GEOLOGICAL SURVEY OF CANADA
COMMISSION GEOLOGIQUE DU CANADA

Open File 2851

DEVONIAN STRATIGRAPHY AND DEPOSITIONAL HISTORY ACROSS PEACE RIVER HIGHLAND, WEST-CENTRAL ALBERTA AND NEARBY BRITISH COLUMBIA

N.C. Meijer Drees,
D.I. Johnston
and
E.G. Fullmer

Institute of Sedimentary and Petroleum Geology
Geological Survey of Canada
3303 33 Street N.W.
Calgary, Alberta
T2L 2A7

JULY 1994

Although every effort has been made to ensure accuracy, this Open File Report has not been edited for conformity with Geological Survey of Canada standards.

DEVONIAN STRATIGRAPHY AND DEPOSITIONAL HISTORY ACROSS PEACE RIVER HIGHLAND, WEST-CENTRAL ALBERTA AND NEARBY BRITISH COLUMBIA

by

N.C. Meijer Drees, D.I. Johnston and E.G. Fullmer

ABSTRACT

The Devonian succession in west central Alberta onlaps and overlies erosional remnants of Peace River Arch, an ancient tectonic uplift composed of Precambrian crystalline rocks. This highland, initially more than 1400 m high, remained emergent during the Devonian and was a source for clastic sediment.

Coarsely grained, non-marine, arkosic sandstones overlie and surround the highland. An interbedded succession of nearshore sandstones, shales, evaporites and carbonates interfingers, onlaps and overlies the non-marine sandstone facies.

The Devonian succession around the highland includes redbeds and evaporites of the Elk Point, carbonates of the Beaverhill Lake, reefal carbonates and basinal shales of the Woodbend, and ramp carbonates of the Winterburn and Wabamun groups. Dark grey shales of the Exshaw Formation form the top of the Devonian succession.

The general transgressive onlap pattern of the marginal clastics is interrupted by regressive lithosomes (the Contact Rapids, Gilwood and Leduc-Peace River carbonate complex) that extend from the margin into the basin. A subtle regressive event is present in the uppermost beds of the Wabamun Formation.

INTRODUCTION

During the Devonian Period an erosional remnant of the Peace River Arch remained emergent and formed an initially high (more than 1400 m of Devonian onlap), paleotopographic region (see O'Connell et al 1990). This highland and its changing outline during the Devonian were mapped by means of several formational onlap edges by Grayston et al. (1964) and Belyea (1964). They showed that this emergent region initially was part of a much larger, northwest trending high known as Western Alberta ridge, but later became a prominent entity by itself.

The present work, intended as a contribution for the Geology of the Peace River Arch (see Bulletin of Canadian Petroleum Geology, v. 38A, 1990), indicates that during the Devonian Period this highland diminished in size because of sedimentary onlap. It was subsequently buried beneath a thick succession of late Paleozoic and Mesozoic sediments. Because the

highland is composed of rigid Precambrian crystalline rocks, and the Devonian sediments onlapping the highland were initially unconsolidated, the Devonian strata were affected by the process of differential compaction. Thus, on stratigraphic sections, the Devonian beds appear to be draped across a gentle tectonic uplift.

The Peace River highland divides the Devonian sedimentary basin of Alberta in two parts and supplied clastic sediment. The general subsidence relative to sealevel of the western margin of the North American continent was several times reversed during the Devonian by uplift or fall in sealevel, causing the ancient shoreline to move back and forth across the wedge of marginal sediments flanking the highland. Each rise in sealevel was followed by a progradation of sediment into the basin. Thus the Devonian succession around the highland includes transgressive and regressive deposits.

The gradual decrease in size of the Devonian highland and its clastic margin through time can be outlined with the aid of the onlap edges of several formations and the lateral facies change between marginal clastics and basinal carbonates and evaporites. Because the relationships between the onlap edges, the facies changes and the positions of the ancient coastline were different for each formation, it is necessary to describe the lithology and regional Devonian stratigraphy around the Peace River highland. Also included are short discussions on the depositional history that outline events thought to have influenced the geology across the highland.

STRATIGRAPHY

The Devonian succession in Alberta was formally subdivided into five groups (Grayston et al., 1964; Belyea, 1964), with each group including a number of formations. The formal subdivision is useful in regions where the Devonian succession is thick and relatively complete. However, in the Peace River region the formal stratigraphy of central Alberta (Grayston et al., 1964; Belyea, 1964) loses its coherence across the Peace River highland because of onlap and related facies-changes. Moore (1989) and Morrow and Geldsetzer (1989) introduced an informal subdivision and defined boundaries on the concepts of sequence stratigraphy. The introduction of a new subdivision based on sequence stratigraphy requires more information about the sedimentology and relative age of the Devonian rock units, before sequence boundaries can be correctly established and traced across the highland.

Because little is known about the relative ages of the various onlapping lithosomes, and there are shortcomings in the formal Devonian stratigraphic nomenclature (such as in the relationship between the Gilwood and the Elk Point and Beaverhill Lake groups), only the use of a subdivision based on both formal and informal units is practical at this time (see Figs. 1 and 2). It is also necessary to include the Exshaw Formation with the Devonian, because it includes a late Devonian conodont fauna (Johnston and Meijer Drees, 1993).

Marginal clastics unit:

The lower part of the Devonian succession in west central Alberta and adjacent British Columbia includes a basal transgressive, conglomeratic sandstone unit. Goodman (1956) and Greenwalt (1956) described this unit as the Granite Wash, a continental lithosome that belongs to the Elk Point Group.

Around the crestal part of the Peace River highland the basal Devonian clastics form a thick, interbedded succession of shaly and coarse-grained, continental clastics. These clastics lack diagnostic fossils, but appear to be equivalent to the Beaverhill Lake, Woodbend and Wabamun groups (see Figs. 1 and 2). They were mapped by Cant (1988) and Trotter and Hein (1988) and included with the Granite Wash unit.

Baillie (1956) and Pugh (1973) argued that the Granite Wash unit should only include the pre-Devonian regolith and its surficial, erosional products. Thus on the accompanying cross sections only the granitic regolith is mapped as granite-wash. The interbedded shaly and sandy, continental and nearshore deposits that overlie the regolith are considered to be part of the overlying formations (Pugh, 1973). Where possible, they are described as distinct units (such as the Basal Red Beds, Contact Rapids and Gilwood map units of the Elk Point Group). In the upper part of the Devonian succession they are discussed together as a "Marginal clastic facies", because it is often difficult to establish precise correlations within the Woodbend, Winterburn and Wabamun groups in the Peace River region.

ELK POINT GROUP

This succession accumulated in paleotopographic depressions and overlies lower Paleozoic and Precambrian rocks with an erosional unconformity. The group is more than 550 m thick in central Alberta and consist of interbedded redbeds, clastics, evaporites and carbonates (Grayston et al., 1964).

The succession was subdivided by Sherwin (1962) into lower and upper sub groups, each containing a number of formations. Around the Peace River highland these formations decrease in thickness and change laterally into marginal clastics (Meijer Drees, 1986).

Diagnostic fossils are scarce in the Elk Point Group. The ostracodes and corals found in the lower part of the group (the Ernestina Lake Formation) suggest an Early to early Middle Devonian age (see van Hees, 1958; Norris, 1963). The upper part of the Elk Point Group includes stromatoporoids, corals, brachiopods, ostracodes, charophytes, fragments of placoderm fishes, tentaculitids, and conodonts characteristic of the Middle Devonian, Eifelian and Givetian stages (see Norris, 1963; Craig et al., 1967; Braun et al., 1989).

The upper boundary of the Elk Point Group in east central Alberta was selected at the top of a redbed unit that has been traced into the Watt Mountain Formation of northern Alberta (Meijer Drees, 1986). In the Peace River region the Watt Mountain Formation includes a sandy interval (Jansa and Fischbuch, 1974) that is in mappable continuity with

the Gilwood sandstone of Guthrie (1956). Since the term Gilwood applies to a unit of arkosic sandstone below the Slave Point Formation that truncates the older formations onlapping Peace River highland, it belongs in the upper part of the Elk Point Group but represents the basal transgressive deposit of the Beaverhill Lake Group (Hemphill, *in* Alberta Society of Petroleum Geologists, 1960, p. 146).

Lower Elk Point sub group:

The redbeds and salt deposits in this sub group, including the Basal Red Beds unit, and the Lotsberg and Cold Lake formations (see Fig. 1), were deposited in topographic depressions separated by highlands. The depressions are indicated on figures 3 and 4 as the central Alberta, northern Alberta, Great Slave Lake and Root basins. The continental sandstones and shales of the Basal Red Beds unit onlap the highlands. The continental salt deposits accumulated in the central part of the depressions (see Fig. 5), where they are overlain by marine carbonate and anhydritic deposits of the Ernestina Lake Formation.

The onlap edge of the Ernestina Lake in northeastern Alberta (see Fig. 5) is interpreted to mark the approximate shoreline during the early Middle Devonian marine invasion. The overlying Cold Lake salt deposits in the northern and central Alberta basins occur within the depositional limit of the Ernestina Lake, suggesting that the extend of the marine invasion diminished because of excessive evaporation and that the marine embayment disintegrated into ephemeral salt water lakes. The limits of the Cold Lake salt beds (Fig. 4) may have marked, at one time, the shoreline of these lakes and suggest the presence of an extensive landmass in western Alberta and adjacent British Columbia, that includes the precursor of Peace River highland.

The upper part of the Lower Elk Point sub group includes the Chinchaga, Contact Rapids and Wokkpash formations (Fig. 1). The Chinchaga, composed of interbedded anhydritic dolostones and nodular anhydrite, occupies the central part of the northern Alberta basin (Fig. 4). The Contact Rapids represents its nearshore, clastic equivalent and onlaps the precursor of Peace River highland. It consists of interbedded greenish grey and reddish brown mottled, sandy shales, dolomitic siltstones and dolomitic or arkosic sandstones. The nearshore sandstones, dolomitic sandstones and argillaceous dolostones of the Wokkpash in northeastern British Columbia (Taylor and MacKenzie, 1970) may extend eastward into the subsurface of the Peace River region and overlie the northern margin of the highland (see Fig. 6).

In the region northeast of Lesser Slave Lake (see Fig. 5) the nearshore clastics unit has been interpreted as the shoreline deposit of the Contact Rapids Formation. Thus its onlap edge marks the approximate position of the shoreline during the early stage of the second incursion of the early Middle Devonian sea. On Figure 6 the onlap edges that define the central and northern Alberta basins have merged to outline a landmass that includes Western Alberta ridge and Peace River highland.

Upper Elk Point sub group:

The evaporites and carbonates of the upper sub group were deposited in an embayment east of the Western Alberta Ridge (the Elk Point embayment on Fig. 6). This embayment was formed during the second early Middle Devonian transgression. Initially the sea reached not far beyond the Lower Elk Point shoreline, but with sea level relatively rising, the boundaries of the embayment expanded in all directions.

In the northern and central parts of the Elk Point embayment shallow marine carbonates of the Keg River and Winnipegosis formations overlie the Lower Elk Point evaporites and nearshore clastics (see Fig. 5). These homotaxial formations only occur in the central part of the Elk Point embayment. They change laterally into sandy carbonates and sandstones of the upper Contact Rapids Formation. In northern Alberta the sandy equivalents of the Keg River are locally known as the "Keg River clastics". It is assumed that the facies change of these clastics into carbonates (see Pugh, 1973, Fig. 11) closely parallels the early Middle Devonian shoreline.

In northern and eastern Alberta the Keg River and Winnipegosis carbonates locally include platformal and reefal deposits. Some reefal deposits form mounds that extend upward into the overlying Muskeg and Prairie Evaporite formations (Fig. 5, eastern part). It is assumed that the mounds grew upward in response to a rapid rise of the Middle Devonian sea level (Bebout and Maiklem, 1973). Apparently, the supply of clastics from the Devonian landmass did not keep up with the relative rise in sea level and the shoreline moved inland.

The platformal and reefal carbonates of the Keg River and Winnipegosis formations (Fig. 5) are overlain by a thick succession of evaporites that includes the Muskeg (interbedded anhydrite and dolostone) and Prairie Evaporite (interbedded halite and anhydrite) formations. Along the western margin of the upper Elk Point embayment both formations change laterally into sandy and shaly nearshore deposits rich in charophyte oogonia (the "Unnamed shale" unit on Fig. 5, western part). The position of this facies change is indicated on Fig. 7. It may be used to reconstruct a mid-Givetian "shoreline", although the presence of the evaporites in the central part of the Elk Point embayment suggests that water levels fluctuated considerably.

The evaporites of the Muskeg and Prairie Evaporite formations are overlain by the Watt Mountain Formation, a thin, green or reddish brown and green mottled, interbedded unit of shales and sandstones, that contains a "brackish water" fauna (plant remains, charophyte oogonia, conchostracans, brachiopods and placoderm fish fragments). Because there is a slight erosional unconformity at the base, or in the basal part of the Watt Mountain Formation in northern Alberta, it has been argued that there was a significant period of non-deposition in the northwestern part of the embayment after the deposition of evaporites (see Braun et al., 1989; Meijer Drees, 1989). During this hiatus the shoreline moved away from the Peace River highland. The southeastern part of the shoreline may have been located in eastern Alberta, near the depositional edge of the evaporites in the Dawson Bay Formation and the northwestern part in northeastern British Columbia and the southern District of Mackenzie, near the seaward edge of the Presqu'ile barrier (see Fig. 8).

During the sub-Watt Mountain regression the more elevated areas of the Devonian landmass were eroded. Erosional products were moved downslope by rain water, filling local depressions and river valleys. During the subsequent transgression these alluvial deposits were redeposited into a thin, widespread unit of clastic sediments (the sandy deposits of the Gilwood member). Jansa and Fischbuch (1974) described, within this unit, ancient alluvial plain, coastal plain, deltaic plain and barrier island deposits. Rottenfusser and Oliver (1977) recognized equivalents of braided-stream, meandering-stream, shoreline, and charophyte-bearing, lacustrine deposits.

The truncation of the Elk Point strata and the onlap pattern of the Gilwood sandstone and the overlying beds of the Beaverhill Lake Group along the northern flank of the Peace River highland east of Worsley is shown on Figure 9. The correlations suggest that the Gilwood sandstone is a diachronous deposit that includes Watt Mountain and Slave Point equivalents.

In northern Alberta the Gilwood sandstone beds overlie the Muskeg evaporites through an intervening green and reddish brown, argillaceous, dolomitic and anhydritic rubble deposit that overlies an erosional unconformity (Meijer Drees, 1989). It is assumed that this unconformity extends southward onto the highland.

In the area east of Worsley (Fig. 9, section 1) the Watt Mountain Formation is an interbedded succession of argillaceous and sandy deposits in which it is difficult to define the Gilwood member on the gamma-ray log, because of the feldspathic nature of the sandstones. The sandstones in the Watt Mountain are thin-bedded, dolomitic, fine- to medium grained and have a mottled, bioturbated appearance. Some argillaceous sandstone beds include brachiopods and fragments of crinoids. Other sandstone beds are porous, glauconitic, fine- to coarsely grained and cross-laminated (see Plate I, figs. a and c). Both types of sandstone are interpreted to represent marine, shallow water deposits.

Going southward on the cross section east of Worsley (Fig. 9) the Watt Mountain Formation becomes increasingly sandy and sections 2 and 3 include several thick, porous sandstone units. In these sections the top of the Gilwood member has moved up-section suggesting, that it is diachronous. The thick sandstone units are composed of porous, light greyish brown, fine- to medium grained, laminated and cross-laminated sandstones, locally including claystone pebbles, and greenish grey, sandy and silty, micaceous shales that locally contain sand-filled burrows or carbonaceous plant fragments (see Plate I, fig. b). The sand grains are subrounded to subangular and include quartz and microcline-feldspar. The presence of the plant fragments and claystone pebbles suggests deposition in a deltaic environment.

The Gilwood sandstone member unconformably overlies Precambrian rocks in section 5 of Figure 9. Here it represents a basal Devonian transgressive deposit. The overlying Waterways strata are only 20 m thick (compared to 139.6 m in section 5 of Fig. 9), suggesting that the member has merged into the Marginal clastics unit of the Beaverhill Lake Group. Samples from the member in a nearby well (Beaton 7-29-88-1W6) include very light grey, fine- to coarse-grained sandstone and very fine to fine-grained glauconitic, in places porous sandstone.

Thus the coarseness and "immaturity" of the sandstones in the Gilwood member increase toward the centre of the Peace River highland (Rottenfusser and Oliver, 1977). This and the fact that a large volume of sand was dispersed suggest that the deposition of the Gilwood member coincided with a period of effective erosion on the highland.

During the Early to early Middle Devonian period of evaporite deposition the combination of low relief and lack of rainfall on the highland prevented the removal of a large volume of weathering products. The presence of deltaic and fluvial sandstone deposits overlying the rubble deposits of the sub-Watt Mountain regression suggest a change to a moist climate. The combination of a tectonic uplift and a fall in sea level could have brought more rainfall, and higher rates of erosion and transportation of clastic sediment.

BEAVERHILL LAKE GROUP

This succession of anhydritic, fossiliferous and argillaceous carbonates overlies the uppermost shaly and sandy beds of the Elk Point Group with a transitional boundary. In central Alberta the group includes the Fort Vermilion, Slave Point, Swan Hills and Waterways formations. The Beaverhill Lake Group is truncated by the pre-Cretaceous unconformity in eastern Alberta, thus the eastern shoreline of the Beaverhill Lake Group is not preserved. The succession attains a thickness of more than 200 m and onlaps the marginal clastics around the Peace River highland which divides the Beaverhill Lake embayment into two parts (Fig. 10).

During the Middle and early Upper Devonian period of carbonate deposition in the Beaverhill Lake embayment (Fig. 10) the paleotopographic highlands in southwestern Alberta (Western Alberta ridge and Peace River highland) gradually decreased in size and only a moderate amount of clastics (mostly fine grained sandstone and siltstone) entered into the basin. Because of the general subsidence relative to sea level and the semi restricted, shallow water environment of deposition in the embayment, deposition of clastics was confined to the basin margin and onlaps the pre-Devonian and sub-Watt Mountain unconformities.

The lower part of the Beaverhill Lake Group is composed of carbonates (the Slave Point and Swan Hills formations), which accumulated in a shallow embayment similar in outline to the upper Elk Point embayment (see Leavitt and Fischbuch, 1968; Jansa and Fischbuch, 1974). In the northeastern part of the Beaverhill Lake embayment the lower part includes at the base an anhydritic unit (the Fort Vermilion Formation of Leavitt and Fischbuch, 1968 and Jansa and Fischbuch, 1974), which overlies the Watt Mountain Formation of the Elk Point Group (see Fig. 5). Around the Peace River highland this anhydritic unit decreases in thickness and interfingers with the overlying carbonates (see Fig. 11).

The Fort Vermilion Formation is overlain by carbonates of the Slave Point and Swan Hills formations. Around the Peace River highland these two formations step over the depositional edge of the anhydritic deposits of the Fort Vermilion and change into sandy carbonates (see Fig. 11) or sandstones of the Gilwood member (see Fig. 9).

The nearshore wedge of semi-restricted Slave Point carbonates around the Peace River highland includes small and large, flat- topped, stromatoporoidal mounds and shelf-edge reefs (Figs. 10 and 11). The large carbonate mounds of the Swan Hills Formation are located in the region south of Lesser Slave Lake (Fig. 10) and overlie the onlap edge of the underlying Fort Vermilion Formation (see Viau, 1987; Keith, 1990). Smaller carbonate mounds and shelf-edge reefs are present north of Lesser Slave Lake (see Craig, 1987; Tooth and Davies, 1989).

The upper part of the Beaverhill Lake Group is represented by the Waterways Formation. This formation includes five argillaceous and calcareous map units that encompass unda-, clino- and fondoform deposits (see Keith, 1990). These map units decrease in thickness toward the Peace River highland and onlap or interfinger with the carbonate wedge deposits of the Slave Point Formation (Keith, 1990; Craig, 1987). The onlap and interfingering facies boundaries are respectively shown on Figure 11, by curving and stepping correlation lines.

Fossils are common in the Beaverhill Lake Group. The Slave Point Formation includes brachiopods, stromatoporoids, corals, gastropods, tentaculitids, a diverse ostracod fauna and a restricted conodont fauna (the *Icriodus subterminus* Fauna, Braun et al., 1989). The Waterways Formation contains a marine fauna of Givetian and Frasnian brachiopods, bryozoans and conodonts (Norris and Uyeno, 1981).

Slave Point Formation:

The Slave Point Formation (Leavitt and Fischbuch, 1968) consists of light brown, nodular bedded, fossiliferous limestone or dolostone. Along the margin of the Peace River highland the lower part grades laterally into the Gilwood sandstone (see Fig. 9). On Figure 9 the top of the Slave Point Formation moves upward with the pre-Devonian paleotopography suggesting that the formation was deposited during a transgression.

In the Peace River region the Slave Point includes 1) a sandy nearshore facies, 2) a progradational platform facies and 3) a reefal mound facies.

The sandy nearshore facies is an interbedded succession of limestone, sandy limestone and calcareous sandstone. It overlies the Gilwood sandstone and changes laterally into the marginal clastics of the Woodbend Group. This lateral facies change is shown for the area northeast of Grande Prairie on Figure 12, between sections 9 and 11. Farther west, in the area south of Grande Prairie, the Slave Point Formation is difficult to distinguish as a separate map unit from the overlying limestone-rich Waterways Formation. Here the Slave Point and the Waterways formations grade northward into an interbedded unit of dark grey, sandy carbonates and light grey sandstones (see Plate I, figs. e to i).

The progradational platform facies of the Slave Point Formation includes the semi-restricted shelf or lagoonal deposits described by Craig (1987) as composed of nodular mudstones, algal-laminated and peloidal pack- and grainstones and amphiporoidal float- and rudstones. The overlying basinal deposits are composed of nodular mudstones, peloidal wackestones

and fossiliferous floatstones, containing scattered atrypid brachiopods, fragments of crinoids, thamnoporid corals and dendroid stromatoporoids.

North and east of the Peace River highland the platform facies interfingers with and is overlain by reefal mounds. These mounds are porous and gas bearing in the Hamburg, Chinchaga and Cranberry fields, whereas those in the Sawn Lake, Golden, Evi, Otter, Red Earth, Loon, Slave, Seal and Gift fields are oil bearing (Stauft, 1987). According to Craig (1987) and Gosselin et al. (1989) the reefal mounds are composed of reef (reef rim), fore reef, lagoon and back-reef deposits. They include stromatoporoidal frame- and bindstones; coraliferous and stromatoporoidal bound-, float- and rudstones; nodular mudstones; algal-laminated and peloidal pack- and grainstones and amphiporoid rud- and floatstones.

Waterways Formation:

This formation was described by Norris (1963) as a succession of nodular interbedded, light grey and greenish grey, argillaceous limestone and greyish green, calcareous or silty shale. The five subsurface units established by Keith (1990) change landwards into interbedded dolomitic or calcareous sandstone and sandy, fossiliferous limestone, or into pale coloured, dolomitic and locally porous sandstone. Along the northern flank of the highland this transition occurs over a short distance. Along the southern flank the transitional succession forms a belt that is about 10 km wide (see Fig. 12). The sandstones in this belt are locally oil bearing in the Giroux area.

The transition between Waterways sections dominated by limestone (see Fig. 9) and those dominated by sandstone along the northern flank of the Peace River highland is shown in Figure 13 between sections 1 and 2. The clastic equivalents of the Waterways have a gamma-ray log signature similar to that of the Worsley 11-23-88-6W6 well (see Fig. 13, section 2). They were cored in the Worsley 2-30-88-4W6 well. In this well the clastics underlie dark grey, dolomitic siltstone beds of the Muskwa Formation and consist of a thinly and nodular interbedded succession of light greyish brown, very fine- to fine-grained, dolomitic, in part glauconitic, well sorted, laminated or bioturbated sandstones, and greenish grey or dark grey, silty shale beds locally including carbonaceous plant imprints (see Plate I, Fig. k). Toward the top the unit becomes increasingly sandy and coarser grained. Some of the beds are conglomeratic and composed of a dolomitic, very finely grained matrix and loosely packed semitranslucent, clear or pale reddish brown quartzite pebbles. Other sandstone beds include scattered fragments of brachiopods, thamnoporid corals and crinoid ossicles (see Plate II, Fig. a). The sandstone beds in the interval that is transitional to the Muskwa Formation are very fine-grained and interbedded with dark grey, silty shale (see Plate II, Figs. b and c).

Parts of the clastic facies of the Waterways Formation were also cored along the southern flank of Peace River highland, particularly in the area near Girouxville (Twps. 76-22W5, 77-21W5, 77-22W5 and 78-21W5). Here the facies includes well sorted, laminated and porous sandstones similar to the ones shown in Plate I, figures a and l. The basal part of this facies was cored in the Kimiwan 9-13-80-21W5 well (see Plate I, Fig. f). In the Pinto Creek 13-19-69-8W6 and Gold Creek 10-16-69-5W6 wells the marginal clastics consist of dark grey

and grey mottled, argillaceous, poorly sorted, very fine- to fine-grained sandstone, interbedded with light grey to grey, bioturbated, very dolomitic sandstone, and include fragments of charophytes, placoderms, crinoids, gastropods and brachiopods (see Plate I, figs. e, g, h and i).

The zero edge of the Slave Point Formation around the Peace River highland marks the transition from carbonates to sandstone at the top of the Beaverhill Lake Group. This transition between sandy shoreline and calcareous nearshore environments of deposition may serve as a rough outline of the coast line. The zero edge of the marginal clastics on Figure 10 indicates that during the early Upper Devonian (early Frasnian) period the Western Alberta Ridge became submerged and the Peace River highland formed an island.

WOODBEND GROUP

The stratigraphic and facies relationships within the Woodbend Group are complex and change from region to region. The Woodbend Group (Geological Staff, Imperial Oil, 1950) in east-central Alberta includes a carbonate platform facies (Cooking Lake Formation), a carbonate mound facies (Leduc Formation), and two basinal shale deposits (Duvernay and Ireton formations). The succession is more than 400 m thick in eastern Alberta. Here it is truncated by pre-Cretaceous erosion, thus shoreline deposits equivalent to the Woodbend Group are not preserved.

In west central Alberta the carbonate platform unit is replaced by a third basinal shale unit (the Majeau Lake Formation) which underlies the Duvernay Formation (Fig. 2). Here the Ireton includes an additional upper unit not present the type section (located in eastern Alberta), because in central Alberta the overlying Winterburn carbonates change into Ireton-like shale (Exploration Staff Chevron Standard, 1979; Stoakes, 1980). The boundary between the lower and upper parts of the Ireton dips to the northwest (see Fig. 2).

In northern Alberta the Cooking Lake and Majeau Lake formations have been replaced by the Muskwa Formation (Fig. 1), and the Muskwa is overlain by the Fort Simpson Formation.

The carbonate mounds that locally interrupt the shaly sediments of the Woodbend Group in central Alberta and overlie the carbonates of the Cooking Lake, Swan Hills or upper Beaverhill Lake, are part of the Leduc Formation. Some of the Leduc mounds reach upward and appear to be continuous with the overlying Winterburn carbonates.

Apparently, the production and accumulation of carbonate sediment was limited to a few favourable areas and could only locally keep up with a continuing, relative rise in sea level. During the early Late Devonian (Frasnian Stage) a wedge of sandy and carbonate deposits, up to 80 km wide and 215 m thick, accumulated around the Peace River highland. Western Alberta Ridge was submerged (Fig. 15).

The Woodbend carbonates are very fossiliferous and contain a diverse fauna of stromatoporoids, corals, bryozoans, foraminifera and algae. The combined presence of crinoidal, brachiopodal and coral fragments in some of the carbonates suggests normal marine conditions. Gastropods, calcispheres and stromatolitic overgrowth on fossil fragments in other carbonates indicate local semi-restricted conditions. The shales of the Woodbend Group are poorly fossiliferous but locally include brachiopods, tentaculitids, plant fragments, ostracodes and Frasnian conodonts.

Leduc Formation, Peace River carbonate complex:

The carbonate mounds of the Leduc Formation (Figs. 1 and 2) can be placed in any of three categories. In the first category the carbonate mounds share a common base or platform, from which the individual reefal mounds rise to different heights. Examples are the porous mounds in the Homeglen-Rimbey to Morinville and the Bashaw to Duhamel chain in southeastern Alberta. In the second category the carbonate mounds form individual entities surrounded by the shaly basin fill of the Ireton Formation. Examples are the Sturgeon Lake (Fig. 2) and Gold Creek reef complexes. The third category includes the reefal deposits associated with the shelf carbonates along the basin margin. Examples are the Grosmont and Peace River carbonate complexes (Fig. 2).

The Sturgeon Lake reef complex, located east of Grande Prairie (see Figs. 2 and 16), was described by Morgan (1964) as an atoll. The atoll has an irregular, mound-like shape on cross section, which decreases in circumference toward the top, and is characterized by a pervasive dolomitization of the original reefal and non-reefal limestones. In the central part of the complex the fine to coarse dolomitization extends upward into the overlying Winterburn platformal carbonates of the Nisku Formation.

The Peace River carbonate complex is a landward thinning wedge of fine to coarsely dolomitized, fossiliferous carbonates that includes shelf edge reefs and nearshore, shoreline, shallow shelf and lagoonal deposits (see Dix, 1990). The southern part of the complex overlies the marginal clastics of the Woodbend Group (the "Marginal Clastics" unit on Fig. 12), overlies equivalents of the Waterways Formation or overlies the lower part of the Ireton Formation. The southern edge of the Peace River carbonate complex is in lateral contact with the upper part of the Ireton (Fig. 12) and locally includes several shelf edge mounds that contain oil in the Puskwaskau (Twp. 74-1W6) and Normandville (Twp. 77-25W5) fields. The stratigraphic section of the carbonate complex in the region northeast of Puskwaskau (Fig. 12) shows that the wedge has the general shape of a prograding platform and includes stratigraphic equivalents of the Nisku Formation.

Dix (1990) recognized within Peace River carbonate complex (including the marginal clastics and excluding the Nisku equivalent) three stages of platform development, suggesting three phases of reef growth and associated carbonate accumulation. During the first phase a mixed assemblage of carbonates and coarse clastics prograded into the basin. The second phase includes the formation of reefs and the formation of a thick wedge of carbonate sediments. During the third phase the carbonate platform diminished in size, suggesting that local carbonate production did not keep up with the general relative rise in sea level.

The Peace River carbonate complex can be traced across the area southeast of Peace River between Girouxville and Worsley (see Fig. 13). In this figure it is assumed, that on the southeastern flank of the Peace River highland, the lower part of the carbonate complex interfingers with the clastics that surround the highland (the "Marginal Clastics" unit). The upper part of the dolomitized carbonate complex first moves upward stratigraphically to the northwest (across the Peace River highland) to incorporate equivalents of the Nisku Formation, and then moves downward to a stratigraphic level below the Winterburn Group, to form the "Platformal unit". The "Platformal unit" is widely distributed across the crestal part and along the northwestern flank of the Peace River highland.

The northern and eastern parts of the Peace River carbonate complex overlie the "Marginal Clastics" unit, composed of interbedded arkosic sandstone and pale grey, sandy dolostone. In the region east of Worsley the "Platformal unit" (Fig. 14), composed of silty and sandy dolostone, is locally overlain by a "Mounding" unit, composed of porous, fossiliferous dolostone. The "Mounding" unit is porous and some are gas bearing. The linear arrangement of these gas fields in the Worsley area (see insert Fig. 14) suggests that the mounds represent individual reefs, that are part of a long chain of reefs that flourished along the north flank of the Peace River highland. The "Platformal" unit extends northward on Fig. 14 and merges into a silty carbonate deposit at the base of the Fort Simpson Formation. Because this "Feather-edge" facies overlies both the Muskwa Formation and the "Marginal Clastics" unit of the Woodbend Group (Figs. 14 and 15), one may argue that the Peace River carbonate complex and the lower part of Fort Simpson Formation are approximately coeval.

The "Platformal unit" of the Leduc Formation was cored in the Worsley 8-6-87-7W6 well (Fig. 14, section 1). It overlies the marginal clastics of the Woodbend Group and consists of thinly interbedded and laminated, light grey, anhydritic dolostone and light greenish grey, dolomitic siltstone. The dolostone beds are fine or fine to medium crystalline and have a laminate peloidal fabric (see Plate II, Fig. g). The "Platformal unit" in the Worsley 10-22-87-7W6 well (located on Fig. 14 near section 3) is similar. It also includes pale greenish grey, argillaceous, fine- to coarse-grained sandstone and green, sandy shale interbeds. Some dolostone beds include nodules that may represent recrystallized gastropods (see Plate II, Fig. h). The laminate peloidal aspect and sandy nature of the "Platformal" carbonates and the paucity of fossils suggest deposition in a semi-restricted, shallow water bay.

The "Mounding unit" (Fig. 14) was cored in several Worsley wells and is composed of massive, brown and light grey mottled, fine-crystalline, fossiliferous dolostone including light grey, coarsely crystalline patches and scattered vugs lined with white dolomite. Some intervals may represent coraliferous rudstones or fossiliferous floatstones, others peloidal packstones including fragments of crinoids, brachiopods, gastropods, corals and bulbous stromatoporoids. The carbonates of the "Mounding" unit have a reefal aspect and represent nearshore, wave resistant deposits in turbulent water.

Marginal clastics:

On the northern and eastern flanks of the Peace River highland the Peace River carbonate complex overlies the "Marginal Clastics" unit (see Fig. 14). The lower interbedded sandstone and silty shale part (the shaly part) of the "Marginal Clastics" unit grades toward the basin centre into the Beaverhill Lake Group suggesting the absence of a sharp boundary with the sandy facies of the Waterways Formation. The upper interbedded dolostone, dolomitic sandstone and sandy dolostone part (the dolomitic part) appears to be more or less equivalent to the Woodbend Group (see Fig. 13). Dix (1990) considered the lower part of the "Marginal Clastics" unit to be the first stage of progradational (mixed carbonate and clastic) platform development around the highland. The upper, dolomitic part of the "Marginal Clastics" unit is in sharp, lateral contact with the Fort Simpson Formation and according to Dix (1990) it represents the second stage of platform progradation. Both stages of mixed clastic and carbonate platform development are considered to be older than the stage of basin-infill represented by the Muskwa and Fort Simpson formations (south of the Peace River highland) or the Majeau Lake, Duvernay and Ireton formations (north of the Peace River highland).

Thus the distribution of the lower part of the "Marginal Clastics" unit of the Woodbend Group is shown on Figure 16 together with the Sturgeon Lake, Gold Creek and Simonette reef complexes. The distribution of the upper part of the "Marginal Clastics" unit is shown on Figure 17 together with the dolomitized Peace River carbonate complex. Here the carbonate complex overlies and surrounds the continental part of the "Marginal Clastics" unit. The outer edge of the marginal clastics on Fig. 16 marks the approximate location of the early Late Devonian (Frasnian) shoreline. Notice that later in the Frasnian Stage (Fig. 17) the shoreline, represented by the outer edge of the Peace River carbonate complex, has moved away from the center of the highland due to carbonate-platform progradation and reef growth.

The "Marginal Clastics" unit of the Woodbend Group were cored in a number of wells drilled in the area around Worsley (Fig. 14). Unfortunately, none of the cores includes a complete section. In a 15 m long core from the Worsley South 10-19-86-7W6 well, the upper part of the unit (interval 7294 to 7342 ft) consists of interbedded light greyish brown conglomeratic sandstones, sandy conglomerates, including grey and pale reddish brown quartzite pebbles, and dark greyish green and dark reddish brown, sandy shales. Some sandstone beds are laminated, cross laminated, relatively well sorted and porous; others are massive, red-brown mottled, argillaceous and non-porous sandy redbeds. Three representative core samples of the "Marginal Clastics" unit are shown in Plate II, figs. e, f and k. The presence of erosional surfaces and truncated paleosols (including traces of roots (Plate II, fig. f) in the unit suggests that the clastics were deposited in a continental, coastal plain environment.

The conglomeratic, basal Devonian redbeds directly underlying the Winterburn succession in the Royce 12-6-83-4W6 well (located near section 10 on Fig. 13) were described by Trotter and Hein (1988) as deposits of an ancient fluvial system. The redbed lithologies are shown in Plate II, fig. m and Plate III, figs. a and b.

Majeau Lake, Duvernay and Muskwa formations:

The Majeau Lake and Duvernay formations comprise the lower part of the shaly basin-fill of the Woodbend Group that surrounds the reef complexes of the Leduc Formation. The Majeau Lake (Pollock, 1967) underlies the Duvernay and is equivalent to the Cooking Lake Formation. The Duvernay Formation represents the lower part of the basin-fill facies in the region east of the Homeglen-Rimbey to Morinville reef trend and overlies the Cooking Lake (see Geological Staff, Imperial Oil, 1950).

In the Lesser Slave Lake region the Majeau Lake and Duvernay formations increase in thickness toward the east and grade into unit LG and the lower Ireton unit of Cutler (1983) that underlie the Grosmont carbonate complex (see Meijer Drees, 1985). Both formations are present on Figure 11 and grade northward into the Muskwa Formation.

The Majeau Lake and Duvernay formations abut the Sturgeon Lake reef complex and grade into the interbedded shale and limestone unit that locally underlies the Leduc Formation of the Peace River carbonate complex (see Fig. 12).

The Muskwa Formation (Gray and Kassube, 1963; Griffin, 1965) in northeastern British Columbia and northern Alberta is a laminated unit of dark grey, radioactive shale and siltstone that resembles the laminated marlstone of the Duvernay Formation. Williams (1977) and Cutler (1983) described the Muskwa Formation as a fondoform deposit which increases in thickness toward the east and includes equivalents of the underlying Waterways and overlying Fort Simpson formations. Correlations in the region north of Lesser Slave Lake (see Fig. 11) demonstrate that the Muskwa correlates with the Majeau Lake and Duvernay formations. Along the northern flank of the Peace River highland the Muskwa Formation grades southward into the marginal clastics of the Woodbend Group (see Figs. 13 and 14).

The Muskwa Formation was partly cored in the Clear Hills No. 1, 2-28-94-9W6 well and consists of very dark grey, slightly dolomitic and silty shale, which is locally micaceous. In the Worsley 2-30-88-4W6 core the Muskwa shale grades downward into dark grey, dolomitic siltstone including several 1-5 cm thick, fine to medium grained, dolomitic sandstone beds, that contain remains of plants, conodonts and brachiopods (see Plate II, Fig. c). The silty and sandy facies of the Muskwa were partly cored in the Siphon Creek 1-26-86-16W6 well (Fig. 15, section 1) and consist of interbedded, grey, and light grey mottled, very fine to medium grained arkosic, dolomitic and pyritic sandstone and greenish grey, sandy shale. The shaly and sandy beds include plant fragments (see Plate II, Fig. d).

The shaly, laminated and bituminous character of the Muskwa, Majeau Lake and Duvernay formations, the lack of sedimentary structures related to current and wave action and the absence of bioturbation by sediment feeders suggest an euxinic, relatively deep water (below the level of storm induced turbulence) environment of deposition. It may be argued that the distribution of the euxinic sediments around the Sturgeon reef complex (Fig. 12) indicates deposition in two different, but initially contemporaneous environments (off-reef and on-reef) and that carbonate production in the on-reef, shallow water environment ceased

because of subsequent euxinic conditions. Schlager (1981) described this process as a "drowning event". In terms of sequence stratigraphy the drowning event marks the beginning of a new cycle of basin-infill and the base of the bituminous sediments represents a "maximum flooding surface". Because the bituminous deposits in Alberta include conodonts of the Upper *asymmetricus* to Lower *gigas* zones (Johnston and Meijer Drees, 1993), the period of maximum flooding falls within the middle part of the Frasnian Stage.

Ireton and Fort Simpson formations:

In central Alberta the Ireton Formation (Geological Staff Imperial Oil, 1950) constitutes a westward prograding wedge of shaly sediments that includes increasingly younger strata toward the west (Stoakes, 1980). In central Alberta the formation includes many clinoform markers. The most prominent marker is the Z-marker of Stoakes and Wendte (1987). It divides the Ireton Formation into two parts. The lower part includes all the strata represented in the type area and forms a wedge-like deposit between the Leduc reef complexes. This wedge becomes thinner toward the northwest (see Fig. 16). The thin edge of the wedge was mapped along the southern flank of the Peace River highland by Dix (1990, Fig. 17). Here it grades into the shaly beds that underlie the Peace River carbonate complex (see Fig. 12). North of Lesser Slave Lake the thin edge grades into the lower part of the Fort Simpson Formation (the "Lower Ireton equivalent" on Fig. 11), whereas east of Lesser Slave Lake the lower part of the Ireton Formation grades into, or abuts, the lower part of the Grosmont carbonate complex (Meijer Drees, 1985). A thick interval of the carbonate deposits of the Peace River and Grosmont complexes is thus younger than the lower part of the Ireton Formation.

The upper part of the Ireton Formation includes the shaly equivalent of the Winterburn carbonates (see Stoakes and Wendte, 1987). Its distribution coincides with the outline of the West Pembina Shale basin (Exploration Staff, Chevron Standard, 1979) shown on Figure 18. Here it is a marginal clinoform deposit and underlies, or grades, toward the basin centre, into a thick succession of silty and argillaceous carbonates, that includes evaporites in the upper part (see Fig. 19). The relationship between the upper part of the Ireton Formation and the lower part of the Winterburn Group at the north end of the Pembina Shale basin (see Fig. 18) is shown in Figure 12.

The upper part of the Ireton Formation in the Peace River region was cored in two wells. In the Sturgeon Lake 6-2-72-24W5 well (Fig. 12, section 16) the cored interval overlies the Sturgeon Lake reef complex. In the Puskwar 14-23-74-1W6 well the cored interval overlies the Peace River carbonate complex and includes the upper part of the Leduc Formation. In both cores the Ireton consist of dark greenish grey, fissile shale with many calcareous nodules or nodular interbeds of greyish brown, very argillaceous limestone. The calcareous nodules and interbeds are locally dolomitized and include scattered fragments of tentaculitids, crinoids and brachiopods. The laminated shale contains lingulid brachiopods, *Spathiocaris* sp. and the plant remains described by Dix (1990); see Plate II, Fig. i.

An interbedded succession of shale, argillaceous limestone and fossiliferous limestone transitional between the upper Ireton and the Peace River carbonate complex was cored in

the Pinto 16-19- 69-8W6 and Kimiwan 9-13-80-21W5 wells. In these cores the shaly intervals are very thinly interbedded with calcareous mudstone or include calcareous nodules. The calcareous intervals are nodular, bioturbated wackestones and peloidal or fragmental packstones including ostracodes, tentaculitids, crinoids, brachiopods, gastropods, corals and mid-Frasnian conodonts (Uyeno, *in* Johnston and Meijer Drees, 1993).

The non-bituminous, fine-grained and fossiliferous nature, the interbedded laminated and bioturbated aspect, and the local presence of sedimentary structures formed by current and wave-generated turbulence in the sediments of the Ireton Formation, suggest deposition in a relative deep water environment under normal marine conditions (below or at the level of storm induced turbulence).

The Fort Simpson Formation (Belyea, 1964) includes the mudstones and shales situated between the Muskwa Formation and the Winterburn carbonates (see Fig. 1). In the region east of the 6th Meridian the formation includes the Lower Ireton equivalent (see Fig. 11). The Lower Ireton equivalent decreases in thickness toward the west and grades into the upper part of the Muskwa Formation.

The basal beds of the Fort Simpson Formation were cored in the Worsley 2-30-88-4W6 well (just outside the location map in Fig. 12). Here they consist of greenish grey, slightly silty and dolomitic shale. In Worsley 10-21-87-7W6 (near section 3, Fig. 12) the contact with the Leduc Formation was cored and the basal part of the Fort Simpson Formation includes several thin, silty, dolomitized, crinoidal interbeds that may have been deposited during the "drowning" event of the Peace River carbonate complex.

Winterburn Group

In the southwestern Interior Plains the Winterburn is composed of two widely distributed, superimposed platform-like carbonate units that include evaporite deposits in the east and grade westward into fossiliferous carbonates and fine clastics. The shoreline deposits of these platformal units were removed by pre-Cretaceous erosion, but the distribution of the various carbonate and evaporitic facies within the platformal units suggest that they must have been located somewhere along the southwestern margin of the North American craton. This situation indicates that the Winterburn sediments were deposited in the Alberta basin by westward progradation.

In northern Alberta the Winterburn Group is more than 120 m thick and includes, in ascending order, the Nisku, Calmar and Graminia formations (Belyea, 1964). The Nisku represents the lower platformal unit and is composed of silty and fossiliferous dolostone. In east central Alberta it overlies the Ireton Formation through an interbedded interval. It is overlain by a relatively thin unit of red and green mottled or greenish grey, shaly and silty dolostone or siltstone (the Calmar Formation) that may include regressive and transgressive deposits. These clastic deposits grade upward into the upper platformal unit represented be the carbonates of the Graminia Formation (the Blue Ridge Member of Choquette, 1955),

composed of anhydritic dolostone, anhydrite and silty dolostone. The Blue Ridge member is overlain by the informal "Siltstone member".

The three formations extend westward for some distance before they lose identity. Within the outline of the West Pembina shale basin (Fig. 18) the Nisku and Calmar are not mappable, because of the facies change to silty carbonates. The Graminia Formation remains a mappable unit across the West Pembina shale basin until the depositional limit of the Siltstone member is reached (Fig. 19).

In the West Pembina shale basin the Ireton Formation grades upward into a thick, poorly bedded unit of sandy and silty carbonates. These silty carbonates are shown on Fig. 12 as a silty facies equivalent to the Nisku that characterizes the West Pembina shale basin in the area east of Grande Prairie. In the region southeast of Grande Prairie the silty facies of the Nisku is locally overlain by a succession of anhydrite, halite, reddish brown shale and sandy, peloidal limestone. This succession is more or less equivalent to the Graminia Formation and its distribution is shown on Figure 19 as the "Economy evaporites".

The Winterburn succession is fossiliferous. The Nisku includes poorly preserved fragments of Frasnian corals, gastropods, brachiopods, stromatoporoids, calcareous algae, crinoids and ostracodes. The Graminia in the Peace River region includes similar Frasnian fossils. The early Famennian (Lower *triangularis* to Upper *crepida*) conodonts found in the sandy and peloidal limestone unit in the central part of the West Pembina shale basin (in the Baseline 10-25-65-27W5 well) indicate that the Frasnian – Famennian boundary lies at the base of the Siltstone member of the Graminia Formation (Johnston and Meijer Drees, 1993).

Nisku Formation:

Along the southern flank of the Peace River highland the Nisku is a fossiliferous carbonate unit that overlies the Ireton Formation, thins toward the northwest, becomes very fossiliferous and increasingly dolomitized and merges into the upper part of the dolomitized Leduc Formation of the Peace River carbonate complex (Figs. 12 and 13). Morgan (1964) also showed the apparent equivalence of the Nisku and the upper part of the Leduc Formation in the central part of the Sturgeon Lake reef complex.

The equivalent of the Nisku Formation in the Leduc Formation of the Peace River carbonate complex was cored in the Whitelaw 6-31-80-1W6 and Whitelaw 15-9-81-2W6 wells (Fig. 13, sections 14 and 15). The two cores in the lower part of the formation in the Whitelaw 15-9-81-2W6 well are composed of light brown, vuggy, fine to coarsely crystalline dolostone including poorly preserved and leached fossils such as brachiopods and bulbous stromatoporoids. The thinly bedded dolostone intervals in the core may represent recrystallized, well sorted medium peloidal or fragmental pack- to rudstones. In the Gage 4-27-81-3W6 well the Nisku equivalent in the Peace River carbonate complex overlies the marginal clastics. Here the basal part consist of brown to greyish brown, very dolomitic siltstone that is interbedded with irregularly wavy, discontinuous shale partings. The siltstone beds include a few scattered white dolomite inclusions and gastropod-like fossils. They are overlain by a brown and white mottled, massive, very fossiliferous dolostone including

recrystallized fragments of thamnoporid and disphyllid corals, and branching corals in growth position.

The platform facies of the Nisku Formation is widely distributed in the southeastern part of the Peace River region and a typical section is present in the Clarkson 11-1-71-23W5 well (Fig. 12, section 20). The lower part of the platform facies was cored in the Clarkson well and consists of a dark greyish brown, fossiliferous limestone including nodular interbeds of shale and dolomitic mottles. The upper part and the contact with the overlying Calmar Formation was cored in a nearby well (the Sturgeon Lake 2-11-70-22W5 well). In this core the dark greyish limestone is transitionally overlain by a massive, light greyish brown, very fossiliferous limestone including poorly preserved digital stromatoporoids, thamnoporid and syringoporid corals, brachiopods, ostracodes and calcareous algae. The pebble-seized fossil fragments are scattered in a dolomitic, fine peloidal and medium to coarsely fragmental matrix. The contact with the overlying green shaly siltstone of the Calmar Formation sharp and erosional.

East of Grande Prairie the platform facies grades into the silty facies of the West Pembina shale basin (see Fig. 12). A representative section of this is shown in the Sturgeon Lake 6-2-72-24W5 well (Fig. 12, section 17). The silty facies was not cored in the Peace River region but is represented in drill cuttings by light greyish brown, very silty and sandy limestone and light grey to greenish grey, calcareous siltstone.

In the region north of the Peace River highland the Nisku formation is a rather thin, but distinct unit that overlies the Fort Simpson Formation (Fig. 13, sections 1-5). In borehole cuttings it is a greyish brown, finely bioclastic limestone.

It is apparent that after the decrease in reefal growth during the middle Frasnian (the middle Frasnian "drowning event"), the production of carbonate sediment during the late Frasnian at the southwestern edge of the Grosmont and around the Peace River carbonate complexes increased to the point that it exceeded the amount of relative subsidence in the basin. Thus the carbonates of the Nisku Formation prograded into the basin from the newly established shoreline. The apparent continuity between the upper part of the Leduc Formation in the central part of the Sturgeon Lake reef complex and the Peace River carbonate complex suggests that the more elevated parts of these complexes were not affected by the middle Frasnian "drowning event". These parts may have served as nuclei for renewed reef growth during the late Frasnian.

Calmar and Graminia formations:

Both the Calmar Formation and the Siltstone member of the Graminia Formation are distinctive marker beds that can be traced northwestward with the aid of geophysical borehole logs from the type sections in central Alberta into west central Alberta, (see Meijer Drees, 1985). In the southern part of the Peace River region the marker beds loose their identity in the succession as a result of the general westward decrease in siltstone and shale interbeds. Thus, on Figure 12, the lower part of the Calmar merges into the Graminia

between sections 15 and 17, and the Graminia into the basal part of the Wabamun Formation between sections 7 and 8.

It is interesting to note that in the Peace River region the Calmar includes a marine fauna and lacks the interbeds of sandstone and reddish brown, dolomitic shale that are commonly present in the type area southeast of Edmonton (see Geological Staff Imperial Oil, 1950). This suggests that the formation has a somewhat transgressive character in the Peace River region.

The Calmar is present as a thin, distinct argillaceous unit in the southern and eastern and parts of the Peace River region. Typical sections in the area northeast of Grande Prairie are shown on figures 12 and 13. The Calmar in section 20 on Figure 12 is similar to the cored interval in the Sturgeon Lake 2-11-70-22W5 well. Here the basal part of the formation consists of poorly interbedded, greenish grey, very calcareous and argillaceous siltstone and greyish brown, nodular, finely peloidal and fragmental, in part very silty limestone (pack and grainstones). The formation includes fragments of gastropods, crinoids, brachiopods, ostracodes, calcareous algae and scattered brachiopods in growth positions. A 10 cm thick, bluish green, silty shale bed marks the boundary with the underlying Nisku.

The cored section in the Puskwaskau 11-6-73-24W5 well is similar to section 12 on Fig. 12. Here the lower part of the formation is a greyish brown, very silty and argillaceous, finely fragmental and peloidal limestone, including coquina interbeds and dark grey marlstone partings. The upper part is an interbedded, fossiliferous succession of grey, very calcareous siltstone, greyish brown, very silty limestone and dark greyish brown, very argillaceous limestone. The argillaceous intervals are thinly and nodular bedded. The non argillaceous siltstone and limestone beds have a massive, bioturbated appearance and include scattered fragments of ostracodes, calcareous algae, brachiopods, gastropods, crinoids and corals (*Phillipsastraea* sp.). Neither the lower nor the upper boundary of the Calmar Formation in the core is sharp.

In sections 15 to 20 of Figure 13 the basal part of the Calmar is a dolomitic or calcareous, silty shale. Here the upper part includes silty and somewhat argillaceous, fossiliferous limestones or very fine to fine-crystalline dolostone. The formation becomes less argillaceous toward the northwest and its depositional limit is crossed twice by the section.

The Graminia Formation is a less distinctive formation than the Calmar Formation in the area northeast of Grande Prairie. It is traced across the Peace River highland on Figure 13, but information from samples and cores was needed to confirm the correlations.

In the Dreau 4-35-77-22W5 well (Fig. 13, section 20) the two fold subdivision in Blue Ridge and Siltstone members is still evident, because the Siltstone member at the top constitutes a thin but recognizable unit on the gamma-ray curve. Going northwestward on Figure 13, it becomes increasingly difficult to recognize the subdivision into Blue Ridge and Siltstone members, because siltstone interbeds are absent. Thus, in the Whitelaw 15-9-81-2W6 well (Fig. 13, section 14), the Siltstone member is absent and the Graminia is composed of a grey

and greyish brown, nodular or nodular bedded, very fine to fine-crystalline, vuggy dolostone, including poorly preserved corals and brachiopods.

The Graminia Formation and the facies change of the Siltstone member in the area northeast of Grande Prairie are also shown on Figure 12. The depositional limit of the Siltstone member occurs between sections 12 and 13 and is drawn on Figure 19 as an north-south oriented, undulating line west of the Smoky River. In the region west of this line the top of the Graminia is selected at the next highest occurrence of siltstone below the peloidal limestone of the Wabamun Group (see Fig. 12, sections 8 to 12). There are no siltstone interbeds in the area west of Grande Prairie to mark the upper boundary of the Graminia Formation and the formation has lost much of its identity as a subsurface map unit. This lateral facies change is depicted on Figure 12 in sections 3 to 8.

The silty limestone of the Graminia Formation in the Smoky River 2-8-76-26W5 well (Fig. 12, section 8) changes northwestward into light brown, locally silty, very fine to fine crystalline dolostone. The upper part of the dolostone facies was cored in the Smokey Heights 16-20-74-2W6 well and is a fine fragmental, partly dolomitized wackestone, including fragments of crinoids, ostracodes and gastropods. In the Wanham 12-20-77-3W6 well (Fig. 12, section 3) the lateral equivalent of the dolostone is a light brown, fine to medium peloidal, locally oolitic limestone partly altered to fine crystalline dolostone. In the cored interval of the Wanham well, the peloidal limestone is locally crinoidal and includes brachiopods. It erosionally overlies (at depth 8992.5 ft) a fossiliferous limestone unit, including Frasnian colonial corals, solitary corals (*Thamnopora*), stromatoporoids and gastropods, that belongs to the Graminia Formation. Because the peloidal limestone facies is typical of the Wabamun Group, it is concluded that, in the western part of the Peace River region, the upper part of the Graminia Formation changes laterally into the Wabamun.

In the northern part of the Peace River region the Winterburn Group does not include the evaporitic deposits characteristic for the Graminia Formation of southern Alberta. Thus neither the Calmar nor the Graminia formation constitute mappable formations in the Winterburn Group. In sections 1 to 6 on Figure 13, and sections 1 to 4 on Figure 15, the approximate equivalent of the Calmar Formation is a calcareous siltstone, including brachiopod shell fragments. The equivalent of the Graminia Formation is a dark grey, argillaceous and silty limestone.

Marginal clastics:

The carbonates of the Winterburn Group change into sandy carbonates and reddish brown mottled, continental sandstones of the "Marginal Clastics" unit. The Winterburn part of the "Marginal Clastics" unit onlaps the crestal part of the Peace River highland and its distribution is schematically shown on Figure 19. The onlap pattern is displayed on two cross sections in the western part of the Peace River region (Figs. 12 and 14). Here the onlap pattern is not interrupted by interfingering, basinward prograding, clastic units. This situation suggests that the Peace River highland ceased to be an effective sediment supplier during the late Frasnian Stage.

Representative sections of marginal clastics interpreted to belong to the Winterburn Group occur in the area north of Dawson Creek and are shown on Figure 15. In sections 4 to 6 of Figure 15, the "Marginal Clastics" unit is composed of light grey, slightly dolomitic, fine to coarsely grained, micaceous and arkosic sandstone; dolostone; fine-grained, calcareous and dolomitic sandstones; fine to coarse-grained, quartzose sandstone; and dark grey siltstone and finely peloidal limestone. The upper part of the clastics and the contact with the overlying limestone of the Wabamun are shown on Plate III, fig. 1.

It is apparent from the geological information in the Peace River region that during the late Frasnian Stage the Peace River highland did not have a major influence on the regional sedimentation pattern in the Winterburn basin. The transgressive event associated with the deposition of the Calmar Formation in southeastern Alberta did not produce a decrease in the rate of carbonate deposition along the margin of the Peace River highland. During the subsequent regression the silt and sand content in the carbonate sediments decreased but the environment of deposition remained unchanged. The sediments include continental sandstones, sandy and peloidal, nearshore carbonates and silty, bioturbated and fossiliferous, shallow water carbonates.

Wabamun Group

The Wabamun Group (Belyea, 1964) consists of carbonate ramp deposits that prograded west and northwestward in a shallow sea that covered the southeastern margin of the North American craton. The group includes redbeds, peritidal evaporites and semi-restricted shallow marine carbonates in the lower part (Stettler Formation). The upper part (Big Valley Formation) is interpreted as a transgressive deposit with an open marine character. The Wabamun is truncated in east central and northeastern Alberta by pre-Cretaceous erosion. It is more than 250 m thick in central and northern Alberta and decreases in thickness to zero because of onlap against the crestal part of the Peace River highland (see Fig. 20). The zero edge of the Wabamun outlines several Precambrian knobs surrounded by coarse grained clastics that were emergent during the Late Devonian (see Fig. 21).

In west-central Alberta the Wabamun Group is not formally subdivided into formations, although Andrichuck (1960) recognized four informal units and correlated the uppermost unit with the Big Valley Formation. The other three units correlate with the upper part of the Stettler Formation.

In northeastern British Columbia the carbonate succession gradually loses its massive character to become an interbedded succession of limestone, argillaceous limestone and calcareous or silty shale (the Kotcho and Tetcho formations). The first shaly interbeds occur west of the facies boundary shown on Fig. 21.

The Wabamun is fossiliferous and includes brachiopods, gastropods, stromatoporoids, algae, crinoids, conodonts and ostracodes. The fossils are typical of the Famennian Stage (see Raasch, 1956; Lethiers, 1981).

The Big Valley Formation has been extended into west-central Alberta (see Meijer Drees and Johnston, 1993) and the lower part of the Wabamun Group was subdivided into four informal log-units (see Halbertsma and Meijer Drees, 1987). These are, in ascending order, the Dixonville, Whitelaw, Normandville and Cardinal Lake. These four units include similar lithologies and can only be defined by the general geophysical log character.

The Dixonville consists of moderately porous and a relatively pure carbonate. The limestone includes mudstones, fragmental and peloidal pack- and grainstones with laminate fenestral structures, oncoids and coated peloids. The limestone is commonly recrystallized into a finely crystalline, porous dolostone.

The Whitelaw unit is relatively non-porous and impermeable. It includes some argillaceous interbeds. The lower part is composed mainly of crinoidal mud- and wackestones; the upper part of wacke- and packstones. The upper part also includes peloidal grainstones, stromatolites and tabular stromatoporoids.

In the Peace River region the upper part of the Whitelaw log-unit changes facies northwestward from "clean" to "shaly" carbonates (see Figs. 13 and 15). The "shaly" carbonates were cored in the Parkland gas field located north of Dawson Creek (Fig. 14, sections 4 and 5) and in the Hamburg 5-34-96-11W6 well and comprise a succession of dark grey, interbedded marlstone and argillaceous lime-mudstone. In Parkland the interval includes sediment filled burrows and brachiopods in the upper part and contains several burrowed horizons in the lower part.

The Normandville unit is relatively pure carbonate and includes porous intervals. The typical lithology is a fragmental and peloidal grainstone, locally including stromatolitic and stromatoporoidal deposits (Nishida, 1987; Halim-Dihardja and Mountjoy, 1989).

The geophysical character of the Cardinal Lake log-unit resembles that of the Whitelaw. The unit is largely composed of crinoidal and peloidal wacke- and packstones. In the upper part and at the top of the unit are one or two bored crusts or hardgrounds overlain by argillaceous, silty and glauconitic limestone. It is assumed that the hardgrounds were formed during periods of non-deposition and minor erosion.

The Big Valley Formation includes a basal, somewhat argillaceous interval that overlies an erosional surface (Plate III, Figs. c and d). The lower part is a fragmental wackestone and contains up to 20 percent of crinoidal debris. The upper part includes glauconite, quartz silt and locally, limestone pebbles (see Plate III, Figs. e, g and i). The contact with the overlying Exshaw is sharp, in places marked by a scoured surface and a thin crinoidal sandstone bed.

The conodonts below and above the contact between the Exshaw and Big Valley formations are from the *expansa* Zone (Johnston and Meijer Drees, 1993). This suggests that the boundary represents a geological time marker. Although there is evidence that the boundary ceases to be a time marker in the crestal region of the Peace River highland (see Fig. 20), it is the best available datum for the construction of regional Devonian stratigraphic cross sections in the Peace River region.

The availability of this datum and the fivefold subdivision of the Wabamun Group make it possible to map the onlap pattern and the facies changes in the Wabamun Group across Peace River highland on figures 12, 13, 15 and 20. The lateral facies change between the upper part of the Winterburn and the lower part of the Wabamun in the western part of the Peace River region, described earlier, is indicated on Figure 12 (between sections 7 and 13) and involves the Dixonville unit and the Graminia Formation. Here the Dixonville unit increases northwestward in thickness at the cost of the underlying Graminia Formation before it decreases in thickness because of onlap and facies change into the Marginal clastics unit.

The Wabamun decreases in thickness across the western part of the Peace River region (Fig. 13) without being involved in onlap. The four log-units extend northward and the Big Valley Formation is only distinctive in the southeastern part. On Figure 13 it reaches its depositional edge in the area southeast of Hines Creek, not far beyond section 12. The Cardinal Lake decreases in thickness between Belloy and Hines Creek sections (on Fig. 13, between sections 8 and 17) but increases again northwest of Hines Creek (on Fig. 13, between sections 1 and 8). The decrease in thickness of the Wabamun across the Peace River highland is thus partly due to compaction, partly due to truncation below the Big Valley Formation and partly due to condensation of strata at the top of the Big Valley.

The Wabamun Group decreases southeastward in thickness in the area north of Dawson Creek. Although the correlations of log-units in this area are uncertain it is postulated that the decrease in thickness is due to onlap against the northern flank of the Peace River highland (see Fig. 15). In the Beaverlodge area, southeast of Dawson Creek (Fig. 15, section 12), the Dixonville and Whitelaw units have amalgamated and the Normandville and Cardinal Lake log-units are present. Subsurface correlations in the area and the absence of the *expansa* conodont fauna in the Beaverlodge 4-23-72-10W6 core (Fig. 15, section 12) suggest that the Big Valley Formation is not represented in the core (Johnston and Meijer Drees, 1993). The presence of *expansa* Zone conodonts in a thin unit of interbedded shaly and crinoidal limestone at the top of the Wabamun in the Golata 8-29-83-15W6 well (Fig. 15, section 3), suggest that this reworked, basal transgressive deposit underlying the Exshaw Formation correlates with the Big Valley.

The facies change, in the western part of the Peace River region, of the "clean" Whitelaw carbonates in the east to the "shaly", interbedded shaly limestone and marlstone unit in the west (Fig. 21) is shown on cross section in Figure 15. The "shaly" facies occurs in the sections 1 to 6 and section 9. These sections are located on the west side of the facies line shown in Figure 20 and include units composed of dark grey marlstone. The conodonts recovered in section 5 confirm that only Famennian strata are present (Johnston and Meijer Drees, 1993).

In the crestal part of the Peace River highland, southwest of Hines Creek (Fig. 20), the Wabamun Group is relatively thin and locally absent. Here the Dixonville, Whitelaw and Normandville units onlap and change facies into the "Marginal Clastics". It is indicated on Figure 20 that the Wabamun Group in the Highland 7-2-82-5W6 well (section 6) includes the Big Valley Formation at the top and marginal clastics equivalent to the lower Whitelaw

unit at the base. The correlations in the Wabamun Group on Figure 20 also suggest that the Big Valley unit changes northwestward into a unit composed of interbedded sandstone and shale. This interbedded unit was cored in the Royce 10-28-83-7W6 well (Fig. 20, section 2), and contains conodonts of the Lower *trachytera* to Upper *expansa* zones (Meijer Drees and Johnston, 1993). It is further suggested on Figure 20 that there is erosional truncation of about 30 m below the Big Valley. Conodonts of the Upper *rhomboidea* to Lower *marginifera* zones in the uppermost strata of the Wabamun Group in the Royce 10-28-83-7W6 well (Fig. 20, section 2) indicate that the upper part of the Cardinal Lake strata (characterized elsewhere by the presence of the Upper *marginifera* to Lower *trachytera* zones) is missing.

Owing to the fact that the truncation below the Big Valley Formation between sections 5 and 6 coincides with a facies change in the Big Valley from limestone to interbedded sandstone and black shale, one can interpret the correlations on Figure 20 in terms of sub-Big Valley erosion, followed by Big Valley and Exshaw onlap, rather than sub-Exshaw erosion and Exshaw onlap (see insert, Fig. 20).

Marginal clastics:

The marginal clastics of the Wabamun Group are an interbedded succession of very light grey, calcareous or dolomitic sandstone and variable sandy, aphanitic, micritic or peloidal limestone or dolostone. The carbonates are locally reddish brown mottled, and the sandstones are composed of fine, well sorted and well rounded grains of quartz and microcline.

It is assumed that during the erosional event, that was responsible for the removal of the upper part of the Cardinal Lake unit in the Hines Creek region, the crestal part of the highland rose about 30 m in relation to its sediment-covered flank as a result of compactional dewatering, and that the sandy, shoreline deposits re-established itself in a more seaward position around the emergent Precambrian knobs. During the subsequent transgression responsible for the deposition of the Big Valley Formation and Exshaw Formation, the sandy sediments around the Precambrian knobs were reworked and redeposited to form the marginal clastics facies of the Big Valley Formation.

EXSHAW FORMATION

In southwestern and west central Alberta the Exshaw Formation includes a lower Black shale unit and an upper Siltstone unit. (Macauley et al., 1964; Macqueen and Sandberg, 1970; Richards et al., 1991). In east central and northern Alberta only the Black shale unit is present, because of lateral facies changes in the beds just above and below the boundary between the Exshaw and overlying Banff formations (see Macauley et al., 1964).

The lower Black shale unit is a relatively thin and widespread unit of very dark grey, bituminous shale. It has a sharp lower contact with the underlying carbonates and is gradationally overlain by an interbedded interval of dark grey, calcareous siltstone and argillaceous limestone, or sharply overlain by a massive unit of calcareous siltstone. Both

the interbedded interval and the massive unit belong to the Siltstone unit. In southwestern Alberta the Siltstone unit is overlain by a dark grey shale bed that constitutes a basal deposit of the Banff Formation. Here the upper boundary of the Exshaw Formation is sharp and well marked on geophysical, borehole logs. In east central and northern Alberta the Siltstone unit grades upward into greenish grey, silty shale or argillaceous siltstone and the boundary between the Exshaw and Banff formations is difficult to establish. Thus the boundary is selected at the top of the Black shale unit (Macauley, 1958). The change in the way the boundary is established reflects the correlations across the Peace River region (see Figs. 12, 13, 15 and 20).

In the Peace River region exists a complex relationship between the Black Shale unit and the upper two map units of the underlying Wabamun Group. The Cardinal Lake unit is truncated by the Big Valley Formation. The Big Valley Formation decreases in thickness to the northwest because it onlaps the sub-Big Valley unconformity and changes facies into Exshaw shale. The Exshaw Formation extends beyond the onlap edge of the Big Valley Formation and changes in composition. The siltstone beds in the Siltstone unit decrease in thickness to the northwest and the Siltstone and Black shale units merge into a succession of dark grey shale. The result of the combined effect of truncation, onlap and facies change in northwestern Alberta is that the sub-Big Valley unconformity becomes the boundary between the Wabamun Group and the Exshaw Formation.

The Black Shale unit is widely distributed in the Peace River region and reaches a maximum thickness of about 9 m. In the region north of Hines Creek (Fig. 13) the unit is absent or too thin to be recognizable as a separate unit on geophysical borehole logs. The Black shale unit is composed of black shale and silty shale and constitutes a euxinic shale deposit similar to the Muskwa Formation. It includes ostracodes, goniatites, lingulid brachiopods and Famennian conodonts of the Lower *expansa* to *praesulcata* zones (Johnston and Meijer Drees, 1993). Raasch (1956) considered the fauna to be characteristic of stagnant, shallow water deposits, such as are found in coastal lagoons. However, the presence of the goniatites and the conodonts of the palmatolepid-polygnathid biofacies of Sandberg (1976) suggest an offshore marine setting.

The Siltstone unit is only present in the southern part of the Peace River region and looses its identity to the northwest because of a facies change from siltstone to shale. It is composed of very dark grey, interbedded calcareous siltstone and silty shale. The shaly beds are laminated and unfossiliferous but the siltstone beds have a mottled, bioturbated aspect and are sparsely fossiliferous.

The decrease in thickness of the Exshaw Formation to the northwest is evident in the area northeast of Grande Prairie (Fig. 12). In the Dreau 4-35-77-22W5 well (Fig. 12, section 20) the thickness is 12 m and in the Howard 11-5-79-4W6 well (Fig. 12, section 1) it is only 5 m. This condensation of strata in the Siltstone unit is related to a facies change from siltstone to shale. The thickness of the underlying Black shale unit ranges between 3 and 5 m and remains relatively constant across Figure 12. In the Peoria 2-35-76-1W6 well (Fig. 12, section 6) and in the nearby Cindy 16-35-77-1W6 well the Black shale unit is about 5 m thick and consists of dark to very dark grey, in part calcareous shale and includes very thin

pyritic and silty interbeds. In the upper part is a 25 to 30 cm thick, greenish grey, bentonitic shale bed. In the lower part are thin, fossiliferous and pyritic interbeds that include conodonts and shell fragments. The contact with the underlying Wabamun Formation is sharp and includes a thin, crinoidal lag-deposit (Meijer Drees and Johnston, 1993; Fig. 8).

The gamma-ray signature of the Exshaw Formation in the Howard 11-5-79-4W6 well (Fig. 12, section 1) is similar to that of the Beaverlodge 4-23-72-10W6 well (Fig. 15, section 12). In the Beaverlodge well the very dark grey, interbedded and interlaminated calcareous siltstone and shale beds of the Siltstone unit grade down into black shale. The unfossiliferous Black shale unit is 1.8 m thick and overlies the Wabamun Formation with a sharp contact marked by an 0.5 – 1 cm thick pyritic sandstone bed (see Meijer Drees and Geldsetzer, 1984; Fig. 37.4b). The absence of the Big Valley unit in the Beaverlodge well (confirmed by conodonts) suggests that this contact is erosional.

The correlations in the western part of the Peace River region (Fig. 15) indicate that the siltstone beds overlying the Black shale unit in the Beaverlodge area decrease in thickness toward the northwest and are replaced by greenish grey shale similar to those of the Banff Formation. The radioactive Black shale unit remains a mappable unit in the region northwest of Dawson Creek on Figure 15 and interfingers with the basal part of the Banff Formation. The Black shale unit is 4.8 m thick in the Golata 8-29-83-14W6 well (Fig. 15, section 3) and includes thin interbeds of crinoidal dolostone (Plate III, Fig. j). Here the Black shale unit yielded conodonts of the Upper? *marginifera* to Upper? *expansa* zones, approximately the same age range as those of the Big Valley Formation.

The decrease in thickness to the northwest and the facies change to shale in the beds that immediately overlie the Wabamun Group in the region north of Hines Creek is shown on Figure 13. The Exshaw gradually decreases in thickness and seems to be absent north of section 5. The Black shale unit and the sharp contact with the underlying Big Valley Formation of the Wabamun Group was cored in Whitelaw 2-1-82-2W6 (Fig. 13, section 13). The Black shale unit includes a fossiliferous lag deposit at the base and is represented by very dark, fissile shale and an interbed of sandstone (see Plate III, Figs. e and f). In a nearby well (Lalby No. 1, 1-12-79-22W5) the Black shale unit includes lingulid brachiopods, ostracodes and conodonts of the Lower *expansa* to *praesulcata* zones (see Johnston and Meijer Drees, 1993). A thin bed of greenish grey bentonite is present in the upper part of the Black shale unit. The contact between the Black shale and Siltstone units is cored in Eaglesham 16-7-77-25W5 and shown on Plate III, Fig. k.

Marginal clastics:

In the area southwest of Hines Creek (Fig. 20), the basal part of the Black shale unit and the underlying limestone of the Big Valley Formation change into an interbedded sandstone and shale facies that onlaps the sub-Big Valley unconformity. This dark grey sandy facies and the underlying unconformity were cored in the Royce 10-28-83-7W6 well (Fig. 20, section 2). The unconformity is shown on Plate III (Fig. h) and may be described as an erosional surface of a transgressive sea. Correlations above the Wabamun suggest that the thickness of the Exshaw Formation decreases to the northwest because of condensation. In

section 2 the Exshaw is an interbedded unit composed of very dark grey, fissile shale and dark grey, fine- to coarsely grained, pyritic and arkosic sandstone, including black, very coarse chert grains. Fossils include crinoid ossicles, *expansa* Zone conodonts, fish bone fragments and lingulid brachiopods.

STRUCTURAL CONFIGURATION

Original depositional dips in the Devonian nearshore deposits may have ranged between 1 and 5 degrees seaward, but in the central part of the basin the depositional dips must have been sub-horizontal. During the Laramide orogeny the Devonian succession, together with the under- and overlying strata, was tilted to the southwest. Thus the upper surface of the Wabamun Group dips to the southwest at a rate of 0.7-1.56 m per km.

This structural configuration can be mathematically approximated by a polynomial equation called a trend-surface. By following the Surface II Graphics System developed by Sampson (1978) a map was obtained of the second-order trend-surface residuals (see Fig. 21). Some of the positive and negative regions displayed on Figure 21 can be attributed to geological structures whereas others are artifacts. The negative residuals in the southwestern part of Figure 21 are related to the gradual increase in regional dip in the southeastern part of the map. The negative area in the northwest is due to the decrease in regional dip associated with the truncation of strata below the pre-Cretaceous erosional unconformity. These two phenomena should define a northwest trending positive region in the centre of the figure. One would also expect to see positive anomalies that are related to differential compaction over the Peace River highland. Instead, the curve in the zero contour line in the central part of the figure outlines a negative area that more or less coincides with the Peace River embayment, a late Paleozoic and Mesozoic sedimentary basin, that appears to have originated through the amalgamation of several fault controlled depressions in the Peace River region (see Cant, 1988; O'Connell et al., 1990).

The location of the tectonic depressions is outlined by the -100 m and -300 m contour lines. The hatched contour lines in British Columbia outline the Fort St. John graben and those in Alberta more or less coincide with the Hines Creek graben. Both are represented in the "axial graben" of Cant (1988).

EPEIROGENESIS

Three events of epeirogenetic uplift or fall in sea level during the Devonian increased the elevation of the Peace River highland temporarily by 30 to 40 m relative to sea level. Clastics from the highland were carried far into the basin and were reworked into marine deposits when the sea returned.

The Cold Lake salt deposits accumulated during the first event and the clastics of the Contact Rapids were deposited when the sea returned. The sub-Watt Mountain unconformity was formed during the second event and the deposition of the Gilwood

sandstone followed when the unconformity was subsequently flooded. The sub-Big Valley unconformity resulted from the third epeirogenic event during which the Cardinal Lake carbonates were exposed and locally eroded. Biostratigraphic evidence suggests that the third event was relatively short-lived. The exposed part of the highland was too small to shed much sediment into the basin during the third epeirogenic uplift.

The relatively short-lived, erosional episodes that mark the top of the Nisku Formation and the Blue Ridge member of the Graminia Formation in southern Alberta are similar to those postulated to be present at the top of the other carbonate platform deposits (such as the Winnipegosis – Keg River, Slave Point – Swan Hills, Beaverhill Lake and Leduc formations). They did not coincide with an increase in the deposition of coarse clastics around the Peace River highland and may be classified as "drowning" events.

ACKNOWLEDGMENTS

The authors are grateful for the help received in the facilities of the Core Research Centre of the Energy Resources Conservation Board in Calgary, Alberta and the Ministry of Energy, Mines and Petroleum Resources Core Laboratory in Fort St. John, British Columbia. They acknowledge the contributions of M. Bergeron, H.L. Halbertsma, A.C. Higgins, T.T. Uyeno, B.C. Rutley, W.B. Sharman, N.Y. Wong and P. Gubitz. The critical comments from T.T. Uyeno, H.H.J. Geldsetzer, J. Packard, G.R. Dix, T.R. Marchant and R.W Macqueen were helpful and improved this report.

REFERENCES

Alberta Society of Petroleum Geologists, 1960. Lexicon of gelogic names in the Western Canada sedimentary basin and Artic Archipelago. Calgary, Alberta.

Andrichuk, J.M. 1960. Facies analysis of Upper Devonian Wabamun Group in west central Alberta. American Association of Petroleum Geologists, Bulletin, v. 44, p. 1651 – 1681.

Baillie, A.D. 1956. Granite Wash in the Clear Hills area. Journal of the Alberta Society of Petroleum Geologists, v. 4, p. 206 – 212.

Bebout, D.G. and Maiklem, W.R. 1973. Ancient anhydrite facies and environments, Middle Devonian Elk Point Basin, Alberta. Canadian Petroleum Geology Bulletin, v. 21, p. 287 – 243.

Belyea, H.R. 1964. Chapter 6, Upper Devonian, part 2, in Geological History of Western Canada, R.G. McCrossan and R.P. Glaister (eds.). Alberta Society of Petroleum Geologists, Calgary, Alberta.

Braun, W.K., Norris, A.W. and Uyeno, T.T. 1989. Late Givetian to Early Frasnian biostratigraphy of western Canada; The Slave Point - Waterways boundary and related

events. *In* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, v. III, N.J. McMillan, A.F. Embry and D.J. Glass (eds.). Canadian Society of Petroleum Geologists, Calgary, p. 93–111.

Cant, D.J. 1988. Regional structure and development of the Peace River Arch, Alberta: A Paleozoic failed-rift system? Bulletin of Canadian Petroleum Geology, v. 36, p. 284–295.

Choquette, A.L. 1955. The Blueridge member of the Graminia Formation. Alberta Society of Petroleum Geologists, Journal, v. 3, p. 70–73.

Craig, J.H. 1987. Depositional environments of the Slave Point Formation, Beaverhill Lake Group, Peace River Arch. *In* Devonian Lithofacies and reservoir styles in Alberta, F.F. Krause and O.G. Burrowes (eds.). 13th CSPG Core Conference, Canadian Society of Petroleum Geologists, Calgary, p. 181–200.

Craig, J., Devine, J., McGill, P. and Meneley, R. 1967. Chinchaga and Keg River formations of Slave River area, northern Alberta. Bulletin of Canadian Petroleum Geology, v. 15, p. 125–137.

Cutler, W.G. 1983. Stratigraphy and sedimentology of the Upper Devonian Grosmont Formation, northern Alberta. Bulletin of Canadian Petroleum Geology, v. 31, p. 282–325.

Dix, G.R. 1990. Upper Devonian (Frasnian) non-calcified algae; Alberta: geologic relevance to Leduc platforms and petroleum source rocks. Bulletin of Canadian Petroleum Geology, v. 38, p. 429–439.

Dix, G.R. 1990. Stages of platform development in the Upper Devonian (Frasnian) Leduc Formation, Peace River Arch, Alberta. Bulletin of Canadian Petroleum Geology, v. 38A(1990), p. 66–92.

Exploration Staff, Chevron Standard Ltd. 1979. The geology, geophysics and significance of the Nisku reef discoveries, west Pembina area, Alberta, Canada. Bulletin of Canadian Petroleum Geology, v. 27, p. 326–359.

Fischbuch, N.R. 1968. Stratigraphy, Devonian Swan Hills reef complexes, Alberta. Bulletin of Canadian Petroleum Geology, v. 16, p. 446–587.

Geological Staff Imperial Oil Ltd. 1950. Devonian nomenclature in Edmonton area. American Association of Petroleum Geologists Bulletin, v. 34, p. 1807–1825.

Goodman, H.W. 1956. Granite Wash of the Bat Lake Area, Alberta. Journal Alberta Society Petroleum Geologists, v. 4, p. 223–226.

Gosselin, E.G., Smith, L. and Mundy, J.C. 1989. The Golden and Evi reef complexes, Middle Devonian, Slave Point Formation, northwestern Alberta. *In* Reefs, Canada and

adjecent Areas, H.H.J. Geldsetzer, N.P. James and G.E. Tebutt (eds.). Canadian Society of Petroleum Geologists, Memoir 13, p. 440–447.

Gray, F.F. and Kasube, J.R. 1963. Geology and stratigraphy of Clarke Lake gas field, British Columbia. American Association of Petroleum Geologists, Bulletin, v. 47, p. 175–179.

Grayston, L.D., Sherwin, D.F. and Allan, J.F. 1964. Chapter 5, Middle Devonian. *In* Geological History of Western Canada, R.G. McCrossan and R.P. Glaister (eds.). Alberta Society of Petroleum Geologists, Calgary, Alberta, p. 49–59.

Greenwalt, Wm. A. 1956. Granite Wash of the Peace River area. Journal of the Alberta Society of Petroleum Geologists, v. 4, p. 204, 205 and 213.

Griffin, D.L. 1965. The Devonian Slave Point, Beaverhill Lake, and Muskwa formations of northeastern British Columbia and adjacent areas. British Columbia Department of Mines and Petoleum Resources, Bulletin 50.

Guthrie, D.C. 1956. Gilwood sandstone in the Giroux Lake area. Alberta Society of Petroleum Geologists, Bulletin, v. 4, p. 227–231.

Halbertsma, H.L. and Meijer Drees, N.C. 1987. Wabamun limestone sequences in north-central Alberta. *In* Devonian lithofacies and reservoir styles in Alberta, F.F. Krause and O.G. Burrowes (eds.). Second International Symposium on the Devonian System, core conference guide, p. 21–37, Alberta Society of Canadian Petroleum Geologists, Calgary, Alberta.

Halim-Dihardja, M.K. and Mountjoy, E. W. 1989. A Stromatoporoid patch reef in the Upper Devonian Wabamun Group, north-central Alberta. *In* Reefs, Canada and adjecent areas, H.H.J. Geldsetzer, N.P. James and G.E. Tebutt (eds.). Canadian Society of Petroleum Geologists, Memoir 13. p. 448–453.

Jansa, L.F. and Fischbuch, N.R. 1974. Evolution of a Middle and Upper Devonian sequence from a clastic coastal plain-deltaic complex into overlying carbonate reef complexes and banks, Sturgeon - Mitsue area, Alberta. Geological Survey of Canada, Bulletin 234.

Johnston, D.I. and Meijer Drees, N.C. 1993. Upper Devonian Conodonts in west central Alberta and adjacent British Columbia. Bulletin of Canadian Petroleum Geology, v. 41, p. 139–149.

Keith, J.W. 1990. The influence of the Peace River Arch on Beaverhill Lake sedimentation. Bulletin of Canadian Petroleum Geology, v. 38A(1990), p. 55–65.

Law, J. 1955. Geology of northwestern Alberta and adjecent areas. American Association of Petroleum Geologists, Bulletin, v. 39, p. 1927–1975.

Leavitt, E.M. and Fischbuch, N.R. 1968 Devonian nomenclatural changes, Swan Hills area, Alberta. Bulletin of Canadian Society of Petroleum Geology, v. 16, p. 288–297.

Lethiers, F. 1981. Ostracodes du Devonien terminal de l'ouest du Canada: Systematique, Biostratigraphie et Paleoecologie. Geobios, memoire special 5, edition de l'universite Claude Bernard, Lyon, France.

Maqueen, R.W. and Sandberg, C.A. 1970. Stratigraphy, age, and interregional correlation of the Exshaw Formation, Alberta Rocky Mountains. Bulletin of Canadian Petroleum Geology, v. 18, p. 32–66.

Meijer Drees, N.C. 1985. Two stratigraphic cross sections, Upper Devonian strata, central Alberta. Geological Survey of Canada, Open File 1274.

Meijer Drees, N.C. 1986. Evaporitic deposits of western Canada. Geological Survey of Canada, Paper 85-20.

Meijer Drees, N.C. 1989. The Middle Devonian sub-Watt Mountain unconformity across the Tathlina Uplift, District of Mackenzie and northern Alberta, Canada. *In* Devonian of the World, Proceedings Second International Symposium on the Devonian System, N.J McMillan, A.F. Embry and D.J. Glass (eds.). Canadian Society of Petrpleum Geologists, Calgary, Alberta, vol. II, p. 477–494.

Meijer Drees, N.C. and Geldsetzer, H.H.J. 1984. Correlation between Upper Devonian surface and subsurface map units in west-central Alberta. Current Research, Part B, Geological Survey of Canada, Paper 84-1B, p. 337–349.

Meijer Drees, N.C. and Johnston, D.I. 1993. Geology of the Devonian–Carboniferous boundary beds in Alberta. *In* Carboniferous to Jurassic Pangea, Core Workshop Guidebook, R. Karvonen, J. Den Haan, K. Jang, D. Robinson, G. Smith, T. Webb and J. Wittenberg (eds.). Canadian Society of Petroleum Geologists, Calgary, Alberta, p. 188–205.

Moore, P.F. 1989. Devonian geohistory of the western interior of Canada. *In* Devonian of the world, Proceedings of the Second International Symposium on the Devonian System, N.J. McMillan, A.F. Embry and D.J. Glass (eds.). Canadian Society of Petroleum Geologists, Calgary, p. 67–83.

Morgan, G.R. 1964. The peripheral rim effect of the Sturgeon Lake atoll, Alberta. Bulletin of Canadian Petroleum Geology, v. 12, p. 133–152.

Morrow, D.W. and Geldsetzer, H.H.J. 1989. Devonian of the eastern Canadian Cordillera. *In* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, N.J. McMillan, A.F. Embry and D.J. Glass (eds.). Canadian Society of Petroleum Geologists, Calgary, Alberta, v. II, p. 85–121.

Nishida, D.K. 1987. A Famennien Stromatoporoid patch reef in the Wabamun Group, west central Alberta, Canada. *In* Devonian Lithofacies and Reservoir Styles in Alberta, F.F. Krause and O.G. Burrowes (eds.). 13th CSPG Core Conference, Canadian Society of Petroleum Geologists, Calgary, p. 63–72.

Norris, A.W. 1963. Devonian stratigraphy of northeastern Alberta and northwestern Saskatchewan. Geological Survey of Canada, Memoir 313.

Norris, A.W. and Uyeno, T.T. 1981. Stratigraphy and Paleontology of the lowermost Upper Devonian Slave Point Formation on Lake Claire and the lower Upper Devonian Waterways Formation on Birch River. Geological Survey of Canada, Bulletin 334.

O'Connell, S.C., Dix, G.R. and Barclay, J.E. 1990. The origin, history, and regional structural development of the Peace River Arch, Westwern Canada. Bulletin of Canadian Petroleum Geology, v. 38A(1990), p. 4–24.

Pollock, C.A. 1967. Reference section for the Majeau Lake Formation. Canadian Journal of Eath Science, v. 4, p. 873–876.

Pugh, D.C. 1973. Subsurface Lower Paleozoic stratigraphy in northern and central Alberta. Geological Survey of Canada, Paper 72-12.

Raasch, G.O. 1956. Late Devonian and/or Mississippian faunal succession in Stettler area, Alberta. Journal Alberta Society of Petroleum Geologists, v. 4, p. 112–118.

Richards, B.C., Henderson, C.M., Higgins, A.C., Johnston, D.I., Mamet, B.L. and Meijer Drees, N.C. 1991. The Upper Devonian (Famennian) and Lower Carboniferous (Tournaisin) at Jura Creek, southwestern Alberta. *In* A field guide to the paleontology of southwestewrn Alberta, P. Smith (ed.). Geological Association of Canada, Paleontology Division, University of British Columbia, Vancouver.

Rottenfusser, B.A. and Oliver, T.A. 1977. Depositional environments and petrology of the Gilwood Member north of the Peace River Arch. Bulletin of Canadian Petroleum Geology, v. 25, p. 907–928.

Sampson, R.J. 1978. Surface II graphics system (Revision one). Kansas Geological Survey, Series on spatial analysis, No. 1.

Sandberg, C.A. 1976. Conodont biofacies of late Devonian *Polygnathus styriacus* Zone in western United States. *In* Conodont Paleoecology, C.R. Barnes (ed.), Geological Association of Canada, Special Paper 15, p. 171–186.

Schlager, W. 1981. The pradox of drowned reefs and carbonate platforms. Geological Society of America, Bulletin, part I, v. 92, p. 991–1055.

Shawa, M.S. 1969. Sedimentary history of the Gilwood sandstone (Devonian), Utikuma Lake area, Alberta, Canada. Bulletin of Canadian Petroleum Geology, v. 17, p. 392–409.

Sherwin, D.F. 1962. Lower Elk Point section in east-central Alberta. Alberta Society of Petroleum Geologists, Journal, v.10, p. 185–191.

Stauft, D. 1987. Introduction Beaverhill Lake Group. *In* Devonian Lithofacies and Reservoir Styles in Alberta, F.F. Krause ang O.G. Burrowes (eds.). 13th CSPG core conference, Canadian Society of Petroleum Geologists, Calgary; p. 171–172.

Stoakes, F.A. 1980. Nature and control of shale basin fill and its effect on reef growth and termination: Upper Devonian Duvernay and Ireton formations of Alberta, Canada. Bulletin of Canadian Petroleum Geology, v. 28. p. 345–410.

Stoakes, F.A. and Wendte, J.C. 1987. The Woodbend group. *In* Devonian Lithofacies and Reservoir Styles in Alberta, F.F. Krause and O.G.Burrowes (eds.). 13th CSPG core conference, Canadian Society of Petroleum Geologists, Calgary, p. 153–170.

Taylor, G.C. and Mackenzie, W.S. 1970. Devonian stratigraphy of northeastern British Columbia. Geological Survey of Canada, Bulletin 186.

Tooth, J.W. and Davies, G.R. 1989. Gift Lake Slave Point reef, Middle Devonian, Alberta. *In* Reefs, Canada and adjacent areas, H.H.J. Geldsetzer, N.P. James and G.E. Tebutt (eds.). Canadian Society of Petroleum Geologists Memoir 13, p. 528–534.

Trotter, R. and Hein, F.J. 1988. Sedimentology and depositional setting of the Granite Wash, northwestern Alberta. *In* Sequences, Stratigraphy, Sedimentology: Surface and Subsurface, D.P. James and D.A. Leckie (eds.). Canadian Society of Petroleum Geologists, Memoir 15, p. 475–484.

van Hees, H. 1958. The Meadow Lake Escapment – Its regional significance to lower Paleozoic stratigraphy. Second International Williston Basin Symposium, p. 70–78.

Viau, C. 1987. The Swan Hills Formation and the Beaverhill Lake Group at Swan Hills field and adjacent areas, central Alberta, Canada. *In* Devonian lithofacies and reservoir styles in Alberta, F.F. Krause and O.G. Burrowes (eds.). 13th CSPG core conference, Canadian Society of Petroleum Geologists, Calgary, p. 201–239.

Williams, G.K. 1977. The Hay River Formation and its relationship to adjacent formations, Slave River map-area, N.W.T.. Gelogical Survey of Canada, Paper 75-12.

Wonfor, J.S. and Andrichuck, J.M. 1956. The Wabamun Group in the Stettler area, Alberta. Journal of the Alberta Society of Petroleum Geologists, v. 4, p. 99–111.

FIGURES

Figure 1. Devonian stratigraphy north of Peace River highland.

Figure 2. Devonian stratigraphy south of Peace River highland.

Figure 3. Map including the distribution of the Lotsberg Formation and its equivalents around the Peace River arch in northern Alberta.

Figure 4. Map including the distribution of the Cold Lake Formation and its equivalents around the Peace River arch in northern Alberta.

Figure 5. Stratigraphic cross section of Elk Point and lower Beaverhill Lake strata in east central Alberta.

Figure 6. Map including the distribution of Chinchaga Formation and equivalents in northern Alberta and adjecent regions.

Figure 7. Map including the distribution of the Muskeg Formation and equivalents in northern Alberta and adjacent regions.

Figure 8. Map of the subcrop facies at the sub-Watt Mountain unconformity in northern Alberta and adjacent regions.

Figure 9. Stratigraphic cross section of Elk Point and Beaverhill Lake strata east of Worsley, central Alberta.

Figure 10. Map including the distribution of Beaverhill Lake carbonates in west central Alberta.

Figure 11. Stratigraphic cross section of Beaverhill Lake and Woodbend strata west of Utikuma Lake, central Alberta.

Figure 12. Stratigraphic cross section of Devonian strata, northwest of Valleyview, west central Alberta.

Figure 13. Stratigraphic cross section of Woodbend strata, east of Worsley, central Alberta.

Figure 14. Stratigraphic cross section of Devonian strata, Belloy to Worsley, central Alberta.

Figure 15. Stratigraphic cross section of Devonian strata, Beaverlodge to Fort St.John, west central Alberta and adjacent British Columbia.

Figure 16. Isopach map of combined Majeau Lake, Duvernay and lower Ireton formations, including the distribution of the equivalent clastics and the outlines of the presently known Leduc reef complexes in west central Alberta.

Figure 17. Map of west central Alberta including the Leduc Peace River carbonate complex and the equivalent clastics around the Peace River highland. The outline of the Leduc reef complexes is also indicated.

Figure 18. Map of west central Alberta outlining the West Pembina Shale basin and the distriburtion of the lower Winterburn clastics around the Peace River highland.

Figure 19. Map of west central Alberta outlining the Economy evaporites and the upper Winterburn clastics around the Peace River highland.

Figure 20. Stratigraphic cross section of Wabamun and Exshaw formations near Hines Creek, central Alberta. A marker bed in the Banff is used as datum.

Figure 21. Map of west central Alberta including the Precambrian knobs and the distrbution of the onlapping clastics equivalent to the Wabamun Formation. The eastern limit of Whitelaw carbonate facies is also indicated.

Figure 22. Contour map of west central Alberta and adjacent British Columbia showing second-degree trend-surface residuals of the top of the Wabamun Formation in relation to the erosional edge of the Cambrian rocks and several facies changes in the Devonian succession that outline the Peace River highland.

Plate I

Core photographs, of the Elk Point and Beaverhill Lake groups.

a: Basal part of light grey, 1.75 m thick, fining upward, laminated and locally cross bedded, dolomitic sandstone, including fine to coarse quartz, feldspar, glauconite and dark grey and green shale pebbles. The sandstone truncates interbedded green, silty shale and greyish green, shaly siltstone and fills burrows. Gilwood, channel-fill facies; 7-10-92-9W6, 2831.7 m.

b: Bedding surface of green, very fine- to fine sandstone includes a plant fragment. Gilwood, deltaic facies; 12-32-90-2W6, 17004 ft.

c: Cross-laminated, very fine to fine sandstone, grades upward into dark greenish grey, micro-micaceous shale. Ripple foresets and reactivation surfaces are present. Gilwood, marine facies; 7-10-92-9W6, 2832 m.

d: Greyish green, shaly siltstone overlain by green mottled very fine to medium, dolomitic sandstone, including sediment-filled burrows. Gilwood, marine facies; 7-10-92-9W6, 2830 m.

e: Porous, fine to very coarse quartzose and feldspathic sandstone including ripple foresets. Waterways, Marginal clastics, marine facies; 13-19-69-8W6, 13827 ft.

f: Greenish grey, very coarse grained, dolomitic sandstone including quartz and pink feldspar grains, quartzite and igneous rock pebbles and Brachiopods overlies a Precambrian gneiss. Beaverhill Lake, Marginal clastics, marine facies; 9-13-80-21W5, 2369.6 m.

g: Light grey mottled, calcareous sandstone overlies dark grey, sandy and shaly siltstone. Sandstone is very fine to fine, includes very coarse quartz grains, charophyte oogonia and shell fragments. Siltstone includes coarse quartz grains and pyrite. Waterways, Marginal clastics; 10-16-69-5W6, 12364 ft.

h: Siltstone, dark grey, very calcareous, nodularly interbedded with shale, includes fragments of brachiopods, gastopods, ostracodes, crinoids and placoderm fish (arrow). Waterways, Marginal clastics, marine facies; 13-19-69-8W6, 13751.5 ft.

i: Very dark brown, silty limestone including crinoid ossicles, fragments of gastropods, brachiopods, charophyte oogonia and oncoids overlies calcareous, very fine sandstone, containing coarse quartz grains and crinoid ossicles. Waterways, Marginal clastics, marine facies; 10-16-69-5W6, 12368 ft.

j: A conglomoratic sandstone composed of quartz, quartzite, pink feldspar and green and dark grey, compressed shale pebbles includes a coarse grained, calcareous, shaly and biotitic matrix. Gilwood, alluvial granite-wash facies; 16-35-74-24W5, 2731 m.

k: Plant fragments in shale. Waterways; 2-30-88-4W6, 2418.4 m.

l: A thin section of a medium to coarse sandstone composed of quartz (clear grains), feldspars (cloudy grains) and dolomitic cement (dark). Beaverhill Lake, Marginal clastics, marine facies; 10-16-69-5W6, 12450 ft.

Plate I

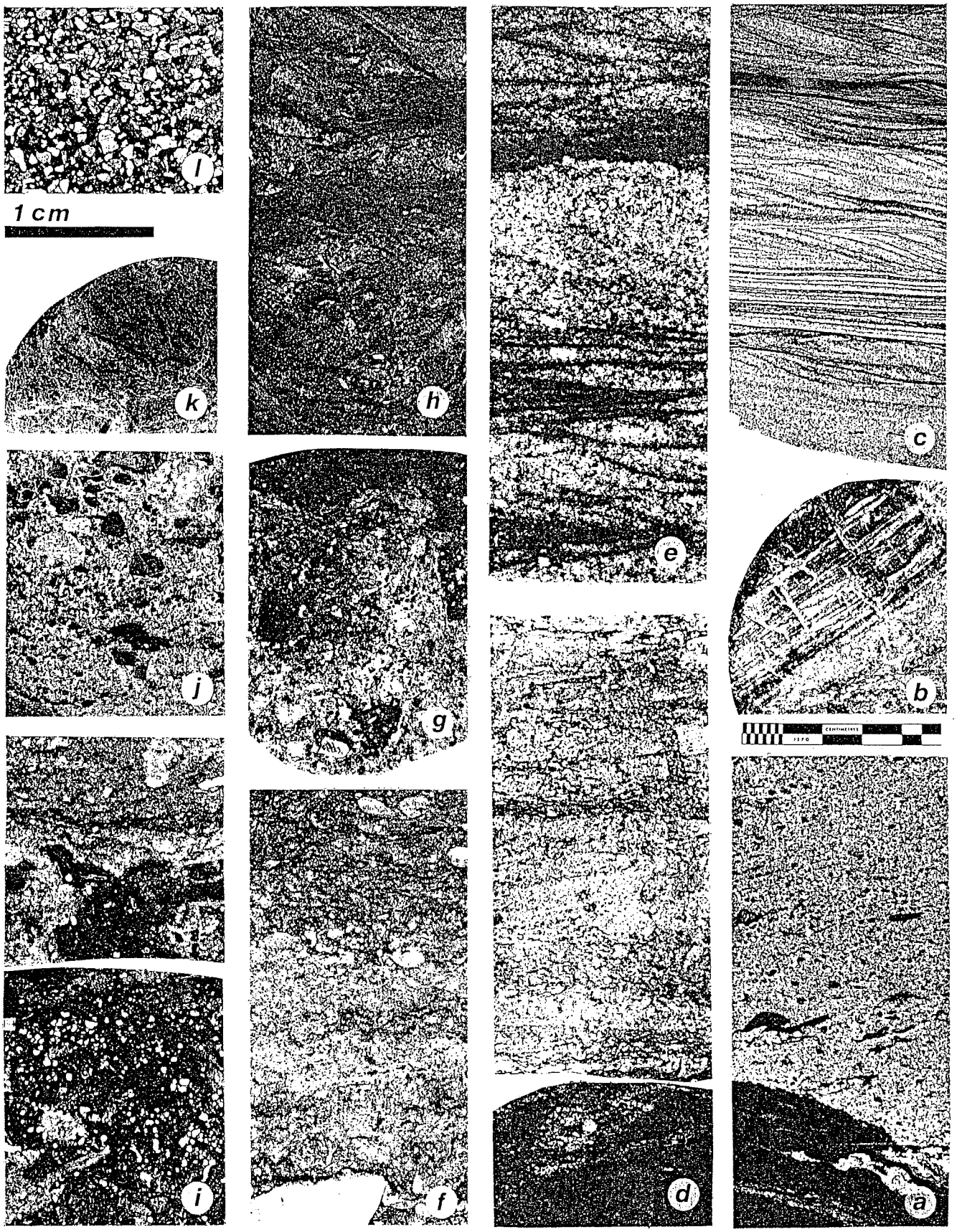


Plate II

Core photographs, Beaverhill Lake and Woodbend groups.

a: Interbedded grey and dark grey, dolomitic siltstone, sandstone and shale, including fine to coarse quartz, feldspar, crinoids and brachiopods. Waterways, marine facies; 2-30-88-4W6, 2406 m.

b: Upward fining, dolomitic sandstone overlies dark grey, sandy shale. Uppermost Waterways; 2-30-88-4W6, 2402.8 m.

c: Nodular sandstone bed in dark grey shale. Fine to medium sandstone is dolomitic and includes plant fragments, conodonts and crinoidal debris. Shale includes plant fragments and lingulid brachiopods. Muskwa, basal part; 2-30-88-4W6, 2401 m.

d: A thin section of sandstone including dark plant fragments, clear quartz grains, cloudy microcline grains and dolomitic cement. Muskwa; 1-26-86-16W6, 10002.5 ft.

e: A porous, cross-bedded, pale reddish brown, fine to coarse grained sandstone composed of quartz and feldspar. Marginal clastics, redbed facies; 10-19-86-7W6, 7348 ft.

f: A green, silty shale overlies green and red mottled, dolomitic, very fine to medium, feldspathic sandstone includes a network of root like structures. Woodbend, Marginal clastics, redbed facies; 8-6-87-7W6, 7336 ft.

g: A laminated, pale green mottled, fine to medium dolostone with pyritic inclusions has a peloidal, laminoid-fenestral fabric. Coarser bed may represent a crinoidal packstone. Leduc Fm., "platformal" unit; 8-6-87-7W6, 7320 ft.

h: Pale, sandy dolostone includes coarse-crystalline nodules and a gastropod. Leduc Fm., "platformal" unit; 10-22-87-7W6, 7461 ft.

i: Plant fragments. Ireton Fm.; 6-2-72-24W5, 2807.2 m.

j: *Spathiocaris* sp.. Ireton Fm; 6-2-72-24W5, 2806 m.

k: A porous, conglomoratic sandstone composed of subrounded, blue and grey quartz and subangular, grey and pink feldspar grains. Woodbend, Marginal clastics; 4-27-81-3W6, 2348.1 m.

l: Marginal clastics overlain by Wabamun Formation. Greyish brown quartzitic and dolomitic conglomerate grades upward into fine to coarse, dolomitic sandstone, nodularly interbedded with dark, pyritic shale. Overlying Wabamun is a dolomitic wacke- to packstone with gastropods, brachiopods, pyritic ostracodes and crinoids. 10-28-81-15W6, 11219.5 ft.

m: A dark red-brown and green mottled, shaly and micaceous siltstone is overlain by green, very fine to fine sandstone. Upper part is a laminated, micaceous, fine-grained, arkosic, green mottled and dark red speckled sandstone. Winterburn, Marginal clastics, redbed facies; 12-6-83-4W6, 8046.5 ft.

Plate II

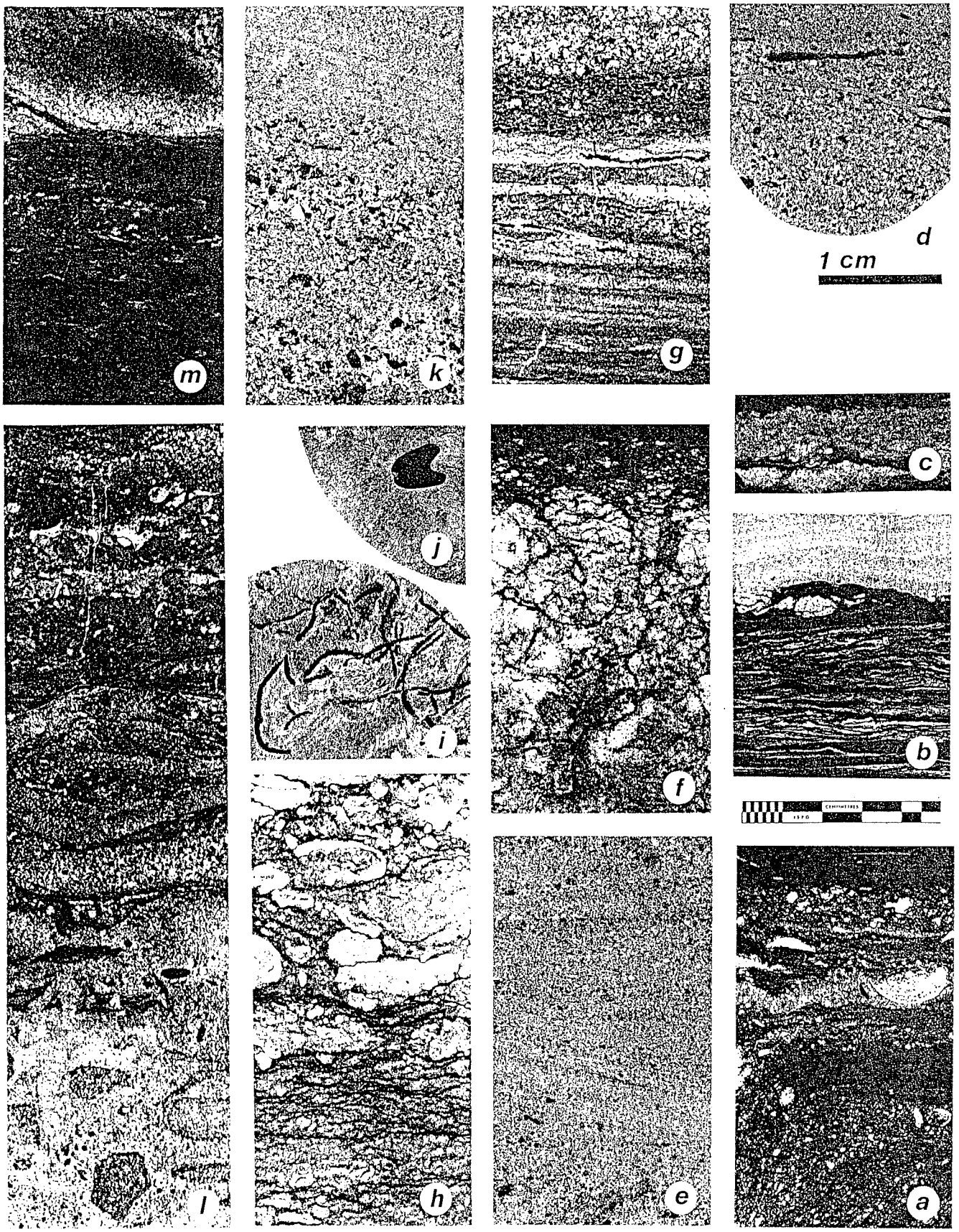


PLATE III

Core photographs, Winterburn, Wabamun, Exshaw and Banff fms.

a: A dark conglomerate grades up into pale sandstone. Pebbles are grey, yellow and red-brown quartzite and pink feldspar. Matrix is green or red-brown shale. Upper contact with green and red banded, shaly and micaceous sandstone is sharp. Winterburn, Marginal clastics, redbed facies; 12-6-83-4W6, 8018 ft.

b: A thin section of red-brown speckled, conglomoratic and cross-bedded sandstone includes clear quartz, quartzite and cloudy microcline grains in dark pyritic, kaolinite matrix. Winterburn, Marginal clastics, redbed facies; 12-6-83-4W6, 8043 ft.

c: A hardground in greyish brown, bioclastic limestone includes sand-filled borings. Overlying sandstone is fine, very pyritic, calcareous and includes crinoids, ostracodes and algae. Wabamun, Cardinal Lake – Big Valley contact. 16-35-77-1W6, 2121.4 m.

d: A hardground in greyish brown limestone includes dark, sediment-filled borings. Limestone is a fine packstone including algae, ostracodes and crinoids. Overlying bed includes silt, pyrite, glauconite, pale limestone and dark mudstone pebbles. Wabamun, Cardinal Lake – Big Valley contact; 2-1-82-2W6, 1923.5 m.

e: Black Exshaw shale overlies grey Wabamun limestone. Limestone is very silty and includes cherty and glauconitic brachiopods, ostracodes and algae. Upper part is interbedded with pyritic shale, calcareous siltstone and micaceous, crinoidal, very fine sandstone. 2-1-82-2W6, 1922.8 m.

f: A conglomoratic sandstone bed in black, silty shale. The sandstone is composed of very fine to very coarse quartz grains, pyritized crinoids, conodonts, ostracodes and brachiopods; plant fragments; mudstone pebbles and oncoids. Exshaw; 2-1-82-2W6, 1922.7 m.

g: A nodular, shaly and sandy, dolomitic limestone grades up into silty and shaly conglomorate. The conglomerate includes pebbles of pale chert, dark shale and pyritic and glauconitic limestone. Big Valley; 6-34-81-23W5, 1759.7 m.

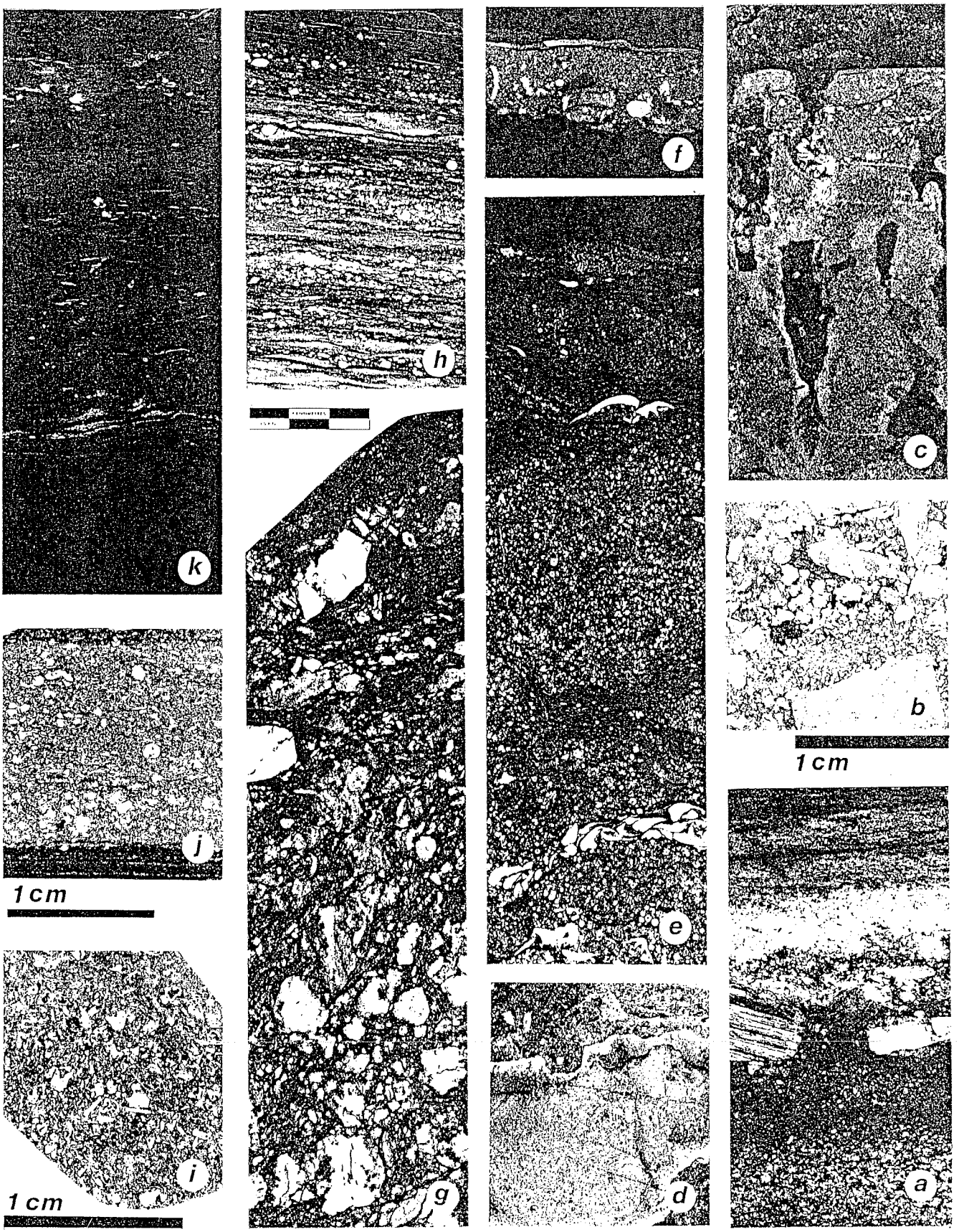
h: Greyish brown limestone (Wabamun) grades up into very dark shale (Exshaw). Limestone is fine-peloidal, coarse-crinoidal and includes shaly mudstone interbeds. 10-28-83-7W6, 7236 ft.

i: A thin section of silty and crinoidal limestone. The ossicles replaced by pyrite and glauconite show as black dots. Big Valley; 6-34-81-23W5, 1758.7 m.

j: A thin section of very thin crinoidal bed in shale. Exshaw; 8-29-83-15W6, 11104.5 ft.

k: Dark Exshaw shale is overlain by greenish grey, calcareous shale (Banff). The Banff shale includes many small, pyritic shell fragments and crinoidal debris. 16-7-77-25W5, 2010.7 m.

Plate III



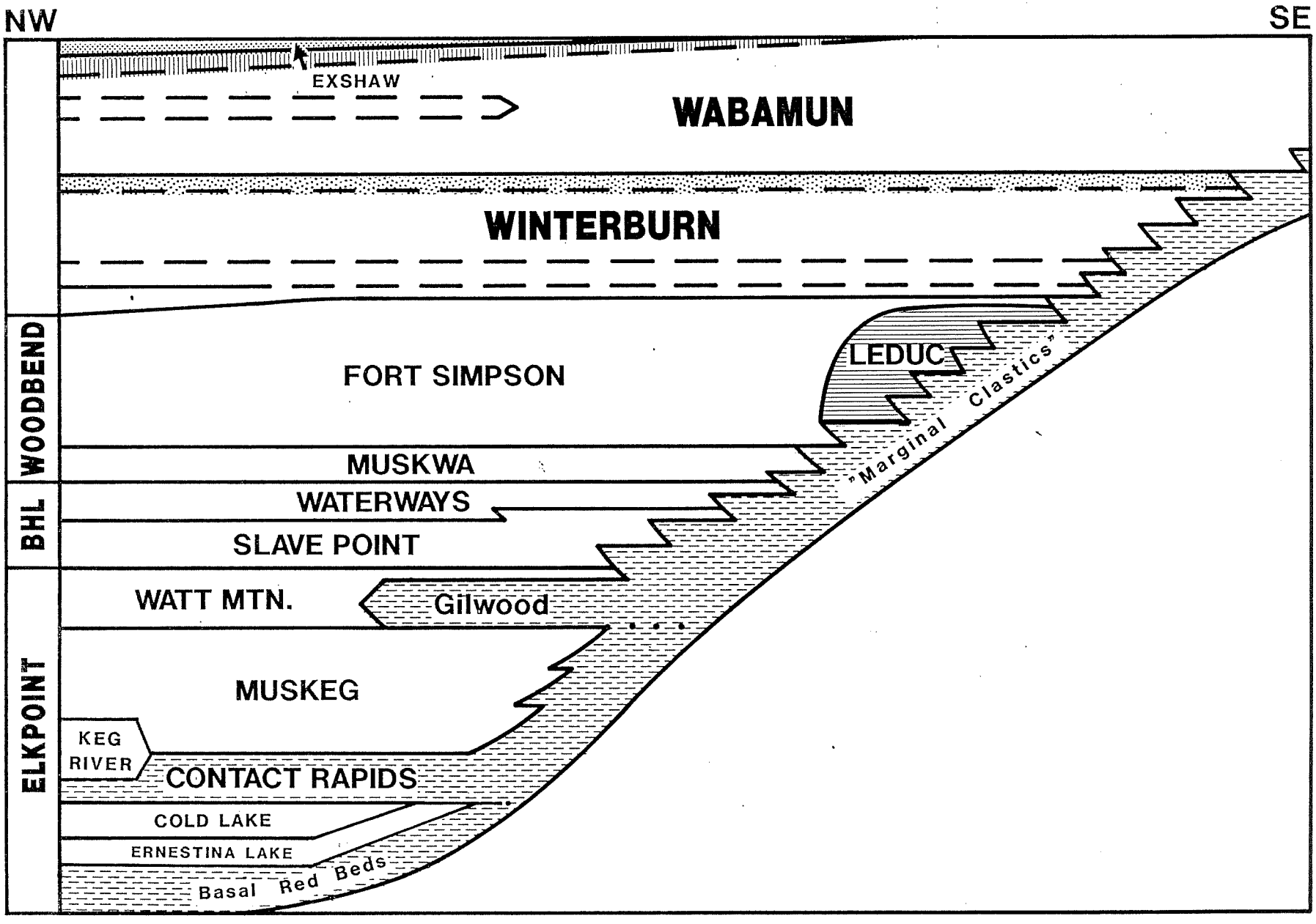

NW
SE
EXSHAW
WABAMUN
WINTERBURN
WOODBEND
FORT SIMPSON
LEDUC
"Marginal Clastics"
MUSKWA
BHL
WATERWAYS
SLAVE POINT
ELKPOINT
WATT MTN.
Gilwood
MUSKEG
KEG RIVER
CONTACT RAPIDS
COLD LAKE
ERNESTINA LAKE
Basal Red Beds

Figure 1

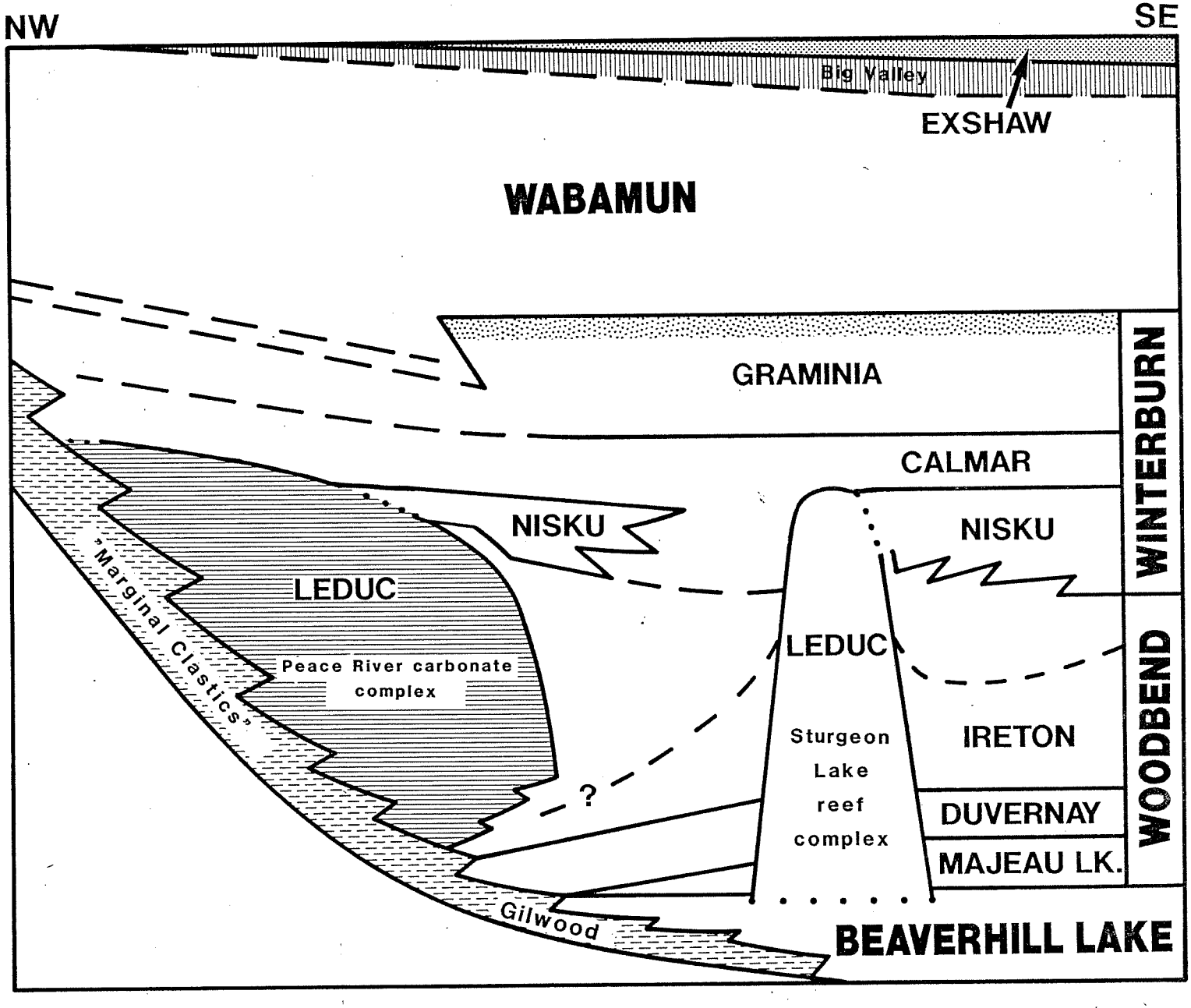

NW
SE
Big Valley
EXSHAW
WABAMUN
GRAMINIA
CALMAR
NISKU
NISKU
LEDUC
"Marginal Clastics"
Peace River carbonate complex
LEDUC
Sturgeon Lake reef complex
IRETON
DUVERNAY
MAJEAU LK.
?
Gilwood
BEAVERHILL LAKE
WINTERBURN
WOODBEND

Figure 2

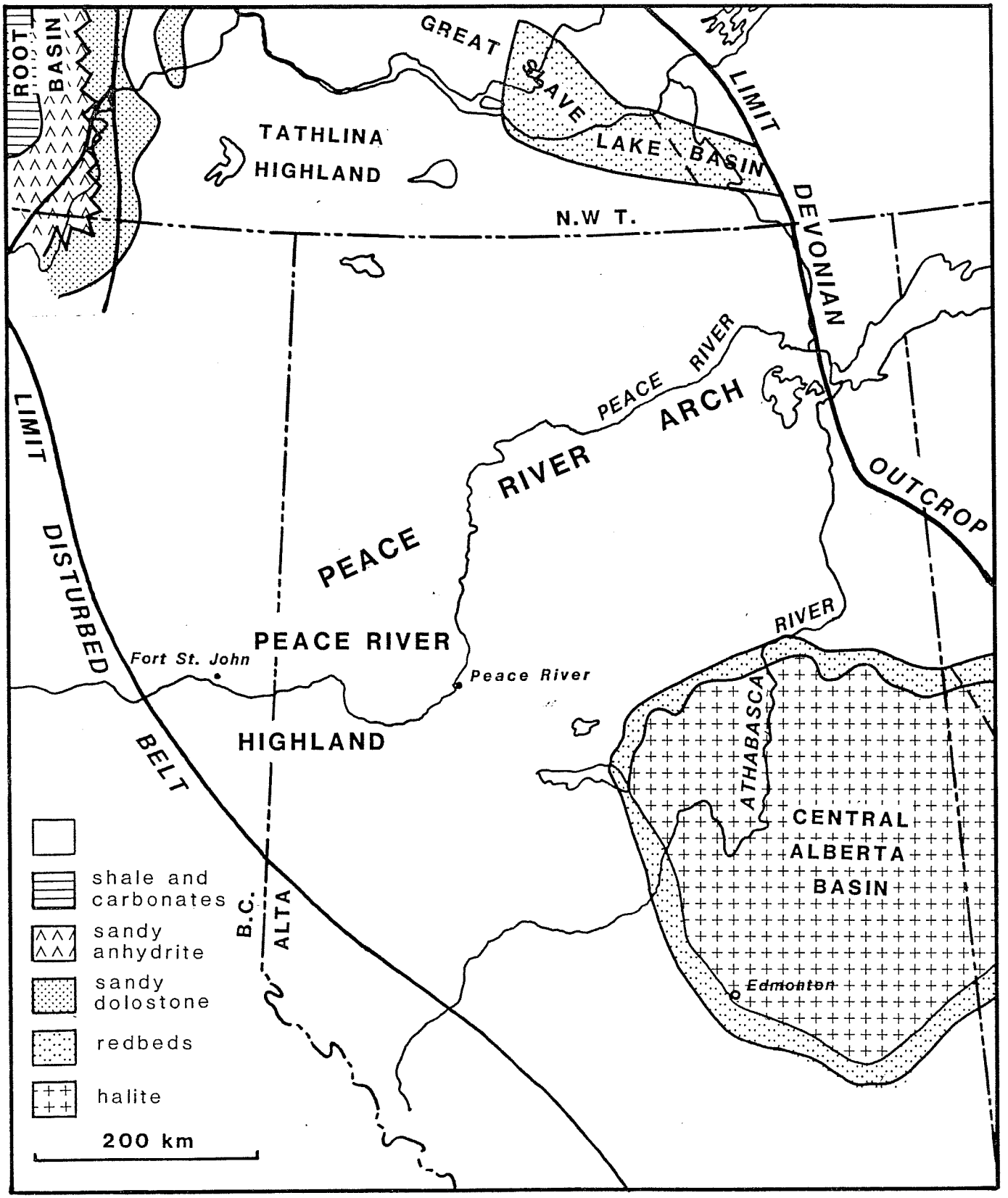

ROOT BASIN
GREAT SLAVE LAKE BASIN
LIMIT
DEVONIAN
OUTCROP
TATHLINA HIGHLAND
N.W T.
PEACE RIVER ARCH
PEACE RIVER
LIMIT
DISTURBED BELT
PEACE
PEACE RIVER
Fort St. John
Peace River
HIGHLAND
RIVER
ATHABASCA
CENTRAL ALBERTA BASIN
Edmonton
B.C.
ALTA
shale and carbonates
sandy anhydrite
sandy dolostone
redbeds
halite
200 km

Figure 3

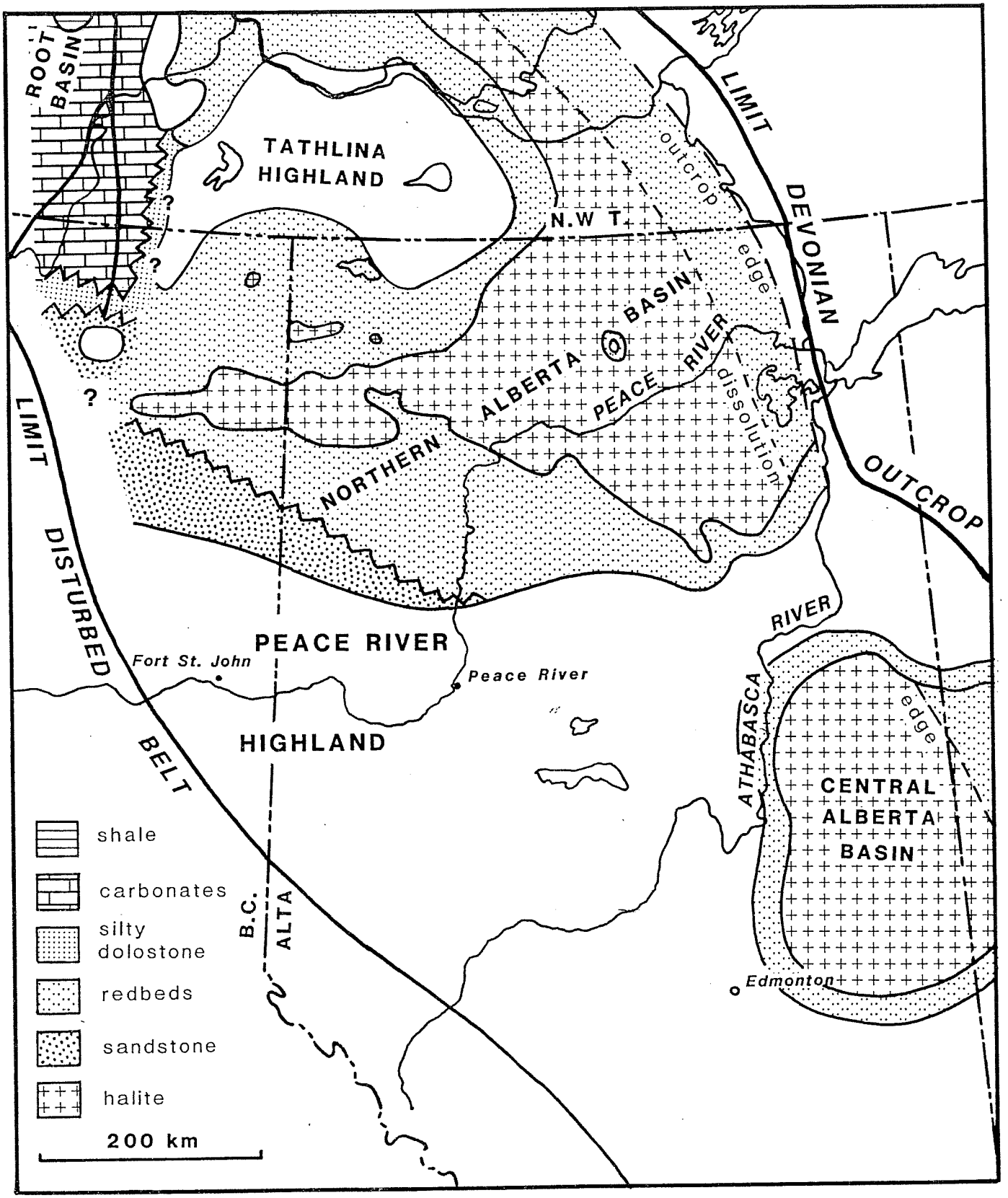

ROOT BASIN
TATHLINA HIGHLAND
N.W.T.
LIMIT
DEVONIAN
OUTCROP
outcrop edge
dissolution
NORTHERN ALBERTA BASIN
PEACE RIVER
LIMIT
DISTURBED BELT
PEACE RIVER HIGHLAND
Fort St. John
Peace River
ATHABASCA RIVER
edge
CENTRAL ALBERTA BASIN
Edmonton
B.C.
ALTA
shale
carbonates
silty dolostone
redbeds
sandstone
halite
200 km

Figure 4

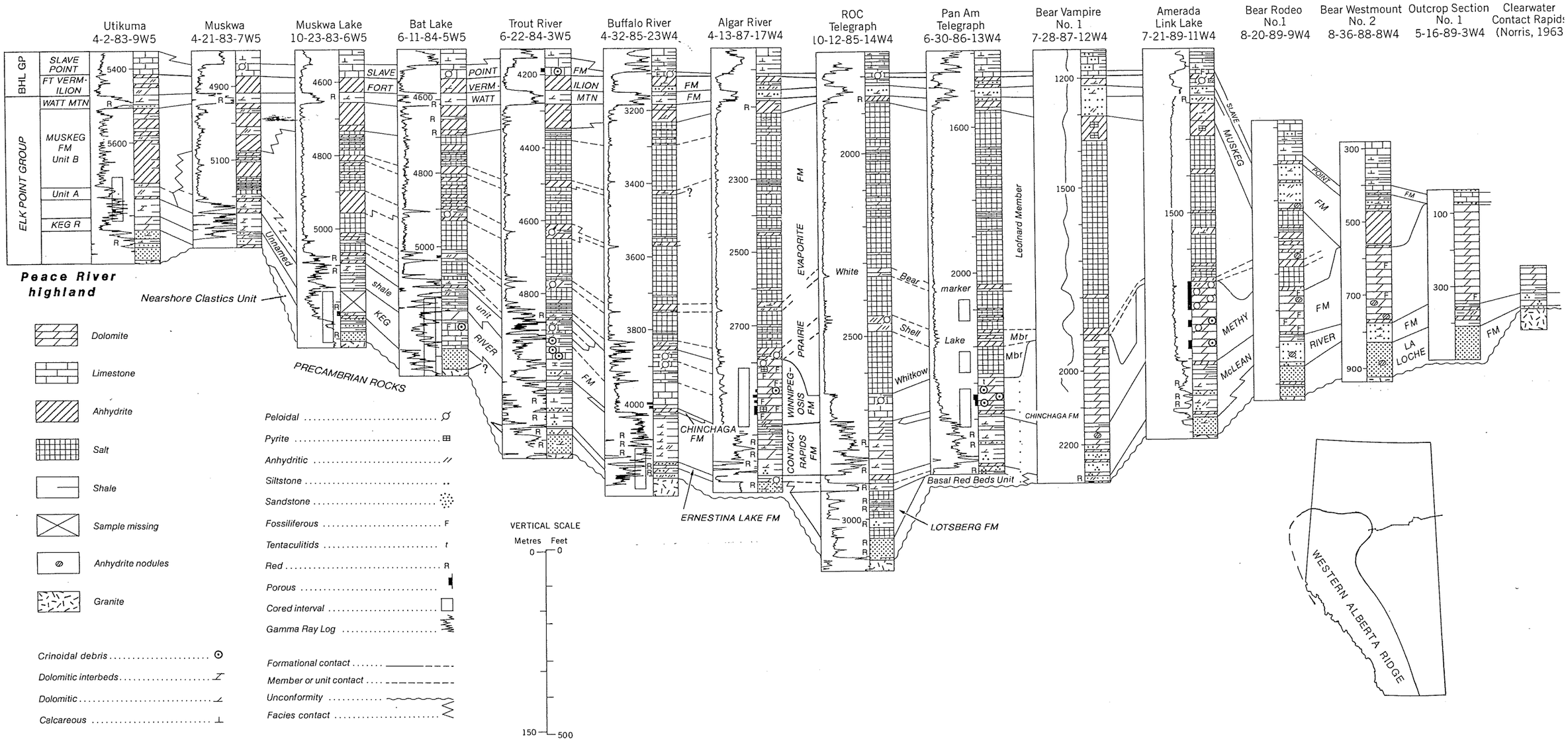

Utikuma 4-2-83-9W5
Muskwa 4-21-83-7W5
Muskwa Lake 10-23-83-6W5
Bat Lake 6-11-84-5W5
Trout River 6-22-84-3W5
Buffalo River 4-32-85-23W4
Algar River 4-13-87-17W4
ROC Telegraph 10-12-85-14W4
Pan Am Telegraph 6-30-86-13W4
Bear Vampire No. 1 7-28-87-12W4
Amerada Link Lake 7-21-89-11W4
Bear Rodeo No.1 8-20-89-9W4
Bear Westmount No. 2 8-36-88-8W4
Outcrop Section No. 1 5-16-89-3W4
Clearwater Contact Rapids (Norris, 1963)
BHL GP
SLAVE POINT
FT VERM-ILION
WATT MTN
ELK POINT GROUP
MUSKEG FM Unit B
Unit A
KEG R
Peace River highland
Nearshore Clastics Unit
PRECAMBRIAN ROCKS
Unnamed unit
SLAVE FORT
POINT VERM WATT
FM ILION MTN
shale KEG RIVER
CHINCHAGA FM
ERNESTINA LAKE FM
EVAPORITE FM
PRAIRIE EVAPORITE
WINNIPEG-OSIS FM
CONTACT RAPIDS FM
White Bear
Shell Whitkow
Leofnard Member
Lake Mbr Mbr
marker
Basal Red Beds Unit
LOTSBERG FM
CHINCHAGA FM
SLAVE MUSKEG
METHY McLEAN
POINT FM RIVER
FM LA LOCHE
Dolomite
Limestone
Anhydrite
Salt
Shale
Sample missing
Anhydrite nodules
Granite
Peloidal
Pyrite
Anhydritic
Siltstone
Sandstone
Fossiliferous
Tentaculitids
Red
Porous
Cored interval
Gamma Ray Log
Crinoidal debris
Dolomitic interbeds
Dolomitic
Calcareous
Formational contact
Member or unit contact
Unconformity
Facies contact
VERTICAL SCALE
Metres Feet
WESTERN ALBERTA RIDGE

Figure 5

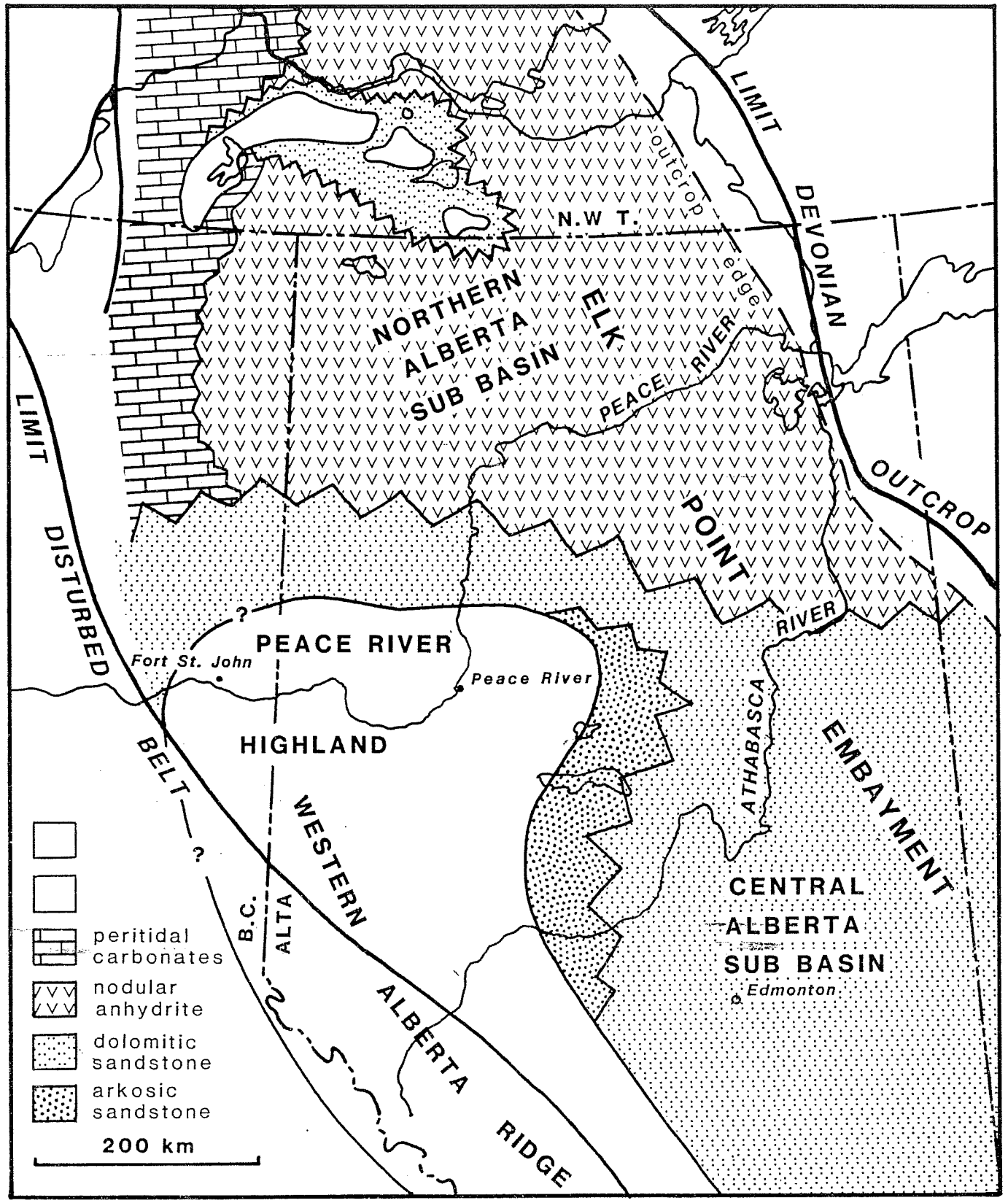

LIMIT
DEVONIAN
OUTCROP
outcrop edge
N.W.T.
NORTHERN
ALBERTA
SUB BASIN
ELK
POINT
PEACE RIVER
RIVER
LIMIT
DISTURBED
BELT
?
PEACE RIVER
HIGHLAND
Fort St. John
Peace River
ATHABASCA
EMBAYMENT
WESTERN
ALBERTA
RIDGE
B.C.
ALTA
CENTRAL
ALBERTA
SUB BASIN
Edmonton
peritidal carbonates
nodular anhydrite
dolomitic sandstone
arkosic sandstone
200 km

Figure 6

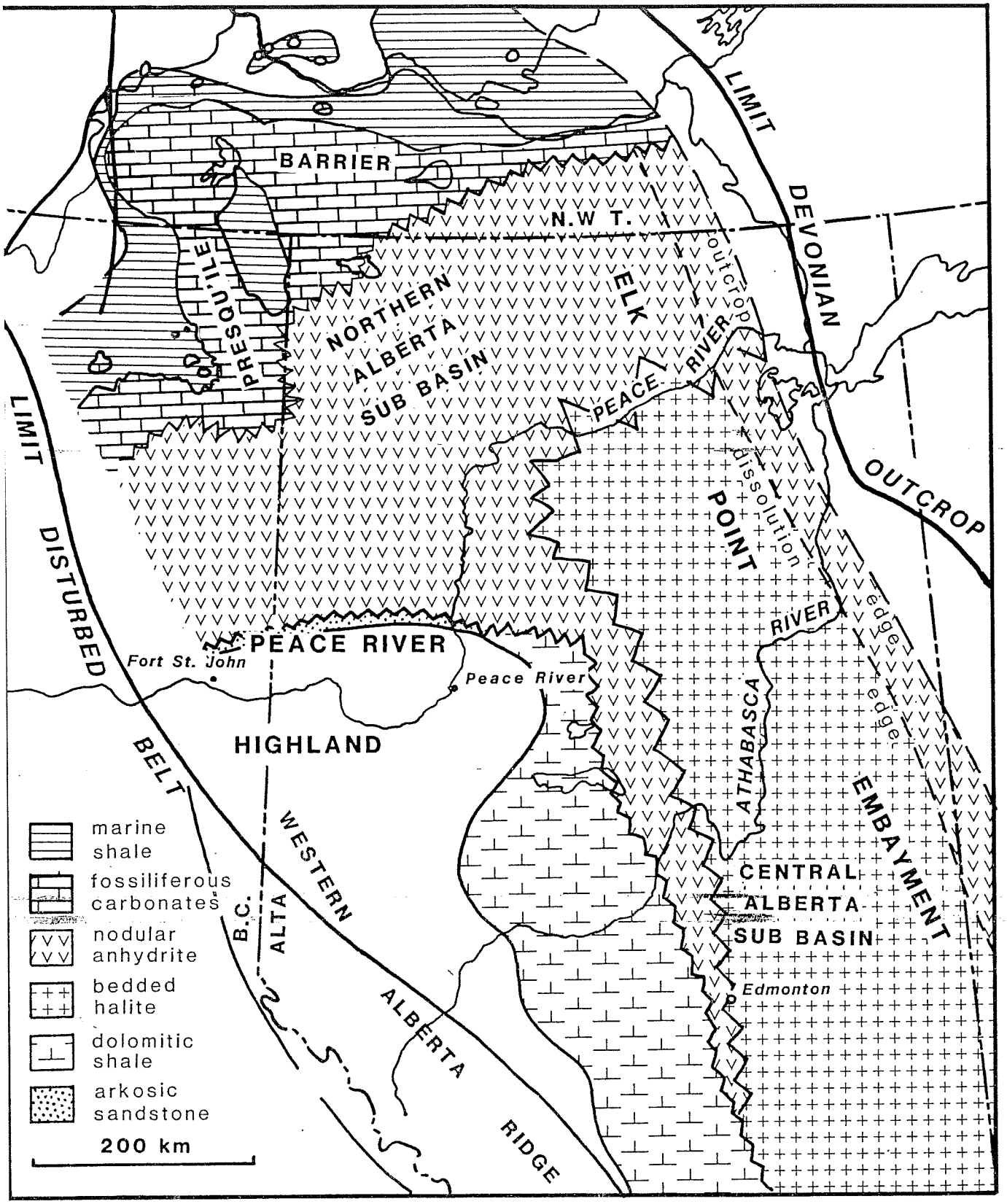

BARRIER
N.W.T.
PRESQUILE
NORTHERN
ALBERTA
SUB BASIN
ELK
POINT
PEACE
RIVER
outcrop
dissolution
edge
LIMIT
DEVONIAN
OUTCROP
LIMIT
DISTURBED
BELT
PEACE RIVER
Fort St. John
Peace River
HIGHLAND
WESTERN
ALBERTA
RIDGE
B.C.
ALTA
ATHABASCA
RIVER
edge
EMBAYMENT
CENTRAL
ALBERTA
SUB BASIN
Edmonton
marine shale
fossiliferous carbonates
nodular anhydrite
bedded halite
dolomitic shale
arkosic sandstone
200 km

Figure 7

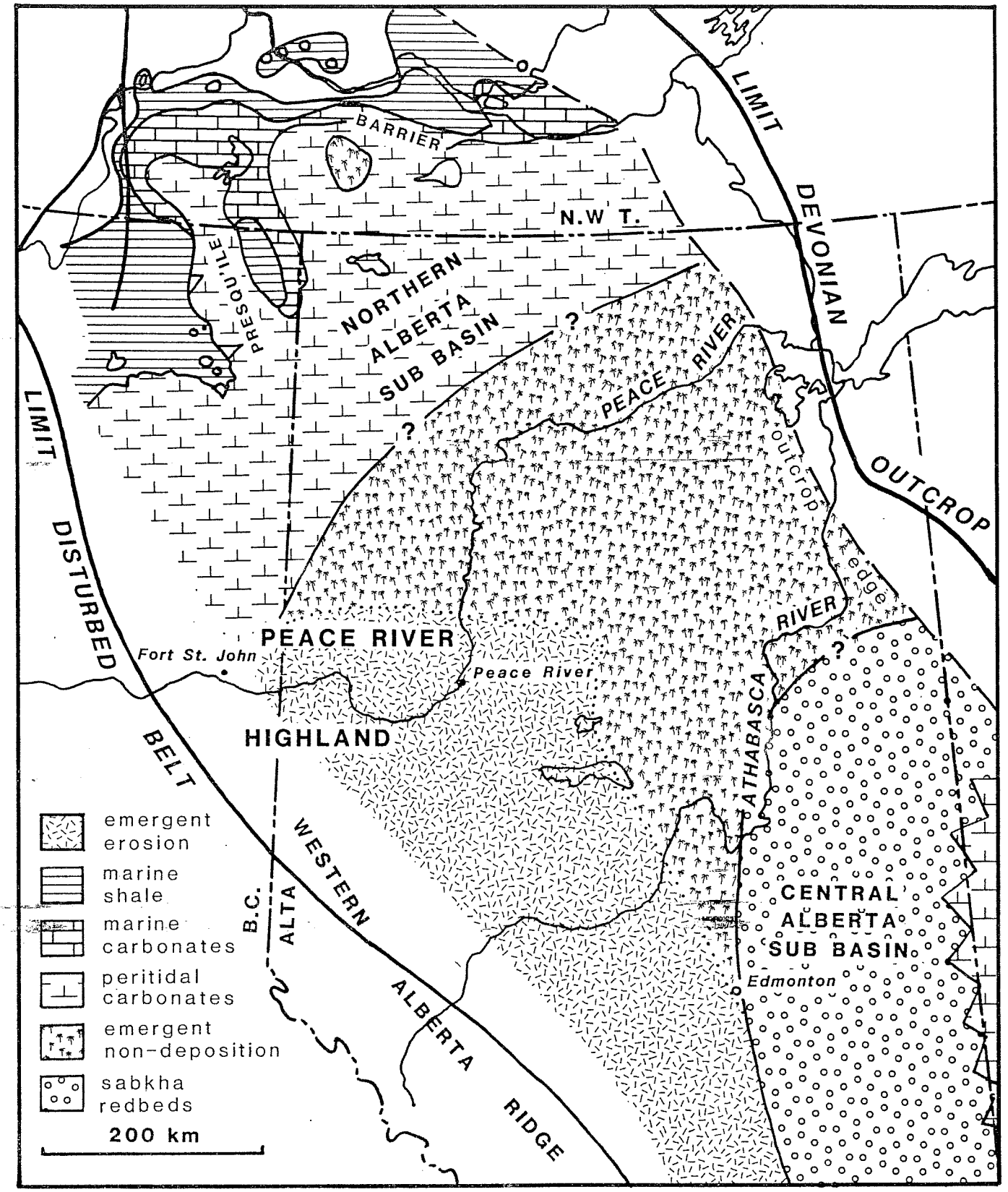

BARRIER
N.W.T.
PRESQU'ILE
NORTHERN
ALBERTA
SUB BASIN
PEACE
RIVER
LIMIT
DEVONIAN
OUTCROP
outcrop
edge
LIMIT
DISTURBED
BELT
PEACE RIVER
Fort St. John
Peace River
HIGHLAND
ATHABASCA
RIVER
WESTERN
ALBERTA
RIDGE
B.C.
ALTA
CENTRAL
ALBERTA
SUB BASIN
Edmonton
emergent
erosion
marine
shale
marine
carbonates
peritidal
carbonates
emergent
non-deposition
sabkha
redbeds
200 km

Figure 8

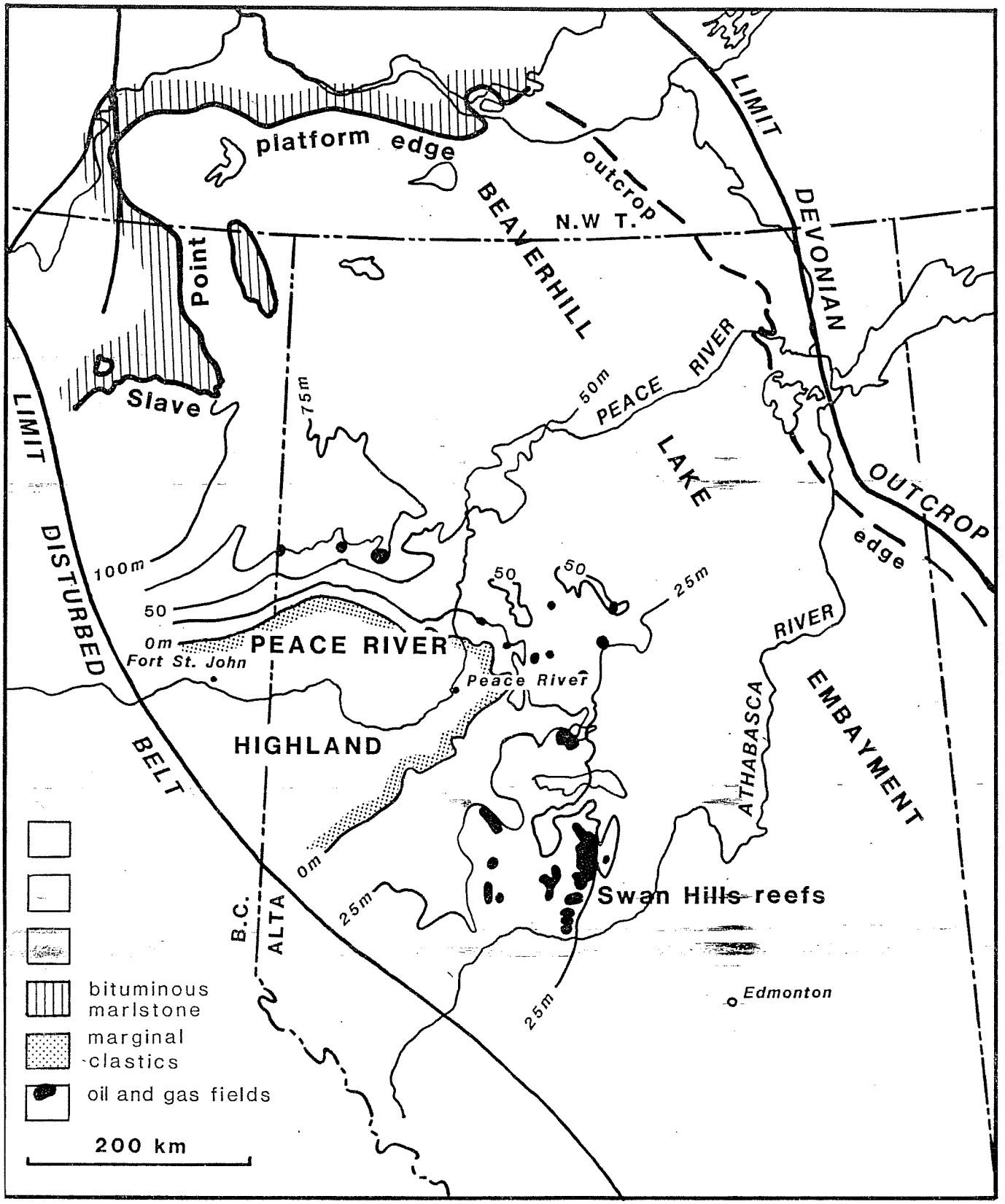

platform edge
BEAVERHILL
outcrop
N.W T.
LIMIT
DEVONIAN
Point
Slave
75m
50m
PEACE RIVER
LAKE
OUTCROP
edge
LIMIT
DISTURBED
BELT
100m
50
0m
PEACE RIVER
Fort St. John
50
50
25m
Peace River
RIVER
ATHABASCA
EMBAYMENT
HIGHLAND
0m
25m
Swan Hills reefs
B.C.
ALTA
25m
Edmonton
bituminous marlstone
marginal clastics
oil and gas fields
200 km

Figure 10

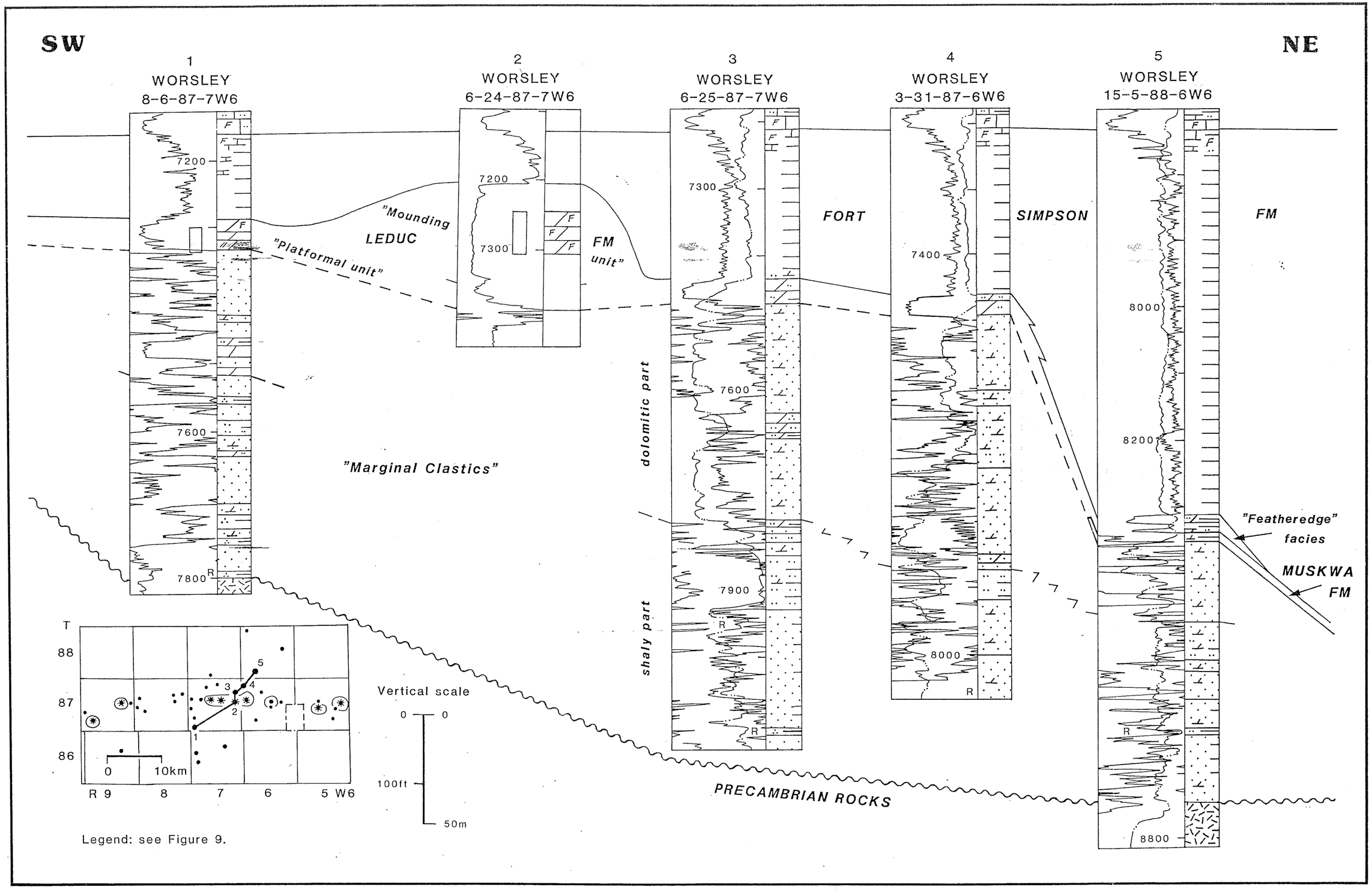

SW
NE
1
WORSLEY
8-6-87-7W6
2
WORSLEY
6-24-87-7W6
3
WORSLEY
6-25-87-7W6
4
WORSLEY
3-31-87-6W6
5
WORSLEY
15-5-88-6W6
7200
7600
7800
7200
7300
7300
7600
7900
7400
8000
8000
8200
8800
"Mounding
LEDUC
"Platformal unit"
FM
unit"
FORT
SIMPSON
FM
"Marginal Clastics"
dolomitic part
shaly part
"Featheredge"
facies
MUSKWA
FM
PRECAMBRIAN ROCKS
T
88
87
86
R 9
8
7
6
5 W6
0
10km
Vertical scale
0
0
100ft
50m
Legend: see Figure 9.

Figure 13

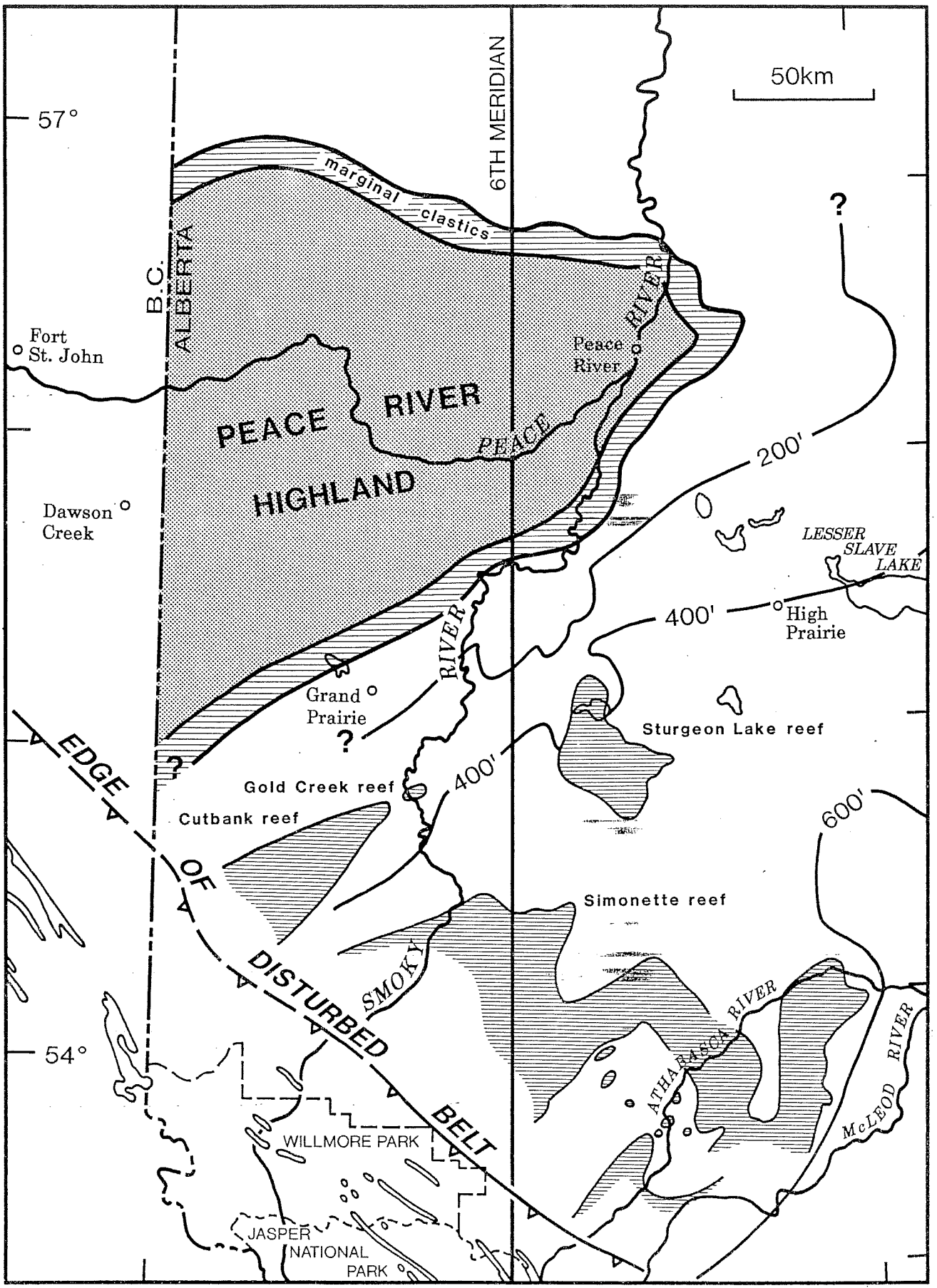

50km
57°
54°
6TH MERIDIAN
B.C.
ALBERTA
marginal clastics
Fort St. John
Dawson Creek
PEACE RIVER HIGHLAND
PEACE RIVER
Peace River
200'
400'
600'
LESSER SLAVE LAKE
High Prairie
Grand Prairie
RIVER
Sturgeon Lake reef
Gold Creek reef
Cutbank reef
Simonette reef
EDGE OF DISTURBED BELT
SMOKY
ATHABASCA RIVER
McLEOD RIVER
WILLMORE PARK
JASPER NATIONAL PARK

Figure 16

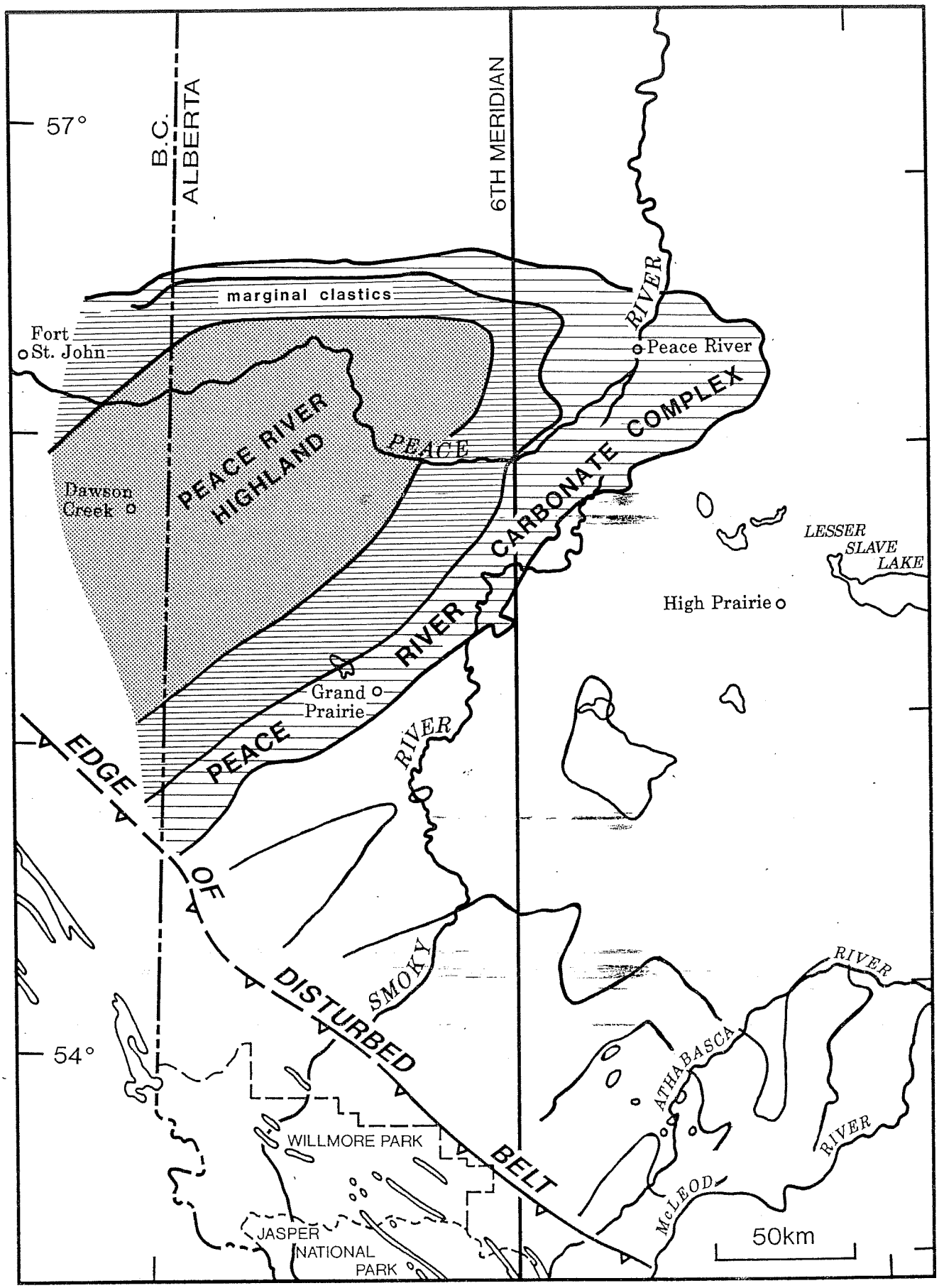

57°
B.C.
ALBERTA
6TH MERIDIAN
marginal clastics
Fort St. John
Peace River
RIVER
PEACE RIVER HIGHLAND
PEACE
CARBONATE COMPLEX
Dawson Creek
LESSER SLAVE LAKE
High Prairie
RIVER
Grand Prairie
PEACE
RIVER
EDGE OF DISTURBED BELT
SMOKY
RIVER
ATHABASCA
RIVER
McLEOD
RIVER
54°
WILLMORE PARK
JASPER NATIONAL PARK
50km

Figure 17

(17)

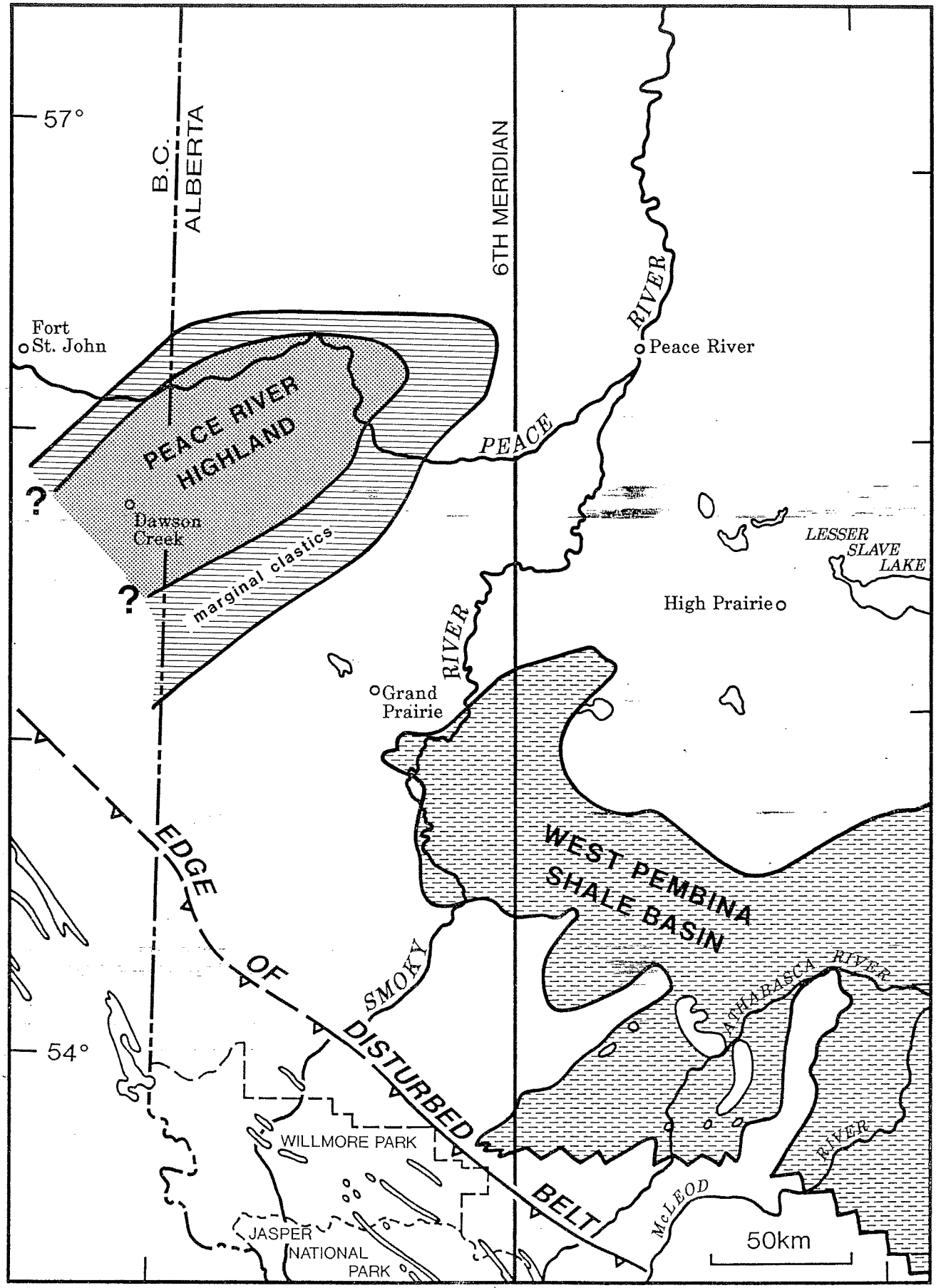

57°
B.C.
ALBERTA
6TH MERIDIAN
RIVER
Peace River
Fort
St. John
PEACE RIVER
HIGHLAND
PEACE
?
Dawson
Creek
marginal clastics
?
LESSER
SLAVE
LAKE
High Prairie
RIVER
Grand
Prairie
WEST PEMBINA
SHALE BASIN
EDGE
OF
DISTURBED
BELT
SMOKY
ATHABASCA RIVER
54°
WILLMORE PARK
JASPER
NATIONAL
PARK
McLEOD
RIVER
50km

Figure 18

18

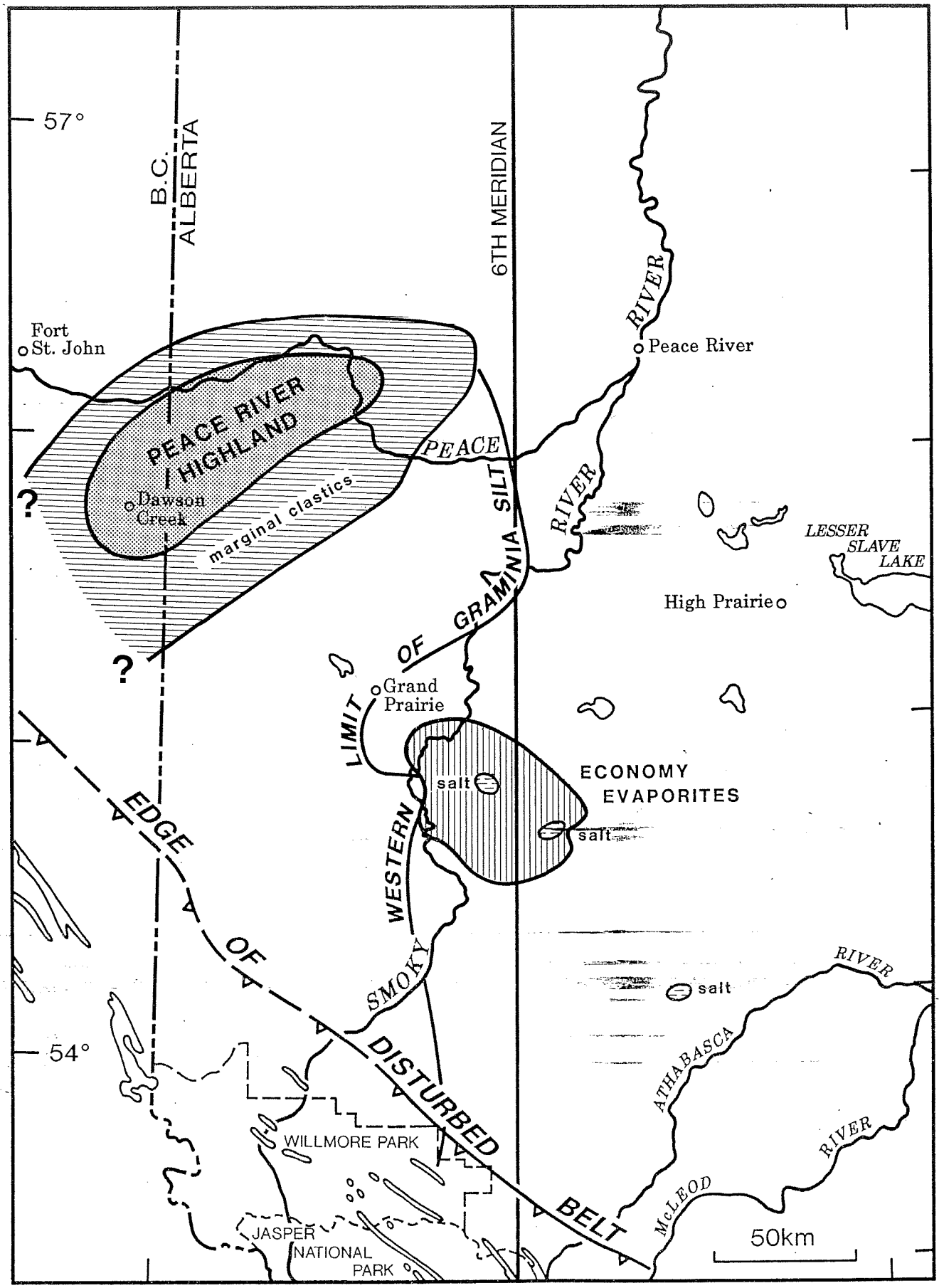

57°
B.C.
ALBERTA
6TH MERIDIAN
RIVER
Peace River
Fort
St. John
PEACE RIVER
HIGHLAND
PEACE
Dawson
Creek
marginal clastics
?
?
SILT
RIVER
LESSER
SLAVE
LAKE
High Prairie
LIMIT OF GRAMINIA
Grand
Prairie
salt
ECONOMY
EVAPORITES
salt
WESTERN
SMOKY
EDGE OF DISTURBED BELT
salt
RIVER
ATHABASCA
RIVER
McLEOD
54°
WILLMORE PARK
JASPER
NATIONAL
PARK
50km

Figure 19

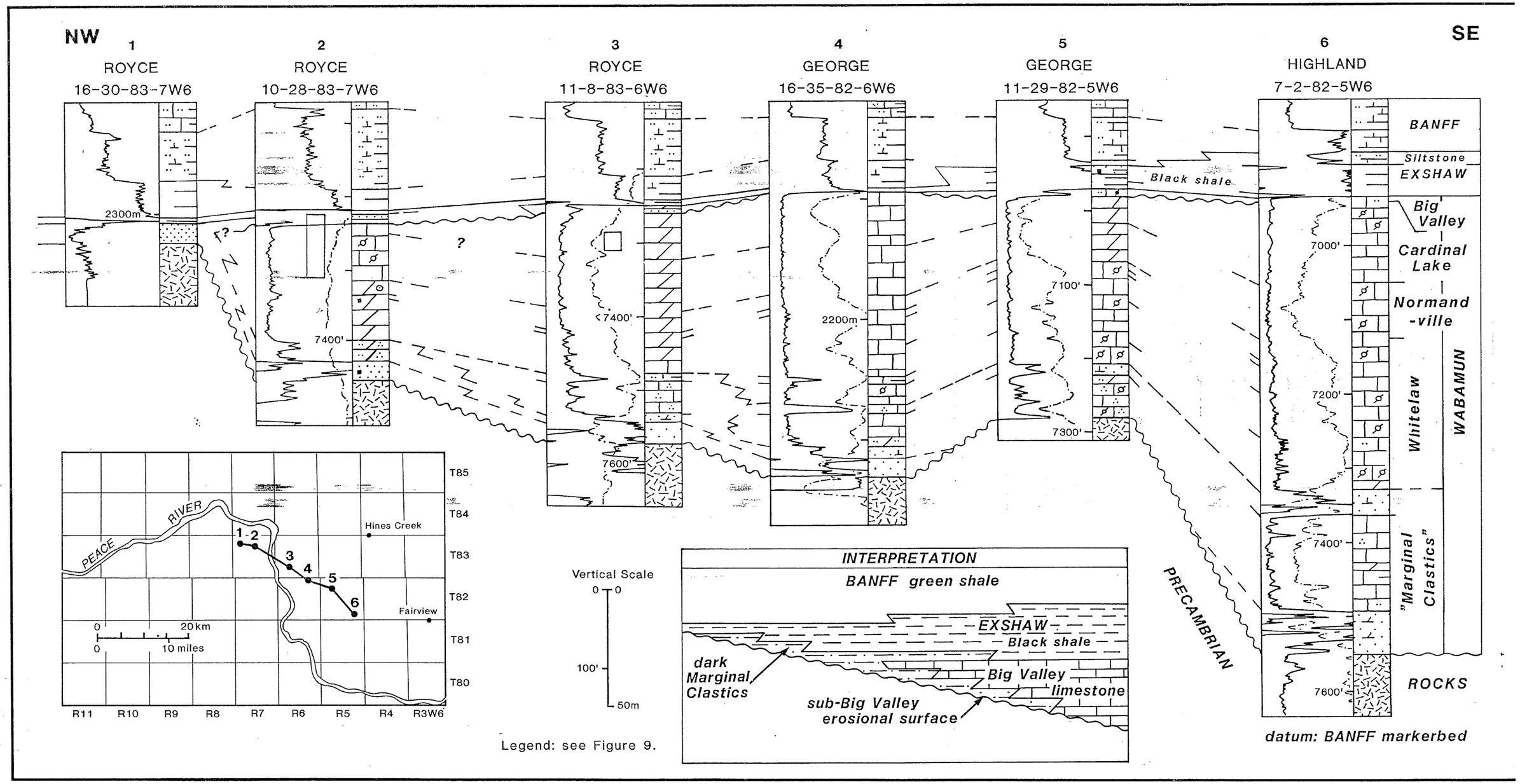

NW
SE
1
ROYCE
16-30-83-7W6
2
ROYCE
10-28-83-7W6
3
ROYCE
11-8-83-6W6
4
GEORGE
16-35-82-6W6
5
GEORGE
11-29-82-5W6
6
HIGHLAND
7-2-82-5W6
BANFF
Siltstone
EXSHAW
Black shale
Big Valley
Cardinal Lake
Normand-ville
Whitelaw
WABAMUN
"Marginal Clastics"
ROCKS
PRECAMBRIAN
2300m
7400'
7600'
2200m
7100'
7300'
7000'
7200'
7400'
7600'
datum: BANFF markerbed
PEACE RIVER
Hines Creek
Fairview
0 20km
0 10 miles
T85
T84
T83
T82
T81
T80
R11
R10
R9
R8
R7
R6
R5
R4
R3W6
Vertical Scale
0 0
100'
50m
INTERPRETATION
BANFF green shale
EXSHAW
Black shale
Big Valley limestone
dark Marginal Clastics
sub-Big Valley erosional surface
Legend: see Figure 9.

Figure 20

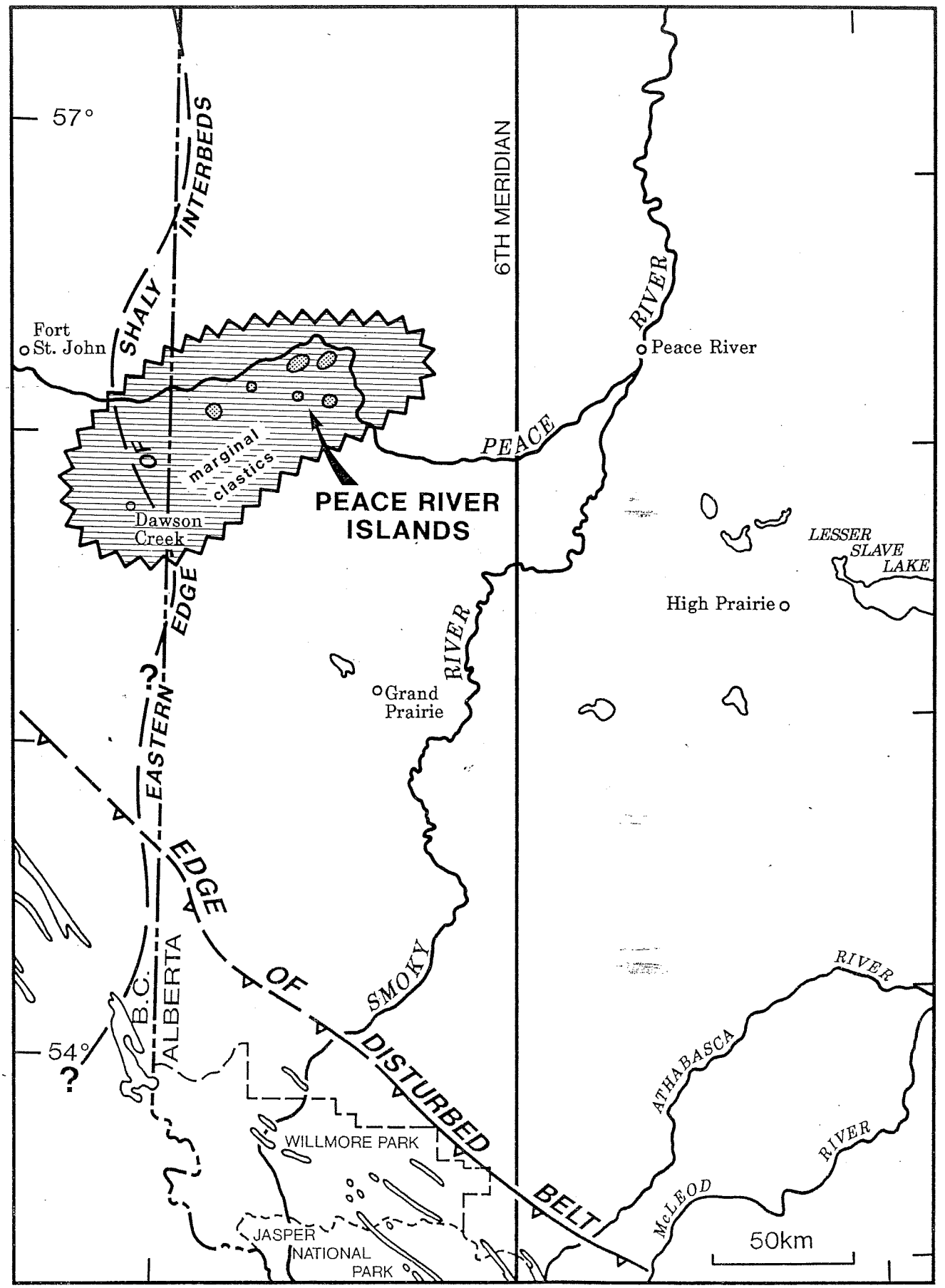

57°
54°
6TH MERIDIAN
SHALY INTERBEDS OF marginal clastics
Fort St. John
Dawson Creek
PEACE RIVER ISLANDS
PEACE RIVER
Peace River
LESSER SLAVE LAKE
High Prairie
RIVER
Grand Prairie
EASTERN EDGE
EDGE OF DISTURBED BELT
SMOKY
B.C.
ALBERTA
WILLMORE PARK
JASPER NATIONAL PARK
ATHABASCA RIVER
McLEOD RIVER
50km

Figure 21

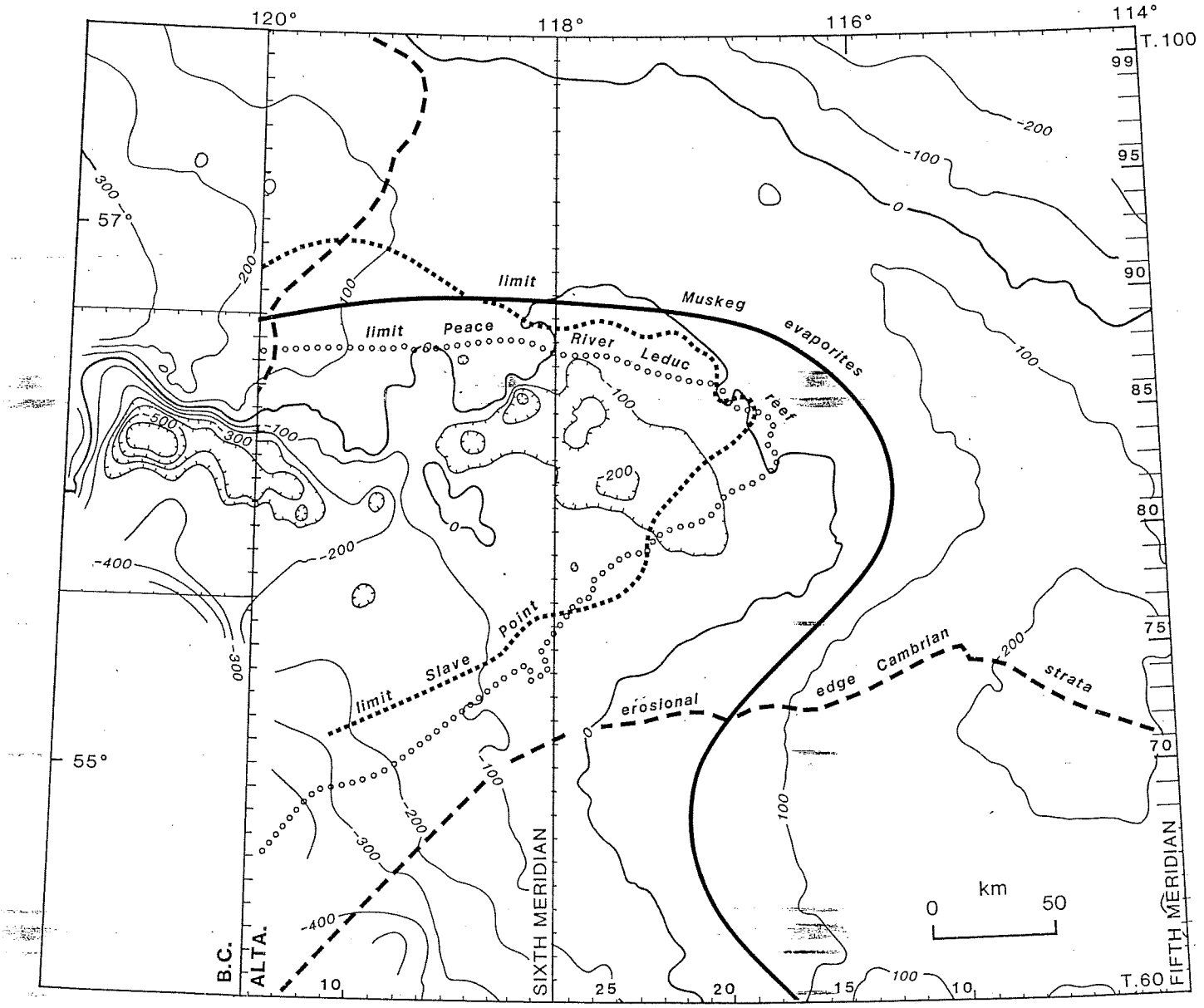

120°
118°
116°
114°
T.100
99
95
90
85
80
75
70
T.60
57°
55°
limit
Muskeg
evaporites
limit
Peace
River
Leduc
reef
Slave
Point
limit
erosional
edge
Cambrian
strata
SIXTH MERIDIAN
FIFTH MERIDIAN
B.C.
ALTA.
km
0
50
10
25
20
15
10
300
200
100
0
-100
-200
-300
-400
-500

Figure 22