-figs. 4 and 6).

The Bearpaw Formation in the South Saskatchewan River valley is divisible into eleven members, ten of which are named Outlook, Broderick, Matador, Sherrard, Demaine, Beechy, Ardkenneth, Snakebite, Cruikshank, and Aquadell (text-fig. 5). The basal member is unnamed. The Broderick, Sherrard, Beechy, Snakebite, and Aquadell Members, together with the basal unnamed member, are composed predominantly of silty clays, the Outlook, Matador, Demaine, Ardkenneth and Cruikshank Members consist of sands, generally silty and locally with clay lenses. The sands are thin compared to the clays with which they are interlayered. Within the river valley, all members are remarkably persistent northward and southward from their type localities, most of which lie in the vicinity of Herbert Ferry: for example, the Broderick Clay can be traced in outcrop from near Saskatchewan Landing to near Outlook, a distance in excess of 50 miles, and the Snakebite Member from Snakebite Creek to the Gardiner Dam, a distance of about 40 miles. It is more difficult to assess their persistence to east and west. These directions are transverse to the depositional strike, and thus are those in which the members might be expected to lose their identities most quickly. Again from outcrop, however, there is no doubt that the Ardkenneth and Snakebite Members continue from west to east for at least 30 miles, and the likelihood is that most of the others extend for comparable distances. Beyond the river valley, many of the members can be traced through the subsurface toward the Cypress Hills and Wood Mountain for distances in the order of 100 miles. Thus, as in the Cypress Hills, the Bearpaw Formation of the South Saskatchewan River valley contains sand members that are widely distributed and valuable as markers. Some of the lower sands are continuous with sands of the Oldman Formation and represent broad tongues of brackish-water and marine coarse-grained terrigenes that encroached eastward and invaded the zone of marine clay deposition; and likewise, the highest sand, a late-stage influx, if it can be traced far enough to the west, should be found to pass into the Eastend Formation. It is to be noted that sand members interrupt the clay sequence of the Bearpaw Formation in the southern Alberta plains (Clark, 1931, p. 117-120; Link and Childerhose, 1931, p. 101-111; Russell *in* Russell and Landes, 1940, p. 73-81;

Lines, 1963, p. 220-221, 226, figs. 4, 5), but, like those cropping out in the river valley, their full areal extent and equivalents have not yet been determined in detail.

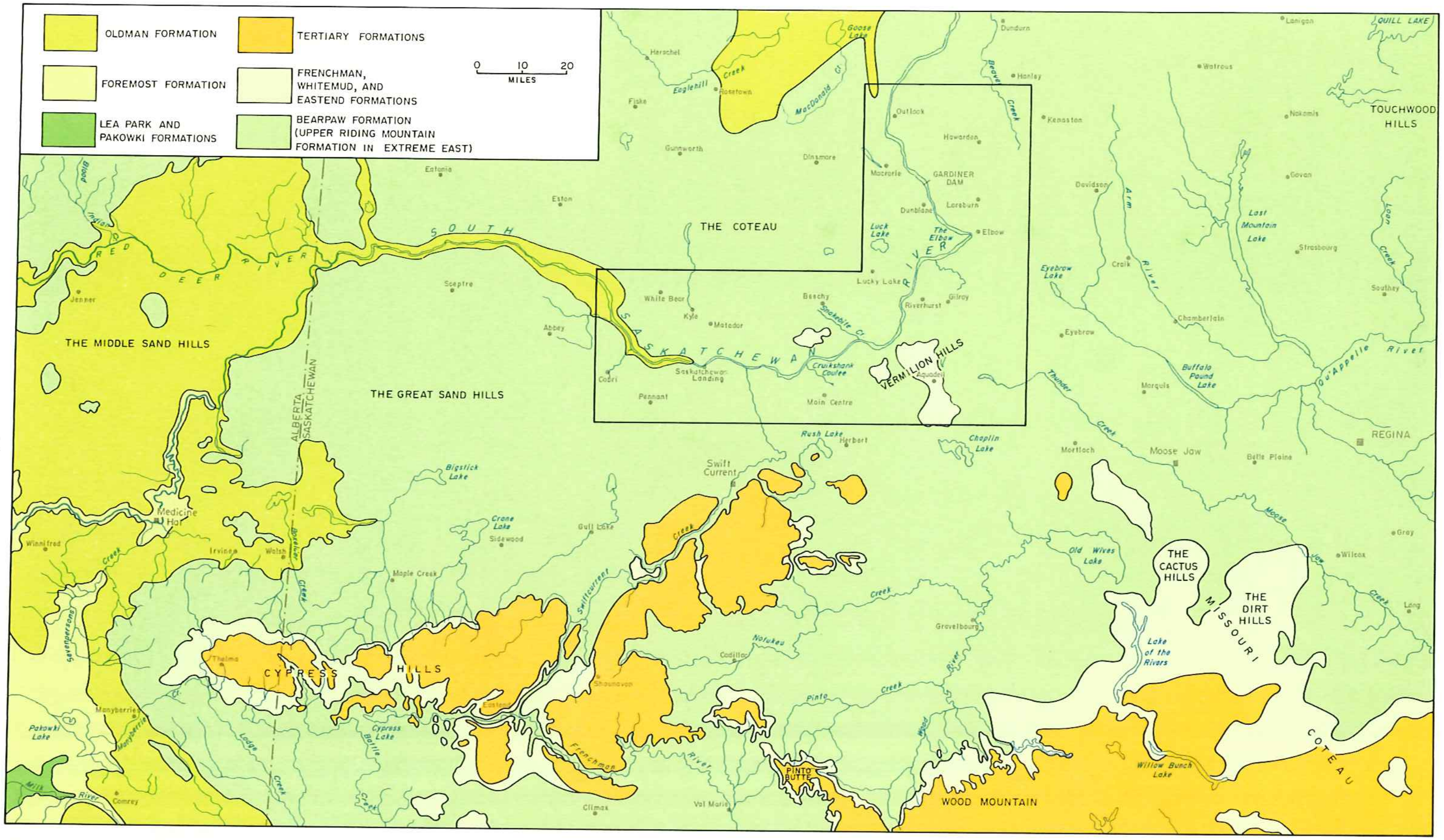
Since the Bearpaw Formation in the South Saskatchewan River valley consists of alternating marine clays and marine and non-marine sands, it lies within the "western facies belt" of Tourtelot (1962, p. 9, fig. 1), but, since most of the sands are entirely marine and they are subordinate to the clays, a position close to the western boundary of the "central facies belt" is indicated. Stratigraphical relationhips, sedimentary structures, and a rich invertebrate fauna combine to suggest that all the Bearpaw sediments were deposited under shallow-water conditions, probably in the littoral and epineritic zones adjacent to the western shore of the interior seaway. In Kauffman's (1967, p. 91-92, fig. 3) terminology for a model of cyclic Cretaceous marine sedimentation in the Western Interior, the Bearpaw sediments of the South Saskatchewan River valley and the region to the west are deposits of the "inner and middle shelf".

Beds between the marine silty clays at the top of the Bearpaw Formation and the kaolinitic clays and sands of the Whitemud Formation have been grouped as the Eastend Formation. The name, proposed by Russell (1932, p. 132-134) is taken from the town of Eastend, which lies in the type area on the south flank of the Cypress Hills. Typically, the lower beds consist of brownish-grey fine-grained sands, silts, and subordinate shales, and they contain a sparse molluscan fauna (McLearn *in* Fraser *et al.,* 1935, p. 24; Russell, 1943, p. 281-288). The upper beds are composed of greenish-yellow fine-grained sands and silts, and thin seams of lignite. Despite the occurrence of marine fossils at one horizon near the top of the formation, there is little doubt that most of the upper Eastend beds accumulated under non-marine conditions: a fluvio-deltaic environment would explain most readily the recurrent lignite partings, and the discovery of the tooth of a carnivorous dinosaur is a further pointer to a continental origin for the sediments. Broadly, grain size decreases toward the base of the formation and the incidence of recognizably marine beds increases, so that the Eastend Formation passes by transition into the underlying Bearpaw Formation.

Russell (*in* Russell and Landes, 1940, p. 86-89) has pointed out that westward, in the southern Alberta plains, the formation is much thicker and includes a greater variety of terrigenous deposits and bentonite seams. It has been shown also to contain a richer and more varied molluscan fauna, which supports correlation of the lower part of the Eastend Formation in Alberta with the upper part of the Bearpaw Formation in southwestern Saskatchewan. In 1941, Furnival (p. 57-69) applied the name Eastend Formation to the upper part only of Russell's thick section in Alberta and incorporated the lower in the Bearpaw Formation. Full appreciation of the complex history and problems of correlation of the Eastend Formation can be had from the account of Furnival (1946, p. 69-77).

North of the Cypress Hills, the Eastend Formation is difficult to identify, and in the vicinity of the South Saskatchewan River valley, it is doubtful if it should have formational status. About 100 feet thick, it consists of greyish-brown muddy sands and silts that collectively form no more distinctive a unit than some of the sands in the Bearpaw Formation. Identification of the Eastend Formation hitherto has been dependent partly, at some localities probably wholly, on recognition of the overlying Whitemud Formation — not on any intrinsically distinctive lithological characteristics — and about all that serves as a criterion for distinction of the Eastend beds is the predominant brown colour of its sediments in contrast to the predominant grey of those of the Bearpaw Formation.

The grey to white kaolinitic clays, silts, and sands that overlie the Eastend Formation form the thin but distinctive Whitemud Formation, named by Davis (1918, p. 9). The type locality is presumed to be at Eastend in the Frenchman



Text-figure 4: Simplified geological map of part of southwestern Saskatchewan and adjacent southeastern Alberta to show the location of the area of study.

(formerly Whitemud) River valley, south of the Cypress Hills. Kupsch (1956, p. 7, 11) established type sections for both the Eastend and Whitemud Formations.

Correlation of the Whitemud Formation has been discussed at length by McLearn (*in* Fraser *et al.,* 1935, p. 34-35). To the south, it is believed to be the correlative of the Colgate Member of the Fox Hills Formation, to the west of some upper part of the St. Mary River Formation, and to the northwest of an upper part of the Edmonton Formation (Sanderson, 1931a, p. 66-67; Russell *in* Russell and Landes, 1940, p. 91). The formation has been traced from southern Alberta eastward across much of southern Saskatchewan.

In the vicinity of the South Saskatchewan River valley, coarse-grained, cross-bedded, white sandstones of the formation form the cliffed flanks of a small outlier south of Beechy (Fraser *et al.,* 1935, Pl. 2), and white clays and silts have been found on the slopes of the Vermilion Hills.

Whitemud sediments were interpreted by McLearn *(op. cit.,* p. 104-111) to have been transported by shifting streams, deposited in shallow, flood-plain lakes and ponds, and subjected to intense and prolonged chemical weathering.

DISTRIBUTION OF OUTCROP

New members

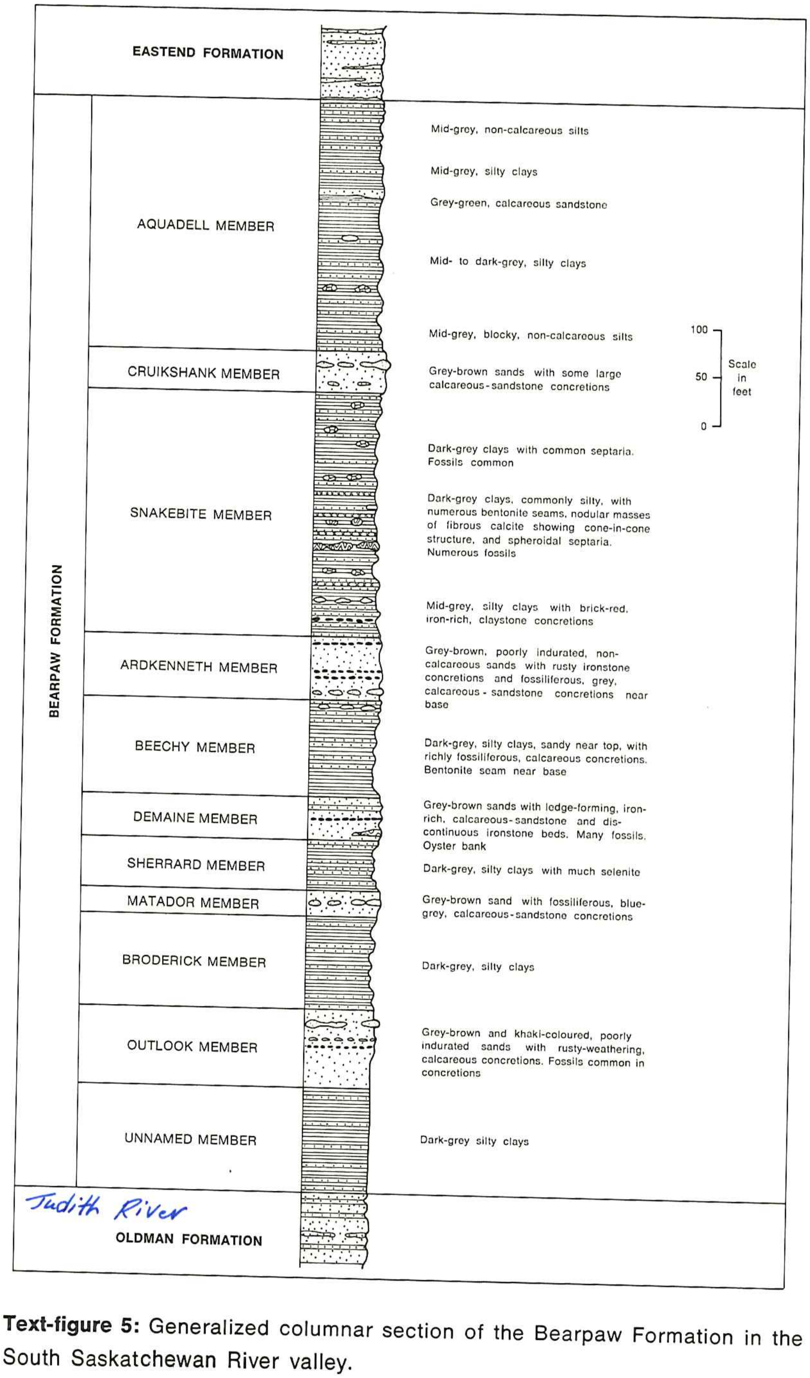
In the studied segment of the South Saskatchewan River valley, the sediments that compose the 1,150-foot thick Bearpaw Formation fall naturally into eleven distinct divisions, six of them of silty clay alternating with five of silty sand. Since these divisions can be traced through much of the valley and some of them far beyond, they are worthy of the status of members. It has been possible, however, to establish formally only ten members. The silty clays at the base of the formation, nowhere exposed, are known only from bore holes and in none of these have the beds been cored continuously to provide a suitable type section. Until such a section becomes available, the basal silty clays fail to meet even the basic requirement for definition as a new stratigraphical unit. Temporarily, they will be referred to as the *unnamed member* — a designation that, although informal, is as convenient and useful as those of the formally established members. Overlying the unnamed clays, the sands of the Outlook Member and silty clays of the Broderick Member are best exposed and have their type sections near the northern limit of the river-valley outcrop belt. Exposures of these members are limited in number and in stratigraphical extent, and they are probably the most poorly known beds in the entire Bearpaw sequence. Above the Broderick Clay, four sand members, named Matador, Demaine, Ardkenneth, and Cruikshank, alternate with three silty clay members, named Sherrard, Beechy, and Snakebite, and the type sections of these members are located between Swiftcurrent Creek and the Vermilion Hills, where the river has trenched deeply into the Missouri Coteau and, as a result, the most continuous sections are to be found. The highest beds of the Bearpaw Formation, silty clays grouped as the Aquadell Member, are best exposed on the northwestern slopes of the Vermilion Hills, but, like the Outlook and Broderick Members, individual outcrops, although numerous, are limited in stratigraphical extent, and no section has been found with sufficient continuity of exposure to warrant its selection as type. Fortunately, however, almost the entire sequence has been cored in bore holes in the Vermilion Hills, and two of these subsurface sections provide a type and a supporting reference section for the member. Members, arranged in stratigraphical order and identified by the names that have been applied to them, are listed in text-figure 5. The new names are drawn from geographical localities in the vicinity of the type sections, and the localities are shown in text-figure 7.

Prior usage of the names of some of the members proposed herein — the names having been taken from unpublished masters' theses of the University of Saskatchewan — is regrettable (see, for example, van Everdingen, 1964, p. 39; 1966a, p. 124-125; 1966b, p. 70; 1967, p. 353-358, fig. 3; 1968, p. 5-8 ff.: Folinsbee *et al.,* 1965, p. 166, fig. 3: Meyboom, 1966, p. 7-12, figs. 2, 3; *in* Brown, 1967, p. 139, 141, 144, fig. 53; Meyboom, van Everdingen, and Freeze, 1966, p. 31-39, figs. 18, 20) and, under the Code of Stratigraphic Nomenclature, the names have no standing whatsoever (American Stratrigraphic Commission, 1961, p. 653-654). Folinsbee and his co-workers must have misread Caldwell (1963, p. 506), who did not indicate that the succession of Bearpaw beds in the South Saskatchewan River valley could be divided into the named members cited, only that it could be interpreted broadly in terms of three shales (lower, middle, and upper) alternating with two sands (lower and upper). Moreover, since one of the names used is doubly preoccupied and has been abandoned, and another was used to designate a group of beds now divided into five named members, the impropriety of the premature publication is emphasized. It is highly desirable, nevertheless, that the valuable data on the absolute ages of certain of the Bearpaw beds, obtained by Folinsbee and his co-workers, and on the movement of groundwater through the Bearpaw beds, analysed principally by Meyboom and van Everdingen, be tied as closely as possible to the stratigraphical sequence now formally to be established. For this reason, the relation of various divisions of the Bearpaw sequence, described in these and other recent publications, to the new divisions is summarized in Table 1.

Structural controls

Structurally, the Bearpaw beds in the South Saskatchewan River valley occupy the core of the shallow, plunging, Moose Jaw syncline — a northwestward extension of the Cretaceous Williston Basin (Williams and Burk, 1964, fig. 12-15). The axis of the syncline is approximately co-incident with the northwest-southeast escarpment of the Missouri Coteau and crosses the river valley in the vicinity of Riverhurst. Oldman beds crop out in the river valley a few miles west of Saskatchewan Landing and give way downstream to progressively younger members of the Bearpaw Formation: the Broderick, Matador, Sherrard, Demaine, Beechy, and Ardkenneth Members occupy most of the valley from Saskatchewan Landing to Herbert Ferry, the Snakebite and Cruikshank Members from Herbert Ferry to Riverhurst, with the Aquadell Member developed locally in the Vermilion Hills. At some localities in this part of the valley, the beds have a measurable dip in an east-northeasterly direction (see also Warren, 1927, p. 40B; *in* Fraser *et al.,* 1935, p. 60-61) — surface expression of the local monoclinal structure depicted in text-figure 6. North of Riverhurst, the dip is regionally to the south-southwest, which brings the Ardkenneth Member to the surface at the Elbow, the Matador to Beechy Members to the surface near Macrorie, and the Broderick and Outlook Members to the surface near Outlook (text-fig. 6). Outcrop distribution, however, indicates that a local syncline, the axis of which traverses the river valley at the site of the Gardiner Dam, breaks the homoclinal structure between Elbow and Outlook, and structure contours drawn on marker horizons beneath the Bearpaw Formation in the Upper Cretaceous Series, indicate a local relatively steep-flanked pericline south of Riverhurst — a fold that probably also affects the Bearpaw beds.

The Moose Jaw syncline is most probably of regional tectonic origin, but recent studies of local structures in south-central Saskatchewan have indicated that pronounced Upper Cretaceous structural depressions generally can be related to collapse of overlying sediments following the solution of salt from the Devonian Prairie Evaporite Formation, wherever salt normally is present (Gorrell and Alderman, 1968, p. 304). Salt collapse, therefore, probably is responsible for the majority of local structural depressions affecting the Bearpaw beds in the South Saskatchewan River valley.



Text-figure 5: Generalized columnar section of the Bearpaw Formation in the South Saskatchewan River valley.

		Caldwell (1963, p. 155) Caldwell and North (1964, p. 147-150, fig. 3)	van Everdingen (1964, p. 39) van Everdingen (1966a, p. 124-125)	Folinsbee *et al.* (1965, p. 166, fig. 3)	Meyboom (1966, p. 7-12, figs. 2, 3)	van Everdingen (1966b, p. 70)	Meyboom, van Everdingen, and Freeze, (1966, p. 31-39, fig. 20)	van Everdingen (1967, p. 353-358, fig. 3)	Meyboom *in* Brown (1967, p. 139, 141, 144, fig. 53)	van Everdingen (1968, p 5-8 ff., figs.)
BEARPAW FORMATION	AQUADELL MEMBER	upper clay member	—	Aquadell Member	Vermilion Member	Vermilion member	—	Vermilion member	—	Vermilion Member
	CRUIKSHANK MEMBER	upper sand member	—	Cruikshank Member	Cruikshank Member	Cruikshank member	—	Cruikshank member	Vermilion member or Sandstone	Cruikshank Member
	SNAKEBITE MEMBER	middle clay member	—	Snakebite Member	Snakebite Member	Snakebite member	Snakebite Member	Snakebite member	—	Snakebite Member or shale
	ARDKENNETH MEMBER	lower sand member	Ardkenneth Member	Ardkenneth Member	Ardkenneth Member	Ardkenneth member or sandstone	Ardkenneth Member	Ardkenneth member or sandstone	Ardkenneth member or sandstone	Ardkenneth Member or (S)sandstone
	BEECHY MEMBER	lower clay member	—	Beechy Member	Beechy Member (Upper shale)	Beechy member (shale 65-110 ft. thick)	Beechy Member (Upper shale unit)	Beechy member (shale 55-71 ft. thick)	—	Beechy Member (5, Upper shale). Upper Beechy member, shale 5
	DEMAINE MEMBER	lower clay member (sand shown in fig. 3)	Beechy Member	Beechy Member	Beechy Member (Middle sandstone)	Beechy member (sandstone 25-45 ft. thick)	Beechy Member (Middle sandstone unit)	Beechy member or sandstone (sand and sandy shale 18-46 ft. thick)	middle Beechy Member or middle Beechy sandstone	Beechy Member or (S)sandstone (4, Upper sand or sandstone). Middle Beechy member, sand 4
	SHERRARD MEMBER	lower clay member	—	Beechy Member	Beechy Member (Lower shale)	Beechy member (shale 50-85 ft. thick)	Beechy Member (Lower shale unit)	Beechy member (shale 72-86 ft. thick)	—	Beechy Member (3, Middle shale). Lower Beechy member shale 3
	MATADOR MEMBER	lower clay member	Beechy Member	Beechy Member	22 to 35-foot sandstone 73 feet below top of 208-foot thick lower shale	Beechy member (sandstone 15-20 ft. thick)	15 to 18-foot shaly sandstone 80 feet below top of 200 to 220-foot thick lower shale	Beechy member or sandstone (sand and silty sand 14-21 ft thick)	—	Beechy Member or sandstone (2, Lower sand or sandstone). Lower Beechy member, sand 2
	BRODERICK MEMBER	lower clay member	—	Beechy Member	Beechy Member (Lower shale)	Beechy member (shale 105-120 ft. thick)	Beechy Member (Lower shale unit)	Beechy member (shale 104-117 ft. thick)	—	Beechy Member (1, Lower shale). Lower Beechy member, shale 1
	OUTLOOK MEMBER	"Belly River Formation"	(?) Belly River Formation	Oldman Formation	Belly River Formation	Belly River Formation	Belly River Formation	Belly River Formation	—	Belly River Formation or (S)sandstone
	UNNAMED MEMBER									

Table I

Slumping has severely disrupted the Bearpaw beds in the South Saskatchewan River valley, and, in many places, it is difficult to establish sequences with much confidence (McConnell, 1886, p. 60c). Fortunately, at a few localities, the beds are comparatively undisturbed, and sections measured at these localities have provided the basis for establishment of the intraformational sequence. Some sections of over 100 feet have been measured, others span only a few tens of feet: but the presence of numerous marker beds facilitiates grouping of the shorter sections into composite sections, and the manner in which these collate confirms the established sequence and demonstrates remarkable lateral persistence of the members and beds. Christiansen (1959, p. 21-23) has described the slumping in the Swiftcurrent Creek valley — a tributary to the South Saskatchewan River valley— and discussed the factors that control it.

Construction of the Gardiner Dam between Elbow and Outlook and simultaneous flooding of the South Saskatchewan River valley to create the 120-mile long reservoir of Diefenbaker Lake has led to a considerable rise in the water level throughout much of the studied portion of the valley, and many exposures used to establish the stratigraphy now are inaccessible (see van Everdingen, 1968, fig. 16). Fortunately, most of the type and important reference sections lie either in the unflooded portion of the valley, north of the dam, or in the high ground southwest of the Missouri Coteau, where the effects of flooding have been (and will be) least. So that reference can be made conveniently to all sections used in the stratigraphical analysis, however, the configuration of the South Saskatchewan River valley, as it was prior to the construction of the dam and reservoir, is used in all illustrations.

The Herbert Ferry district
(based mainly on the work of J. K. Evans)

West of the Missouri Coteau, the South Saskatchewan River valley is gouged into relatively high ground, and it is in this stretch of the valley that the best outcrops of the Bearpaw beds are to be found. Between Swiftcurrent Creek and Herbert Ferry in particular, many of the lower Bearpaw beds are completely and continuously exposed, and the outcrops contain the type sections of the Matador, Sherrard, Demaine, Beechy, and Ardkenneth Members. Not only does the Herbert Ferry district stand as an important type locality, but also it makes a logical stratigraphical base from which to trace the Bearpaw beds into the less well-exposed tracts of the valley.

Named from the old settlement of Matador, close to the sizeable town of Kyle, the Matador Member consists of poorly indurated and patchily iron-stained greyish-brown sands. They overlie the silty clays of the Broderick Member with which they have a sharp contact. The sands are completely exposed 5 miles west of Herbert Ferry (Secs. 31 and 32-19-11W3), where they are 22 feet thick, and the section at this location, detailed on p. 21, is designated as type. Twelve feet above the base, the sands contain an impersistent bed of rusty-weathering, ovoid, bluish-grey, calcareous sandstone concretions, which weather to project as a prominent ledge from the comparatively unconsolidated host. These nodules contain numerous molluscs among which *Arctica ovata* (Meek and Hayden)[1] is most common. Other notable fossils found in the concretions include large specimens of *Placenticeras meeki* Boehm and a single valve of the rudist *Ichthyosarcolites* cf. *coraloidea* (Hall and Meek). *Gervillia borealis* Whiteaves occurs in the sands above the concretionary layer. The Matador sands crop out a few miles farther west, near the mouth of Swiftcurrent Creek, where they display a similar lithology and possibly a slight increase in thickness. To the east of the type locality, a

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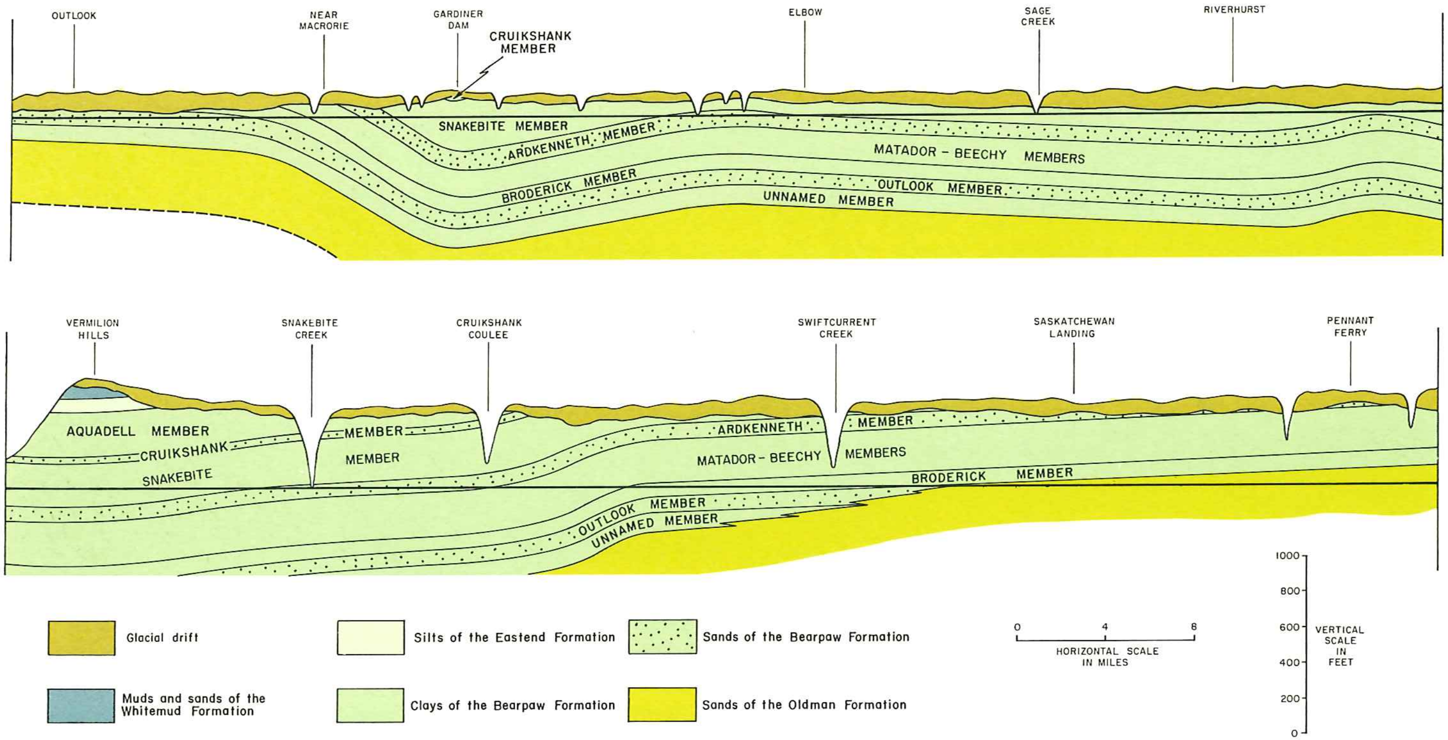
1 Authors of species-names are given at first mention and, for convenience, are repeated in the section entitled 'Stratigraphical Palaeontology' toward the end of the report.

gentle dip carries them beneath river level well within a mile, and they do not reappear west of the Missouri escarpment.

Clays of the Sherrard Member, 50 feet thick, succeed the Matador Sand, the contact being marked by an impersistent bed of dark-brown lignitic clay, 2 to 3 inches thick. The clays contain a high proportion of silt and, locally, of sand and a notable amount of selenite. The selenite occurs in thin iron-stained veins discordant to the bedding, and in well-formed prismatic crystals (commonly twinned) several inches long. Continuous vertically with the type sections of the underlying Matador and overlying Demaine Members. that of the Sherrard Member is described below in an account of the entire section exposed in Sections 31 and 32-19-11W3. The name is taken from the old Sherrard Post Office, located on the Missouri Coteau, about 6 miles west of Beechy.

Above these clays, greyish-brown sands recur. Developed to a thickness of about 45 feet, the sands are grouped as the Demaine Member, the name being taken from the town of that name, situated about 6 miles east of Beechy. Unlike the Matador sands, the Demaine sands cannot be separated abruptly from the clays beneath them, and the contact is placed arbitrarily within 10 to 15 feet of silty transitional beds. These gradational silts contain at least one lense of comminuted and entire oyster shells, which must have an areal extent of nearly half a square mile. The lense is not to be looked upon as a patch reef, for the oysters are not cemented to any solid foundation or to each other and show no signs of having been buried in position of growth. Most of the shells are disarticulated, some of them broken, and they appear to have suffered abrasion. The lense is interpreted to be a bank deposit, the shells having been washed and assembled in a mound by wave and current action at a site close to where they lived. At the type locality, the lense forms a resistant cap to a number of outliers. Above the transitional beds, the sands contain numerous thin, discontinuous, ironstone beds, which become more numerous in upward sequence, and, 6 feet below the top, they contain a 1-foot thick, ledge-forming bed of iron-rich calcareous sandstone. The sandstone bed is richly fossiliferous: pockets of *Pteria linguaeformis* (Evans and Shumard), *Oxytoma nebrascana* (Evans and Shumard), and a small mytilaceid, together with limited numbers of *Inoceramus* sp., weather from the hard host rock, and the upper surface carries a dense system of branching thick-walled tubes, which probably are the fillings of a maze of *Callianassa*-like burrows formed by shrimps or some other marine organisms. Similar structures have been found in the Bearpaw and associated formations in other regions and have been described under the name of *Halymenites* or *Ophiomorpha* (see Irwin *in* Sanderson, 1931b, p. 1262-1263; Brown, 1939, p. 253-254; Furnival, 1946, p. 42, 59, 63; Weimer and Hoyt, 1964, p. 761-767). Logs, branches, and chips of wood, remarkably well preserved, are common in these sands. Many of the wood fragments are riddled by the empty and sediment-filled burrows of boring bivalves, and some of the bivalves are preserved, fossilized in their life-position, at the bottom of their burrows. Some of the sand beds are weakly cross-bedded. Nowhere is the complete Demaine Member exposed: 26 feet of the sands can be seen directly above, and in sequence with, the type section of the Sherrard Member, and these 26 feet constitute the type section of the Demaine Member.

Where the river reaches the most southerly point in its course (the boundary between Sections 31 and 32-19-11W3), the cliffs along the river bank and the badlands of the valley floor have been etched in beds ranging from the Broderick Clay to the Demaine Sand, and it is these beds that form the type sections of the Matador, Sherrard, and Demaine Members. The exposures can be reached conveniently by road. They lie in badland country at the western end of a segment of the flood plain of the South Saskatchewan River. A winding trail crosses the plain from the Perrin Ranch, which is readily accessible by road from the Herbert Ferry. Details of the complete sequence exposed are as follows:



Text-figure 6: Two sections (more or less continuous one with the other) drawn along the South Saskatchewan River valley to illustrate the general synclinal structure between Outlook in the northeast and Pennant Ferry in the southwest. Apparent also from sections is the markedly higher topographical level of the ground to the southwest of the Missouri Coteau (marked by the Vermilion Hills). The datum in each section is river level (about 1,675 feet above sea level in the upper section and about 1,750 feet above sea level in the lower). The course of the river (and therefore of the lines of section) is shown in text-figures 4 and 7. Glacial drift cover is diagrammatic, and no attempt has been made to calculate or estimate its true thickness.

BEARPAW FORMATION

	Thickness in ft.	in.
Demaine Sand Member (type section)—		
Sand, grey, weathering pale greyish brown, variable in grain size, poorly indurated, non-calcareous, iron stained (preferentially along bedding planes), with small ironstone concretions and thin veins of fibrous calcite	15	(seen)
Sand, grey, weathering greyish brown, silty, with thin seams of reddish-brown ironstone concretions and rare concretions of sandstone	4	6
Gravel, composed wholly of oyster shells, a few of them articulated and entire, the majority disarticulated and broken: a local (although widespread) shell bank	1	6
Sand, grey, weathering greyish brown, very silty, with pockets and lenses of "pure" silt and clay, patchily iron stained	5	
Sherrard Clay Member (type section)—		
Clay, dark grey, weathering grey to brownish grey, silty and locally sandy, irregularly iron stained, containing thin veins of selenite discordant to the bedding and many prismatic crystals of selenite; the basal few inches locally lignitic	50	
Matador Sand Member (type section)—		
Sand, mid-grey, weathering pale brownish grey, silty, poorly indurated, iron stained along bedding planes, with thin selenite veins that extend into the underlying beds	1	6
Sand, greyish brown, weathering rusty due to intense iron staining, locally ledge forming, containing nodules of calcareous sandstone with *Arctica ovata* and *Oxytoma nebrascana*	1	6
Sand, dark greenish grey, grading down into dark brownish grey, weathering pale brown, poorly consolidated, silty, iron stained (preferentially along bedding planes), with *Arctica ovata*	7	
Concretions of grey, calcareous sandstone, ovoid, 2 to 3 feet diameter, deeply weathered to rusty brown, with many *Placenticeras meeki, Arctica ovata, Oxytoma nebrascana,* and *Yoldia evansi* (Meek and Hayden)	2	
Sand, brownish grey, weathering pale brown, silty, non-calcareous irregularly iron stained, containing *Gervillia borealis* and *Pecten saskatchewanensis* Warren	10	
Broderick Clay Member—		
Clay, dark grey, weathering brownish grey, silty, patchily iron stained, with thin calcareous sandstone ribs containing *Oxytoma nebrascana.* Clays near top contained one specimen (loose) of *Baculites rugosus* Cobban	25	

The upper clays of the Broderick Member are nowhere else exposed in the river valley and thus this 25-foot section, near Herbert Ferry, is important as a reference section for the member.

Named from the town of Beechy, the nearest sizeable settlement to the type locality, the Beechy Member consists of 110 feet of silty clays, which overlie the Demaine Sand and underlie the Ardkenneth Sand. Immediately above the top of the Demaine Sand, 7 feet of grey-brown silty clays, containing numerous shells of *Ostrea patina* Meek and Hayden, are succeeded by a 3-inch seam of yellow bentonite. The *O. patina* clays and the bentonite seam are valuable markers, which have been used to correlate the Beechy and its contiguous members both within the river valley and beyond. Toward the top, the Beechy clays become sandy, and commonly the top few beds are transitional to the overlying sands of the Ardkenneth Member. Ovoid concretions of calcareous sandstone, containing *Baculites compressus robinsoni* Cobban, other ammonites, and bivalves are developed within these gradational beds.

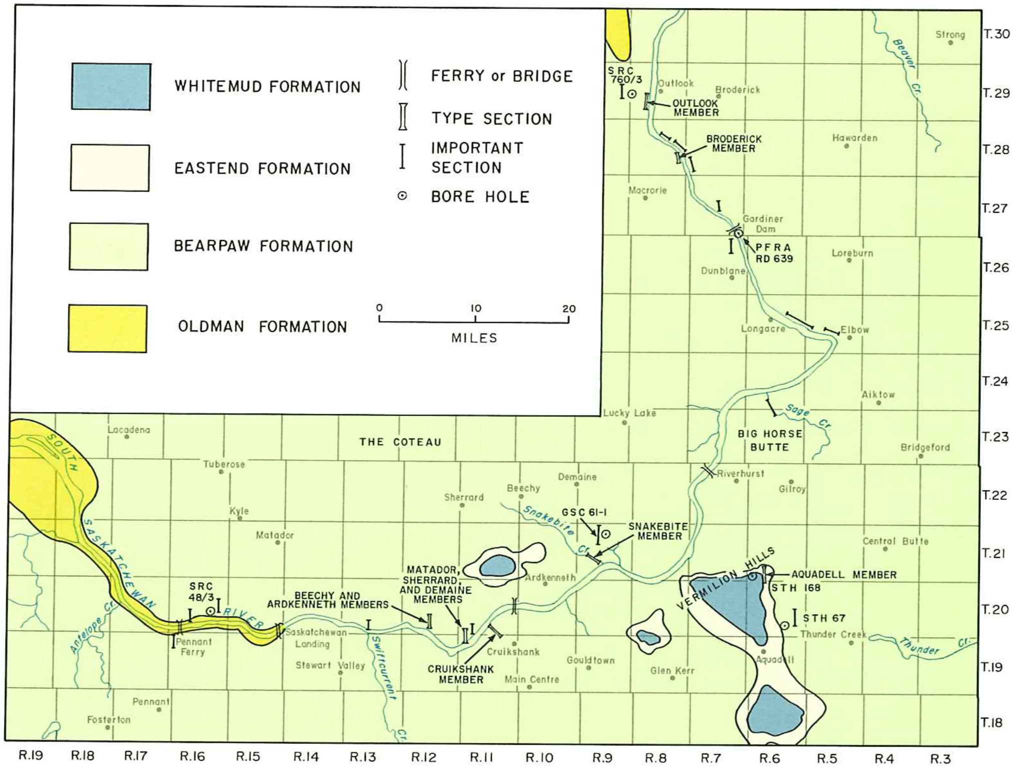
The Beechy Member is succeeded by sands, 70 feet thick, which are distinguished as the Ardkenneth Member, the name being taken from the old Ardkenneth Post Office, 3 miles northeast of Herbert Ferry. These sands, like most others in the Bearpaw Formation, although seldom lithified to any marked degree, are least well indurated at outcrop surfaces, where any cement normally present probably has been leached. Mostly too, the fresh sediment is grey, whereas in weathered surface it is predominantly brown or mottled grey to brown, no doubt due to the oxidation of iron.

All of the Beechy and Ardkenneth beds are exposed in a creek, which drains the badlands on the north side of the South Saskatchewan River valley, 9 miles west of Herbert Ferry (Secs. 4 and 10-20-12W3). Readily accessible from a road leading to the Hermannson ranch and more extensive stratigraphically than any other in the type locality, this section is selected to be the type for both members. For convenience, however, it is to be noted that some of the lower beds in the section are better exposed in a small butte on the valley floor, lying a few hundred yards west of the creek section. The following beds are exposed:

BEARPAW FORMATION	Thickness in ft.	in.
Snakebite Clay Member—		
Silt, grey, weathering greyish brown, clayey, patchily iron stained	2	
Ardkenneth Sand Member (type section)—		
Sand, pale grey, weathering brownish grey, poorly indurated, non-calcareous, irregularly iron stained, with prominent 3-inch bed of rusty sand at contact with overlying silts	4	
Ironstone, dark brown, weathering orange-brown, with abundant thin cylindrical structures, ⅛ inch in diameter, that may be the casts of burrows		9
Sand, grey, weathering pale grey, well bedded, weakly indurated, non-calcareous	7	
Sand, grey, weathering pale greyish brown, with grains of dark minerals conspicuous, patchily iron stained, poorly consolidated, with three thin, rusty, iron-stained seams, one 3 inches thick at the base, one 4 inches thick 4 feet above the base, and one 6 inches thick at the top	9	
Sand, grey, weathering pale grey, poorly consolidated, non-calcareous	8	
Sand, grey, weathering pale greyish brown, poorly consolidated, non-calcareous, with numerous 1-inch diameter concretions of rusty-weathering, iron-rich sand concentrated in several 1-foot thick beds, the concretions weathering out from the host sand and giving it a spotted appearance	10	
Sand, grey, weathering pale grey, poorly consolidated, non-calcareous, with rare impersistent seams, 4 inches thick, and concretions, 6 inches in diameter, of rusty ironstone with much visible sandy and clayey detritus	10	
Sand, greyish brown, weathering buff, weakly cross-bedded, poorly consolidated, non-calcareous, patchily iron stained, with numerous 1 to 2-foot diameter, ovoid concretions of grey, calcereous sandstone, containing numerous *Baculites compressus robinsoni, Placenticeras intercalare* (Meek), *P. meeki,* and other molluscs, in the lower beds	20	
Beechy Clay Member (type section)—		
Clay, mid- to dark grey, weathering mid-grey and greyish brown, silty and locally sandy, non-calcareous, with impersistent iron-stained seams and patches; contains some concretions similar to those in overlying sands	17	
Covered interval: probably occupied by clays similar to above	19	
Clay, dark grey, weathering mid-grey and greyish brown, non-calcareous, iron stained, with scattered, unfossiliferous, siltstone concretions: crushed bivalves occur rarely in the clay	64	
Bentonite, yellow, weathering yellowish brown, soft, mealy textured		3
Clay, dark grey, weathering light brownish grey, silty and locally sandy, non-calcareous, with numerous, generally disarticulated shells of *Ostrea patina*	7	
Demaine Sand Member—		
Sand, grey, weathering pale brownish grey, dark mineral grains conspicuous, silty, poorly consolidated, non-calcareous, with cigar-shaped, rusty, ironstone concretions	6	
Sandstone, grey, weathering dark brown due to high concentration of iron oxides, calcareous, hard, ledge forming, locally nodular, with numerous bivalves including *Inoceramus* sp., *Oxytoma nebrascana, Pteria linguaeformis* and with *(?)Ophiomorpha* sp.	1	
Sand, grey, weathering pale brownish grey, silty, poorly consolidated, non-calcareous, with thin, discontinuous, rusty, ironstone ribs and cigar-shaped ironstone concretions	12	(seen)

As the upper sands of the Demaine Member are exposed and the type section farther east spans only the lower sands, this section assumes additional significance by serving as a complementary reference section for the Demaine Member and providing essentially complete exposure of the member within the type locality. The upper Demaine sands are rendered distinct by the partings of ironstone they contain. These become more numerous and thicker in upward sequence and are concentrated in the top 20 feet, from which the ironstones weather as thin resistant ribs. Iron oxides have been concentrated also in cigar-shaped concretions, 4 to 6 inches long, which are composed of a thin shell of clay ironstone, commonly concentrically layered, surrounding a core of grey to brown sand. Some carry conspicuous lenses and stringers of silt and sand between the layers of ironstone.

All exposed members of the Bearpaw Formation maintain remarkable lithological consistency within the confines of the Herbert Ferry district. Near the upstream limit of the dense outcrop belt, it is mostly the clays and sands of the Matador, Sherrard, Demaine and Beechy Members that occupy the valley slopes, the Ardkenneth Member being confined to a position high on the valley sides: but downstream, the regional east-northeasterly dip carries the sub-Ardkenneth beds



Text-figure 7: Simplified geological map of the Bearpaw outcrop belt in the South Saskatchewan River valley and environs to show the location of the type and principal reference sections of the new members.

into the subsurface and brings the Ardkenneth Sand almost to river level at the mouth of Snakebite Creek, 9 miles below Herbert Ferry.

Swiftcurrent Creek to Pennant Ferry

To the east and west of Saskatchewan Landing, Bearpaw beds are nowhere exposed in continuous sequences comparable to those of Herbert Ferry. Nevertheless, surface and subsurface data are sufficient to show that some of the clays and sands toward the base of the formation, when traced into the Pennant Ferry country, undergo striking changes and pass into sands and silts of Oldman facies, which are, in part, included in the Oldman Formation.

Between Swiftcurrent Creek and Saskatchewan Landing, beds of the Broderick, Matador, Sherrard, Demaine, and Beechy Members are exposed, and lithologically, these are indistinguishable on a superficial basis from their homotaxial equivalents near Herbert Ferry. McConnell (1886, p. 60c-61c) and Warren (*in* Fraser *et al.*, 1935, p. 21) noted the occurrence of thick sands in the clay sequence on the north bank of the river opposite the mouth of Swiftcurrent Creek, and McConnell's measured section is to be interpreted in terms of the following members:

BEARPAW FORMATION	Thickness in feet
Beechy Clay Member—	
"Dark brownish shales	20"
Demaine Sand Member—	
"Yellowish and greyish sands, becoming argillaceous near bottom	50"
Sherrard Clay Member—	
"Brownish shales, surface covered with crystals of selenite	50"
Matador Sand Member—	
"Yellowish ferruginous sands and sandstones, filled with large ironstone nodules	50"

McConnell found numerous molluscs in the sands and reported these to include "*Placenticeras placenta* [probably *P. meeki*], *Baculites grandis* [probably *B. compressus robinsoni*], *Haminea occidentalis* [(Meek and Hayden)], *Liopistha undata* [(Meek and Hayden)], *Protocardia subquadrata* [(Evans and Shumard)] *et borealis* [Whiteaves], *Cyprina* [*Arctica*] *ovata, Yoldia evansi, Inoceramus sagensis* var. *nebrascensis* [Owen], *Gervil*[*l*]*ia recta* [probably G. borealis], *Pteria linguiformis et* [*Oxytoma*] *nebrascana.*" Similar and almost certainly equivalent sands, together with clays, are exposed patchily in Swiftcurrent Creek itself, within a few miles of its point of confluence with the river.

Between Saskatchewan Landing and Pennant Ferry the stratigraphy is very different. About half a mile west of the old ferry crossing, at least 50 feet of Oldman sands and silts are immediately overlain by 100 to 150 feet of Bearpaw silty clays. Using knowledge of the general sequence obtained from local bore holes, it can be shown that the highest Oldman sands and silts are a facies equivalent of the highest Outlook sands of the Bearpaw sequence farther east, and the lowest Bearpaw silty clays belong to the Broderick Clay and not to the basal unnamed member as normally would be assumed (compare basal sequences in text-figs. 14 and 15). Near the ferry crossing, higher beds of the Bearpaw sequence are exposed in the valley slopes on the south side of the river, and, from the patchy and slumped outcrops, it can be determined that a sequence extending at least as high as the middle of the Beechy Member is preserved.

On the opposite bank of the river, about half a mile east of Pennant Ferry, more than 60 feet of sands, silts, and clays of the Matador Member are exposed. The sequence includes the following beds:

BEARPAW FORMATION	Thickness in ft.	in
Matador Sand Member—		
Sand, pale grey, weathering pale brown, iron stained, fine grained, silty, with scattered 1-inch diameter, reddish-brown, ironstone nodules	6	
Clay, greyish white, weathering pale grey, rusty in patches due to deep iron staining, becoming more silty upward	5	6
Sand, pale brownish grey, weathering pale grey, weakly cross-bedded, the lower 10 feet iron stained along bedding planes and in isolated patches	14	
Clay, greyish white, weathering pale grey, with carbonaceous films common at some levels	1	
Sand, pale grey, weathering pale greyish brown, coarse grained near base, becoming finer grained upward, cross-bedded, with a few 1-inch diameter brown to purple ironstone nodules: basal beds locally calcareous	9	
Clay, brownish grey, weathering pale to dark grey (brown where iron stained), with a layer, a few inches thick, of dark purple to brown, non-calcareous, ironstone nodules 5 feet above the base	10	
Clay, pale grey, weathering greyish white, faintly iron stained	10	
Silt, pale brown, weathering pale brownish grey, sandy	5	

This section does not span the complete sequence of the Matador Member: the top beds are truncated and overlain by glacial drift, the basal beds obscured by slumped bedrock. Where traced for short distances laterally, the beds display considerable variation. Some clays near the exposed base, for example, pass laterally into lignitic shales with coaly seams, and some sands become strongly calcareous sandstones, resistant to erosion and stand out as prominent ledges and pillars.

These beds can be followed eastward in the high ground on the north side of the valley for about 3 miles, and most of the sequence is again exposed in a creek, known locally as Coal Mine Coulee, about four miles west of Saskatchewan Landing. At this locality, pale-grey-weathering, brownish-grey, patchily iron-stained sands predominate, some of which contain bedded, rusty-weathering, brownish-grey, iron-rich, claystone concretions, others the remains of marine molluscs. Among the fossils, scaphopods are common, and are accompanied by gastropods and fragmented bivalves. Some of the sands contain a high proportion of carbonaceous material, and a few thin seams of lignite and lignitic shale are interbedded with them. Apparently, most of the seams are discontinuous, but it is uncertain whether the discontinuity reflects original patchy accumulation of plant debris or is a result of post-depositional, non-tectonic disturbance. The sands of the Matador Member at Coal Mine Coulee rest on dark-brownish-grey, silty clays, similar to, and believed to form a continuous sequence with, those at the top of the Broderick Member on the south bank of the river, beyond Pennant Ferry.

It is difficult to assess the thickness of the Matador beds from outcrop, but evidently it is in excess of 60 feet. A bore hole, drilled by the Saskatchewan Research Council above Coal Mine Coulee (for details see p. 48), penetrated 63 feet of these beds — a much greater thickness than at the type locality, but a reasonable figure to assume for their thickness west of Saskatchewan Landing.

Warren (*in* Fraser *et al.*, 1935, p. 19, 88) was misled by the atypical lithology of the Matador beds (in particular by the presence of a 3 to 5-foot coal seam) near Pennant Ferry and he concluded that they belonged to the Belly River Formation. He was then at a loss to explain the cropping out of Belly River beds topographically, and apparently also stratigraphically, well above clays, which he suspected to be the basal beds of the Bearpaw Formation.

The clays and silty clays of the Broderick Member are rich in outcrops, but they have been severely disrupted by slumping and it is impossible to obtain a complete section through them.

West of Saskatchewan Landing, therefore, in addition to loss of the unnamed clay and Outlook Sand to the Oldman Formation, the presence of a thickened Matador Sand, developed mainly in Oldman facies, is forewarning of further loss of lower Bearpaw sediments to the westward-thickening, Oldman alluvial wedge.

Snakebite Creek, Cruikshank Coulee, and the Vermilion Hills

(based mainly on the work of J. K. Evans)

The Snakebite Member, named for its extensive outcrops in Snakebite Creek, which is designated type locality, is perhaps the most distinctive lithologically of all the members of the Bearpaw Formation. It consists of 250 feet of mid- to dark-grey clays with numerous bentonite seams, bedded clay-ironstone and limestone concretions, nodules of fibrous calcite, and septaria.

The contact between the Ardkenneth sands and Snakebite clays, where it is exposed in the Herbert Ferry area, is sharp. In the type section, located in the lower reaches of Snakebite Creek, hollow limonitic concretions, about 1 inch in diameter, are developed in the top sands and basal clays, and they are found also in some other sections in which the contact is exposed. From the contact upward for about 55 feet, mid-grey clays contain a high (although gradually decreasing) proportion of silt, randomly distributed, brick-red, iron-rich, claystone concretions with pteriaceids, and, near the top, septaria with flattened baculites. Coarse-ribbed species of *Inoceramus* are common in the concretions, and *Gervillia borealis* in the enclosing clays. Locally the clays are reddish brown due to intense iron oxidation.

Dark-grey clays, about 100 feet thick, containing numerous bentonite seams and nodular masses of calcite with strongly developed cone-in-cone structure, overlie the basal mid-grey clays, the boundary being marked by a thin seam of ochreous bentonite. Easily recognized and developed widely, these bentonitic clays with nodules of calcite make a lithological marker that has proved valuable in correlation. Equivalent beds of the same kind have been described from the Cypress Hills by Furnival (1946, p. 43) and Lines (*in* Loranger and Gleddie, 1953, fig. 4; 1963, p. 215, fig. 1), who referred to them collectively as the "aragonite zone" and the "bentonite-aragonite zone" respectively. Previous workers, undoubtedly influenced by the acicular crystalline habit of the nodule-forming carbonate, called it aragonite. but the X-ray diffraction pattern leaves no doubt that it is calcite. Probably the carbonate was deposited as aragonite and altered to calcite subsequently. Within the Snakebite clays, the fibrous calcite is developed most consistently in a bed 120 feet above the contact with the Ardkenneth sands. Showing strong cone-in-cone structure, the buff fibres crop out in patches, 2 to 3 feet in diameter and nearly 1 foot thick, united by a thin bed of bentonite. The mineral has a woody appearance, and the patches, no doubt reflecting nodular development, have been interpreted for many years as fossil tree stumps by the local residents. Within these distinctive, nodule-bearing, bentonitic clays, this "tree stump" bed is useful for correlating the Bearpaw beds of the river valley. Numerous dark-bluish-grey spheroidal septaria, the concentric and radial fractures filled with coarse-grained brown calcite, are scattered throughout the 65 feet of clays below the "tree stump" bed. Many of the septaria and similar bodies are partly enveloped by yellowish-buff fibrous calcite commonly displaying strong cone-in-cone structure, the calcite forming caps on the poles of the spheroids and thinning to disappear round the equators. The relationship of the calcitic caps to the septarian cores suggests that the caps developed penecontemporaneously or later than the cores. Fossils are common in the septaria, and include baculites, scaphites, and inoceramids. Seldom can they be identified to species, however, for their preservation is poor, and, cut by the veins of the septaria, they are generally recovered in fragments. The clays above the "tree stump" marker contain more silt than those below. Bentonite seams are less numerous, but two prominent seams, with associated reddish-brown ironstone concretions, lie at successive 15-foot intervals above the marker.

Mid- to dark-grey clays, 95 feet thick, and containing dark-bluish-grey-weathering septaria, complete the sequence in the Snakebite Member. Generally the septaria contain few fossils, but in some beds they have formed around clusters of inoceramid shells.

At the type section of the Snakebite Member, near the mouth of Snakebite Creek (Sec. 9-21-9W3), the bulk of the beds composing the member, together with the top sands of the underlying Ardkenneth Member and basal sands of the overlying Cruikshank Member, are exposed. Details of the section are given below:

BEARPAW FORMATION	Thickness in ft.	in.
Cruikshank Sand Member—		
Sand, greyish brown, weathering yellowish brown, iron stained, non-calcareous	16	
Sand, brownish grey, weathering greyish brown, non-calcareous, silty, with mid-grey-weathering, dark-grey, calcareous sandstone concretions containing *Scaphites (Hoploscaphites)* sp. and *Pecten saskatchewanensis* transitional to underlying clays	4	
Snakebite Clay Member (type section)—		
Clay, mid-grey, silty, with blue-weathering fossiliferous septaria containing *Rhaeboceras* sp. and *Scaphites (Hoploscaphites) nodosus* Owen	25	
Covered interval: (almost certainly occupied by clays)	70	
Clay, dark grey, weathering brownish grey, silty, with bentonite seams and partings, including two prominent seams, each about 1 inch thick, 5 and 20 feet below the top of the unit: blue-weathering septaria, some crowded with inoceramids, present in the clays	35	
Fibrous calcite, yellow to buff, in nodular masses 2 to 3 feet in diameter and 1 foot thick, united by a thin seam of yellow bentonite: the "tree stump" bed	1	
Clay, dark grey, weathering brownish grey, silty, with bentonitic partings, the clays containing numerous septaria and similar bodies partly surrounded by buff fibrous calcite showing strong cone-in-cone structure: the septaria contain *Baculites reesidei* Elias, *Scaphites (Hoploscaphites) nodosus,* and other fossils	35	
Bentonite, yellow, weathering ochreous, clayey		2½
Clay, dark grey, weathering brownish grey, silty, containing septaria similar to those in beds above immediately overlying bentonite seam, these septaria, however, containing specimens of *Baculites cuneatus,* many of them flattened	21	
Bentonite, yellow, weathering ochreous, clayey		2
Clay, mid- to dark grey, weathering brownish grey, with a few blue-weathering, unfossiliferous nodules	27	
Clay, dark grey, weathering brownish grey, silty, with a few blue-weathering brick-red concretions with *Placenticeras meeki* and *Inoceramus* sp.	22	
Clay, mid-grey, weathering brownish grey, with *Gervillia borealis*	8	
Ardkenneth Sand Member—		
Sand, greyish brown, weathering pale brown, well compacted, containing small limonitic concretions and thin clay-ironstone partings	9	

Overlying the Snakebite Member, some 40 feet of greyish-brown sands are given the name Cruikshank Member — the name being taken from the town of Cruikshank, which lies at the type locality and close to the type section. A prominent gully, known locally as Cruikshank Coulee, has been trenched into the south side of the South Saskatchewan River valley between the town and the river, and this gully, which contains the type section, is designated type locality.

At the type locality, precise position of the contact between the Snakebite and Cruikshank Members is difficult to determine in the field. Sand increases notably in proportion through some 10 feet of beds between unmistakable Snakebite clays and unmistakable Cruikshank sands, and these beds form a transitional zone within which the contact is placed arbitrarily. Since the uppermost 50 feet of the Snakebite silty clays contain a relatively high proportion of sand, and the lowermost 10 feet of the Cruikshank silty sands a relatively high proportion of clay, however, it is to be appreciated that the passage from one member to the other is even more gradual, and could be held to involve 60 feet of beds. Nine feet of greyish-brown clayey and silty sand, forming part of the 10-foot transitional zone, are included in the Cruikshank Member. Grey-weathering, erosion-resistant nodules of calcareous sandstone are present in the transitional beds, but, unlike similar nodules at other horizons, apparently these are devoid of fossils.

Yellow-weathering, brownish-grey, iron-stained sands, 30 feet thick, and containing a much lower proportion of clay and silt, overlie the transitional beds. Bedded, rusty-weathering, tabular, grey, calcareous sandstone concretions, which locally are sufficiently closely spaced to form a continuous pavement 3 to 4 feet thick, interrupt the sand sequence 16 feet above its base. No fossils were recovered from the concretions.

A 2-foot unit of sandy and silty clays marks the boundary between the Cruikshank and Aquadell Members, and introduces an overlying sequence of silts and clays. These clays contain hollow, spheroidal, limonitic concretions, varying from one-half to 2 inches in diameter, which are similar to the concretions described from the contact beds of the Ardkenneth and Snakebite Members at Snakebite Creek.

At the type section in Cruikshank Coulee (north-east portion of Section 35-19-11W3), the entire Cruikshank Member, together with underlying beds of the Snakebite and overlying beds of the Aquadell Members, is exposed. Details of the complete section are as follows:

BEARPAW FORMATION	Thickness in ft.	in.
Aquadell Clay Member—		
Clay, dark grey, weathering brownish grey, silty, with a few blue-weathering nodules containing *Pecten saskatchewanensis*	20	
Bentonite, weathering reddish brown, granular to mealy textured, clayey near contact with overlying and underlying beds		3
Clay, dark grey, weathering grey, blocky, iron stained	1	4
Bentonite, weathering greenish yellow, mealy textured		1
Clay, dark grey, weathering brownish grey, silty	6	
Clay, grey, weathering brownish grey, silty and sandy, with many hollow, spheroidal, limonitic concretions: transitional to underlying sands	2	
Cruikshank Sand Member (type section)—		
Sand, greyish brown, weathering yellowish brown, iron stained, non-calcareous	12	
Concretions of grey, calcareous sandstone, weathering rusty brown, ovoid to to tabular, 2 to 3 feet in diameter, locally forming pavement	3	
Sand, greyish brown, weathering yellowish brown, iron stained, non-calcareous, compacted	16	
Sand, grey, weathering greyish brown, clayey and silty, with a few concretions of grey, calcareous sandstone: transitional to underlying clays	9	
Snakebite Clay Member—		
Clay, grey, weathering brownish grey, silty and sandy particularly in upper part, with many dark-blue-weathering, dark-grey, claystone concretions and septaria, some with *Inoceramus* sp.	100	
Bentonite, weathering brownish yellow, shaly, associated with bedded, small, reddish-brown concretions		3
Clay, dark grey, weathering brownish grey, silty	16	
Bentonite, weathering brownish yellow, shaly, with associated bed of small reddish-brown concretions		2
Clay, dark grey, weathering brownish grey, silty	15	
Fibrous calcite, yellow to buff, in nodular patches a few feet in diameter, united by a thin seam of bright-yellow bentonite: the "tree stump" bed		10
Clay, dark grey, weathering brownish grey, silty, containing septaria and similar bodies partly surrounded by buff fibrous calcite showing strong cone-in-cone structure, the concretions containing *Baculites* sp. and *Inoceramus* sp.	35	
Bentonite, yellow, ochreous weathering, silty, with associated thin layer of cone-in-cone calcite		3
Clay, dark grey, weathering brownish grey, silty, containing septaria, and calcite-capped concretions similar to those in beds above immediately overlying bentonite seam, many of them containing flattened baculites	20	
Covered interval: (almost certainly occupied by clays)	19	
Clay, dark grey, weathering brownish grey, silty, with a few blue-weathering, unfossiliferous nodules	24	

Sands, cropping out stratigraphically high in the Snakebite Creek section, almost certainly belong to the Cruikshank Member. In the creek, a much disturbed exposure indicates that about 20 feet of sand overlies a 6-foot transitional zone containing concretions similar to those of the transitional zone in Cruikshank Coulee. These nodules have yielded rare specimens of *Scaphites (Hoploscaphites)* sp. and *Pecten saskatchewanensis.*

The Vermilion Hills form a topographically prominent segment of the north-east-facing escarpment of the Missouri Coteau and lie adjacent to the South Saskatchewan River valley about 25 miles south of the Elbow. Geologically, they are formed by an outlier of the youngest Cretaceous formations in the region — the Eastend and Whitemud Formations — and these rest on the youngest member of the Bearpaw Formation. Exposures, however, are quite inadequate to determine intraformational sequences in detail. On the high ground, a cap of morainic drift almost completely obscures the Eastend and Whitemud beds, and on the flanks of the hills, the Bearpaw beds have been grossly disrupted by slumping.

Clays and silts belonging to the Aquadell Member have a limited outcrop distribution and are poorly exposed in the South Saskatchewan River valley. Outcrops are most numerous where the valley has been eroded into the north-western slopes of the Vermilion Hills, but mostly, no more than a few tens of feet of uninterrupted sequence can be examined in any outcrop, and no section has been found with continuity of exposure through a sufficiently extensive interval to warrant its selection as type. As a result, the Aquadell Clay is based upon a subsurface section from the same general area (see p. 44).

Riverhurst to Elbow

Outcrops of Bearpaw beds are sparse between Riverhurst and Elbow, but yet this tract of the valley has been investigated more thoroughly than any other in the Bearpaw outcrop belt.

In 1927, Warren (p. 39B-42B) commented on the geology of the Riverhurst district, and drew attention to the local accumulation of natural gas in sandstones of the Belly River Formation. It is likely that the gas-bearing sandstones, which lie at an elevation of 1,180 feet at Riverhurst, do not form part of the Belly River Formation as suggested, but belong to the Outlook Member of the Bearpaw Formation. Overlying sandstones, occurring at an elevation of about 1,600 feet, certainly do not belong to the Belly River Formation and can be referred with confidence to the Ardkenneth Member of the Bearpaw Formation (see Warren, *op. cit.,* p. 41B and compare Hume, 1933, p. 276 and Tremblay *in* Meyboom, 1966, p. 10).

The artesian basin of the Darmody-Riverhurst country was described in 1932 by Maddox (p. 58B-71B), who presented useful information on local and regional structures. Recently, the basin has been restudied by Meyboom (1966), and there is little doubt now that the aquifers are sands of the Bearpaw Formation. Most of the wells drilled in the vicinity of Riverhurst probably draw their water from sands of the Ardkenneth Member, and some near Central Butte from sands both of the Ardkenneth and Demaine Members.

Recent geophysical investigation of the plains flanking the South Saskatchewan River valley between Riverhurst and Elbow has revealed that, at two localities, each a few square miles in extent, the Mesozoic and deep-seated Palaeozoic rocks that form the foundation of the plains have been severely disrupted and domed. It has been postulated that these domes mark centres of crypto-volcanism (deMille, 1960, p. 154-162). The smaller Gilroy dome is located about 6 miles east of Riverhurst and is without surface expression, but the larger Elbow dome, situated about 8 miles northeast of Riverhurst, is marked by a prominent hill known locally as Big Horse Butte.

Sands and sandstones, believed to belong to a sub-Ardkenneth Member of the Bearpaw Formation, crop out near the summit of Big Horse Butte. The sequence consists of a 2-foot bed of brown-weathering, grey, hard, calcareous sandstone overlain by 6 feet of pale-brown-weathering, patchily iron-stained, grey sands containing nodules of a sandstone similar to that forming the underlying bed. The sandstones are richly fossiliferous: *Pteria linguaeformis* occurs in profusion and rarely is found associated with other bivalves, including *Ostrea* cf. *glabra,* ammonites of the *Baculites compressus* group and sharks' teeth (Edmunds, 1939, p. 19-20). There is little doubt about the general stratigraphical position of the beds. Lithologically, they are similar to beds of the Outlook, Matador, Demaine, and Ardkenneth Members in the Herbert Ferry exposures, and faunally, the ammonites and bivalves have been found only in sub-Snakebite beds of the Bearpaw Formation in the South Saskatchewan River valley. More specifically, the fossils suggest the beds belong to either the Outlook or the Demaine Sands.

Only two outcrops, worthy of description, were found in the river valley between Riverhurst and Elbow. Firstly, in Sage Creek, which drains the country immediately north of Big Horse Butte, Bearpaw clays are exposed between half a mile and a mile from the point of confluence of the creek and the South Saskatchewan River. At four localities, between 4 and 6 feet of pale-brownish-grey-weathering, dark-brownish-grey, patchily iron-stained, soft clays, containing barite rosettes, are exposed, and at one locality the clays contain fragments of rusty-brown-weathering, grey claystone with the remains of *Baculites* sp. A stratigraphical position in the lowest 100 feet of the Snakebite Member is suggested by the occurrence of the barite rosettes. Secondly, Snakebite beds were found to crop out on the west bank of the river not far from the mouth of Sage Creek (Sec. 3-24-7-W3). About 15 feet of greyish-brown-weathering, dark-brownish-grey, iron-stained clays, blocky and silty in the uppermost 5 feet, are exposed. The clays contain an impersistent bentonite seam, less than 2 inches thick, the normal yellow colour of the bentonite modified by numerous rusty blotches caused by iron-staining. The bentonite seam contains numerous small well-formed selenite crystals, and larger selenite crystals are distributed through the clays above and below. At the level of the bentonite bed, ovoid nodules of hard mudstone, encased in a deposit of fibrous calcite displaying cone-in-cone structure, are developed. The nodules are generally about 2 feet in long diameter, and the mudstone cores of some of them contain baculites and coarse-ribbed inoceramids. Almost certainly, these beds fall within the Bentonite-Calcite Zone of the Snakebite Member, which, in the type section, occupies the interval of 60 to 120 feet above the base.

Elbow to Macrorie

Between Elbow and Macrorie, exposures of the Bearpaw Formation are limited in number and individually in stratigraphical range; but collectively they span all but the uppermost 300 feet of the beds that are exposed at the type localities between Swiftcurrent Creek and the Vermilion Hills. Although the river valley between Elbow and Macrorie is many tens of miles north and east of the type localities, individual members can still be recognized, and, rarely, even marker beds within these members.

Principal outcrop sections in their relative stratigraphical positions are illustrated in text-figure 8.

For over a mile east of the site of the former Elbow road-rail bridge, clays of the Snakebite Member crop out along the east bank of the river and in the railway embankment. The sequence has been disturbed by slumping, but more than 70 feet of beds are exposed. The clays weather with an overall dark-grey or deep-chocolate-brown hue, are soft, silty, and patchily iron stained, and contain traces of bentonite, patches of fibrous calcite, numerous fossiliferous septaria, and rare rosettes of barite. It is probable that the stratigraphical position of these clays is between 50 and 150 feet above the base of the Snakebite Member.

On the east bank of the river, between 1.3 and 1.4 miles north and 5.6 and 5.8 miles west of Elbow, the top beds of the Ardkenneth Member (compare van Everdingen, 1968, p. 7-8) and the basal beds of the Snakebite Member are exposed in an unbroken sequence comprising:

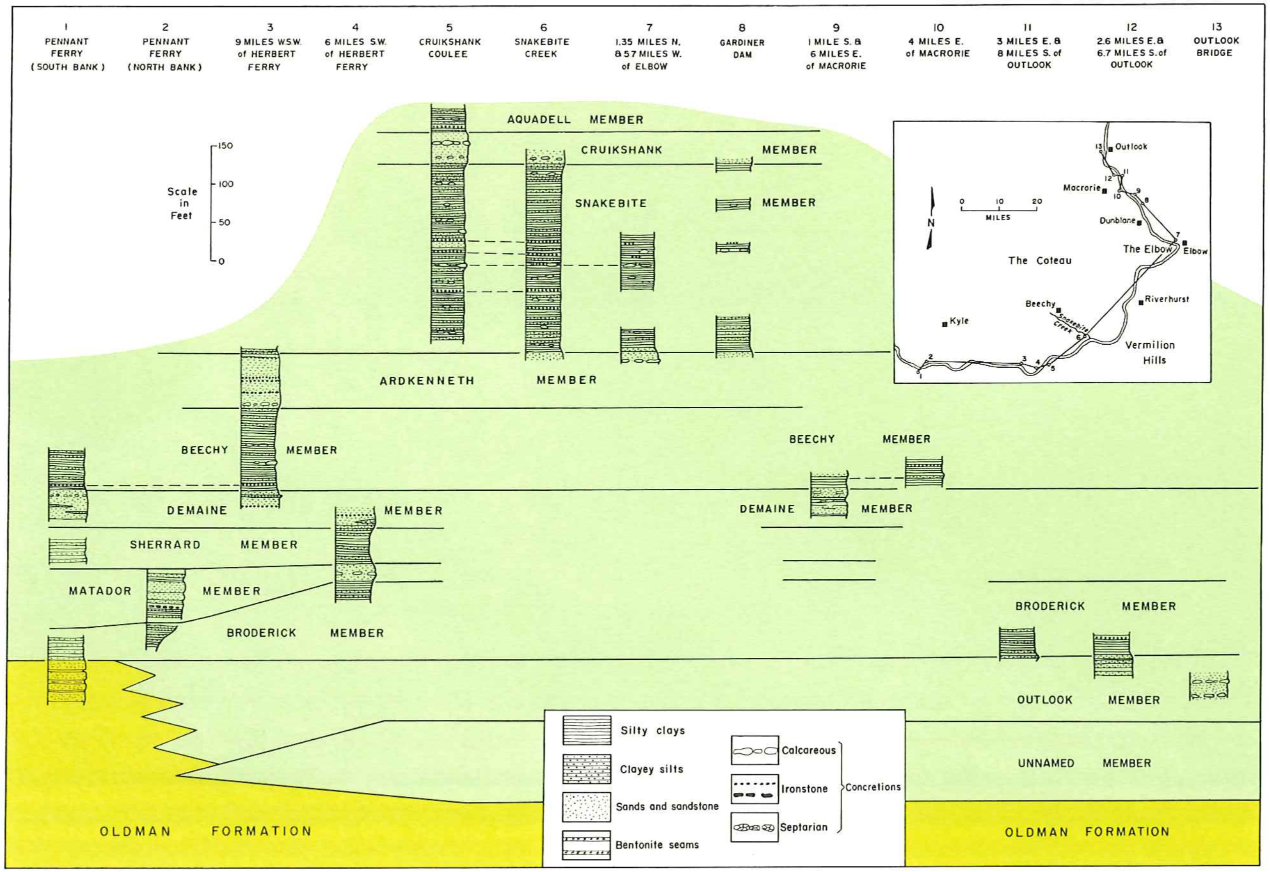
BEARPAW FORMATION

	Thickness in ft.	in.
Snakebite Clay Member—		
Clay, dark brownish grey, weathering pale brownish grey, with rusty and yellow patches of iron oxides; selenite crystals common	5	
Calcareous mudstone concretions, grey, weathering dark bluish purple, hard, fractured, containing flattened baculites, capped by fibrous calcite showing weak cone-in-cone structure	1	3
Clay, dark brownish grey, weathering pale brownish grey, stained by patches of rusty and yellow iron oxides	14	6
Clay, as above, but distinguished by numerous pockets and patches of yellow iron oxides which decrease in number and size (from 1 to 2 in. maximum) upward	5	6
Clay, dark brownish grey, weathering pale brownish grey, with many small lenses of sand and silt; stained by patches of rusty and yellow iron oxides, and containing many small yellow iron-oxide nodules	1	
Ardkenneth Sand Member—		
Sand, grey, weathering pale greyish brown, poorly consolidated, with silt and clay lenses common; numerous nodules and patches of yellow iron oxides	1	
Sand, pale brown, weathering rusty due to iron staining, poorly consolidated, with silt and clay lenses common		8
Sand, pale greyish brown, weathering pale brown, poorly consolidated	4	
Sand, pale greyish brown, patchily but strongly iron stained causing it to weather with a variegated appearance in tones of pale and mid-brown, poorly consolidated; ovoid concretions of brown-weathering, grey, calcareous sandstone, 3 feet in long diameter, rare; rhizocretions, from 1 to 7 in. long, common	2	3
Sand, pale brownish grey, becoming pale brown in the uppermost few feet, weathering pale grey, poorly consolidated; rare rusty and yellow iron-stained patches present	5	6
Sandstone, mid-grey, weathering brownish grey, hard, concretionary, ledge forming, with numerous trace fossils	3	

Where the section was measured, the basal 3-foot sandstone bed forms a hummocky pavement, the hummocks being the surface expression of ill-defined, irregular concretions. Trace fossils, having the form of branched and unbranched, sinuous, flattened cylinders of sandstone, about half an inch in diameter, occur in groups on the pavement surface. Probably these structures are casts of the burrows of sand-grubbing organisms. It is doubtful if this sandstone bed is a continuous ledge-former: in some 2 miles of outcrops along the river bank it appears only at intervals at river level, suggesting that the pavements themselves are huge tabular concretions, which pass laterally into comparatively unindurated sands. Such is obviously the character of a prominent, grey, ledge-forming sandstone, developed 6 feet higher in the sequence, which locally replaces strongly iron-stained, poorly consolidated sands. At this level, within a few tens of feet, concretions can be seen to pass from discrete ovoids to a chain of contiguous and coalescent ovoids, and eventually to a continuous ledge-forming sandstone bed.

Clays of the Snakebite Member, higher stratigraphically than those described overlying the Ardkenneth sands, crop out on the sides of the valley near where the section was measured. The sequence has been disturbed by slumping, but probably 75 feet of dark-grey, iron-stained clays with several concretionary beds are exposed. There are at least two horizons at which dark-brown, purple-weathering septaria with caps of yellow-weathering fibrous calcite are developed. The septaria contain *Baculites* sp., *Pecten (Chlamys) nebrascensis* Meek and Hayden, and *Inoceramus* sp. Selenite is particularly common in the lower 25 feet, and, in the upper 25 feet, lenses of fibrous calcite, about 1 foot thick and 3 feet in diameter, are developed at approximately the same level. They are interpreted to be a continuation of the "tree stump" bed of the Snakebite Creek outcrops. These Snakebite clays occupy the same stratigraphical interval as those cropping out at Elbow bridge.

The Ardkenneth-Snakebite beds of the measured section north of Elbow can be traced along the east bank of the river for about 4 miles, and, at several localities, overlying beds of the Snakebite Member are exposed. In this distance, the various beds distinguished within the Ardkenneth sands vary in thickness by not more than inches, and in lithology, only in the number of contained nodules and in the extent and intensity of iron staining. Although subject to some lateral



Text-figure 8: Comparative outcrop sections in the Bearpaw Formation of the South Saskatchewan River valley.

variation, the beds of rusty-weathering, iron-stained sandstone (2 feet 3 inches and 8 inches thick) prove conspicuous markers and can be traced for almost the complete extent of the outcrop belt. No significant lithological variation can be recognized in the overlying Snakebite shales. The exposures north of Elbow provide an illuminating illustration of the remarkable lateral persistence of parts of the Bearpaw sequence.

Historically, the Elbow of the Saskatchewan River ranks as the most famous Bearpaw outcrop and fossil locality in Saskatchewan in that it was visited in consecutive years by two, distinguished, pioneer geologists — James Hector, surgeon and geologist of Captain John Palliser's British North American Expedition of 1857 to 1859, and Henry Youle Hind, leader of the Assiniboine and Saskatchewan exploring expedition of 1858 (see Kupsch, 1955, fig. 1). Hector reached the Elbow in 1857, carefully studied the exposed clays, and listed many of the lithological characteristics which now serve to identify these clays as belonging to the Snakebite Member — colour, nature of the weathered surface, the presence of selenite crystals, masses of fibrous calcite displaying cone-in-cone structure, and septaria, which Hector described as ". . . nodular masses of ironstone, with veins or cavities filled with calc-spar" (*in* Palliser, 1863, p. 228). Hector collected many of the fossils that the septaria and other concretions contain, including *Baculites* (undoubtedly *reesidei* Elias), *Inoceramus* (many species of which are to be found), and many other smaller bivalves, and these he took to England, where they were identified by a palaeontologist of the Geological Survey. To Hector too must go the credit for making the first correlation of what are now the Bearpaw beds of Saskatchewan. He placed the Elbow clays in Group C of his five-fold grouping of the Cretaceous System and to this group he also ascribed beds cropping out in the lower slopes of the Cypress Hills — beds doubtless belonging to the upper part of the Manyberries Member of the sequence in that area and equivalent to the Snakebite Clay of the South Saskatchewan River valley. Longer range correlation with the section established by Meek and Hayden in 1853 in the Nebraska Territory also was attempted.

Hind (1860, p. 338-344), if less informative on the lithological nature of the Elbow clays, provided more information on the fossils and even illustrated some of them (*ibid.* and see also Kupsch, *op. cit.,* fig. 10). His fauna, interpreted by Elkanah Billings, palaeontologist with the Geological Survey of Canada, included the bivalves and cephalopods now known as *Pteria linguaeformis, Oxytoma nebrascana, Eutrephoceras dekayi* (Morton), *Placenticeras* sp., and *Scaphites (Hoploscaphites) nodosus.* From this assemblage, it seems likely that Hind collected in part from the Snakebite Clay at the Elbow *(E. dekayi* and *S. (H.) nodosus)* and in part from the Ardkenneth Sand exposed on the east bank of the river more than a mile north of the Elbow *(O. nebrascana, P. linguaeformis,* and *Placenticeras* sp.). Hind also was more successful than Hector in placing the Elbow beds in a regional stratigraphical context. He recognized them to belong to Formation no. 4 of the Cretaceous section established in 1853 by Meek and Hayden in the Nebraska Territory, a division that has come now to be called the Pierre Formation and of which the Bearpaw is a partial correlative. As Kupsch (*op. cit.,* p. 37) has pointed out, Hind clearly recognized the wide distribution of the Bearpaw Formation, and stated that Formation No. 4 was the most important of the Cretaceous System in the northwest.

Near the site of the Gardiner Dam, 5 miles north of Dunblane, exposures of mid-Bearpaw beds are found on both sides of the river (see also Pollock, 1962, p. 5-6). In Coteau Creek, prior to construction of the dam spillway, Snakebite clays overlain by a few feet of Cruikshank sands were exposed. These outcrops now have been covered. The contact between the Snakebite and Cruikshank Members occurred about 100 feet above river level, and, at this approximate elevation, several feet of sands overlying clays were recorded in a number of exploratory bore holes drilled by the Prairie Farm Rehabilitation Administration (for example, see text-fig. 10).

Differences between the clays of the Snakebite Member in weathered and fresh surface are remarkable and noteworthy. In the vicinity of the dam, for example, Snakebite beds, cropping out at a number of localities, weather as dark brownish-grey, iron-stained, soft, silty clays, with bedded concretions containing many molluscs. The same beds, examined in the subsurface during construction of the shafts and tunnels of the dam, were found to be mid-grey, massive, hard silty clays, recognizable as the equivalent of the river bank exposures only by the presence of the concretionery molluscan marker beds.

On the east bank of the river about a mile north of the dam site, the following section of Ardkenneth and Snakebite beds is to be found:

BEARPAW FORMATION	Thickness in ft.
Snakebite Clay Member—	
Clay, dark grey and dark brownish grey, weathering pale brownish grey, silty, blocky, with rusty iron oxide along sub-horizontal and sub-vertical fractures causing patchy staining on weathered surface; dark grey, less blocky, and less iron stained in lower 20 feet: selenite present throughout, common between 27 and 32 feet from base	45
Ardkenneth Sand Member—	
Sand, mid- to dark grey, weathering pale greyish brown, silty, with small pockets of silt-free sand and small lentils of clay, the latter most common in the upper 1 foot	2
Sand, dark brown, weathering rusty, iron stained	2
Sand, mid- to dark grey, weathering pale brownish grey, patchily iron stained	1

Similarities exist between the few feet of Ardkenneth beds in this section and those cropping out north of Elbow. In both sections, the top few feet include rust-shot sandstones overlain by silty sands transitional to the overlying clays. Oddly enough, the Snakebite clays of the measured section do not carry concretions, but, in several exposures, between the section and the dam site, blue-weathering, fractured, claystone concretions occur, several of them with the distinctive capping of fibrous calcite and housing flattened baculites, inoceramids, and other molluscan fossils.

Clays, silts, and sands, referred to the underlying Beechy and Demaine Members of the Bearpaw Formation, crop out at two localities a few miles north of the dam site. At the first, located less than a mile south and 6 miles east of Macrorie, more than 50 feet of Beechy and Demaine beds, as detailed below, are exposed in steep cliffs on the east bank of the river.

BEARPAW FORMATION	Thickness in ft.
Beechy Clay Member—	
Sand, greyish brown, weathering pale brownish grey, fine grained, silty, poorly consolidated, stained by rusty and yellow iron oxides: "pure" sand, silt, and clay lentils and pockets common	3
Clay, dark brownish grey, weathering pale brownish grey, stained rusty by patches of iron oxides	7
Clay, dark grey, weathering greyish brown, blocky, patchily iron stained, with small inclusions of yellow limonite becoming more common toward base, and with some selenite crystals; rare large oyster shells present; sharp contact with underlying sand	8
Demaine Sand Member—	
Sand, dark grey, pale brownish grey weathering, massive, poorly consolidated, stained rusty and yellow in patches by iron oxides: silt and clay, commonly in discrete lentils and pockets, forms high proportion of sediment, reflected by a surface variegation in tones of grey; contains rare ovoid nodules of sandstone with *Pteria* sp..	12
Clay, dark brownish grey, weathering greyish brown, randomly stained rusty and yellow by patches of iron oxides; basal beds silty and transitional to underlying sand: clays carry prominent concretionary bed, 3 feet above base; concretions ovoid, about 18 inches in long diameter, with septarian core enclosed by 3-inch coat of grey sandstone veined by seams of fibrous calcite which follow contour of concretions	6
Sand, dark grey, weathering pale grey, silty, with rare, rusty, iron-stained patches; "pure" sand, silt, and clay commonly occurring in pockets, lentils, and stringers	16
Clay, dark grey, silty, grading into overlying sand	1

At the second locality, more than 30 feet of beds are exposed on the west bank of the river, 4 miles due east of Macrorie. It is difficult to determine the full sequence, for the highest beds have been disturbed by ice-drag and slumping, but the following units can be distinguished:

BEARPAW FORMATION	Thickness in ft.	in.
(?)Beechy Clay Member—		
Clay, dark grey, weathering pale brownish grey, silty, blocky, considerably iron stained	6	
Bentonite, yellow, weathering greenish yellow, with some rusty, iron-stained blotches		2
Clay, dark grey, weathering brownish grey, silty, patchily iron stained	10	
Sand, grey, weathering greyish brown, silty, patchily iron stained	5	
Clay, dark grey, weathering greyish brown, soft, crumbly, becoming silty in upper 2 feet	11	

These sections reveal certain differences in the lithology of what are concluded to be Beechy and Demaine beds compared to the type section. Firstly, the sediments themselves are more mixed. It can be appreciated readily in hand specimen that the sands contain high proportions of clay and silt and many of the clays comparable proportions of silt and sand. Secondly, the members themselves are not so consistent: the Beechy Clay contains at least one bed of sand, the Demaine Sand at least two of clay. Partly as a result of these lithological variations, the precise stratigraphical position of the beds is brought into question. Regional considerations leave it in little doubt that the beds occupy relatively high positions in the sub-Ardkenneth sequence. In the longer section, the 8-foot clay occurring above the main sand contains poorly preserved, partly mineralized, large ostreids, which recall *Ostrea patina* in general outline, and, within the South Saskatchewan River valley, this species has been found only in the lowest few feet of the Beechy Clay. Moreover, the underlying sands contain pteriids, strongly resembling *Pteria linguaeformis,* a common fossil of the Demaine Sand. The clay and overlying sand at the base of the shorter section possibly equate to the clay and sand at the top of the longer section.

The Outlook district

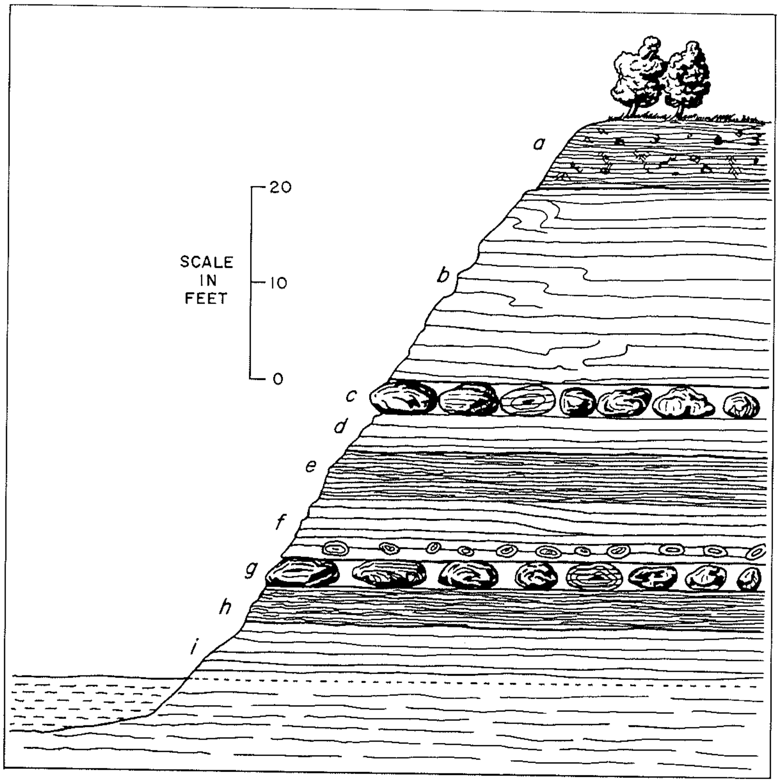
Only near the northern end of the studied portion of the South Saskatchewan River valley do the lowest exposed members of the Bearpaw Formation, the Broderick Clay and Outlook Sand, have any kind of extensive outcrop, and it is the 8-mile stretch of the valley due south of the towns of Outlook and nearby Broderick (from which the names of the members are drawn) that contains the type sections and so becomes the type locality.

On the west bank of the river, at the site of the Outlook road bridge, sands, not unlike those already described from the Bearpaw Formation, are exposed to a thickness of more than 30 feet. Superficially, the best exposed beds are uniform in their drab colour, negligible induration, and weak stratification, and are conspicuous only because they contain huge, layered, ovoid, rusty-weathering, dark-grey, sandy-limestone concretions, from 3 to 10 feet (mostly 3 to 4 feet) in diameter, bearing numerous marine molluscs. Unlike many of the concretions in the Bearpaw beds, these do not seem to have been built around a nucleus of fossil shells, for rare fossils seem to occur only near the surface. Underlying sands contain much less well-consolidated concretions of brown calcareous sandstone, the majority of which seem to have formed around nests of molluscan shells and fragments of wood.

Similar (or the same) sand beds crop out between 4 and 5 miles south of Outlook on the east bank of the river. They are overlain by a variable thickness of glacial drift and obscured by a veneer of drift "wash", but, at a few localities, several tens of feet are exposed, at most others much less. The fresh sand is yellowish grey, the weathered sand variegated in tones of brown, and iron-staining, showing preferential development along sub-horizontal and sub-vertical planes, is common and more conspicuous than in the beds at Outlook bridge. Concretions, indistinguishable from those at Outlook bridge, form a prominent, if discontinuous, bed in the outcrop, and are strewn along the river bank. Similar, less indurated, richly fossiliferous concretions also are present, many of them built around nuclei of bivalve and other molluscan shells. The disarticulation of these bivalves suggests that they were washed into mounds, and so buried, these mounds became centres for concretionary growth.

These and other exposures of the Outlook Sand in the 8-mile stretch of the river valley south of the Outlook road and rail bridges initially were investigated by Hind and described by him (1860, p. 380-382) in his account of the Assiniboine and Saskatchewan exploring expedition. As Kupsch (1955, p. 37) pointed out, Hind descended the South Saskatchewan River by canoe from the Elbow and encountered a sequence of sands near the present-day townsite of Outlook. Hind's detailed description and graphical illustration of the section, annotated and emended respectively, are repeated here:

> "The first rock in position on the South Branch [of the Saskatchewan River] below the Qu'Appelle [River] valley is a [C]retaceous sandstone, exposed on the river bank, for some miles. The altitude of the highest part of the exposure is sixty feet above the level of the water. It is capped by about seven feet of drift (a), which rests on twenty feet of soft and easily disintegrated sandstone of a pale yellowish-grey colour (b), containing a large number of small, pale yellow, spheroidal bodies [concretions], varying from one tenth of an inch to one inch and a half in diameter, and composed of sand. Below this soft stratum there occurs a layer of sandstone (c) about three feet six inches thick, which is broken into an irregular projecting outline by the protrusion of a series of immense concretions of a flat spheroidal form, like that of a lemon slightly compressed parallel to its longest diameter [see Kupsch, *op. cit.,* fig. 12]. The concretions vary from three feet to six feet [and rarely up to ten feet] in horizontal dimensions. They are very hard in the centre, and show concentric rings for at least six inches from their outer casing, which is a shell of gypsum, often passing into selenite. Selenite is found in this and lower strata in veins and fragments. Some of the concretions thrust out their rounded forms from the face of the cliff, others have been broken off and show their internal structure. A grey sandstone (d) with a slight tinge of green [due to the presence of glauconite], soft and friable, then occurs for a space of four feet [beneath (c)]; it is succeeded below by five feet of hard sandstone (e) containing a vast number of cylindrical forms, slightly conical, and showing traces of organization. Below this stratum a layer of sandstone six feet thick occurs (f), holding spheroidal forms [concretions], which vary in size from six inches to two feet in diameter; they are formed of yellow sand containing a hard central calcareous nucleus often four inches to one foot in thickness, and composed almost altogether of an aggregation of *Avicula Nebrascana* [*Oxytoma nebrascana*] (Evans and Shumard). The stratum in which they are embedded holds *Avicula Linguaeformis* [*Pteria linguaeformis*] (Evans and Shumard).
>
> A second layer (g) of large concretions follows [beneath], similar in external aspect to those already described. Below them there is a persistent layer of hard calcareous sandstone about four feet thick (h), containing *Avicula Linguaeformis* [*Pteria linguaeformis*].
>
> The lowest stratum exposed is a soft sandstone (i) about six feet above the river, and passing beneath its level. The rock is worn into caves by the action of the water. The formation is nearly horizontal, with a slight north-westerly dip. For several miles this [U]pper [C]retaceous



Text-figure 9: H. Y. Hind's section through the sand beds near Outlook, taken with slight emendation from Hind (1860, p. 381). For the last forty years at least these beds have been referred to the Belly River Formation but are now included in the Bearpaw Formation as the Outlook Sand Member.

rock continues to form the river bank. The concretionary masses are persistent, bold, and prominent, and about three miles in a north-westerly direction from the point where they were first observed, those of the lower stratum are nearly on the same level as the water, thus showing a northwesterly dip of about three feet in the mile."

Nowhere in the tract of the valley in which the Outlook Sand crops out can such an extensive section be found today. Hind's section may be composite, but there is no doubt that it is based in part (and quite probably entirely) on the exposures in the west bank of the river at the Outlook road and rail bridges. The section must have been measured at extremely low water but, even under comparable conditions today, the lowest two divisions of his sequence would not be visible. Evident particularly where the river is braided, vast quantities of sediment are being shifted by the constantly changing current pattern of the river, and the narrow-tiered wedge of sediment now present beneath the cliffed exposures at the road bridge well may have accumulated in the more than one hundred years since Hind examined the same outcrops. Today, the base of the exposed section falls about the boundary between Hind's divisions (f) and (g), and the section is between 30 and 40 feet thick.

Hind oversimplified the development of concretionary layers near the base of division (f). Apparently three layers are present: the lowest is composed of limy concretions, generally less than a foot long, packed with *Corbula sprouli* Warren, the intermediate layer is formed by sparse limy concretions, only slightly larger, with abundant *Oxytoma nebrascana,* and the upper is composed of similar but still larger concretions with a rich and impressively varied fauna, in which, however, bivalves are dominant. These three kinds of concretions lie at about the level to which the river sediments now are banked and they occur loose, lying on these sediments, along the river bank. Because of the partial cover of superficial deposits, their concentration in a zone only a few feet thick, and their sparse distribution, it is difficult to be certain of their precise relative order.

Aside from these modifications, Hind's detailed account remains valid, and, as it applies to the exposures immediately upstream from the Outlook road bridge, it is accepted as a description of the type section of the Outlook Sand. By such action, a notable early contribution to Saskatchewan geology is acknowledged.

Hind's only serious mistake in his study of the beds at Outlook was to conclude that the sands had a regional dip to the northwest. He may have arrived at this conclusion by confusing the two prominent concretionary beds (see the concluding remarks in his measured section), but there is no doubt that the sands emerge from beneath clays and silts that, some distance above the contact, carry fragmented oysters strongly reminiscent of *Ostrea patina* and certainly suggestive of a sub-Snakebite horizon, and these clays and silts in turn underlie the Snakebite Clay, which is well exposed in the vicinity of the Gardiner Dam. Moreover, Dr. E. A. Christiansen of the Saskatchewan Research Council informs me that northward, beyond the limit of outcrop of the Outlook sands, Oldman beds underlie the superficial deposits and form the bedrock surface (see text-figs. 4 and 7 in which the Oldman-Bearpaw boundary north of Outlook is based upon Christiansen's work). The regional dip of the beds, therefore, must be broadly to the south (see also Pollock 1962, p. 6).

His mistaken idea of the regional dip probably caused Hind to misidentify the relative position of the Outlook sands, for he assumed that they lay above the (Snakebite) clays exposed at the Elbow, and correlated them with the sandstones of Formation no. 5 in Meek and Hayden's sequence from the United States. Warren (*in* Fraser *et al.,* 1935, p. 21) believed the Outlook sands to be a marine facies of the Belly River Formation, developed near the eastern seaward limit of the regional non-marine tongue that has been so designated, and, except for van Everdingen (1968, p. 7-8), such a view has held sway until the present time.

Transitional beds, linking the uppermost Outlook sands and lowermost Broderick clays, are exposed in two clefts in the west bank of the river, 2.6 miles east and 6.7 miles south of Outlook. The section, of which the transitional beds form a part, is given below:

BEARPAW FORMATION	Thickness in ft.	in.
Broderick Clay Member—		
Clay, dark grey, weathering brownish grey, silty	2 (seen)	
Bentonite, yellow, weathering pale greyish yellow, mealy textured, iron stained: a preferred horizon for slumping		3
Silt, grey, weathering greyish brown, with varying proportions of clay and sand, blocky, iron stained: locally silt grades into silty sand and clay occurs in discrete lenticles	ca.10	
Clay, dark grey, weathering greyish brown, silty, soft, iron stained	ca.10	
Outlook Sand Member—		
Sand and clay or shale, alternating in thin beds or elongate lenticles of variable thickness, containing different kinds of concretions. Sands, grey, brown, or olive green, weathering greyish brown to greyish green, buff or rusty, commonly cross-bedded, patchily iron stained, occurring in beds commonly 1 to 2 in. thick, less commonly 4 to 5 in. thick, and rarely in 1-foot lenticles in which cross-bedding is conspicuous: clays or shales, dark grey, weathering brownish grey, iron stained, commonly occurring in beds 1 to 5 in. thick	15	
Sand, brown to dark greenish grey, weathering buff, locally colour banded, with thin shaly and silty intercalations and ironstone concretions; concretions numerous at contact with overlying sands and clays/shales	12	

It is meaningless to present a detailed section of the sands and clays or shales that form the 15-foot transitional sequence, for individual beds seldom extend for more than a few tens of feet and local facies changes are rife. The transitional beds contain concretions of variable size, shape, and composition: some are ovoid and composed of poorly indurated, bedded, grey sandstone from which the iron oxides have been leached, others, in contrast, are composed of bedded, rusty sandstone in which iron oxides have been concentrated; some brownish-purple-weathering, grey, claystone concretions are as much as 20 feet long and 1 foot thick, others, of much the same appearance, are only 9 inches long and 3 inches thick. Occurrence of tabular, iron-rich, claystone concretions at the top of the transitional beds at more than one locality suggests the concretions may form impersistent beds of considerable areal extent. Some concretions carry large numbers of *Pteria* sp.

Between 6 and 8 miles south of Outlook, the basal clays of the Broderick Member can be seen resting on the top sandstones or sands-with-clays of the Outlook Member. Sections can be measured conveniently at four localities within this segment of the valley: at the most northerly, 5 feet of Outlook-Broderick transitional beds, much like those already described, are overlain by 20 feet of Broderick clays and silts, and at the most southerly, the longest continuous section of the Broderick Clay, and therefore that selected to be the type, is to be found. The following beds, cropping out on the east bank of the river a little over 3 miles east and 8 miles south of Outlook, can be distinguished in the type section:

BEARPAW FORMATION	Thickness in ft.
Broderick Clay Member (type section)—	
Clay, greyish brown, weathering in small brownish-grey chips, soft, much stained by rusty and yellow iron oxides, with abundant small selenite crystals	15
Clay, dark grey, weathering paler grey, blocky, weakly ledge forming, irregularly iron stained	5
Clay, dark grey, weathering brownish grey, soft, patchily iron stained, with small selenite crystals	9
Covered interval (probably occupied by clay)	5
Outlook Sand Member—	
Sandstone, mid-grey, weathering brownish grey, iron stained in bands parallel to bedding (reflected in weathering colours), hard, pavement forming, with abundant small chips of wood (from a fraction of an inch to 3 inches in length), commonly partly carbonized	2

Superficially, the clays of this section appear to contain a negligible quantity of silt, which is in contrast to those of the other localities, where they contain not only silt but some sand. When traced laterally, the clays display increased but variable proportions of silt and sand, indicating that distribution of the coarser detritus, no doubt controlled at the time of deposition by current interplay, is irregular. The strong induration of the top bed of the Outlook Sand likewise is atypical, and the sandstone bed probably is part of a huge tabular concretion embedded in poorly indurated sands with clay seams upon which the basal Broderick clays most commonly rest.

DISTRIBUTION IN THE SUBSURFACE

Cored sections

During an exploration program in 1943 to 1945, the Imperial Oil Company drilled numerous structure test holes in and near the South Saskatchewan River valley. Cores from these borings, together with the cores from the Geological Survey of Canada stratigraphical test hole GSC 61-1, near Beechy, and the Prairie Farm Rehabilitation Administration (P.F.R.A.) RD 2299 hole, at the site of the Gardiner Dam, amount to all the available continuously cored sections of the Bearpaw and overlying formations in the area of study.

Few of the Imperial Oil Company cores span more than one member of the Bearpaw sequence but, collectively, they embrace completely the interval from the base of the Ardkenneth Sand to the top of the Aquadell Clay. Core recovery, particularly from the sand members, is poor. Only the G.S.C. 61-1 bore hole extended to any depth below the Ardkenneth Sand, and the core from this hole includes the Beechy Clay, the Demaine Sand, and part of the Sherrard Clay. The P.F.R.A. RD 2299 core spans only part of the Snakebite Clay. Core recovery from the G.S.C. 61-1 and P.F.R.A. RD 2299 holes is relatively good.

Sequences in the more important of the cores studied are illustrated in text-figure 10.

Although the entire Aquadell Clay is present in the Vermilion Hills, outcrops are extremely limited in stratigraphical extent and no section has been found with continuity of exposure through a sufficiently extensive interval to warrant its selection as type. Fortunately, almost the entire sequence of Aquadell beds has been cored in bore holes drilled in the Vermilion Hills, and it has been possible to establish a type section and supporting reference section using core from two of these — Imperial Oil Structure Test Holes 67 and 168.

Located on the eastern flank of the Vermilion Hills (Sec. 10-20-6W3) and less than a mile from the settlement of Aquadell, from which the member takes its name, Test Hole 67 penetrated 565 feet from a surface elevation of approximately 2,050 feet to an elevation of approximately 1,485 feet. It penetrated part of the Aquadell Clay, the entire Cruikshank Sand and Snakebite Clay, and part of the Ardkenneth Sand. The interval occupied by beds of the Aquadell Clay is approximately that from 1,995 feet to 1,895 feet and, by underlying beds of the Cruikshank Sand, that from 1,895 feet to 1,852 feet. The sequence of beds in the Aquadell Clay and its relation to the Cruikshank Sand can be summarized as follows:

BEARPAW FORMATION	Depth in feet	Thickness in feet
Aquadell Clay Member—		
Silt, mid-grey, blocky, non-calcareous, with thin (?)carbonaceous seams; some layers paler coloured and sandy, others darker coloured and clayey (25 feet recovered)	55-115	60
Clay, mid-grey, massive, non-calcareous (12 feet recovered)	115-135	20
Silt, mid-grey, hard, blocky, non-calcareous, with seams and pockets of clay and sandy silt; sand content increasing with depth forming beds transitional to underlying sands (10 feet recovered)	135-155	20

Cruikshank Sand Member—		
Sand, brownish grey to greenish grey, some beds friable, others comparatively well indurated, fairly even grained, becoming coarser with depth, non-calcareous (27 feet recovered)	155-198	43

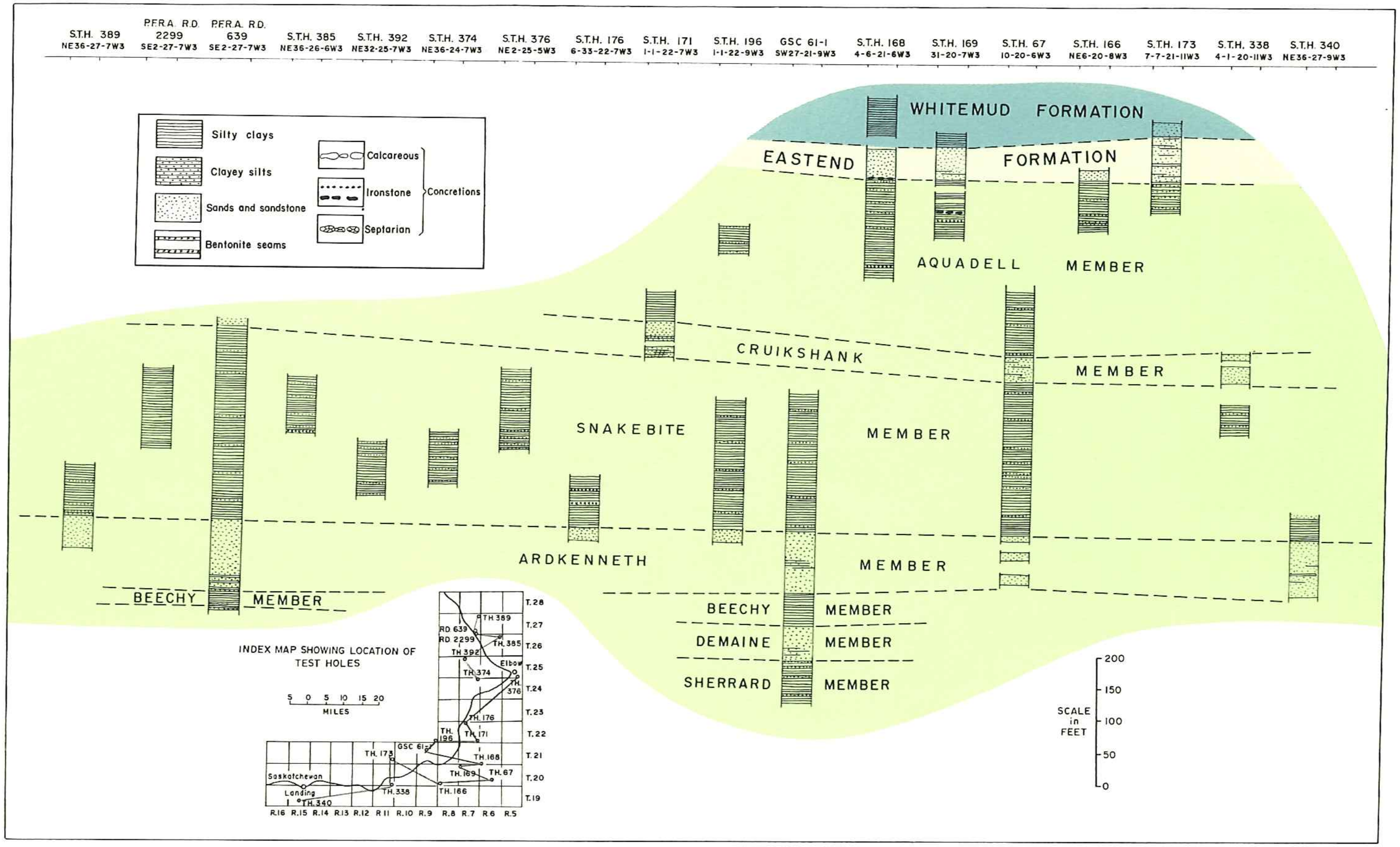
Test Hole 168 is located at the northern end of the Vermilion Hills (Sec. 6-21-6-W3) and penetrated 360 feet from a surface elevation of approximately 2,350 feet to an elevation of approximately 1,990 feet. The site of this bore hole is designated type locality. Clays and silts of the Aquadell Member occupy the interval from approximately 2,155 feet to 1,990 feet, and these beds form the type section. Overlying beds of the Eastend Formation occupy the interval from approximately 2,220 feet to 2,155 feet. Beds cored from the Aquadell Member and the base of the overlying Eastend Formation are described below:

	Depth in feet	Thickness in feet
EASTEND FORMATION		
Sandstone, yellowish brown with rusty iron-stained flecks, even grained, poorly indurated, non-calcareous (7 feet recovered)	168-195	27
BEARPAW FORMATION		
Aquadell Clay Member (type section)—		
Silt, mid-grey, clayey, non-calcareous (15 feet recovered)	195-250	55
Clay, mid-grey, silty, non-calcareous (4 feet recovered)	250-262	12
Clay, mid-grey, with notably silty seams at some levels, non-calcareous (12 feet recovered)	262-280	18
Sand, greenish grey, fine grained, well indurated, calcareous (6 inches recovered)	280-290	10
Clay, mid-grey, non-calcareous, with irregular silty lenses at some levels (14 feet recovered)	290-321	31
Clay, mid-grey, non-calcareous, massive, hard, with some irregular silty lenses (27 feet recovered)	321-360	39

The Aquadell beds in these two cores combine to form a section that must span approximately the entire member — indeed the possibility that the two cored sections may overlap by a few feet cannot be excluded.

Almost all the remaining cored section of the Bearpaw Formation is contained in the core of the G.S.C. 61-1 bore hole, which partly has been described by Price (*in* Meyboom, 1966, p. 8-9). The hole was drilled on the north side of Snakebite Creek, 200 yards east of the southwest corner of Section 27-21-9-W3, from a surface elevation of 2,135 feet, and encountered the Bearpaw Formation beneath glacial drift at a depth of 180 feet. Unlike the older structure test holes, the G.S.C. 61-1 bore hole carries an electric log, and since it was drilled close to the type localities of the members it penetrated, it provides an important standard for the interpretation of the electric logs of other bore holes, both within the river valley and beyond. Price's section, emended, interpreted in terms of the intraformational sequence now established, and with the addition of the sequence of beds in the Snakebite Clay, is presented below:

BEARPAW FORMATION:	Depth in feet	Thickness in feet
Snakebite Clay Member—		
Clay, medium to light grey	180-190	10
Clay (15 ft. recovered): 0-2 ft. 9 in., clay, silty to sandy, medium grey, micaceous, with partings of silt and streaks of pyrite in the form of minute spheres; 2 ft. 9 in - 3 ft. 6 in., bentonite, silty and clayey, light grey, blocky, firm; 3 ft. 6 in. - 15 ft., clay, silty, particularly in lowest 4 ft., medium grey, blocky, with glauconite and streaks of pyrite	190-205	15
Clay, more or less silty throughout, medium grey, blocky, with glauconite and streaks of pyrite (15 ft. recovered)	205-220	15
Clay, medium grey, micaceous, pyritic, with some finely disseminated glauconite (12 ft. recovered)	220-235	15
Clay and silt (10 ft. 4 in. recovered): 0-1 ft., clay, silty, medium grey, blocky, glauconitic, micaceous; 1 ft. - 4 ft. 6 in., clay, bentonitic, slightly silty except in top 2 in., blocky, glauconitic, with much biotite and some pyrite streaks; 4 ft. 6 in. - 5 ft., silt, clayey, grading into silty clay, with biotite and glauconite; 5 ft. - 10 ft. 4 in., clay, silty in parts, silt increasing downward, possibly slightly bentonitic	235-255	20



Text-figure 10: Comparative bore-hole sections (mostly based on core) in the Bearpaw and overlying formations of the South Saskatchewan River valley.

Clay (13 ft. recovered): 0-8 ft. 6 in., clay, medium grey, blocky, bentonitic, with recognizable biotite, and pyrite streaks confined to 1-ft. bed; 8 ft. 6 in. - 12 ft., clay, slightly silty, medium-light grey, blocky, firm, with streaks of pyrite; 12 ft. - 13 ft., clay, light grey, bentonitic, with 2-in. bentonite seam at base	255-275	20
Clay (6 ft. 6 in. recovered): 0-7 in., clay, highly bentonitic, with much biotite; 7 in. - 6 ft. 6 in., clay, highly bentonitic, but with a few beds of firm, blocky clay with pyrite streaks	275-295	20
Clay, medium grey, blocky, with specks of carbon and streaks of finely divided pyrite (6 ft. recovered)	295-315	20
Clay, medium-light grey, blocky, firm, with finely divided pyrite (5 ft. recovered)	315-325	10
Clay (14 ft. recovered): 0-1 ft. 6 in., clay, medium-light grey, blocky, glauconitic, with pyritized, tube-like trace fossils, 1 mm. in diameter, commonly in vertical, rarely horizontal, position; 1 ft. 6 in. - 10 ft., clay, slightly silty and becoming more silty downward, blocky; 10 ft. - 14 ft., clay, slightly silty, blocky	325-345	20
Clay and sand (8 ft. recovered): 0-2 ft. 8 in., clay, partly silty, medium-light grey, traces of glauconite and pyrite; 2 ft. 8 in. - 7 ft. 8 in., clay, silty to sandy silt present in ill-defined laminae, sand content increasing downward, medium-light grey, blocky, glauconitic; 7 ft. 8 in. - 8 ft., sand, fine grained, clayey, glauconitic, with shell fragments and specks of carbon	345-365	20
Clay and silt (8 ft. recovered): 0-4 in., clay, silty, medium-light grey, glauconitic, grading downward into clayey silt; 4 in. - 8 ft., silt, clayey, intergraded with silty clay, medium-light grey, blocky, massive except for cross-bedding in top 6 in.	365-375½	10½
Silt, clayey, intergraded with silty clay and clayey sand, brownish grey, glauconitic, firm	375½-392	16½
Ardkenneth Sand Member—		
Sand, loose	392-395	3
Sand, fine grained, dark grey, loose to poorly indurated, angular quartz grains 65%, glauconite and other soft minerals 23%, dark chert and other rock fragments 12%, shell fragments (2 ft. 6 in. recovered)	395-415	20
Sand, dark greenish grey, largely clayey, poorly indurated to firm, recovered material tight with intermittent slight porosity (8 ft. recovered)	415-435	20
Sand (8 ft. recovered): 0-1 ft. 2 in., sand, fine grained, glauconitic, loose; 1 ft. 2 in. - 6 ft. 6 in., sand, clayey, abundant firm grains of white clay; 6 ft. 6 in. - 8 ft., sand, clayey, firm	435-455	20
Sand (14 ft. recovered): 0-2 ft., sand, fine grained, light grey, glauconitic, firm, porous, organic fragments; 2 ft. - 8 ft. 4 in., sand, fine grained, clayey, mid-light grey, glauconitic, grading to sandy clay near base; 8 ft. 4 in. - 10 ft. 10 in., sand, in part clayey, more or less porous; 10 ft. 10 in. - 14 ft., sand, clayey, mid-light green, firm, tight, glauconitic, dark chert, biotite, shell fragments	455-469	14
Sand, clayey, glauconitic, grading downward into clayey sand, firm, blocky (14 ft. recovered)	469-483	14
Beechy Clay Member—		
Clay, silty, with stringers of silt and sand	483-552	69
Demaine Sand Member—		
Sand (9 ft. 6 in. recovered): 0-2 ft. 3 in., sand, fine grained, greyish green, glauconitic, loose; 2 ft. 3 in. - 9 ft. 6 in., sand, clayey, greenish grey, glauconitic, firm	552-572	20
Sand (15 ft. recovered): 0-7 in., sand, clayey, firm, glauconitic, slightly harder than above; 7 in. - 6 ft., sand, fine grained, greyish green, glauconitic, loose; 6 ft. - 7 ft. 6 in., sand, clayey, greyish green, glauconitic, with brown laminae of organic material at base; 7 ft. 6 in. - 8 ft. 4 in., sand, clayey in parts, poorly indurated in others, greenish grey, glauconitic; 8 ft. 4 in. - 9 ft. 6 in., sand, clayey and firm in parts, soft in others, greenish grey, glauconitic; 9 ft. 6 in. - 13 ft. 2 in., sand, clayey, grading to sandy clay at base, some beds with much brown organic matter; 13 ft. 2 in. - 15 ft., sand, clayey, slightly indurated, greyish green, glauconitic	572-592	20
Sand (14 ft. recovered): 0-1 ft. 4 in., sand, fine grained, greenish grey, clayey, slightly indurated; 1 ft. 4 in. - 13 ft. 6 in., sand or silt, very clayey, intergrading and interlaminated with silty clay, mid-grey, firm, grains of chert, glauconite, white clay; 13 ft. 6 in. - 13 ft. 8 in., sand, loose, very fine grained, glauconitic; 13 ft. 8 in. - 14 ft., clay, soft, sandy, some glauconite grains	592-612	20
Sherrard Clay Member—		
Clay, mid-grey, fractures conchoidally	612-652	40

The bore holes with the longest cored sections, G.S.C. 61-1 and Imperial Oil Structure Test Holes 67 and 168, lie on a northwest-southeast line more or less coincident with the Missouri Coteau, where the Bearpaw beds are preserved most completely. Shorter cored sections, spanning, at the most, parts of two contiguous members, show the members to undergo negligible change in lithology as they are traced into the country to the north and west, and summary of these sections is confined to graphical representation in text-figure 10.

Uncored sections

Much useful stratigraphical information has been gleaned also from uncored or partly cored bore holes, in which the sequences encountered were reconstructed from chips brought to the surface during the drilling process and (in some) from samples retrieved from the sides of the bore hole by a side-hole sampling device. Certain bore holes, belonging to this category, deserve special mention.

In 1959, the Saskatchewan Research Council, using a cable-tool rig with excavator, drilled three bore holes to shallow depth on the north bank of the South Saskatchewan River, near Pennant Ferry, and encountered the Bearpaw Formation beneath 50 to 150 feet of glacial drift. S.R.C. Project 48 (Kyle) no. 1 was drilled from a surface elevation of approximately 2,150 feet in the northeast corner of Legal Subdivision 13-14-20-16W3 and encountered 62 feet of silty clay beneath the drift at a depth of 127 feet. Similarly, S.R.C. Project 48 (Kyle) no. 2, drilled from essentially the same surface elevation to a depth of 104 feet in the southeast corner of Legal Subdivision 4-14-20-16-W3, penetrated 17 feet of the same clay beneath drift at a depth of 87 feet. By far the longest bedrock section was encountered in S.R.C. Project 48 (Kyle) no. 3, drilled in the southeast corner of Legal Subdivision 9-8-20-16W3 from a surface elevation of 2,159 feet to a depth of 150 feet. Beneath a 57-foot drift section, 3 feet of silty clay, followed by 63 feet of varicoloured sands and silts and 27 feet of grey clays and silts were penetrated. Two short lengths of the core have been preserved.

The section encountered in the no. 3 bore hole is a useful supplement to the exposed section in Coal Mine Coulee (see p. 26) and details of the bedrock portion (courtesy Mr. J. Hudson, Engineering Division, Saskatchewan Research Council) with emendations, are presented below:

BEARPAW FORMATION	Depth in feet	Thickness in feet
Sherrard Clay Member—		
Clay, yellowish grey, silty	57-60	3
Matador Sand Member—		
Sand, buff to dark brownish grey, silty	60-63½	3½
Silt, mostly pale yellowish grey but purplish grey near top, clayey	63½-71	7½
Silt, yellowish brown	71-73	2
Sand, brownish grey in upper beds, orange-brown in lower beds, some interbedded silts	73-82	9
Silt, brownish grey, clayey	82-88	6
Sand, rusty, fine grained	88-90	2
Sand, greyish brown, medium to fine grained	90-95	5
Sand, rusty, fine grained	95-96	1
Sand, buff, fine grained, silty	96-99	3
Silt, mostly greyish brown but some beds rusty, others with rusty streaks, clayey; lowest 1 ft. dark purplish grey with lenses of carbonaceous matter	99-106	7
Silt, greyish brown, clayey, with traces of lignite	106-108	2
Silt, dark grey, yellowish grey, and brownish grey, some beds with lenses of carbonaceous matter, others with carbonaceous matter disseminated throughout	108-112	4
Silt, coarse grained, brown to greyish brown	112-116	4
Sand, grey, becoming increasingly rusty in lower beds, medium grained, "salt and pepper"	116-123	7
Broderick Clay Member—		
Clay, dark grey, silty, carbonaceous at top	123-124	1
Sand, dark brown, carbonaceous	124-125	1
Clay, dark grey, silty, with pockets of greyish green, bentonitic clay	125-126	1
Sand, dark brown, carbonaceous, with pockets of lignite	126-128	2
Silt, greyish to blueish green, soft, clayey	128-133	5
Silt, grey, clayey, with some organic matter toward base	133-134	1
Silt, dark grey, greyish green, greyish blue, clayey	134-146	12

West of Saskatchewan Landing, Oldman beds crop out along the river banks and, at Pennant Ferry, at least 50 feet of Oldman sands and silts are overlain by

100 to 150 feet of Bearpaw silty clays. Furthermore, in the Pennant Ferry district, the Oldman-Bearpaw contact lies at the base of the Broderick Clay and not at the base of the unnamed clay member (compare the basal sequences in text-figs. 14 and 15). Almost certainly, therefore, the silty clays encountered in all three bore holes belong to the Broderick Clay, the overlying sand in the no. 3 hole is a facies variant of the Matador Sand, and the few feet of clay above this sand are the basal beds of the Sherrard Clay.

Thus, in the Pennant Ferry district, the poorly exposed outcrop sections can be supplemented by bore-hole sections, and, in terms of the lithology and the thickness of the members encountered, the two are in perfect accord.

In contrast, farther east, near Herbert Ferry, the section of Bearpaw beds encountered in the Rush Lake bore hole, described by Wickenden (1932, p. 185-186, figs. 1-2; *in* Fraser *et al.,* 1935, p. 19-20) cannot be reconciled easily with the established section. The bore hole, drilled by the Northwest Company in 1920, in Legal Subdivision 2-30-19-11W3, has a surface elevation of approximately 1,750 feet, and Wickenden reported the following succession:

	Depth in feet	Thickness in feet
DRIFT	0-20	20
BEARPAW FORMATION		
Shale, medium grey	20-40	20
(?)BIRCH LAKE or BELLY RIVER FORMATION		
Missing	40-50	10
Sand, grey, pepper and salt	50-70	20
Sandy shale, medium to light grey	70-110	40
GRIZZLY BEAR FORMATION		
Shale, medium grey; *Haplophragmoides rugosa* fauna	110-340	230
RIBSTONE CREEK FORMATION		
Sand, medium grey, pepper and salt; little shale	340-350	10
Sandy shale, brownish grey	350-400	50
Sand, pepper and salt, fine grained	400-420	20
LEA PARK FORMATION		
Shale, somewhat sandy, medium grey; *Verneuilina* sp. fauna	420-910	490

The bore hole was drilled on the south bank of the river more or less directly opposite the outcrops that include the type sections of the Matador, Sherrard, and Demaine Members (see p. 18, 21) and, since the surface elevation of the bore hole and the elevation of the lowest exposed clays among the outcrops are essentially the same and lie only a few feet above river level, there is no question that the 20 feet of "shale" encountered immediately beneath the drift belongs to the Bearpaw Formation and, more specifically, to the Broderick Clay. In all likelihood then, the 20 feet of sand, occupying the 50 to 70-foot depth interval, and possibly part (or all) of the bedrock sediments occupying the overlying 40 to 50-foot depth interval, belong to the Outlook Sand. Extrapolating further, the sandy "shales" and grey "shales" with the *Haplophragmoides rugosa* fauna, lying between depths of 70 and 340 feet, might then be interpreted as the unnamed member at the base of the Bearpaw Formation, and the 80 feet of sand and sandy "shales", referred to the Ribstone Creek Formation, as the Oldman Formation.

Wickenden *(ibid.)* had little reason to refer parts of the section tentatively to the Birch Lake and to the Grizzly Bear and Ribstone Creek Formations, which commonly are regarded as members of the Belly River Formation in the area to the north and west of the river valley. Clearly he was uncertain about this interpretation, because he wrote, "The age of the upper part of this well is somewhat problematic although it is known that the well started in the lower part of the Bearpaw" and, "If the series at the top of the Rush Lake well represents the eastern extension of the Birch Lake, Grizzly Bear and Ribstone Creek, it is difficult to explain the sudden total disappearance of the Pale [Oldman] and Foremost beds of southern Alberta or the Variegated beds [an old name for beds equivalent to the lower Oldman Formation] of the North." Recently, Christiansen (1965, fig. 4) has shown that the Ribstone Creek Member of the Foremost Formation, if traced eastward into Saskatchewan, loses its identity, and, together with the Grizzly Bear Member of the same formation, becomes a non-distinct part of the upper Lea Park Formation between Kindersley and Rosetown. The transition takes place, therefore, several tens of miles to the west of the site of the Rush Lake bore hole and, by implication, only the Oldman Formation should be present as a sand between the Lea Park and Bearpaw Formations in the studied segment of the river valley.

The Northwest Company's Rush Lake bore hole is ringed to the southwest by other bore holes, the sequences in four of which, Gulf Tidewater Rice no. 5, Tidewater Rush Lake nos. 4 and 5, and Shell-Tidewater Beaver Flat no. 9-5, are depicted in text-figures 12, 13, and 14. It is evident that these conform to the outcrop sequence and can be correlated closely with other bore-hole sequences still farther removed from the site of the original Rush Lake hole. Comparative figures in feet for the thicknesses of pertinent units in these bore holes listed and in the reinterpreted Northwest Company Rush Lake bore hole are summarized below:

Table 2

Bore Hole / Formation or Member	Northwest Co. Rush Lake 2-30 L.s.d. 2-30-19-11 W3	Gulf Tide-water Rice no. 5 L.s.d. 5-34-20-10 W3	Tidewater Rush Lake no. 4 L.s.d. 3-36-19-11 W3	Tidewater Rush Lake no. 5 L.s.d. 4-34-18-11 W3	Shell-Tide-water Beaver Flat no. 9-5 L.s.d. 9-5-18-12 W3
Broderick Clay Member	65[1]	115	115	100	70
Outlook Sand Member	20 (?30)	105	55	70	100
Unnamed Clay Member	270	110	125	135	200
Oldman Formation	80	230	195	220	235
Base Oldman Formation to top Broderick Member	445	560	490	525	605

1 Includes 20-foot drift section and 25 feet exposed below Matador Sand in outcrop section (p. 21, 49).

If the 40 feet of medium to light-grey sandy "shale" found in the original Rush Lake bore hole were to be regarded as part of the Outlook Sand rather than the unnamed clay (the Bearpaw sands show a marked increase in clay content downward and Wickenden does include this unit in his Birch Lake or Belly River Formation, both of which are predominantly sandy and silty formations), the anomalous thicknesses of the Outlook Sand and unnamed clay members partly would be resolved, and the below-average thickness of the entire sequence listed then could be accounted for in terms of an oddly localized and unusually thin development of the Oldman Formation.

Haplophragmoides rugosa is not in itself an index of the Grizzly Bear beds — the species ranges through the "Belly River" equivalent into the Bearpaw Formation — and Wickenden never made clear what he meant by the *H. rugosa* fauna.

Farther north, the greater part of the Bearpaw sequence was penetrated in a series of hydrogeological test holes, drilled by the Geological Survey of Canada, near Riverhurst, in the southwest quarter of Section 5-23-7W3. Drilled from a surface elevation of 1,930 feet, the holes encountered drift to a depth of 164 feet and an underlying sequence of Bearpaw and so-called Belly River beds, summarized by Tremblay *in* Meyboom, 1966, p. 10), to a depth of 808 feet. Tremblay's sequence can be emended and reinterpreted as follows:

BEARPAW FORMATION	Depth in feet	Thickness in feet
Snakebite Clay Member — Clay, sandy at top	164-340	176
Ardkenneth Sand Member — Sand, clayey at base, loosely cemented	340-439	99
Beechy Clay Member — Clay and sandy clay	439-505	66
Demaine Sand Member— Sand (top at 1,425 ft. above sea level)	505-545	40
Sherrard Clay Member — Clay, somewhat sandy at top	545-618	73
Matador Sand Member — Sand, silty	618-640	22
Broderick Clay Member — Clay	640-753	113
Outlook Sand Member — Sand	753-808	55

Matador Sand detected in the electric log of one hole only.

Tremblay's test holes (presumably a nest of close-spaced borings since all have the same surface elevation and encountered the same sequence) lie about a mile from the Geological Survey of Canada Lucky Lake R.D.H. no. 8 bore hole, which was drilled from a surface elevation of 1,870 feet in southwest Legal Subdivision 13-32-22-7W3 (see text-figs. 11 and 13), and there is close agreement between the two sequences. From the evidence of the Lucky Lake bore hole, there is little doubt that the 55 feet of sands, referred to the Belly River Formation by Tremblay, represent the upper beds of the Outlook Sand, and the true base of the Bearpaw Formation lies more than 100 feet deeper.

Meyboom *(op. cit.,* p. 11) presented data on three borings between Central Butte and Chaplin, to the southeast of the Vermilion Hills, and interpreted the sequences encountered in terms of the Ardkenneth and Snakebite Members. Probably he was quite correct in regarding the sands at the bottom of all three holes as Ardkenneth sands, but there is a possibility (duly considered by Meyboom) that the sands in two of them (northwest quarter of Section 19-20-4W3 and southwest quarter of Section 13-19-5W3) belong to the Cruikshank Sand and the overlying "shales" to the Aquadell Clay. Certainly in the third boring mentioned (northeast quarter of Section 27-18-5W3), the 490 feet of "shale", succeeding the 14 feet of sand at the bottom of the hole, must include both Snakebite and Aquadell beds, the 14 feet of sand can only reasonably be assumed to belong to the Ardkenneth Sand, and it must be concluded that the Cruikshank Sand, if present, was not recognized.

Prior to and during construction of the Gardiner Dam, the nature of the dam foundation was tested exhaustively by means of bore holes, and many of these penetrated deeply into bedrock. The P.F.R.A. RD 639 bore hole (Pollock, 1962, p. 6) yielded the longest section of Bearpaw beds — one ranging from the Cruikshank Sand to the Demaine Sand — and is notable for the information it affords on the thicknesses of the members relative to their thickness in type locality. Drilled from a surface elevation of 1,771.1 feet, the P.F.R.A. RD 639 boring encountered the basal 6 feet of the Cruikshank Sand between 1,750 and 1,756 feet and the Snakebite Clay (300 feet thick) and the Ardkenneth Sand (115 feet thick) between 1,450 and 1,750 and 1,335 and 1,450 feet respectively. Beneath the Ardkenneth Sand, clays, 22 feet thick, and sands, about 16 feet thick, presumably represent respectively the Beechy Clay and the Demaine Sand, and the bottom of the hole lies at an elevation of 1,296.7 feet. Glacial drift was found above the Cruikshank Sand. Clearly the Snakebite Clay and the Ardkenneth Sand are much thicker and the Beechy Clay much thinner than in their type localities between Herbert Ferry and Snakebite Creek. The Cruikshank sands are fine grained and clayey, the Snakebite clays contain numerous seams, lenses, and traces of bentonite, and the lowest 28 feet of the Ardkenneth sands are interbedded with clays. It can be observed in outcrops and is readily confirmed by electric logs from bore holes that, generally, the contacts between sand and overlying clay members are sharp, whereas those between clay and overlying sand members lie in a series of transitional beds, and correlation diagrams, using columnar sections based upon electric-log characteristics, reveal that variations in the thicknesses of the members commonly are to be accounted for in terms of facies variation between the highest clays and lowest sands of contiguous members. The 28 feet of sand-with-clays at the base of the Ardkenneth section in the P.F.R.A. RD 639 bore hole may represent just such a local facies variation, and the anomalous thicknesses of the Beechy and Ardkenneth Members partly may be accounted for in this way. The 16 feet of Demaine Sand and the Beechy Clay and Demaine Sand, cropping out a few miles north of the dam site (see p. 36-37), also, however, show interbedding of clays and sands.

At the northern extremity of the studied segment of the South Saskatchewan River valley, the Saskatchewan Research Council (S.R.C.) 720/6 Outlook test hole provides invaluable information regarding the nature and sequence of the basal members of the Bearpaw Formation — members entirely without or with only limited exposure, and less well defined than to the south. The Outlook test hole (see text-fig. 12) was drilled in northeast Legal Subdivision 5-18-29-8W3, from a surface elevation of approximately 1,800 feet to a depth of 484 feet, and, beneath 110 feet of drift, encountered the following sequence of Bearpaw beds (interpreted from the lithological log compiled by Drs. S. H. Whitaker and E. A. Christiansen of the Saskatchewan Research Council):

BEARPAW FORMATION	Depth in feet	Thickness in feet
Broderick Clay Member —		
Silt, grey, with some fine-grained sand toward the top, clayey toward the base, non-calcareous to slightly calcareous	110-171	61
Outlook Sand Member —		
Sand, fine grained, silty, "salt and pepper", non-calcareous	171-179	8
Sand, fine grained to silty, light grey, non-calcareous	179-194	15
Sand, fine grained, intermixed with some silt and clay, slightly calcareous	194-200	6
Sand, fine grained, silty "salt and pepper", non-calcareous to slightly calcareous	200-213	13
Sand, fine grained to silty, light grey, slightly calcareous	213-217	4
Unnamed Member —		
Silt, fine grained, sandy at some levels, grey, non-calcareous	217-238	21
Sand, fine grained to silty, grey, slightly calcareous	238-240	2
Silt, with a high proportion of fine-grained, "salt and pepper" sand, non-calcareous	240-249	9
Sand, fine grained, silty, "salt and pepper", non-calcareous	249-253	4

Silt, with a high proportion of fine-grained "salt and pepper" sand, non-calcareous	253-256	3
Sand, fine grained, silty, grey, slightly calcareous	256-260	4
Silt, with a high proportion of fine-grained "salt and pepper" sand, slightly calcareous and carbonaceous	260-280	20

OLDMAN FORMATION

Silt, with much fine-grained sand, light grey, slightly calcareous; thin beds with numerous coal chips at top and base	280-285	5

Wickenden (*in* Fraser *et al.,* 1935, p. 21) indicated that, near Outlook and Hanley (the latter about 25 miles east-northeast of Outlook), bore holes penetrated about 200 feet of sands and he believed these to represent an eastern, thinned equivalent of some part of the true Belly River Formation. In all likelihood, he had in mind the beds occupying the interval from the top of the Outlook Sand to the base of the Oldman Formation — an interval of about 250 feet in the S.R.C. Outlook test hole — and although within this interval sands predominate, undoubtedly they are not uniformly buff-coloured, fine-grained sands with marine fossils as Wickenden implied.

Van Everdingen (1968, p. 7-8) has stated that the sands exposed at Outlook bridge must be equivalent to those of the Cruikshank Member. Mineralogical, palaeontological, and structural evidence all militate against such a correlation, and the S.R.C. Outlook test hole, insofar as it reveals the relation of the Outlook Sand to the Oldman Formation, corroborates the mis-correlation.

Electric logs

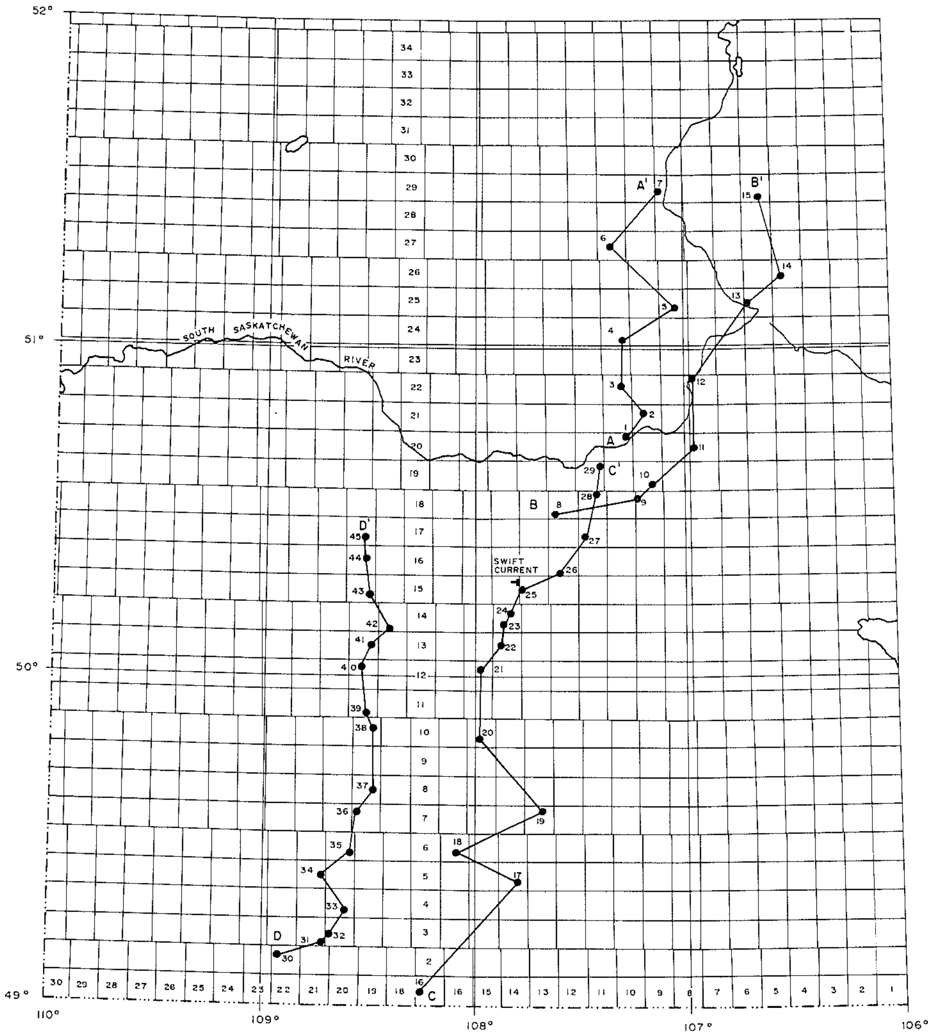
Although the outcrop and cored bore-hole sequences of the Bearpaw Formation in the South Saskatchewan River valley suffice to establish almost the entire succession of members, too few of the sequences have a great enough stratigraphical extent to permit any kind of accurate and comprehensive reconstruction of the behaviour of the various members as they are traced laterally from their type localities. To this end, comparative sections, based upon the sequences encountered in some uncored, oil-company bore holes — and these sequences in turn upon the electric-log characteristics of the component sediments — contribute substantially. Four sets of comparative sections are provided (text-fig. 11), two within the area of study (text-figs. 12 and 13) and two extending from the southwestern end of the area to the vicinity of the Cypress Hills. Of the two regional groups of sections, one (text-fig. 15) skirts the East Block of the Cypress Hills and runs to Boundary Plateau, the other (text-fig. 14) transects the Swift Current Plateau and the Frenchman River valley near Climax. The regional sections were chosen with a view to relating the Bearpaw succession in the South Saskatchewan River valley to that in the Cypress Hills, where the formation has been studied more thoroughly than in any other part of the Canadian Great Plains. Collectively, the comparative sections express certain geophysical characteristics of the new members, supplement outcrop and cored sequences in determining the relative thickness and facies of the members, demonstrate the lateral continuity and persistence (thereby substantiating the validity) of the members, and provide graphic illustrations of local and regional lithostratigraphical correlation.

For two reasons, comparative sections A-A' (text-figs. 11 and 12), on the west side of the river valley, warrant primary consideration. Firstly, the sequences in the Gulf Tidewater Rice no. 5 and the Geological Survey of Canada (G.S.C.) 61-1 bore holes illustrate development of all but the highest members in that part of the river valley in which most of the type localities are situated. Secondly, the G.S.C. 61-1 bore hole was completely cored and the Saskatchewan Research Council (S.R.C.) 720/6 Outlook test hole was densely sampled using a side-hole coring device, so that precise correlation of sediment type and electric log expression is possible. These two bore holes, therefore, provide standards from which extrapolations readily can be made. Notable also from this set of sections is the relative thinness and poor definition of the Outlook Sand in and near its type locality. Such an anomalous situation is unavoidable, however, for it remains that it is only in the Outlook district that the member is exposed and has been partly cored.

Comparative sections B-B' (text-figs. 11 and 13), on the east side of the valley, confirm the loss in definition and wedging of the Outlook Sand north of Township 25. This is expressed by thinning and ultimate elimination of the sand itself and is accompanied by thinning of the entire sequence between the top of the Oldman Formation and the base of the Matador Member. Despite the latter, disappearance of the Outlook Sand almost certainly is not the result of overlap but of facies variation, involving not only the sand itself but also the underlying and overlying unnamed and Broderick Clays respectively. Combining the evidence of the electric logs and the lithological log of the S.R.C. Outlook test hole (p. 52-53), it would appear that gradual increase northward in the clay and silt fractions of the sand is paralleled by increase in the silt and sand content of the clays. In the most northerly three bore holes of the B-B' sections, the strongest positive deflections of the resistivity curves (occurring slightly above midway) between the top of the Oldman Formation and the base of the Matador Member may mark particularly silty beds equivalent lithologically to the Outlook Sand.

Apart from the fact that the Ardkenneth Sand is notably thicker on the eastern side of the river valley, the two groups of sections A-A' and B-B' display striking similarity in the consistency or variation in thickness of the other members represented.

Both regional groups of comparative sections yield important information on the relationship between the Oldman and the Bearpaw Formations. In section C-C' (text-figs. 11 and 14), the Oldman-Bearpaw contact is taken as the base of the unnamed clay, except close to the International Boundary, where it is regarded as the base of the lithostratigraphical equivalent of the Broderick Clay, the unnamed clay and overlying Outlook Sand having changed in facies and passed into the Oldman Formation. Similarly, in section D-D', (text-figs. 11 and 15) the Oldman-Bearpaw contact is taken as the base of the Broderick Clay, except again in the extreme south, where it is regarded as coincident with the base of the equivalent of the Sherrard Clay, the Broderick Clay and Matador Sand having passed by facies change into the Oldman Formation. Nor does the interformational contact remain constant at that level: sections drawn to the western border of the province show the Oldman-Bearpaw boundary locally at the base of the equivalent of the Beechy Clay, and the Sherrard Clay and Demaine Sand lost to the Oldman Formation by facies change. Clearly, the Oldman-Bearpaw contact lies at progressively higher lithostratigraphical levels southwestward from the South Saskatchewan River valley to the Cypress Hills and, since the ammonites suggest that individual members in themselves are negligibly diachronous, the contact can be assumed to lie in progressively higher biostratigraphical range zones as it is traced between these two localities. In short, the base of the Bearpaw Formation in southwestern Saskatchewan is held to be a diachronous horizon and to reflect gradual transgression of the Bearpaw sea; and since that transgression probably took place more to the west than the south, it is likely that the regional cross-sections afford only an apparent and weak measure of the diachronous rise. A complementary relationship in thickness between the Oldman and Bearpaw Formations, readily appreciable from the regional sections, substantiates the facies equivalency of parts of the two formations. Between Ranges 11 and 16, the Oldman Formation thickens only from about 200 to 250 feet, but with the incorporation of the unnamed clay and the Outlook Sand, together about 150 feet thick, the formational thickness becomes 300 to 400 feet between Ranges 17 and 21, and with the incorporation of the Broderick



Text-figure 11: Index map to show the locations of bore holes used as a basis for the four sets of comparative sections in the section lines A-A', B-B', C-C', and D-D' (text-figs. 12 to 15, folds-out at back).

Clay and Matador Sand, together about 175 feet thick, that thickness jumps to 550 feet in Range 22.

To be noted also from the regional comparative sections is the manner in which some of the sands wedge out between the river valley and the Cypress Hills. Along the lines of section, the Outlook and Matador Sands can be traced through the intervening ground and into the Oldman Formation, but the Demaine and Ardkenneth Sands thin and disappear between Townships 4 and 7 and 10 and 12 respectively. It is known, however, that, farther to the west, the Demaine Sand, like those sands beneath it, can be traced into the Oldman Formation. The Cruikshank Sand has not been encountered in a sufficient number of bore holes to assess accurately its regional behaviour, but from sections D-D' it can be seen to become thinner southward between Townships 5 and 11 and so reasonably can be assumed to conform to the regional pattern. Extrapolating between the lines of sections, at least the Matador, Demaine, and Ardkenneth Sands thin and disappear southeastwards and have their edges trending between east-west and northeast-southwest. Such a distribution suggests that these (and perhaps also the other) sands represent wedges of sediment swept into the Bearpaw sea from the northwest. Like the Outlook Sand in the northern part of the South Saskatchewan River valley, the thinning and ultimate elimination of these sands between the river valley and the Cypress Hills undoubtedly is brought about by facies change, but there is no accompanying thinning of the overall sequence containing them.

Recalling too, the sets of comparative sections flanking the river valley, the Ardkenneth Sand, rather surprisingly, is thicker in the more easterly of the regional sections, but, apart from that, the members of the Bearpaw Formation obviously are remarkably consistent in their thickness relative to their enormous areal spread.

In their analysis of the Upper Cretaceous Series in the Canadian Great Plains, Williams and Burk (1964, p. 175, fig. 12-7) presented a cross-section extending from the South Saskatchewan River valley in southwestern Saskatchewan to the Missouri River valley in northeastern Montana. They identified the predominantly non-marine and sandy sub-Bearpaw beds as the Belly River Formation and, within the studied portion of the South Saskatchewan River valley, referred nearly 1,000 feet of beds to this formation. But this anomalous thickness results from the inclusion of more than 700 feet of the marine clays and sands of the Bearpaw Formation. The sequence in the Gulf-Tidewater Burrell No. 9 bore hole (L.s.d. 9-27-22-10W3) is common to both Williams and Burk's figure 12-7 (cross-section E-E') and figure 12 (cross-section A-A') of this report and illustrates the contrasted interpretations.

RELATIONSHIP TO THE OLDMAN FORMATION

Facies variation

Considering the scrappy outcrops and limited borehole information at his disposal, it is not surprising that Warren (*in* Fraser *et al.*, 1935, p. 19-21) was perplexed by the relationship of the Belly River (as he called it) and the Bearpaw Formations in the South Saskatchewan River valley.

Warren was misled by the anomalous sequence encountered in the Northwest Company's Rush Lake bore hole and Wickenden's (1932, p. 185-186) identification of the formations represented in that sequence (see p. 49). He sought to interpret the exposures between Saskatchewan Landing and Pennant Ferry in terms of the same formations, although he also considered, but did not favour, a generalized version of the interpretation presented in this paper — one in which it is accepted that beds, similar to those of the Oldman Formation (Pale Beds of Warren and others) and at least partly non-marine in origin, occur between marine beds in the Bearpaw Formation. Warren's apparent reluctance to accept this latter view may have caused him to fail to entertain the possibility that the sands exposed (and some of those encountered in a bore hole) at Herschel, 50 miles west of Outlook, might lie well above his Belly River Formation, and, although he gave no hint of it, the same could be true of the beds exposed and penetrated in bore holes near Hanley, 25 miles east-northeast of Outlook. Knowing that the sands exposed at Outlook contain a rich and varied marine fauna, Warren seems to have assumed or obtained the information that the 200 feet of so-called Belly River beds encountered in the Outlook bore hole not only were entirely fine-grained sands but were sands of the same type as those exposed. Aware from his observations of the sands in the Bearpaw Formation (for example, near Herbert Ferry and opposite the mouth of Swiftcurrent Creek) that no Bearpaw sand attained half of this thickness, he concluded the Outlook sands must belong to the Belly River Formation and represent . . . "all that remains of the Belly River sands of the west." No doubt envisaging these sands deposited near the seaward edge of the Belly River alluvial plain, Warren was untroubled by their presence in marine facies.

Subsurface information indicates that, in the vicinity of the type locality, the Outlook Sand is a rather vaguely defined silty sand bedded between clayey silts; that to the southwest, around Herbert Ferry for example, it is probably a "purer" sand, strongly defined and sharply delimited from "purer" clays above and below; and that, near Saskatchewan Landing (about Ranges 17 and 18), it changes in facies and becomes the uppermost part of the Oldman Formation. Implicit in Warren's interpretation is a lateral transition between beds of non-marine, "Pale Beds" facies at Pennant Ferry and marine, Bearpaw facies at Outlook and, insofar as such a passage does take place, he was correct. He erred only in his concept of the scope of these changes. It is demonstrable now that the highest "Pale Beds" of Warren's Belly River Formation are transmuted to become not only the Outlook Sand but also the unnamed silt beneath. It is to be noted, too, that markers within the upper Lea Park Formation point to a complementary thickness relationship between that formation and the Belly River, possibly to be explained in terms of eastward facies replacement of Belly River sands by Lea Park clays. Nevertheless, a distinct Belly River (in the sense of Warren) or Oldman Formation (as it is called herein), 100 to 200 feet thick, can be traced from Pennant Ferry into the Outlook country, and there is no reason to suppose that in that distance it has undergone any fundamental change in lithology.

At Pennant Ferry, not only have the unnamed clay and Outlook Sand changed in facies and passed into the Oldman Formation but the Matador Sand has thickened and in great measure been subject to a comparable lateral transition (for details of lithology see p. 25-26, 48-49) preparatory to its incorporation into the Oldman Formation a few tens of miles to the west. The Matador Sand is overlain directly by glacial drift so there is no way of assessing whether or not the Demaine Sand might also be showing signs of passage into Oldman facies as far east as Pennant Ferry. Combining such surface and subsurface information as is available, however, it is evident that at least the Outlook and Matador Sands have a dual character in the South Saskatchewan River valley — to the east they are fairly massive and uniform, concretion bearing, brownish grey, and marine, to the west they are thinner bedded, associated with clays and silts, dominantly pale coloured, and in good part non-marine. Alternatively, to the east they are in Bearpaw facies and only reasonably can be included in the Bearpaw Formation: to the west they are in Oldman facies and, for convenience, are included arbitrarily in the Bearpaw Formation. Undoubtedly the same comments are applicable to the Demaine Sand to the west of the river valley, where, locally, it also loses its identity and becomes engulfed in the thickening wedge of the Oldman Formation. There is no convenient way of delineating the transition between the two facies of the Outlook Sand, but, in the case of the Matador Sand, it can be localized at least to a ten-mile stretch of the valley. Westward from Herbert Ferry to the mouth of Swiftcurrent Creek, the Matador Sand is in Bearpaw facies, eastward from Pennant Ferry to Coal Mine Coulee, it is in Oldman facies. The transition, therefore, must take place close to Saskatchewan Landing.

Positions of the strandlines

The facies changes in the Outlook and Matador Sands carry considerable palaeogeographical implications. It seems probable that the bulk of the uppermost Oldman sands and silts around Pennant Ferry accumulated in waters of insignificant depth on the fringe of the Oldman alluvial plain, and that the sediments were transported by fluctuating streams and negligibly disturbed after deposition. Seams and partings of lignite in the sands indicate that periodically the waters must have carried numerous drifted plant remains, or, alternatively, must have become so shallow that marshes and swamps were established briefly. The environment may have been that of brackish-water embayments along an alluvial prograded coast, or perhaps of fresh-water lagoons protected from the open sea by beach ridges or coastal bars of sand. Absence of the remains of marine organisms—even those believed to have been tolerant of brackish waters—supports the suggestion that some barriers existed separating shoreward lagoons from the open sea. The Matador Sand in Oldman facies presumably is a product of similar environmental conditions, except that, if barriers were present during the time of deposition, they acted intermittently, allowing the sea to transgress and marine and non-marine sediments to become intertongued. In contrast, the Outlook and Matador Sands in Bearpaw facies suggest considerable reworking of Oldman-type sediments by current interplay in shallow waters, winnowing of some of the mud, and blanket deposition of the resultant thoroughly mixed sediment — basically a sand but with a notable clay and silt content gradually decreasing upward. In terms of lithotope, the two facies are in marked contrast: the Oldman facies is a product of the non-marine, fluvio-deltaic, alluvial plain; the Bearpaw facies of the marine, epineritic, inner shelf or platform. The line of transition between the facies in all likelihood denotes the position of the shoreline at the time of deposition. Thus, so far as the early Bearpaw history and geography of the river valley and its environs are concerned, the Bearpaw sea initially transgressed almost as far west as Pennant Ferry (about Ranges 16 and 17) and the basal unnamed clays and silts were deposited. It then regressed to some position between Pennant Ferry and Outlook under encroachment of the tongue of river-borne, Oldman-like sediments, which, together with its off-shore derivatives, gave rise to the Outlook Sand. A second advance, which took the sea well beyond its former western limits and led to the accumulation of the Broderick Clay, was repulsed by a second eastward-migrating, rapid accumulation of Oldman-like sediments with sheet-like seaward outgrowth, the Matador Sand, deposited with the shoreline about the position of Saskatchewan Landing. A third transgressive pulse, marked by the Sherrard clays, probably pushed the shoreline nearly as far west as the inter-provincial boundary (about Ranges 22 to 24) only for it to be carried eastward again in the sweep of a third influx of non-marine and marine terrigenes, that which resulted in deposition of the Demaine Sand. Expansion of the Bearpaw sea and inundation of the Oldman alluvial plain, therefore, was not only gradual but pulsatory. Overall westward transgression was offset by several, temporary, eastward regressions, during which conditions of the alluvial plain were restored to progressively more restricted and westerly parts of the province and, beyond the edge of the alluvial flats, reworked alluvial sediment was spread across several tens of miles of adjacent sea-covered platform. The magnitude of the geographical changes probably is a misleading measure of the strength of the causative earth movements. Undoubtedly the sea was extremely shallow and the western borderland a plain of negligible relief, so that slight epeirogenic movements led to radical modifications in the distribution of land and sea.

Warren's (*op. cit.,* p. 20-21) identification of the beds exposed and encountered in bore holes at Herschel, Outlook, and Hanley as belonging to the Belly River Formation was responsible in the main for the position of the most northerly boundary between the so-called Belly River and the Bearpaw Formations on the Regina Sheet (Map 267A of the Geological Survey of Canada, accompanying Memoir 176)—a boundary that lies many tens of miles south of its true position (compare Byers, Caldwell, and Kupsch, 1968). Like the beds at Outlook, those at Herschel and Hanley undoubtedly belong to the Bearpaw Formation. Near Herschel, 50 miles west of Outlook, Warren described so-called Belly River beds, some of which are non-marine and recall the Oldman Formation in appearance. ". . . Light grey sandstone and sandy shale, with one indurated bed of buff-coloured, rusty-weathering, marine, fine sandstone and a small coal seam," 30 feet thick, are exposed, the indurated bed containing marine fossils found also in the Bearpaw Formation (Warren, *op. cit.,* p. 20, 123-126). Christiansen (1965, Pls. 2 and 4) has shown that the exposed beds lie about 250 feet above the top of the Oldman Formation, and the Oldman Formation must be about 230 feet thick at the site of the outcrops. Longitudinally, Herschel lies only a few miles west of Pennant Ferry, where the Oldman Formation has a comparable thickness, the upper beds of the Matador Sand lie at a similar footage above the Oldman-Bearpaw contact, and the Matador Sand includes marine and non-marine beds. The probability is, therefore, that the exposed beds at Herschel belong to the Matador Sand and, as a bore hole at Herschel penetrated 370 feet of beds that Warren was prepared to regard as part of a more than 400 foot-thick Belly River Formation, the underlying Broderick Clay likely has become silty prior to its incorporation, together with the Matador Sand, into the Oldman Formation a few miles farther to the west.

At the town of Hanley, 25 miles east-northeast of Outlook, Warren *(ibid.)* found buff sands with marine fossils similar to those at Outlook, and noted that bore holes indicate these sands to be about 200 feet thick. Although partly destroyed by recent road construction, exposures of sands and clays can still be found in Brightwater Creek, 5 miles west of Hanley. At one locality, 5 feet of buff to white-weathering, poorly indurated, fine and even-grained, grey sand, with numerous hollow iron-oxide concretions concentrated in some beds, is exposed; and at another, 1 foot of brown-weathering, even-grained, grey sand is overlain by 3 feet of pale-brownish-grey-weathering, dark-grey, soft, iron-stained clay, with numerous acicular gypsum crystals. Again, these are not Belly River beds as Warren believed but lie in the middle part of the Bearpaw Formation. Dr. E. A. Christiansen has calculated that the exposures lie at least 350 feet above the Oldman-Bearpaw contact, and extrapolation of the sections in various Saskatchewan Research Council bore holes in the area (the sections as yet unpublished), together with the evidence of lithology, leaves it in little doubt that the sands belong to the Ardkenneth Member, the clays to the Snakebite Member.

In summary, it can be said that, from the studied segment of the South Saskatchewan River valley westward, the lower sands of the Bearpaw Formation change in facies from marine, through mixed, into non-marine facies and are incorporated into the Oldman Formation, the top of which therefore rises stratigraphically in that direction. Northeastward, the lowest Outlook Sand shows signs of losing its individuality and becoming a non-distinct part of a silty sequence that extends from the top of the Oldman Formation to the base of the Matador Member of the Bearpaw Formation. Northward and southward, the lower sands of the Bearpaw Formation (and the clays that they serve to distinguish) are notably consistent in their range of thickness and (so far as the limited evidence goes) in gross lithology; and they have truly remarkable extent. The behaviour of the sands is in perfect harmony with the long-held view that the sea transgressed broadly westward from the South Saskatchewan River valley district in early Bearpaw time.

The evidence of the relationship between the Oldman and Bearpaw Formations presented in various parts of this paper refutes the interpretation presented by Meyboom (1966, p. 11-12, figs. 2 and 3) for the area between the South Saskatchewan River and Last Mountain Lake. At least so far as the western part of the area is concerned, the various sand members are known to be discrete (compare Meyboom's fig. 2, cross section A-B, with text-figs. 11 and 13, comparative sections B-B', of this paper), and it is extremely difficult to relate Meyboom's interpretation to any plausible palaeogeographical setting or pattern of sedimentation.

THE EASTEND-WHITEMUD OUTLIERS

The Vermilion Hills

On the escarpment of the Missouri Coteau, where it is transected by the South Saskatchewan River, two outliers of the Eastend and Whitemud Formations, capped by glacial deposits, form conspicuous hills.

The hour glass-shaped remnant of these formations, nearly 20 miles long by 8 miles broad, aligned north-south, and underlying the Vermilion Hills, is by far the larger (text-fig. 7). Outcrops of the Eastend and Whitemud beds are scanty, but borings have shown that the complete Eastend and what is probably the greater part of the Whitemud are preserved. The most complete section is that in the core of Imperial Oil Structure Test Hole 168 (L.s.d. 4-6-21-6W3):

	Depth in ft.	Depth in in.	Thickness in ft.	Thickness in in.
WHITEMUD FORMATION				
Silt, greyish white, black carbonaceous flecks conspicuous, weakly calcareous, with (?)pebbles of greenish-grey, waxy clay	77			6
Clay, pale greenish grey, massive non-calcareous, waxy	77	6		6
Clay, predominantly pale grey, locally pale pink to pale green, hard, waxy, with granules and pebbles of chalk limestone	78		1	
Sand, pale greyish white, with black carbonaceous flecks, non-calcareous, poorly indurated, carrying small, irregularly shaped inclusions of white calcareous sand	79		1	
Clay, pale grey, locally pale pink to pale green, hard, waxy	80		5	
Clay, mainly greyish pink and greyish green, non-calcareous, hard, waxy, with thin lenses, granules, and pebbles (locally abundant) of chalky limestone	85		10	6
Sand, pale grey, non-calcareous, poorly indurated with carbonaceous streaks (?plant remains)	95	6		6
Clay, indistinguishable from that developed immediately above overlying 6-inch sand	96		14	
Clay, predominately pale grey rarely pinkish grey, non-calcareous, hard, waxy, with seams and lenses of pale-grey, calcareous silt, containing grains and pebbles of white, chalky limestone; locally clay and silt interlaminated, the laminae disturbed by post-depositional movement	110		5	
Clay, predominantly pale grey, locally pale pink to pale green, hard, waxy	115		15	
No recovery	130		22	
EASTEND FORMATION				
Silt, pale greyish yellow, becoming more distinctly yellow downwards, clayey, becoming less clayey downwards, non-calcareous, hard, with irregular, rusty, iron-stained partings, containing pebbles of limestone of maximum diameter 1 in., between 1 and 2 feet above base of the unit	152		8	
Silt, rusty brown, laminated, iron-staining emphasizing the laminae, which in places are contorted, generally non-calcareous but with locally developed beds and lenses of coarser-grained, calcareous silt	160		1	6
Clay, greyish brown, with much interlayered yellowish-brown, iron-stained silt, the iron-staining emphasizing a crude irregular lamination	161	6	3	6
Sand, yellowish brown, iron stained, weakly consolidated, non-calcareous	165		30	
BEARPAW FORMATION				
Aquadell Clay Member—				
Silt, mid-grey, poorly consolidated, non-calcareous. (Poor recovery) For remainder of section in Aquadell Member, see p. 44.	195		55	

Comparable in elevation, the smaller outlier is only a few miles in length and breath and lies close to the west flank of the Vermilion Hills. Whitemud beds neither crop out nor have been found in borings, so that probably these beds largely were removed by pre-Pleistocene erosion and, over most of the outlier, glacial drift rests directly on Eastend sands. Imperial Oil Structure Test Hole 166, located in Legal Subdivision 4-6-20-8W3, penetrated a few tens of feet of the Eastend Formation overlying a comparable thickness of the Aquadell Member of the Bearpaw Formation. The section cored is as follows:

	Depth in ft.	Depth in in.	Thickness in ft.	Thickness in in.
EASTEND FORMATION				
Silt, brownish yellow, clayey, with prominent iron-stained seams	75		6	
Sand, brownish yellow, poorly indurated, iron stained in thin seams and patches, non-calcareous. (Poor recovery)	75	6	39	6
BEARPAW FORMATION				
Aquadell Clay Member—				
Silt, pale brownish grey or variegated in tones of pale brown and pale grey, sandy, non-calcareous, poorly indurated, with iron-oxides concentrated in patches and seams	115		20	
Sandstone, greyish brown, medium to coarse grained, strongly calcareous, hard; probably part of a concretion	135		1	6
Silt, pale brownish grey, non-calcareous, poorly indurated, iron stained, locally sandy and clayey, the clay tending to be concentrated in seams 1 to 2 in. thick	136	6	8	6
Clays and silts, grey, poorly indurated, non-calcareous	145		32	

In these and other bore-hole sections, there is no obvious boundary between the Bearpaw Formation and the Eastend Formation. The Aquadell clays become more silty and sandy in upward sequence, generally accompanied by a colour change from predominantly grey to predominantly brown, and pass into yellowish-brown silts and sands typical of the Eastend beds.

Beechy

Between 5 and 8 miles south of Beechy and straddling the road that leads from the town to Herbert Ferry, a figure eight-shaped patch of Eastend and Whitemud beds, 10 miles long and aligned east-west, is preserved in a group of hills rising prominently from the flat plain north of the river valley (text-fig. 7). Beds of the Eastend Formation do not crop out, but erosion-resistant sandstones of the Whitemud Formation form a low cliffed escarpment near the top of the hills (Fraser *et al.,* 1935, p. 32, Pl. 2). These beds are pale-grey, weathering greyish-white, strongly cross-bedded, coarse-grained, friable, kaolinized, feldspathic sandstones, which are in marked contrast to all the Whitemud beds described from the Vermilion Hills. A position at the base of the formation is indicated by their relation to the Eastend beds in the core of Imperial Oil Structure Test Hole 173, which was drilled on the outlier and penetrated to silts of the Aquadell Member of the Bearpaw Formation. The sequence in the bore hole, located in Legal Subdivision 7-7-21-11W3, is given below:

	Depth in feet	Thickness in feet
WHITEMUD FORMATION		
Sandstone, pale grey to white, medium to coarse grained, kaolinized, feldspathic, friable, non-calcareous but with small 1-inch diameter, calcareous-sandstone concretions at base. (Poor recovery)	15	10
EASTEND FORMATION		
Sand, pale brown, medium grained with some coarse-grained beds, poorly consolidated, non-calcareous	25	10
Silt, pale brown, clayey but with much sand interbedded near the top, locally with carbonaceous partings and streaks, pockets of sand, and rusty, iron-stained patches; some beds irregularly laminated	35	17
Sand, pale brown, poorly consolidated, non-calcareous. (Poor recovery)	52	3
Silt, pale brown, clayey, locally with pockets of sand and rusty iron-stained patches; many beds irregularly laminated. (Poor recovery)	55	24
Sandstone, greyish brown, fine grained, hard, calcareous; probably part of a concretion	79	1

Silt, pale brown, clayey, locally with pockets of sand and rusty iron-stained patches; many beds unevenly laminated	80	10
Sand, pale brown, patchily iron stained, non-calcareous, with some thin clayey intercalations	90	3
Sand, generally pale brown but varying to pale brownish grey, in places interbedded and interlaminated with silt and clay or with lenses and pockets of silt and clay, weakly consolidated, non-calcareous, with rare, rusty, iron-stained flecks and patches	93	49
Sandstone, pale grey, fine grained, dense, hard, calcareous; probably part of a concretion	142	1
Sand, pale brown, silty, patchily iron stained, non-calcareous	143	2
BEARPAW FORMATION		
Aquadell Clay Member—		
Silt, grey, sandy, weakly consolidated, non-calcareous, making marked colour contrast with overlying beds	145	8

There is a wide discrepancy in thickness between the Eastend Formation in the Beechy outlier (120 feet) and that in the Vermilion Hills outlier (43 feet recovered of a possible 65 feet). The basal feldspathic sandstones of the Whitemud Formation, not less than 10 feet thick at Beechy, were not recovered in the Vermilion Hills, although they can be accommodated in the 22-foot "no recovery" interval immediately above the Eastend silts in the section of Structure Test Hole 168. Assuming these sandstones occupy the top 10 feet of this interval, the Eastend-Whitemud contact then would lie at a depth of 140 feet, and the Eastend Formation would have a thickness of 55 feet — less than one half the thickness of the formation in the Beechy section. Among a number of possible explanations of the discrepancy, two are more probable than the others. Firstly, since the Eastend Formation is not always readily identifiable on the Swift Current Plateau (its recognition being based on the predominantly brown tones of the sediments compared to the predominant grey of the Bearpaw sediments), some of the grey silts included in the Aquadell Member of the Bearpaw Formation in the Vermilion Hills may be a facies equivalent of the brown sands and silts in the lower part of the Eastend Formation at Beechy. Secondly, the variation in thickness may be due to a period of erosion prior to or during deposition of the Whitemud sediments. Disconformable contacts within the Whitemud Formation have been described from a number of localities in southern Saskatchewan (McLearn *in* Fraser *et al.,* 1935, p. 32-34, figs. 1, 2), and, in the Whitemud beds of the Vermilion Hills, the presence in some beds of granules and pebbles of foreign rock, suggests that at times the poorly consolidated sediments were subject to subaereal erosion or strong, subaqueous, current scour. Thus, it is quite possible that the feldspathic sandstones of the Whitemud Formation at Beechy are not basal, and that they rest disconformably on lower beds of the Eastend Formation.

In the South Saskatchewan River valley, as in the type area, the Eastend Formation records the transition from the open-sea environment of Bearpaw times to the river and pond environments under which Whitemud sediments accumulated. The presence of calcareous-walled foraminifers indicates that the lower beds of the Eastend Formation are marine, but the absence of marine fossils in the higher beds suggest they accumulated under conditions inimical to marine life.

STRATIGRAPHICAL PALAEONTOLOGY

Nature and occurrence of the fossils

The fauna of the Bearpaw Formation in the South Saskatchewan River valley is predominantly one of Foraminifera and Mollusca: the foraminifers are the subject of a complementary paper (Saskatchewan Research Council, Geology Division, Report 9), and most of the molluscs are listed by Warren (*in* Fraser *et al.,* 1935, p. 122-126). Moreover, Whiteaves (1885, p. 29-54; 1889, p. 151-196); Dowling (1917, p. 26-32), Williams (1930, p. 1-6); Landes (*in* Russell and Landes, 1940,

p. 132-181), Warren (1931, p. 157-163; 1934, p. 81-100; 1937, p. 2-3) and Douglas (1942, p. 60-64) have listed or described and illustrated most of the Bearpaw molluscs to be found in the southern plains of Alberta and Saskatchewan. Although parts of Warren's list now are in need of revision, the list, in combination with the available descriptions and illustrations, has resulted in the molluscs of the river valley for thirty years being infinitely better known than the sequence of sediments that contain them. Detailed restudy of the macrofossils has not been undertaken at this time, and the following remarks pertain only to those groups important in stratigraphical analysis or hitherto insufficiently stressed as components of the formational assemblage.

Most of the fossils in the Bearpaw Formation occur in close to wide-spaced, ovoid, layered concretions of limestone, sandy limestone, and clay-ironstone. Not all the concretions in any layer necessarily bear fossils: varying numbers of them can be barren. Concretions enclosing single sizeable fossils commonly reflect the shapes of their shelly cores. Those concretions carrying specimens of *Placenticeras,* for example, tend to have near-circular bedding-plane profiles, those carrying specimens of *Baculites* elongate-ovoid profiles.

Generally, the assemblage from any single concretionary layer is dominated by one or two species, which occur in profusion. Examples abound. Near the base of the type section of the Outlook Sand, limy concretions, seldom reaching a foot in length, are packed with the tiny *Corbula sprouli* Warren; overlying, somewhat larger, limy concretions contain nests of *Pteria linguaeformis* (Evans and Shumard); and, in the midst of the section, enormous concretions, up to 10 feet long, are barren in their limestone cores and carry only scattered bivalves in their sandy limestone peripheries. Close to the contact with the Matador Sand, the Broderick Clay contains concretionary ribs of sandy limestone in which the shells of *Oxytoma nebrascana* (Evans and Shumard) are profuse; and bedded limestone concretions, a few feet long, some with abundant randomly oriented *Arctica ovata* (Meek and Hayden), others with single specimens of *Placenticeras meeki* Boehm lying parallel to bedding and in the plane of the long axis of the concretion, weather prominently from the midst of the Matador sands themselves. At the base of the Ardkenneth Sand, concretions, similar in kind and size to those of the Matador Sand, carry *P. meeki, P. intercalare* Meek, and *Baculites compressus robinsoni* Cobban.

Many of the concretionary beds, rendered distinct by their fossil content, are valuable markers. They were used at some localities to reconstruct the detailed sequence from fragmentary, slumped outcrops, and at others, conversely, to assess the extent of slumping. Several layers of limestone concretions, each containing a different species of *Inoceramus,* are present in a limited section of the Snakebite Clay, and these were used to map the structures encountered in coring the diversion tunnels for the newly constructed Gardiner Dam (*fide* Mr. E. H. Frison).

Some concretionary layers contain not only a rich but a varied molluscan fauna. For example, low in the Outlook sands, limestone concretions yield small baculites, a host of different bivalves, gastropods, scaphopods, and some non-molluscan fossils, including chips of driftwood and the dismembered arms and oral disc of an ophioderm; and in the Snakebite clays, several concretionary beds house a comparably mixed molluscan fauna with, in addition, fairly common involute nautiloids, and, among the non-molluscan elements, linguloid brachiopods and calcareous worm tubes.

The molluscan faunas of other formations in the Upper Cretaceous Series of the Western Interior have a comparable mode of occurrence, but, despite this, there have been few attempts to explain it. Recently, Waage (1964, p. 544-562; 1967, p. 244-265) described the sequence of fossiliferous concretionary layers in the Fox Hills Formation of the type area in South Dakota, noted the general resemblance between the distribution of the fossil assemblages and that of modern, marine, benthonic assemblages, and attributed the mode of occurrence of the fossils to recurrent mass mortalities with relatively little disturbance by currents prior to burial. It was suggested tentatively that burial under conditions of excessive turbidity and reduced salinity, possibly brought about by repeated influxes of sediment-charged fresh waters from rivers in flood, may have caused the repeated exterminations. Such an hypothesis well might be applicable to the origin of the concretionary layers in the Bearpaw Formation of the South Saskatchewan River valley.

Environmental conditions

Various lines of evidence suggest that, at all times, the Bearpaw sea was shallow and that littoral-neritic conditions prevailed.

In terms of regional facies, the presence of sands, the products of both marine and non-marine environments, places the Bearpaw beds of the South Saskatchewan River valley in the "western facies belt" of Tourtelot (1962, p. 9)—a belt that corresponds to the zone of sedimentation nearest the western shoreline in which the waters were generally at their shallowest and in which the coarsest-grained terrigenous clastic sediments were deposited.

The sands locally exceed 100 feet in thickness, and all of them bear the stamp of deposition under near-shore, shallow-water conditions. At some localities they are uniform through several tens of feet — the run of the bedding betrayed only by rare thin ribs of concretionary ironstone — and the massive aspect of them points to rapid accumulation under an even rate of supply of the same kind of detritus. At others, they are cross-bedded, the fore-sets variable in their direction of dip and each group of them only a few feet in extent, suggesting that, at the time of deposition, these sands were caught in the grip of vagrant currents.

The wide transitional zone between the Matador and Oldman sands, near Saskatchewan Landing, suggests that there was no abrupt edge to the Oldman alluvial plain but that it was gently graded into the littoral and epineritic zones of the flanking sea-covered shelf, and the constant facies and fairly constant thickness of the thin Matador Sand over a relatively vast area indicate that these zones had great extent beyond the fringe of the alluvial plain.

Some beds of the Demaine Sand contain huge lenses of calcareous sandstone packed with the shells of sessile bivalves (*Pteria linguaeformis, Oxytoma nebrascana,* and small mytilids); others carry the tubular burrows of decapod crustaceans; others again, logs and branches riddled with the burrows of wood-boring bivalves. The preservation of the shells in the calcareous-sandstone lenses suggests that the shells were not transported any distance from their living sites before burial and probably represent only slightly displaced original shell beds. Similarly, the oyster bank, preserved high in the Demaine Sand near Herbert Ferry, probably developed on or near an original carpet of cemented shells growing in extremely shallow water. Beds containing a profusion of sessile bivalves are to be found also in the Outlook and Ardkenneth Sands.

While there can be no doubt that the waters covering the sea bed on which the sands accumulated were constantly stirred by current and wave action, apparently they seldom became sufficiently agitated or the substrate sufficiently hard to cause damage to the shells or to destroy them. Some damaged bivalves occur in a concretionary bed near the exposed base of the Outlook Sand, and the fact that many single valves occur at the same level in a remarkably varied assortment of bivalves, cephalopods, gastropods, scaphopods, ophioderms, and chips of wood suggests that the fossils of that locality represent a current-swept assemblage from the surrounding sea floor.

It is perhaps less easy to envisage the clays as a product of sedimentation under shallow-water conditions, but yet, if they accumulated in deeper waters than the sands, in all probability the increase in depth was negligible. The clays are anything but "pure" clays, and the great bulk of them contain a high proportion of silt. Even the Snakebite clays, which probably accumulated farthest from the shoreline, contain 35 to 45 per cent silt. Furthermore, beneath their thick weathering mantle, they are seen to be quite massive rocks, seldom showing any kind of marked lamination. They are not to be compared, therefore, to modern deep-sea muds. Much of the evidence cited by Gill and Cobban (1966, p. A37-A43) in support of a shallow-water origin for the Pierre argillaceous rocks of the Red Bird section in Wyoming is applicable also to the clay members of the Bearpaw Formation in the South Saskatchewan River valley. A rich, benthonic, molluscan fauna, which must have lived under well-aerated bottom conditions, is present in most of the members. Among the bivalves, *Inoceramus* is most common, and the largest specimens (with hinge line a foot or more in length) are found in the Snakebite Clay. As Gill and Cobban point out, present-day bivalves, comparable in size to *Inoceramus,* are not found in deep water. Pyriporoid and membraniporoid bryozoans have been found inside the living chambers of specimens of *Baculites reesidei* Elias from the Snakebite Clay, and, by analogy with living forms, these suggest that the sea bed was at no great depth. Corroborating evidence derives from other specimens of *B. reesidei* which carry abundant unglauconitized faecal pellets in their living chambers (compare Gill and Cobban, *op. cit.,* p. A38, pl. 7; Moore, 1939, p. 521).

Periodically, during deposition of the clays, the sea bed must have been swept strongly by currents and the sediments and shelled organisms living there considerably disturbed. Few of the bentonite seams have sharp contacts and many of them are no more than discontinuous streaks and traces. This suggests that settling of the volcanic ash on the sea bed was disrupted by bottom turbulence and some of the bentonite disseminated through subsequently deposited clays. The most consistent and "purest" of the bentonites are the seams in the Bentonite-Calcite Zone of the Snakebite Member. Some concretions in the Snakebite Clay at the type locality contain a rich and varied molluscan fauna, and specimens of *B. reesidei* in this fauna carry other smaller baculites, bivalves, gastropods, scaphopods, and wood chips in their living chambers. Other concretions in the Snakebite Clay near the Gardiner Dam seem to have been built around a nucleus of randomly oriented, single, inoceramid valves.

Although the evidence of the sediments and the fossils strongly supports a shallow-water origin for the Bearpaw Formation of the South Saskatchewan River valley, none of it gives a direct indication of what the water depths might have been. Most workers believe that the waters were extremely shallow over thousands of square miles of the Western Interior in Late Cretaceous time (Gill and Cobban, *ibid.)* and favour a littoral-epineritic environment for the marine sediments within the confines of Tourtelot's "western facies belt." Considering the local and regional evidence, a depth range between zero and 150 feet for the Bearpaw sea of the South Saskatchewan River valley seems most reasonable.

Gill and Cobban (*op. cit.,* p. A39-A41) have concluded from the dissolution of molluscan shells that the waters of the interior seaway, at least as far south as northern New Mexico and as far north as southern Saskatchewan, had a low pH value as a result of regional acidification. Baculites both from the South Saskatchewan River valley and from the Cypress Hills show some of the dissolution effects described.

Assemblage zones

Cobban's baculite zones for the Bearpaw Formation and equivalent rocks of the Western Interior (see, for example, Cobban, 1962a and b) represent the ultimate refinement in zonal stratigraphy, but recognition of his indices and application of his zonal scheme to full advantage requires that the sedimentary column be developed continuously in baculite-bearing facies and sufficiently well exposed to permit sequential collection of the zonal indices. In the South Saskatchewan River valley, the baculite-bearing sequence is poorly exposed at the base, to some extent replaced by scaphite-bearing clays in the middle, and poorly exposed again toward the top, so that baculites were obtained from only about half of the formation. Although baculites are the most recurrent of the suitable zone fossils in the southern Canadian plains, it is perhaps their patchy distribution in most sections that has led various authors to attempt to formulate a series of faunal assemblages, generally broader in their application, to distinguish parts of the Bearpaw section in Canada.

Warren (*in* Fraser *et al.*, 1935, p. 21-22) called the Bearpaw Formation a sequence of marine shales bearing ". . . the *Scaphites nodosus* or *Inoceramus barabini* fauna," and, beyond noting that "*Placenticeras* [*intercalare* and *P. meeki*] and *Arctica* [*ovata*] were obtained mostly in the basal, and *Scaphites* [*(Hoploscaphites) albertensis* Warren, *S. (H.) brevis* (Meek), *S. (H.) nodosus* (Owen), *S. (H.) quadrangularis* (Meek and Hayden), and *S. (H.) plenus* (Meek and Hayden)] in the upper beds," could find no "definite zoning of the fossils."

In describing the fossils of the formation in the southern Alberta plains, Landes *(in* Russell and Landes, 1940, p. 185-186) established the *Baculites compressus* and *Inoceramus fibrosus* Zones, coincident with the Bearpaw and Eastend Formations, noting however, that, farther east in Saskatchewan, where the Bearpaw-Eastend contact lies at a higher stratigraphical level, the *Inoceramus fibrosus* fauna could occur in the Bearpaw Formation. Landes agreed with Warren that scaphites occur in the upper part but found the other common ammonites, *Baculites compressus* Say, *Placenticeras intercalare,* and *P. meeki,* to range throughout the Bearpaw Formation.

Synthesizing all published information on faunal distribution in the Bearpaw Formation of the southern Canadian plains and interpreting it in the light of distribution of the same and similar faunal elements in the United States and Europe, Jeletzky (1968, p. 46-55) proposed a much more detailed zonal scheme for the Bearpaw and equivalent beds. He adopted Landes' *Baculites compressus* Zone but indicated that it could be divided (from base to top) into an unnamed zone K, distinguished by the common occurence of *Arctica ovata* and an extreme rarity of members of the *Scaphites nodusus* species group, a *Scaphites nodosus* and *Rhaeboceras* spp. Zone, and a *Scaphites quadrangularis* and *Scaphites brevis* Zone. Recognizing, as had Landes (*op. cit.,* p. 185) and Cobban and Reeside (1952, p. 1019-1020), that *Inoceramus barabini* Morton ranged beyond the limits of the *B. compressus* Zone, he rejected it as a reliable index of that zone and, accordingly, of the Bearpaw Formation. Jeletzky accepted also Landes' *Inoceramus fibrosus* Zone but, on the basis that the *Discoscaphites abyssinus* (Morton), described by Landes from his *I. fibrosus* Zone, actually belongs to *Scaphites (Hoploscaphites) constrictus* Sowerby *sensu lato* (see Jeletzky *in* Cobban and Reeside, 1952, p. 1027), emended the zonal designation to the *Scaphites constrictus* and *Inoceramus fibrosus* Zone. Finally, he accepted Cobban and Reeside's (*op. cit.,* p. 1020) *Baculites grandis* Zone, and to these last two zones, he believed the higher beds of the Bearpaw Formation should be referred. The *B. compressus* Zone, with its three divisional zones, and the *S. constrictus* - *I. fibrosus* Zone, as adopted by Jeletzky, correspond approximately to the *B. compressus* Zone, with its proposed five subzones, and the *Baculites baculus* Zone respectively of Cobban and Reeside's *(op. cit.,* p. 1020-1022) sequence in the United States.

Interpreting the Bearpaw sequence in the South Saskatchewan River valley in terms of Jeletzky's zones is not altogether easy, and discrimination of his *S. quadrangularis* - *S. brevis* and *S. constrictus* - *I. fibrosus* Zones in particular is beset with difficulties. Jeletzky (*in* Cobban and Reeside, *op. cit.,* p. 1026-1028) himself stressed an insufficiency of reliable information on the precise ranges of these important scaphite species and noted that ". . . such species of the *B. compressus* Zone as *Scaphites (Scaphites) quadrangularis* Meek, *Scaphites (Scaphites) brevis* Meek and apparently *Scaphites (Scaphites) elegans* Tate appear to ascend into the zone of *B. baculus* and to occur there together with *S. (S.) plenus* Meek and *S. (H.) pungens* Binckhorst through an uncertain part of this zone. This appears to be true of the middle part of the Bearpaw formation in Canada, including the Belanger member [of the Cypress Hills] . . ." Dr. W. A. Cobban *(in litt.)* supports Jeletzky's suspicions by identifying two specimens of *S. (H.) quadrangularis* and two of *S. (H.)* sp. (as yet unnamed) from the Aquadell Clay of Snakebite Creek and indicating that these specimens probably were derived from beds of the *B. baculus* Zone. Moreover, he has identified *S. (H.) plenus* from the highest Snakebite Clay exposed at the Gardiner dam (probably the Zone of *Baculites eliasi* Cobban) and indicated that this species ranges through the Zones of *B. eliasi* and *B. baculus:* that is to say, *S. (H.) plenus* extends as low as the highest beds of the *B. compressus* Zone in the sense of Jeletzky. It is clear, however, that the entire section from (at least) the base of the Outlook Sand to the top of the Ardkenneth Sand and including also the basal 80 feet of the overlying Snakebite Clay fall within the unnamed zone, the succeeding 150 feet of the Snakebite beds belong to the *S. nodosus* and *Rhaeboceras* spp. Zone, and not much more than the remainder of the Snakebite Clay to the *S. quadrangularis* and *S. brevis* Zone. The Cruikshank Sand and Aquadell Clay probably fall within the *Scaphites constrictus* and *Inoceramus fibrosus,* and the *Baculites grandis* Zones.

Considering the sequence only in the South Saskatchewan River valley, it is immediately evident that two broad assemblages are recognizable based on the distribution of contrasted ammonite groups. The division between them lies some 100 feet above the base of the Snakebite Clay, the level at which baculites and placenticeratids disappear in upward sequence and their place is taken by scaphites. A number of bivalves are confined to the *Baculites - Placenticeras* assemblage and these include *Arctica ovata, Pteria linguaeformis* (Evans and Shumard), *Protocardia borealis* Whiteaves, *Ostrea patina* Meek and Hayden, and *O.* cf. *glabra* Meek and Hayden. Some boreal elements are contained in this fauna. Dr. W. A. Cobban *(in litt.)* informs me that *Arctica ovata* and *Protocardia borealis* are two such elements: the former, known widely from Alberta and Saskatchewan, can be traced southward only along the west side of the Sweetgrass Arch in western Montana, and the latter is not known south of Fort Peck in northeastern Montana. Moreover, these bivalves commonly occur in association with *Baculites compressus robinsoni,* the northern subspecies indicative of the *B. compressus* Zone *(sensu* Cobban, 1958b, p. 116 and later papers) in the northern Great Plains. Apart from the various species of *Scaphites (Hoploscaphites)* in the *S. (H.)* assemblage of the higher beds, few elements are restricted to this fauna. The scaphites are associated with the nautilicone, *Eutrephoceras dekayi* (Morton), a variety of inoceramids, gastropods, including *Anisomyon centrale* Meek (for range, see Sohl, 1967, p. B40) and *Drepanochilus,* and scaphopods.

Baculite range zones

Between thirty and forty zones have been established in the Upper Cretaceous Series of the Western Interior of North America (see Cobban, 1958a, p. 114, 116-119 for a convenient synopsis of the zones established to that year), and the bulk of these are range zones of baculite and scaphite ammonites. The Upper Campanian and Lower Maestrichtian beds, which include those of the Bearpaw Formation, are divided into eighteen zones almost exclusively on baculites, which, in Cobban's hands, have proved to be most reliable and sensitive stratigraphical indices (see Cobban, 1951; 1958a,b; 1962a,b; Scott and Cobban, 1965; Gill and Cobban, 1966).

Older records of baculites from the Bearpaw Formation suggest that comparatively few species are present, most of the specimens recovered having been referred to *Baculites compressus* Say, a few to *B. grandis* Hall and Meek. Prior to 1952, *B. compressus* was interpreted broadly and, consequently, accorded a considerable time range. But, in that year, Cobban and Reeside (p. 1020-1022) pointed out that this species included five distinct forms, which regularly succeed one another in upward stratigraphical sequence and could be used to designate subzones of the *B. compressus* Zone. These forms they recognized as *B. pseudovatus* Elias, *B. compressus* var. *corrugatus* Elias, *B. compressus sensu stricto, B. compressus* var. *reesidei* Elias, and "an unnamed form with stout cross-section and smooth venter." Cobban (1958a, p. 114-117) regarded these forms as distinct species and, later that year (1958b, p. 663-664), he named the last form *B. eliasi* and index of a zone of that name lying between the Zones of *B. compressus sensu lato* and *B. grandis*. In 1962(b), he further restricted *B. compressus,* renamed *B. compressus* var. *ornatus* Robinson *B. compressus robinsoni,* a northern subspecies of *B. compressus sensu stricto*, and named three forms, formerly included in *B. compressus sensu lato,* as the new species *B. rugosus, B. cuneatus,* and *B. jenseni.* He thereby established the baculite zonal scheme for the Bearpaw and equivalent rocks that is accepted and used today. Certain older publications suggest also that some large specimens of *B. compressus sensu lato* and of *B. baculus* Meek and Hayden were misidentified as *B. grandis.*

It is known now that at least half a dozen baculite species occur in the Bearpaw Formation of the South Saskatchewan River valley, and the probability is that several others, not yet recovered, are present in the poorly exposed lowest and highest beds. The bulk of the baculites that have been found belong to the *Baculites compressus-cuneatus-reesidei* lineage. *B. reesidei* can be distinguished readily from the other two by having smooth flanks at diameters of less than 50 mm. and by having a distinctive narrow cross-section and a common ventrolateral depression between diameters of 30 and 50 mm. *B. compressus robinsoni* and *B. cuneatus* are much more alike, especially at the neanic growth stages. At diameters of 30 to 40 mm., however, specimens of *B. compressus robinsoni* commonly have ribbed flanks, whereas those of *B. cuneatus* are smooth, and, at the ephebic stage, *B. cuneatus* has an inflated triangular cross-section, whereas *B. compressus robinsoni* tends to be more compressed with a somewhat broader venter. A number of baculites, found at various localities in beds ranging from the Outlook to the Demaine Sands, apparently are new: they have simple sutures and do not fall within the *B. compressus-cuneatus-reesidei* lineage.

The Bearpaw Formation in the Powder River Basin of southeastern Montana spans the Zones of *Baculites pseudovatus* to *Baculites grandis* (Cobban, 1958a, p. 117), and farther north, at Porcupine Dome and Fort Peck, it ranges from the Zone of *Didymoceras nebrascense* (Meek and Hayden) to that of *B. grandis* (Drs. W. A. Cobban and J. R. Gill *in litt.;* Jensen and Varnes, 1964, p. F8-F10 respectively). Although the lowest and highest beds in the South Saskatchewan River valley have yielded only scattered fragmentary ammonite remains, insufficient to determine the detailed zonal sequence, it is probable that the formation has a comparable zonal range to that in eastern Montana. The following zones (oldest to youngest) either have been identified positively or, if preceded by a question mark, are thought likely to be present: (?)*Didymoceras stevensoni* (Whitfield), *Exiteloceras jenneyi* (Whitfield), (?)*Didymoceras cheyennense* (Meek and Hayden), *Baculites compressus* Say, *Baculites cuneatus* Cobban, *Baculites reesidei* Elias, *(?)Baculites jenseni* Cobban, *(?)Baculites eliasi* Cobban, *Baculites baculus* Meek and Hayden, and *(?)Baculites grandis* Hall and Meek.

No fossils have been recovered from the basal unnamed member of the Bearpaw Formation.

From a series of stratified concretions, low in the type section of the Outlook Member and containing a mixed assemblage of mainly bivalves, gastropods, and scaphopods, a few consistently small baculite fragments have been recovered. These remains, probably all juvenile forms, are doubtfully identifiable to species.

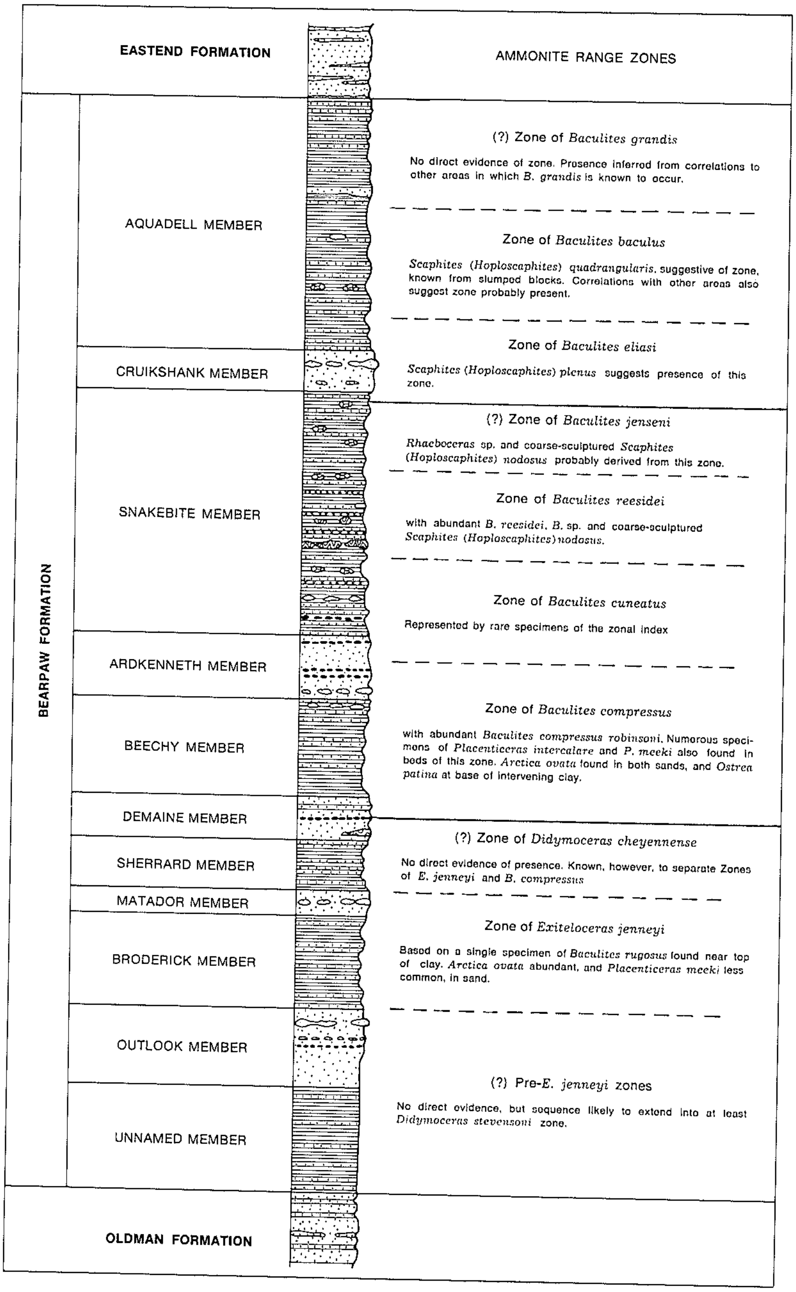
From the highest silty beds of the Broderick Clay, exposed beneath the type section of the Matador Sand, the lowest positively identifiable baculite species was obtained — a single specimen of *Baculites rugosus,* indicative of the Zone of *Exiteloceras jenneyi.* This specimen was not found in place but probably was little removed from its original stratigraphical position. Concretions containing *B. compressus robinsoni* occur in the upper Demaine Sand, so that the intervening Zone of *Didymoceras cheyennense* (with *B. corrugatus),* assuming it is developed, must fall within the Matador, Sherrard, and lower Demaine Members. It is reasonable to suppose, therefore, that the single specimen of *B. rugosus* came either from the highest beds of the Broderick Clay or from the Matador Sand and that the Sherrard Clay and lower Demaine Sand should yield *B. corrugatus* or some other index of the *D. cheyennense* Zone.

The *B. compressus* Zone, represented by the northern subspecies *B. compressus robinsoni,* is marked by the occurrence of many specimens in concretionary layers in the Demaine, Beechy, and Ardkenneth Members. This zone spans at least 150 feet of beds, which include the upper 25 feet of the Demaine, all of the Beechy, and the lower 20 feet of the Ardkenneth Members as these are developed in type section. Robinson (1945, p. 52) described his *B. compressus* var. *ornatus* (because of preoccupation of the name *ornatus* renamed *B. compressus robinsoni)* as being most common in the basal beds of the Bearpaw Formation in southern Saskatchewan. The "holotype" was collected from a sandstone about 150 feet above the base in Little Boxelder Creek, on the northern side of the Cypress Hills. In all probability, this sandstone is the "lower *Arctica ovata* sand" of Furnival (1946, p. 43, 48), a prominent marker in the Manyberries Member and probable correlative of the Demaine Sand in the sequence of the South Saskatchewan River valley, a sand that, in its upper part, also carries *B. compressus robinsoni.* The Demaine Sand lies more than 400 feet above the base of the Bearpaw Formation in the river valley and the base rises diachronously westward toward the Cypress Hills. Thus distribution of this species in the basal beds probably is valid only for the type area of the Cypress Hills and not for all of the southern part of the province.

No fossils were found in the main body of the Ardkenneth Sand at the type locality, but bedded concretions near the top contain *B. cuneatus.* Specimens of this species, however, are rare. The *B. cuneatus* Zone may span the higher beds of the Ardkenneth and the lower beds of the overlying Snakebite Clay, as the succeeding baculite index, *B. reesidei,* does not appear in the 80 feet above the contact between the members.

Like the *B. compressus* Zone, that of *B. reesidei* is strongly represented by many specimens and these occur in close-spaced concretionary layers through more than 50 feet of beds. Some of the specimens show clearly that, prior to burial of the shells, pyriporoid and membraniporoid bryozoans lived inside the chambers, and others carry concentrations of faecal pellets.

Evidence for the sequence of baculite zones above that of *B. reesidei* is fragmentary. At Snakebite Creek, the last of the baculites occurs about 135 feet above the contact between the Ardkenneth Sand and the Snakebite Clay and between 10 and 20 feet above the highest unequivocal *B. reesidei.* These highest specimens are preserved in clay-ironstone concretions and are badly crushed, but the suture line is clearly of pre-*baculus* type and presence of lateral ribs eliminates *B. eliasi* as a possible species. The specimens, therefore, belong either to *B. reesidei* or *B. jenseni,* and this is supported by their occurrence with coarsely sculptured scaphites referable to *Scaphites (Hoploscaphites) nodosus* Owen. Scaphites belonging to this species (including many juvenile forms) recur between 225 feet and 235 feet above the Ardkenneth contact and, at 235 feet, they were found associated with a juvenile specimen of *Rhaeboceras* sp., again indicating a position within the *B. reesidei-B. jenseni* Zones.



Text-figure 16: Columnar section of the Bearpaw Formation in the South Saskatchewan River valley showing the probable sequence of ammonite range zones that it spans. Few of the boundaries between the range zones can be drawn with any certainty: the position of the base of the *Baculites compressus* Zone is known fairly accurately, and there is little doubt about the position of the boundary between the *B. reesidei-jenseni* and the *B. eliasi-baculus* Zones. The other zonal boundaries are selected arbitrarily (and denoted by broken lines), and no great credence should be attached to the positions selected. Some of the evidence, upon which the identification of the zones is based, is given, and for some of the zones, fossils of common occurrence, other than the zonal indices, are mentioned.

To the northeast, around Riverhurst, lower beds of the Snakebite Clay, containing *B. reesidei,* and higher beds, containing *S. (H.) nodosus,* crop out patchily on the river banks, and the gentle southwesterly dip brings the lower *reesidei*-bearing clays, resting on the upper Ardkenneth sands, to the surface at the Elbow. Higher beds of the Snakebite Clay, together with the overlying Cruikshank Sand, occupy the core of a local syncline in the vicinity of the Gardiner Dam. At the dam site, the highest Snakebite beds have yielded an extremely well-preserved but fragmentary specimen of *S. (H.) plenus,* and this scaphite ranges through the Zones of *B. eliasi* and *B. baculus.* Since Snakebite Creek and the dam site lie only 35 miles apart and more or less on the depositional strike, diachronism between the two localities is unlikely, and the top of the Snakebite Clay at the type locality is assumed also to fall not lower than the *B. eliasi* Zone.

Although there is no direct evidence, the probability is that the bulk of the Aquadell Member falls into the Zones of *B. baculus* and *B. grandis.* From concretions in a slumped block of silty clays high in Snakebite Creek, two specimens of *S. (H.) quadrangularis* and two of *S. (H.)* sp. (as yet unnamed) were obtained, and this collection probably was derived from beds of the *B. baculus* Zone. Much of the Aquadell Clay undoubtedly is preserved in the upper reaches of Snakebite Creek, but the negligible exposure prevents the stratigraphical position being determined with any certainty, and the silty clays of this member are not in themselves easily distinguished from similar clays beneath. Alternatively, this and other blocks of the Aquadell Clay well may have slumped into the creek prior to removal of much of the member by pre-Pleistocene erosion. Moreover, lithostratigraphical correlation through the subsurface shows that the Cruikshank Sand can be equated with beds occupying an interval about the base of the Oxarart Sand of the Cypress Hills (see Furnival, 1941, p. 60, 63; 1946, p. 42 ff.; Russell, 1948, p. 11 ff.)—possibly the Black Eagle Sand of Russell (*op. cit.,* p. 20, 58), possibly part of the Oxarart Sand itself. Overlying the Oxarart, the Belanger Sand contains *B. baculus* and, in all likelihood, correlates with lower beds of the Aquadell Clay. Overlying the Belanger Sand in the Cypress Hills, the Thelma Sand and Medicine Lodge Clay are probably correlatives of upper beds of the Aquadell Clay in the South Saskatchewan River valley, and these beds of the Cypress Hills sequence are known to lie at least in part in the Zone of *B. grandis* (Gill and Cobban, 1966, p. A36).

Rare invertebrates

Waage (1965) recently has redescribed the Late Cretaceous coleoid *Actinosepia canadensis* Whiteaves, which occurs in the Late Campanian and Maestrichtian rocks of the northern Great Plains, both in Canada and the United States. Initially the species was recorded by Whiteaves (1897, p. 459) ". . . from the Montana or Pierre-Fox Hills formation of the Later North American Cretaceous, at the South Saskatchewan, opposite the mouth of Swift Current Creek." Waage (p. 5) concluded correctly that the four specimens, upon which Whiteaves based his species, were recovered from beds in the Bearpaw Formation but was unable to date the beds more precisely than to suggest a probable Campanian age. Opposite the mouth of Swiftcurrent Creek, the Matador and Demaine Sands crop out prominently, and numerous molluscs can be collected from bedded concretions developed within them. Whiteaves' specimens were entombed in ". . . a fine-grained, glauconitic sandstone firmly held together on the underside of the specimens by ferruginous cement," which suggests that it was the Demaine rather than the Matador Sand that yielded the original specimens. It is almost certain, therefore, that the holotype and paratypes of *A. canadensis* came from beds not older than those of the *Exiteloceras jenneyi (Baculites rugosus)* Zone and not younger than those of the *Baculites compressus robinsoni* Zone (see p. 25, 70) and likely that they belong to the younger of these two zones.

Landes (*in* Russell and Landes, 1940, p. 180-181) reported three specimens of *A. canadensis* from 290 feet above the base of the Manyberries Member of the

Bearpaw Formation at Manyberries (Russell *in* Russell and Landes, *op. cit.,* p. 76; Lines, 1963, p. 213-215). As Waage *(op. cit.,* p. 5) pointed out, Russell *(op. cit.,* p. 81) listed *Placenticeras meeki, P. intercalare,* and *Baculites compressus* from the part of the section in which the coleoid was found, and Landes *(op. cit.,* p. 173) listed *B. crickmayi* from these same beds. Almost certainly Landes' identification of *B. crickmayi* (indicating the Zone of *Didymoceras stevensoni)* is in error. The base of the Bearpaw Formation rises diachronously to the west, and, at Manyberries, it probably lies in the Zone of *B. compressus robinsoni* — a zone that in the Cypress Hills and to the west of the Sweetgrass Arch seems to span a much thicker sequence of beds than in the South Saskatchewan River valley. Footage above the base, associated fossils, and correlation to adjacent sections suggest strongly that the *Actinosepia*-bearing concretions lie in the *B. compressus robinsoni* Zone, close to the boundary with the overlying *B. cuneatus* Zone.

Jensen and Varnes (1964, p. F9) recorded *A. canadensis* from younger beds with *Scaphites (Hoploscaphites) brevis, S. (H.) plenus,* and *S. (H.) quadrangularis,* near the top of the Bearpaw Formation in the Fort Peck area of Montana.

Thus, although the Canadian specimens are the oldest in the Late Campanian-Maestrichtian range of *A. canadensis,* the specimens are almost certainly not as old as has been supposed.

Another unusual mollusc from the Bearpaw Formation of the South Saskatchewan River valley — the rudist *Ichthyosarcolites* cf. *coraloidea* (Hall and Meek)— was described by Caldwell and Evans (1963), but, at that time, the locality from which the specimen was obtained could not be described in terms of the stratigraphical succession known today. It is known now that the specimen came from a layer of bedded concretions, 10 feet above the base of the type section of the Matador Sand, and 36 feet above the exposed base and approximately 300 feet above the true base of the formation. The part of the Matador Sand that contains the bedded concretions possibly falls within the Zone of *Exiteloceras jenneyi* (represented by *Baculites rugosus).*

Since the Saskatchewan rudist was described, Dr. H. J. MacGillavry of the University of Amsterdam kindly has pointed out *(in litt.)* that the discussion of its generic affinity failed to take cognizance of his (1937, p. 46-59) extensive revision of *Ichthyosarcolites* Desmarest, 1812 and his comments on *I. coraloidea* (Hall and Meek) from Nebraska. MacGillavry (p. 47-53) presented a valuable annotated bibliography of *Ichthyosarcolites* and compiled from the literature a concise description ("Diagnosis" of p. 54-56), drawing together the important features of the shells that various authors have referred to Desmarest's genus. Discussing *I.* (formerly *Caprinella) coraloidea* from Nebraska, to which the Saskatchewan rudist is compared, MacGillavry (p. 57) conceded that the species is insufficiently known but stressed that, since the prisms of the shell around the body chamber are tabulated, the species does not belong to Desmarest's genus. He added that, if the prismatic tabulae, vague in the original illustrations, should prove to be of the type that are arranged independently from prism to prism, the Nebraskan rudist probably is a radiolitinid, if, on the other hand, they are arranged in "funnel-plates," it is related to the trechmanellinids. MacGillavry well may be correct in claiming that Hall and Meek's rudist (and so, by implication, the closely similar form found in the South Saskatchewan River valley) should be excluded from *Ichthyosarcolites,* but, until the original specimen or type species is re-described and the distinctive attributes of the genus exposed, it seems acceptable to allow the designation used by Hall and Meek to stand (see Caldwell and Evans, *op. cit.,* p. 616).

Among the rare invertebrates, the most notable non-molluscan element is the wellerellid rhynchonellacean *Hesperorhynchia superba* Warren, which he (1937, p. 2-3) described new from the Bearpaw Formation of the South Saskatchewan River valley, near Riverhurst. Two specimens, obtained by the late Professor F. H. Edmunds from the original group (the only specimens ever found in Saskatchewan), display all the diagnostic features (*ibid.;* Ager, 1965, p. H608) and, except for a denser costation in what is interpreted to be a a mature individual, agree closely with Warren's description. These topotypes now are housed in the Geological Museum of the University of Saskatchewan.

The specimens were collected from a loose concretion on the bank of the river in Section 33-22-7W3 — a locality underlain by Snakebite Clay. But the concretion was composed of sandy material and contained *Oxytoma nebrascana* and "other Cretaceous species" (Warren, *op. cit.,* p.1) and thus, since neither sands nor sandy concretions have been found in the Snakebite Clay and *Oxytoma nebrascana* is uncommon in the the *Scaphites (Hoploscaphites)* fauna of the Snakebite and higher members, it is unlikely that the concretion originated in the Snakebite Clay. More probably the concretion was transported downstream from the outcrops of the Matador and Demaine Sands in the Herbert Ferry district (the Matador being particularly rich in *Oxytoma nebrascana)* and, if so, *Hesperorhynchia superba* is of Late Campanian *(Exiteloceras jenneyi* to *Baculites compressus robinsoni*) age. It is to be noted, however, that Dr. W. A. Cobban has identified *Hesperorhynchia superba* in beds not older than the highest Snakebite Clay in the Fort Peck area of Montana (Jensen and Varnes, 1964, p. F10). The beds at Fort Peck contain *Baculites compressus (sensu lato), Scaphites (Hoploscaphites) brevis, S. (H.) nodosus, S. (H.) plenus, Solenoceras mortoni* (Meek and Hayden) and *Oxytoma nebrascana* — an assemblage suggestive of the Zone of *Baculites eliasi.*

Vertebrates

Bearpaw vertebrates are sufficiently distinctive and occur in sufficient numbers to establish an assemblage characteristic of the formation and its equivalents, and study of this assemblage in the South Saskatchewan River valley is being undertaken jointly by the National Museum of Canada and the Saskatchewan Museum of Natural History (Mr. B. A. McCorquodale, *in litt.).*

There is little doubt that the sub-Snakebite sediments were deposited under agitated, shallow-water (and possibly, at times, brackish and turbid-water) conditions, similar to (if not in fact) those of a near-shore zone, and the Snakebite sediments under quieter, probably somewhat deeper-water conditions, such as prevail in offshore zones. The vertebrate remains tend to support such contrasted environments, the fossils of the sub-Snakebite clays and sands being notably incomplete and fragmentary, those of the Snakebite and Aquadell Clays being not only more complete but commonly articulated.

Plesiosaur and mosasaur remains, more or less mutually exclusive in stratigraphical distribution, are the most common fossils, plesiosaurs being dominant in the sequence between the Broderick and Beechy Members and mosasaurs in the Snakebite and Aquadell Members. No vertebrate remains of note have been found in the Ardkenneth and Cruikshank Members. The plesiosaur and mosasaur localities occur in adjacent but distinct geographical areas lying east and west of a line approximately coincident with the boundary between Ranges 10 and 11, west of the third meridian. Among the rich exposures west of the Missouri Coteau, plesiosaurs have been found mainly between Saskatchewan Landing and Herbert Ferry, mosasaurs between Herbert Ferry and Riverhurst. But since these tracts correspond to the main outcrop belts of the Broderick to Beechy and Snakebite to Aquadell Members respectively (text-fig. 6), it is difficult to ascertain to what extent geographical distribution is controlled by stratigraphical distribution and to what extent it reflects varying environmental conditions controlled by distance from the western shore. Probably the distribution of the vertebrates within the studied segment of the river valley is a function of both factors, because preservation within the Snakebite Clay alone suggests increasingly quieter conditions, governed by increasing water depth, from west to east.

Among the discoveries of vertebrate remains, that of a large hadrosaur a little above the middle of the Snakebite Clay in the type area is exceptional insofar as the hadrosaur occurs in beds least likely to preserve such remains. More than any other member in the Bearpaw sequence, the Snakebite Clay marks a time of open-sea conditions in the South Saskatchewan River valley and far beyond. The western shoreline probably lay close to the present-day Rocky Mountain foothills, certainly to the west of the Sweetgrass Arch, and the northern shoreline probably was comparably distant. Land, in other directions, was even more remote. It can be inferred only that the hadrosaur carcass — perhaps bloated, and ravaged by sea-dwelling carnivores (for certain parts are missing) — drifted well over a hundred miles before finally settling on the sea bed. A few comparable occurrences are known from the United States. Lull and Wright (1942, p. 24-25, 27, 134-138) redescribed *Claosaurus agilis* Marsh from the Niobrara Formation, near the Smoky Hill River of Kansas and *"Claosaurus affinis"* Wieland from the Pierre Formation near the Black Hills of South Dakota. It is stressed that their occurrence in these sequences of open-sea sediments is thoroughly atypical and assumed that the individuals, dead or moribund, were carried out to sea by powerful river currents. From its stratigraphical position, the Saskatchewan hadrosaur can be concluded to be of Late Campanian age (*Baculites reesidei-jenseni* Zones).

Fish remains are rare in the Bearpaw Formation. Sharks' teeth have been recovered from the *Pteria*-bearing sandstones of pre-Beechy age cropping out in the Big Horse Butte inlier, near Riverhurst, and single skeletal elements, mostly vertebrae of bony fishes, in the Snakebite and underlying clays.

Wood

Remarkably well-preserved wood occurs at various localities throughout the Bearpaw outcrop belt. All sizes of fragments from logs, several feet long and little more than a foot in diameter, to twigs, comparably proportioned in inches, are buried in the sands, and most notably in the Demaine Sand. Only twigs are found in the clays, particularly in the Snakebite Clay, where they occur with molluscs in some of the bedded limestone concretions. Undoubtedly the wood was derived from the western landmass and carried by streams to the sea. The twigs alone could have been borne by feeble streams and drifted some considerable distance from the shore before coming to lie on the muddy sea bed: the logs and other assorted fragments are more likely to have been been transported by stronger streams, charged with sandy sediment, and been trapped in this sediment at no great distance from the shore. When settled on the sea bed, many of the logs became inhabited by the wood-boring bivalve *Martesia,* some of which died and became entombed in their burrows. Most of the sinuous, cylindrical burrows are filled with sediment, commonly that of the host bed, less commonly different in colour and grain size from that of the host, suggesting that some of the logs were buried (partly or wholly), exhumed, transported farther, and reburied.

Some specimens of the wood are lignitic, others are calcareous petrifactions; growth rings are conspicuous in all specimens; and many are preserved with the bark intact. When demineralized, imbedded in celloidin, and sectioned by microtome to a thickness of 20 microns, the lignite reveals considerable detail of the microscopic structure, and the same is true of the petrified material, when sectioned to a comparable thickness using the standard technique for rock sections. The wood is pycnoxylic. Bordered pits are circular and confined to the radial walls of the tracheids; rays commonly are uniseriate, rarely biseriate; wood parenchyma is present, diffuse in some specimens, concentrated on the face of the late wood in others; and neither crassulae nor tori are visible. These factors indicate clearly that the wood is of conifer-type, and in all probability the specimens belong to the Coniferales. It is notable that conifers are dominant among the fossil plants also in the Judith River Formation of Montana (Knowlton, 1905, p. 154).

AGE SPAN OF THE FORMATION AND ITS IMPLICATIONS

Bearpaw ammonites from the South Saskatchewan River valley indicate that the base of the formation lies at least as low as the Zone of *Exiteloceras jenneyi*, the top at least as high as the Zone of *Baculites baculus*, and there are grounds for considering a range between a pre-*E. jenneyi Zone* (perhaps the Zone of *Didymoceras stevensoni*) and the Zone of *Baculites grandis*. Accepting Jeletzky's positioning of the Campanian-Maestrichtian boundary at the base of the *B. baculus* Zone (see *in* Cobban and Reeside, 1952, p. 1026-1028), the relative age span of the Bearpaw Formation is then from Late Campanian to Early Maestrichtian.

As Gill and Cobban (1966, p. A34-A37) have shown by their study of the Pierre Shale at Red Bird in Wyoming, an absolute age span of any Late Cretaceous formation carrying a number of ammonite zonal indices can be appraised by relating the ammonite zones to evaluated dates obtained from the potassium-argon chronometer. Gill and Cobban (*op. cit.*, Table 2), using dates determined by Folinsbee, Baadsgaard, and Lipson (1961, p. 355) and Folinsbee, Baadsgaard and Cumming (1963, p. 75-77) from bentonites in the southern Canadian plains, concluded the *D. stevensoni* and *E. jenneyi* beds to be 74 to 75 million years old and the *B. baculus* and *B. grandis* beds to be 70 to 71 million years old and so, by their calculations, the Bearpaw Formation at maximum development in the South Saskatchewan River valley probably has an absolute age span of 4.5 million years (from 70 to 74.5 million years). Folinsbee and his co-workers (*in* Baadsgaard *et al.*, 1964, p. 29) suggested an average date of 72 + 3 million years for the base of the Bearpaw Formation in the Lethbridge district of the southern Alberta plains. Various lines of evidence indicate that, over these plains, the base of the Bearpaw Formation approaches an isochronous surface and lies in the Zone of *Baculites compressus robinsoni*, so that Gill and Cobban's estimated date of 73 million years for this zone is reasonably in keeping also with this further age determination.

Two other dates, determined still more recently by Folinsbee and his co-workers for the Bearpaw beds of the South Saskatchewan River valley, can be reconciled much less easily with dates of longer standing and thus with Gill and Cobban's estimated scale. Folinsbee *et al.* (1965, p. 169, 171) reported an age of 69 or 70 million years for the "Outlook Bentonite", present near the base of the Broderick Clay about 8 miles south of Outlook (for stratigraphic section, see p. 42) and the same age of 69 million years for the "Beechy Ferry Bentonite" in the midst of the Snakebite Clay, about midway between Herbert Ferry and the mouth of Snakebite Creek. In all probability, the Broderick Clay lies in the Zone of *E. jenneyi* or *D. stevensoni*, the mid-Snakebite Clay lies in the Zone of *B. reesidei* — one below, the other above the Zone of *B. compressus robinsoni* (see text-fig. 14). If the *B. compressus robinsoni* beds are to be regarded as 72 to 73 million years old, then using Gill and Cobban's (*op. cit.*, p. A36) estimate of a half-million-year age span for each fossil zone, the *E. jenneyi-D. stevensoni* beds assume the already suggested age of 74 to 75 million years, the *B. reesidei* beds an age of 71 to 72 million years.

Relation of the thickness of the formation to the inferred time of deposition of the original sediments supports the argument that the Bearpaw sediments in the South Saskatchewan River valley accumulated fairly rapidly for sediments in the North American interior seaway of Cretaceous time. In the eastern portion of the valley, the entire formation is about 1,150 feet thick. It is known to span at least eight and thought likely to span nine or ten ammonite range zones, resulting in a probable average figure lying between 115 and 130 feet of rock per zone, and if it be accepted that the age span of the 1,150-foot formation is 4.5 million years, the average rate of accumulation was 256 feet of rock per million years. These figures are considerably less than those of 172 feet per zone and 344 feet per million years obtained by Gill and Cobban (*op. cit.,* p. A42) for the Red Bird section of the Pierre Shale in Wyoming but, oddly enough, considerably greater than the estimate by Folinsbee *et al.* (1961, p. 357) of 150 feet per million years for the Middle Albian to Late Maestrichtian rocks of the Alberta and Peace River basins.

SUMMARY

The Bearpaw Formation is a westward-thinning wedge of predominantly marine silty clays and sands in the Upper Cretaceous Series, which can be traced northward from Montana into adjacent parts of Alberta and Saskatchewan. It forms the bedrock surface over much of southwestern Saskatchewan, where it is underlain and overlain by complementary eastward-thinning wedges of predominantly non-marine sands, silts, and clays formed by the Foremost and (mainly) Oldman Formations and the Eastend and Whitemud Formations respectively.

Lying in the core of the shallow, plunging Moose Jaw syncline, the 1,150-foot thick Bearpaw Formation of the South Saskatchewan River valley consists of an alternating sequence of silty clays and sands divisible into eleven members, all of which can be traced through the river valley and far beyond. Clays at the base of the formation, more than 100 feet thick, are known only from the subsurface, and, since no suitable type section exists, they remain unnamed. Succeeding clays are designated Broderick, Sherrard, Beechy, Snakebite, and Aquadell. Within the river valley, the Snakebite, 250 feet thick in type section, and the Beechy, anomalously thick at 110 feet in type section, are most consistently the thickest and thinnest of the clay members. Generally thinner than the clays with which they are interlayered, the sands are named Outlook, Matador, Demaine, Ardkenneth, and Cruikshank. The Ardkenneth, nearly 70 feet thick in type section, and the Matador, 22 feet thick in type section, are most consistently the thickest and thinnest of the sands. Most of the type localities lie between Swiftcurrent Creek and the Vermilion Hills, where the river has trenched deeply into the Missouri Coteau and where the most continuous sections are to be found. Numerous bore holes, both within the river valley and in the surrounding plains, penetrate the Bearpaw beds and supplement the outcrop sections by providing additional information on sequence, lateral continuity, facies, persistence, and thickness of the members; and since many of the holes carry electric logs, they are invaluable in effecting local and regional lithostratigraphical correlation.

The macrofauna of the Bearpaw Formation is predominantly molluscan. Bivalves are most common, ammonites and gastropods fairly common, nautiloids and scaphopods rare. A rudist bivalve and a teuthidid coleoid are each recorded from a single locality in the lower sands. Most of the molluscs occur in concretionary beds and, generally, the assemblage in any such bed is dominated by one or two species, which occur in profusion. Two broad faunal assemblages are recognizable in the South Saskatchewan River valley: a *Baculites-Placenticeras* assemblage, containing a number of boreal elements, in the lower half of the formation, and a *Scaphites (Hoploscaphites)* assemblage in the upper. Numerous baculites, mostly belonging to the *Baculites compressus-cuneatus-reesidei* lineage, occur in the Bearpaw beds and permit biostratigraphical analysis within the frame of the zonal scheme established in the Western Interior of the United States. In all probability, the Bearpaw Formation in the South Saskatchewan River valley ranges from the Zone of *Didymoceras stevensoni* (Whitfield) to that of *Baculites grandis* (Hall and Meek) — a range comparable to that of the formation in east-central Montana — although the lowest and highest zones positively identified are those of *Exiteloceras jenneyi* (Whitfield) and *Baculites baculus* Meek and Hayden.

Mosasaur and plesiosaur remains, more or less mutually exclusive in stratigraphical distribution, are the most common vertebrate fossils. The presence of an incomplete hadrosaur in the open-sea clays of the Snakebite Member is exceptional and can be accounted for only by assuming that the carcass was borne out to sea, possibly by strong river currents, for well over 100 miles before it sank and became entombed in the mud. Fish remains are rare.

Most characteristics of the sediments and fossils suggest that epineritic conditions prevailed over the Bearpaw sea bed in the area of the South Saskatchewan River valley. Cross-bedding is common in the sands, and the clays are silty and massive, seldom showing any marked lamination. Some bentonite seams have ragged contacts, others are no more than impersistent streaks, suggesting that the sedimentation of the volcanic ash possibly was disrupted by bottom turbulence. The rich and varied molluscan fauna, together with linguloid and rhynchonelloid brachiopods, pyriporoid and membraniporoid bryozoans, probably decapod crustaceans, tube-secreting worms, and even the odd brittle star, only could have thrived in no great depth of water — in all probability not more than 150 feet. Furthermore, in some sands, spreads of oysters and pteriaceids look to be original shell beds only slightly displaced, and in others, logs and branches of coniferous trees, riddled by wood-boring bivalves, must have been trapped by sediments under extremely shallow-water conditions.

A Late Campanian-Early Maestrichtian relative age span for the Bearpaw Formation in the South Saskatchewan River valley is indicated by the ammonites. By relating the ammonite zones to evaluated radiometric dates, calculated using bentonites from the southern Canadian plains and the potassium-argon chronometer, it can be estimated that the formation has a 4.5 million year absolute age span and accumulated between 74.5 and 70 million years ago. By considering the thickness of the formation in terms of the inferred time of deposition, it can be calculated that the Bearpaw Formation in the South Saskatchewan River valley developed at a rate of 256 feet of rock per million years — oddly enough, a faster rate, apparently, than that of the Late Creteceous rocks closer to the contemporary shorelines farther west.

The Bearpaw Formation is the sedimentary record of a broadly westward and eastward, oscillatory transgression and regression triggered by pulsatory movements of the Cordilleran highlands and flanking sea-covered platform. Drastic changes in the quantity, kind, and rate of supply of terrigenous clastic detritus were attendant upon these movements. Formerly, it was believed that transgression of the Bearpaw sea was so rapid that, over vast areas of the southern Canadian plains, the onlap sequence was essentially synchronous, and regression extremely gradual so that the offlap sequence was strongly diachronous. But the biostratigraphy of the formation in the South Saskatchewan River valley contributes substantially to refuting this notion. Within the breadth of the studied segment of the river valley, the unnamed clay and the Outlook Sand, probably deposited at least in part during *Didymoceras stevensoni* time, pass by facies change into alluvial-plain sands and silts and are incorporated into the Oldman Formation, and the Matador Sand, in all probability an accumulation of *Exiteloceras jenneyi-Didymoceras cheyennense* time, undergoes much the same kind of transition. In all likelihood, the Bearpaw sea was restricted to southwestern Saskatchewan until *Baculites compressus* time, when it swept rapidly across much of southern Alberta, and it probably did not establish its most westerly shoreline until *B. cuneatus* or *B. reesidei* time. It retreated from Alberta through Saskatchewan in *B. eliasi* to *B. grandis* times. Like the regression, transgression of the Bearpaw sea was gradual, the stratal record is more a cycle than a rhythm of sedimentation, both lower and upper formational contacts are diachronous, and facies changes are rife throughout most of the sequence.

LITERATURE CITED

Ager, D. V., 1965, Mesozoic and Cenozoic Rhychonellacea: *in* Treatise on Invertebrate Paleontology, Moore, R. C., ed., Pt. H. (Brachiopoda) v. 2, p. H597-H625, figs. 478-510, Geol. Soc. America and Univ. Kansas Press.

Allan, J. A., 1919, Sections along North Saskatchewan River and Red Deer and South Saskatchewan Rivers, between the third and fifth meridians: Geol. Survey Canada, Summ. Rept., 1917, pt. C, p. 9C-13C, fig. 2.

American Commission on Stratigraphic Nomenclature, 1961, Code of Stratigraphic Nomenclature: Bull. Amer. Assoc. Petroleum Geologists, v. 45, no. 5, p. 645-665.

Baadsgaard, Halfdan, Cumming, G. L., Folinsbee, R. E., and Godfrey, J. D., 1964, Limitations of radiometric dating: *in* Geochronology in Canada, Osborne, F. F., ed., Roy. Soc. Canada, Spec. Pub. 8, p. 20-38, 7 figs., Univ. Toronto Press.

Brown, R. W., 1939, Fossil plants from the Colgate Member of the Fox Hills Sandstone and adjacent strata: U.S. Geol. Survey, Prof. Paper 189-I, p. iv, 239-275, 1 fig., 17 pls.

Byers, A. R., Caldwell, W, G. E., and Kupsch, W. O., 1968, Geological map of Saskatchewan (with explanation): *in* Atlas of Saskatchewan, Richards, J. H., ed., Univ. of Saskatchewan and Modern Press, Saskatoon.

Caldwell, W. G. E., 1963, Faunal distribution in the Cretaceous Bearpaw Formation in the South Saskatchewan River valley: Bull. Canadian Inst. Mining and Metallurgy, v. 56, p. 155 (abst).

Caldwell, W. G. E., and Evans, J. K., 1963, A Cretaceous rudist from Canada, and a redescription of the holotype of *Ichthyosarcolites coraloidea* (Hall & Meek): Journ. Paleontology, v. 37, no. 3, p. 615-620, pl. 75.

Caldwell, W. G. E., and North, B. R., 1964, Foraminiferal faunas in the Cretaceous Montana Group of southwestern Saskatchewan: *in* Third Internat. Williston Basin Symposium, p. 143-151, 3 figs., Sask. Geol. Soc., Regina.

Christiansen, E. A., 1959, Glacial geology of the Swift Current area, Saskatchewan: Province Sask., Dept. Mineral Resources, Petroleum and Nat. Gas Br., Rept. 32, 62 p., 30 figs., 1 pl., 4 tabs.

————, 1965, Geology and groundwater resources of the Kindersley area (72-N) Saskatchewan: Sask. Research Council, Geology Div., Rept. 7, 26 p., 7 figs., 2 tabs., 8 pls.

————, 1967, Geology and groundwater resources of the Battleford area (73-C) Saskatchewan: Sask. Research Council, Geology Div., Map no. 4, Scale 1:250,000.

Clark, C. M., 1931, Sections of Bearpaw Shale from Keho Lake to Bassano, southern Alberta: Bull. Amer. Assoc. Petroleum Geologists, v. 15, no. 10, p. 1243-1249, 2 figs.

Cobban, W. A., 1951, New species of *Baculites* from the Upper Cretaceous of Montana and South Dakota: Journ. Paleontology, vol. 25, no. 6, p. 817-821, pl. 118, 13 text-figs.

————, 1958a, Late Cretaceous fossil zones of the Powder River Basin, Wyoming and Montana: Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conference, p. 114-119, 2 figs.

————, 1958b, Two new species of *Baculites* from the Western Interior region: Journ. Paleontology, v. 32, no. 4, p. 660-665, pls. 90-91, 1 text-fig.

————, 1962a, New baculites from the Bearpaw Shale and equivalent rocks of Western Interior: Journ. Paleontology, v. 36, no. 1, p. 126-135, pls. 25-28, 1 text-fig.

————, 1962b, Baculites from the lower part of the Pierre Shale and equivalent rocks in the Western Interior: Journ. Paleontology, v. 36, no. 4, p. 704-718, pls. 105-108, 1 text-fig.

Cobban, W. A., and Reeside, J. B. Jr., 1952, Correlation of the Cretaceous formations of the Western Interior of the United States: Bull. Geol. Soc. America, v. 63, p. 1011-1044, 2 figs., 1 pl.

Crockford, M. B. B., 1949, Oldman and Foremost Formations of southern Alberta: Bull. Amer. Assoc. Petroleum Geologists, v. 33, no. 4, p. 500-510, 4 figs.

Davis, N. B., 1918, Report on the clay resources of southern Saskatchewan: Mines Branch, Canada Dept. Mines, Rept. no. 468, 93 p., 1 fig., 21 pls., 2 maps.

Dawson, G. M., 1884, Report on the region in the vicinity of the Bow and Belly Rivers, North-West Territory: Geol. & Nat. History Survey & Mus. Canada, Rept. Progress (1882-4), p. 1C-169C, 7 figs., 4 pls., 2 tabs., map, Dawson Bros., Montreal.

deMille, George, 1960, The Elbow structure of south-central Saskatchewan: Journ. Alta. Soc. Petroleum Geologists, v. 8, no. 5, p. 154-162, 7 figs.

Douglas, R. J. W., 1942, New species of *Inoceramus* from the Cretaceous Bearpaw Formation: Trans. Roy. Soc. Canada, ser. 3, v. 36, sec. 4, p. 59-66, 3 pls.

Dowling, D. B., 1916, Water supply, southeastern Alberta: Geol. Survey Canada, Summ. Rept., 1915, p. 102-110, map. no. 1604.

————, 1917, The southern plains of Alberta: Geol. Survey Canada, Mem. 93, ii + 200 p., 3 figs., 35 pls., 3 maps.

Edmunds, F. H., 1939, Report to the Department of Natural Resources on the Riverhurst area: Sask. Dept. Nat. Resources, Ann. Rept. 1939, pt. 2, p. 19-22.

Eldridge, G. H., 1889, Some suggestions upon the method of grouping the formations of the middle Cretaceous and the employment of an additional term in its nomenclature: Amer. Journ. Sci., ser. 3, v. 38, p. 313-321.

Folinsbee, R. E., Baadsgaard, Halfdan, and Lipson, Joseph, 1961, Potassium-argon dates of Upper Cretaceous ash falls, Alberta, Canada: Annals New York Acad. Sci., v. 91, art. 2, p. 352-359, 3 figs.

Folinsbee, R. E., Baadsgaard, Halfdan, and Cumming, G. L., 1963, Dating of volcanic ash beds (bentonites) by the K-Ar method: Natl. Acad. Sci. - Natl. Research Council Pub. 1075, p. 70-82, 4 figs., 2 tabs.

Follinsbee, R. E., Baadsgaard, Halfdan, Cumming, G. L., Nascimbene, Giovanni, and Shafiquallah, Mohammed, 1965, Late Cretaceous radiometric dates from the Cypress Hills of Western Canada: Alta. Soc. Petroleum Geologists, 15th Ann. Field Conference Guidebook, pt. 1, p. 162-174, 3 figs., 1 tab.

Fraser, F. J., McLearn, F. H., Russell, L. S., Warren, P. S., and Wickenden, R. T. D., 1935, Geology of southern Saskatchewan: Geol. Survey Canada, Mem. 176, v + 137 p., 4 figs., 5 pls.

Furnival, G. M., 1941, The Belanger and Oxarart Members of the Bearpaw Formation, Cypress Hills area, Saskatchewan: Trans. Roy. Soc. Canada, ser. 3, v. 35, sec. 4, p. 57-69, 1 fig., 1 tab.

————, 1946, Cypress Lake map-area, Saskatchewan: Geol. Survey Canada, Mem. 242, v + 161 p., 5 figs., 4 pls.

Gill, J. R., and Cobban, W. A., 1966, The Red Bird section of the Upper Cretaceous Pierre Shale in Wyoming: U.S. Geol. Survey, Prof. Paper 393-A, iv + 73 p., 17 figs., 12 pls.

Gorrell, H. A. and Alderman, G. R., 1968, Elk Point Group saline basins of Alberta, Saskatchewan, and Manitoba, Canada: *in* Saline deposits, Mattox, R. B., ed., Geol. Soc. America, Spec. Paper 88, p. 291-317, 10 figs., 1 pl.

Hind, H. Y., 1860, Narrative of the Canadian Red River exploring expedition of 1857 and of the Assiniboine and Saskatchewan exploring expedition of 1858, v. 2, xvi + 472 p., figs., pls., maps, London, Longman, Green, Longman, and Roberts.

Hume, G. S., 1933, Oil and gas in western Canada (Second Ed.): Geol. Survey Canada, Econ. Geology Ser., no. 5, v + 359 p., 26 figs.

———, 1937, The stratigraphy and oil and gas prospects of east-central Alberta: Trans. Canadian Inst. Mining and Metallurgy, v. 40, p. 126-140, 7 figs.

Hume, G. S., and Hage, C. O., 1941, The geology of east-central Alberta: Geol. Survey Canada, Mem. 232, ii + 101 p., 12 figs., 2 maps.

Jeletzky, J. A., 1968, Macrofossil zones of the marine Cretaceous of the Western Interior of Canada and their correlation with the zones and stages of Europe and the Western Interior of the United States: Geol. Survey Canada, Paper 67-72, v + 66 p., 2 figs.

Jensen, F. S., and Varnes, H. D., 1964, Geology of the Fort Peck area, Garfield, McCone and Valley Counties, Montana: U. S. Geol. Survey, Prof. Paper 414-F, iii + 49 p., 19 figs., 3 pls.

Kauffman, E. G., 1967, Coloradoan macroinvertebrate assemblages, central Western Interior, United States: *in* Paleoenvironments of the Cretaceous seaway in the Western Interior Symposium, p. 67-143, 12 figs., Dept. Publications, Colorado School of Mines, Golden.

Knowlton, F. H., 1905, Fossil plants of the Judith River beds *in* Geology and paleontology of the Judith River beds: U. S. Geol. Survey, Bull. 257, p. 129-168, pls. 15-19.

Kupsch, W. O., 1955, Pioneer geologists in Saskatchewan. Province Sask., Dept. Mineral Resources, Regina, 50 p. 14 figs.

———, 1956, Geology of eastern Cypress Hills, Saskatchewan: Province Sask., Dept. Mineral Resources, Geol. Sci. Branch, Sedimentary Geology Div., Rept. 20, 30 p., 8 figs., 4 pls.

Lines, F. G., 1963, Stratigraphy of Bearpaw Formation of southern Alberta: Bull. Canadian Petroleum Geology, v. 11, no. 3, p. 212-227, 6 figs., map.

Link, T. A., and Childerhose, A. J., 1931, Bearpaw Shale and contigous formations in Lethbridge area, Alberta: Bull. Amer. Assoc. Petroleum Geologists, v. 15, no. 10, p. 1227-1242, 11 figs.

Loranger, D. M., and Gleddie, J., 1953, Some Bearpaw zones in southwestern Saskatchewan and southern Alberta: Alta. Soc. Petroleum Geologists, 3rd Ann. Field Conference Guidebook, p. 158-175, 4 figs., 3 pls.

Lull, R. S., and Wright, N. E., 1942, Hadrosaurian dinosaurs of North America: Geol. Soc. America, Spec. Paper 40, xi + 242 p., 90 figs., 31 pls., 8 tabs.

MacGillavry, H. J., 1937, Geology of the Province of Camaguey, Cuba with revisional studies in rudist paleontology (mainly based upon collections from Cuba): Geographische en geologische Mededeelingen, Publicaties uit het Geographisch en uit het Mineralogisch-Geologisch Institut der Rijks-Universiteit te Utrecht, Physiographisch-Geologische Reeks, no. 14, iv + 168., 10 pls., map. Drukkerij J. van Boekhoven, Utrecht.

McConnell, R. G., 1886, Report on the Cypress Hills, Wood Mountain and adjacent country, embracing that portion of the district of Assiniboia, lying between the international boundary and the 51st parallel and extending from lon. 106° to lon. 110° 50': Geol. & Nat. Hist. Survey Canada, Ann. Rept., n.s., v. 1 (1885), p. Ic-78c 3 pls., 4 figs., Dawson Bros., Montreal.

Maddox, D. C., 1932, The Darmody-Riverhurst artesian water area, southern Saskatchewan: Geol. Survey Canada, Summ. Rept., 1931, pt. B, p. 58B-71B, fig. 9.

Meyboom, Peter, 1966, Groundwater studies in the Assiniboine River drainage basin. Part 1: The evaluation of a flow system in south-central Saskatchewan: Geol. Survey Canada, Bull. 139, xii + 65 p., 22 figs., 2 pls., 5 tabs.

----------, 1967, Interior plains hydrogeological region: *in* Groundwater in Canada, Brown, I. C., ed., p. 131-158, 7 figs., 3 tabs.

Meyboom, Peter, van Everdingen, R. O., and Freeze, R. A., 1966, Patterns of groundwater flow in seven discharge areas in Saskatchewan and Manitoba; Geol. Survey Canada, Bull. 147, x + 57 p., 20 figs., 5 pls., 14 tabs.

Moore, H. B., 1939, Faecal pellets in relation to marine deposists: *in* Recent marine sediments — a symposium, Trask, P. D., ed., p. 516-524, 1 fig., Amer. Assoc. Petroleum Geologists, Tulsa.

Nauss, A. W., 1945, Cretaceous stratigraphy of Vermilion area, Alberta, Canada: Bull. Amer. Asoc. Petroleum Geologists, v. 29, no. 11, p. 1605-1629, 5 figs.

Palliser, John, 1863, Exploration — British North America. The journals, detailed reports and observations relative to the exploration by Captain Palliser of that portion of British North America, which in latitude lies between the British boundary line and the height of land or watershed of the Northern or Frozen Ocean respectively, and in longitude, between the western shore of Lake Superior and the Pacific Ocean, during the years 1857, 1858, 1859, and 1860: 325 p., 101 tabs., illus., map, London, George Edward Eyre and William Spottiswoode [Printers] for H. M. Stationery Office.

Pollock, D. H., 1962, Geology of the South Saskatchewan River project: Engineering Journ. v. 45, no. 4, p. 37-46, 11 figs.

Robinson, H. R., 1945, New baculites from the Cretaceous Bearpaw Formation of southwestern Saskatchewan: Trans. Roy. Soc. Canada, ser. 3, v. 39, sec. 4, p. 51-54, 1 pl.

Russell, L. S., 1932, The Cretaceous-Tertiary transition of Alberta: Trans. Roy. Soc. Canada, ser. 3, v. 26, sec. 4, p. 121-156, 2 pls., 2 tabs.

----------, 1939, Land and sea movements in the late Cretaceous of western Canada: Trans. Roy. Soc. Canada, ser. 3, v. 33, sec. 4, p. 81-99, 8 figs.

----------, 1943, Marine fauna of the Eastend Formation of Saskatchewan: Journ. Paleontology, v. 17, no. 3, p. 281-288, 3 figs., pls. 47-49.

----------, 1948, Preliminary report [on] the geology of the southern part of the Cypress Hills, southwestern Saskatchewan: Province Sask. Dept. Mineral Resources, Petroleum and Nat. Gas Br., Rept. 8, 60 p., 2 figs., 7 pls., 1 tab.

Russell, L. S., and Landes, R. W., 1940, Geology of the southern Alberta plains: Geol. Survey Canada, Mem. 221, iv + 223 p., 21 figs., 8 pls.

Sanderson, J. O. G., 1931a, Upper Cretaceous volcanic ash beds in Alberta: Trans. Roy. Soc. Canada, ser. 3, v. 25, sec. 4, p. 61-70, 1 pl.

----------, 1931b, Fox Hills formation in southern Alberta: Bull. Amer. Assoc. Petroleum Geologists, v. 15, p. 1251-1263, 6 figs.

Scott, G. R., and Cobban, W. A., 1965, Geologic and biostratigraphic map of the Pierre Shale between Jarre Creek and Loveland, Colorado: U.S. Geol. Survey, Misc. Geol. Investigations, Map I-439, 1:48,000, separate text, 4 p.

Shaw, E. W., and Harding, S. R. L., 1949, Lea Park and Belly River Formations of east-central Alberta: Bull. Amer. Assoc. Petroleum Geologists, v. 33, no. 4. p. 487-499, 4 figs., 2 tabs.

Slipper, S. E., 1919, Viking gas field. Structure of area: Geol. Survey Canada. Summ. Rept., 1917, pt. C, p. 6c-9c, 1 tab.

Sohl, N. F., 1967, Upper Cretaceous gastropods from the Pierre Shale at Red Bird, Wyoming: U. S. Geol. Survey. Prof. Paper 393-B. iv + 46 p., 11 figs., 11 pls., 2 tabs.

Stanton, T. W., and Hatcher, J. B., 1903. The stratigraphic position of the Judith River beds and their correlation with the Belly River beds: Science. n. s., v. 18, p. 211-212.

——————, 1905, Geology and palaeontology of the Judith River beds: U. S. Geol. Survey, Bull. 257, 128 p., 13 pls.

Tourtelot, H. A., 1962, Preliminary investigation of the geologic setting and chemical composition of the Pierre Shale, Great Plains region: U. S. Geol. Survey, Prof. Paper 390, iv + 74 p., 22 figs., 4 pls., 20 tabs.

van Everdingen, R. O., 1964, Groundwater in bedrock aquifers in the Prairies: *in* Summary of Activities: Field, 1963, Geol. Survey Canada, Paper 64-1, p. 39.

——————, 1966a, Influence of the South Saskatchewan reservoir on piezometric pressures in confined bedrock aquifers: *in* Report of Activities, May to October, 1965, Geol. Survey Canada, Paper 77-1, p. 124-127, 2 figs., 2 pls.

——————, 1966b, Use of pressure transducers for the determination of piezometric pressures in confined aquifers under the South Saskatchewan reservoir, Canada: Journ. Hydrology, v. 4, p. 70-78, 4 figs., 2 tabs.

——————, 1967, Influence of the South Saskatchewan reservoir (Canada) on piezometric levels in underlying bed-rock aquifers: Journ. Hydrology, v. 5, p. 351-359, 4 figs., 3 tabs.

——————, 1968, The influence of the South Saskatchewan reservoir on the local groundwater regime — a prognosis: Geol. Survey Canada, Paper 65-39, ix + 85 p., 20 figs., 1 pl., 8 tabs., 4 append.

Waage, K. M., 1964, Origin of repeated fossiliferous concretion layers in the Fox Hills Formation: Kansas Geol. Survey, Bull. 169, p. 541-563, 10 figs.

——————, 1965, The Late Cretaceous coleoid cephalopod *Actinosepia canadensis* Whiteaves: Postilla Peabody Mus. Nat. History, Yale Univ., no. 94, 33 p., 4 pls., 4 figs., 2 tabs.

——————, 1967, Cretaceous transitional environments and faunas in central South Dakota: *in* Paleoenvironments of the Cretaceous seaway in the Western Interior Symposium, p. 237-266, 4 figs., Dept. Publications, Colorado School of Mines, Golden.

Wall, J. H., 1967, Paleoecology of Cretaceous marine micro-faunas in the Rocky Mountain foothills of Alberta and British Columbia: *in* Paleoenvironments of the Cretaceous seaway in the Western Interior Symposium, p. 173-196, 3 figs., 2 tabs., Dept. Publications, Colorado School of Mines, Golden.

Warren, P. S., 1927, Geology and oil prospects in the vicinity of Riverhurst, Saskatchewan: Geol. Survey Canada, Summ. Rept., 1926, Pt. B, p. 39B-42B.

——————, 1931, Invertebrate paleontology of southern plains of Alberta: Bull. Amer. Assoc. Petroleum Geologists, v. 15, p. 1283-1291, 3 pls.

——————, 1934, Paleontology of the Bearpaw Formation: Trans. Roy. Soc. Canada, ser. 3, v. 28, sec. 4, p. 81-100, 3 pls.

———, 1937, A rhynchonellid brachiopod from the Bearpaw Formation of Saskatchewan: Trans. Roy. Soc. Canada, ser. 3, v. 31, sec. 4, p. 1-4, 1 pl.

Weimer, R. J., 1960, Upper Cretaceous stratigraphy, Rocky Mountain area: Bull. Amer. Assoc. Petroleum Geologists, v. 44, no. 1, p. 1-20, 10 figs.

Weimer, R. J., and Hoyt, J. H., 1964, Burrows of *Callianassa major* Say, geologic indicators of littoral and shallow neritic environments: Journ. Paleontology, v. 38, no. 4, p. 761-767, pls. 123-124, 2 text-figs.

Whiteaves, J. F., 1885, Report on the Invertebrata of the Laramie and Cretaceous rocks of the vicinity of the Bow and Belly Rivers and adjacent localities in the North-West Territory: Geol & Nat. History Survey Canada, Contrib. Canadian Palaeontology, v. 1, pt. 1, ii + 89 p., 11 pls.

———, 1889, On some Cretaceous fossils from British Columbia, the North West Territory and Manitoba: Geol. & Nat. History Survey Canada, Contrib. Canadian Palaeontology, v. 1, pt. 4, p. 151-196, 54 figs.

Whiteaves, J. F., 1897, On some remains of a *Sepia*-like cuttlefish from the Cretaceous rocks of the South Saskatchewan: Canadian Rec. Sci., v. 7, p. 459-460, pl. 2.

Wickenden, R. T. D., 1932, Notes on some deep wells in Saskatchewan: Trans. Roy. Soc. Canada, ser. 3, v. 26, sec. 4, p. 177-196, 2 figs.

Williams, G. D., and Burk, C. F., Jr., 1964, Upper Cretaceous: *in* Geological history of Western Canada, R. G. McCrossan and R. P. Glaister, eds., p. 169-189, figs. 12-1-12-20, Alta. Soc. Petroleum Geologists and Alcraft Printing Co. Ltd., Calgary.

Williams, M. Y., 1930, New species of marine invertebrate fossils from the Bearpaw Formation of southern Alberta: Natl. Mus. Canada, Contrib. Canadian Palaeontology, Bull. 63, Geol. Ser. 51, p. 1-6, 68-71, pls. 1-2.

Williams, M. Y., and Dyer, W. S., 1930, Geology of southern Alberta and southwestern Saskatchewan: Geol. Survey Canada, Mem. 163, ii + 160 p., 4 figs., 5 pls.

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- Oldman Formation
- Lea Park Formation
- Clays and silty clays of the Bearpaw Formation
- Sands and silty sands of the Bearpaw Formation
- Sands, silts, clays, and lignite seams of Oldman Formation
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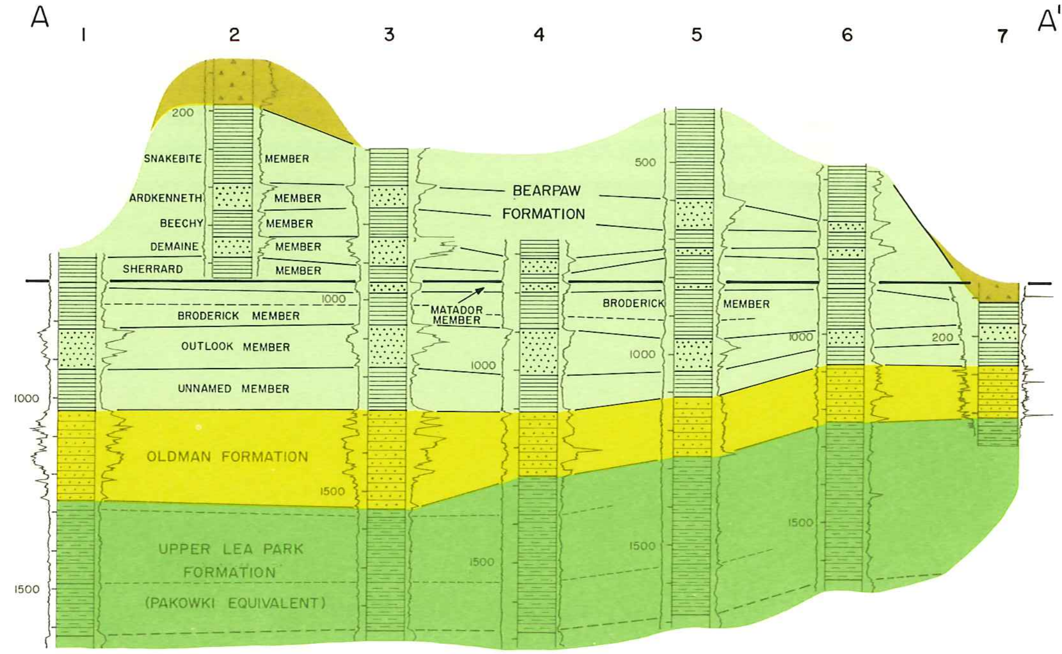

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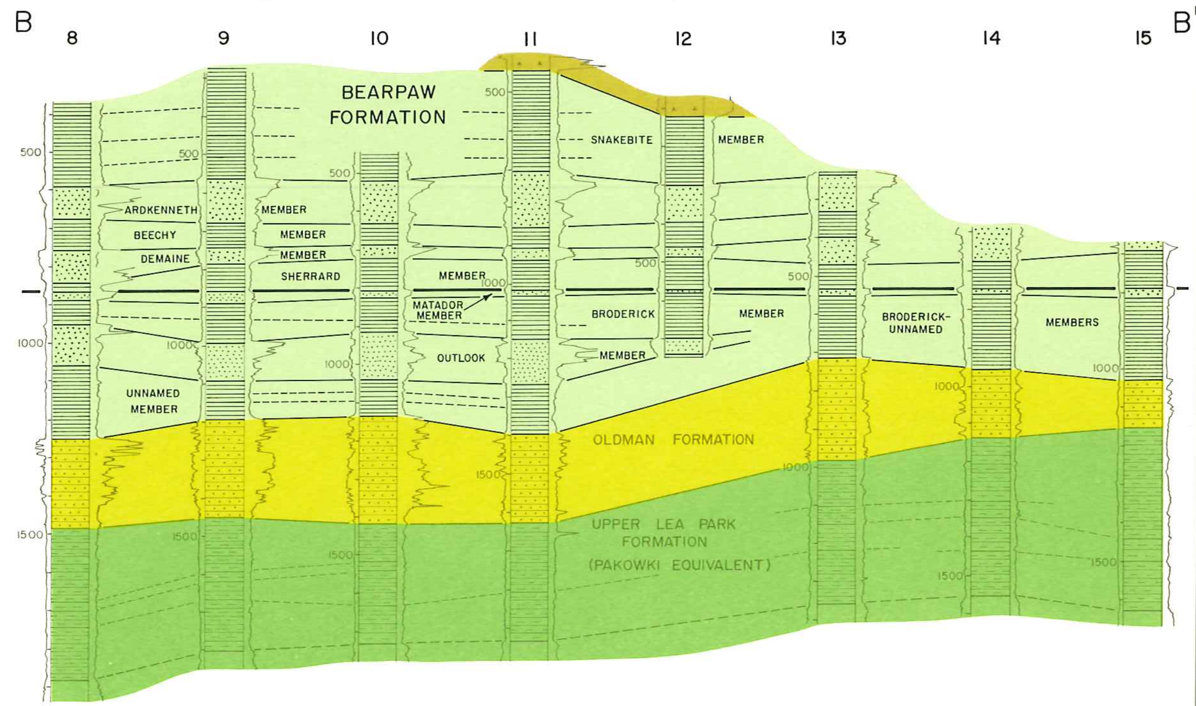

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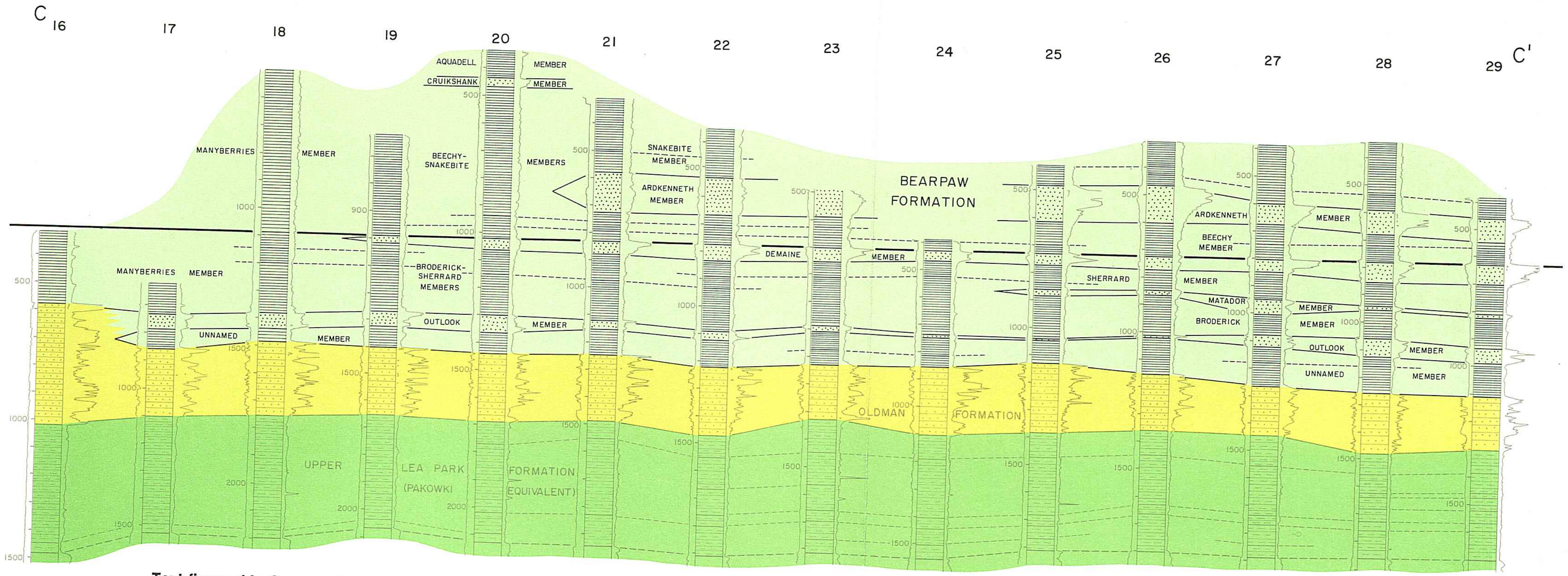
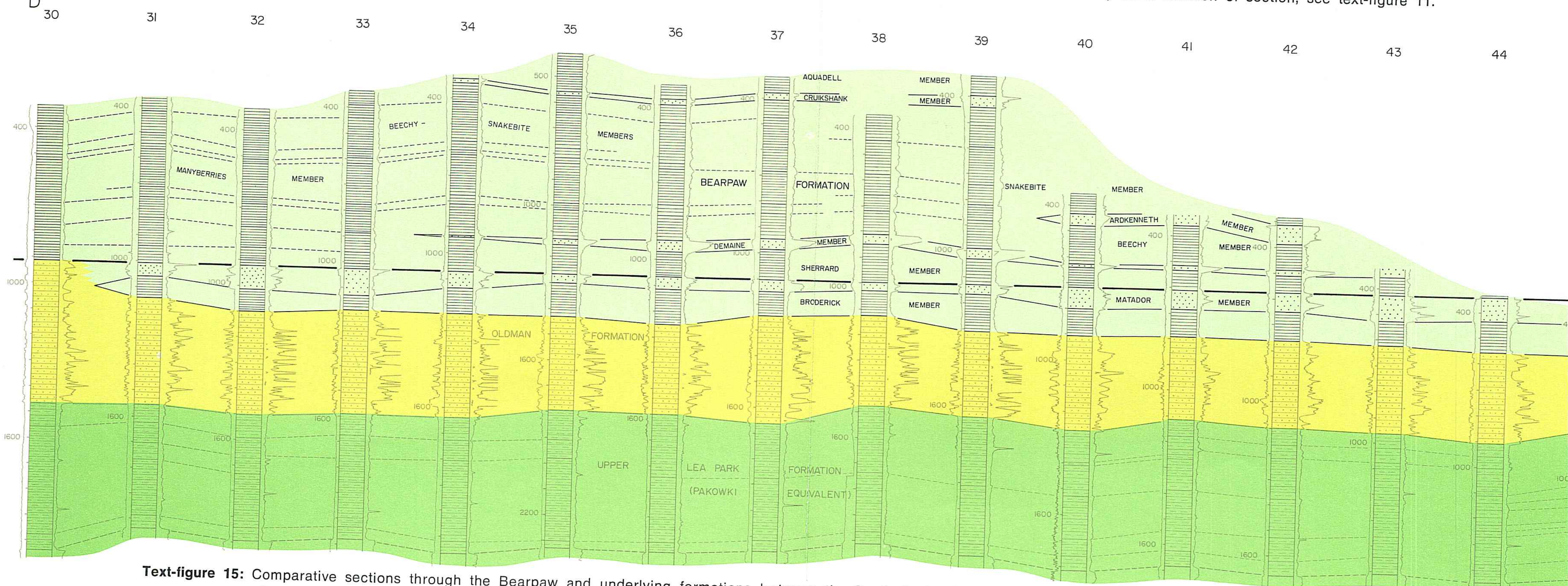
26. Tidewater Waldeck 2-4-16-12W3 K.B. 2584
27. Shell Tidewater Rush Lake 10-17-17-11-W3 K.B. 2554
28. Tidewater Rush Lake 4-34-18-11-W3 K.B. 2466
29. Tidewater Rush Lake 3-36-19-11-W3 K.B. 2363
30. Tidewater Staynor 1-29-2-22-W3 K.B. 2987
31. Tidewater Loomis SW 5-1-3-21-W3 K.B. 2977
32. Tidewater Fam 15-18-3-20-W3 K.B. 2963
33. Tidewater Rapdan 5-14-4-20-W3 K.B. 3044
34. McAlester Goldston Whitemud 13-24-5-21-W3 K.B. 3060
35. Tidewater Eastend 13-13-6-20-W3 K.B. 3228
36. Fargo Dollard 15-30-7-19-W3 K.B. 3019
37. Tidewater Leon Lake 3-23-8-19-W3 K.B. 2994
38. Hudson's Bay Bone Creek 4-26-10-19-W3 K.B. 2784
39. Co-op Bone Creek 7-3-11-19-W3 K.B. 2980
40. Anglo American Gridoil Gull Lake 15-33-12-19-W3 K.B. 2677
41. Anglo American Gridoil Gull Lake 12-26-13-19-W3 K.B. 2614
42. Socony Woodley Southern S.E. Midway 10-3-14-18-W3 K.B. 2629
43. Socony Woodley Southern N.E. Midway 13-13-15-19-W3 K.B. 2504
44. Mobil Oil Woodley Southern Verlo 14-22-16-19-W3 K.B. 2417
45. Socony Western Prairie Roseray 10-10-17-19-W3 K.B. 2412



Text-figure 14: Comparative sections through the Bearpaw and underlying formations between the South Saskatchewan River valley, near Herbert Ferry, and the Frenchman River valley, near Climax, based upon the electric logs of oil-company bore holes. Datum: top of the Demaine Sand. For precise location of section, see text-figure 11.



Text-figure 15: Comparative sections through the Bearpaw and underlying formations between the South Saskatchewan River valley, south of Pennant Ferry, and the East Block of the Cypress Hills, based upon the electric logs of oil-company bore holes. Datum: top of the Matador Sand. For precise location of section, see text-figure 11.