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The Root Basin

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INTRODUCTION

The Root Basin is one of the most interesting but least known subbasins within the Western Canada Sedimentary Basin. It's name does not appear in the influential summaries such as Economic Geology #1 (Douglas et al., 1970), the Cordillera guide book (Ziegler, 1967), the Internation Devonian Symposium (Bassett and Stout (1967), or Future Petroleum Provinces (McCrossan, 1973). Nor is the fact that the area was a pronounced early Paleozoic depocentre evident from the maps of the above reports, with the exception of those of Douglas et al. (1970) where what is now known as the Root Basin is included within a larger, equally unpublicized tectonic feature therein called the Mackenzie Trough.

The initial field work within the Root Basin was part of 'Operation Mackenzie', initiated in 1957; reports and maps by Douglas and Norris (1960, 1961, 1963) cover the eastern two thirds of the basin. The Root Basin is separated from the larger Selwyn Basin by the Redstone Arch (Fig. 1). That the basin was a discrete tectonic cell could not be appreciated until the arch had been mapped, and this feature, as well as the western third of the Root Basin lay within the area of 'Operation Nahanni' (Gabrielse et al., 1965, 1973). The term 'Root Basin' was first used in print by Gabrielse (1967).

There is a large amount of information available on the Root Basin, however much of it occurs in reports for which the Root Basin is a peripheral, often unnamed, entity. Furthermore, obtaining a coherent picture of the stratigraphy is rendered difficult by the fact that the meanings of several formation names have evolved almost beyond recognition from their original meanings. The main purpose of this report is to provide a summary of what is known about the Root Basin, to trace the evolution of ideas concerning its history, and to point out how very much remains to be considered.

This report is based on all available published information, much of which is by the Geological Survey of Canada, on selected unpublished industry reports available through DIAND or COGLA, and, for the eastern part of the basin, on subsurface data. Subsurface data comes from company well reports, lithologs by Canadian Stratigraphic Services Ltd., and by various geologists of the Geological Survey of Canada; I have examined the samples and core of most wells of the Root Basin and adjacent areas.

Tectonic setting

As depicted on Figure 1 the Root Basin is bounded on three sides by arches but to the south and southwest it melds with the Liard and Selwyn basins. The eastern margins of both the Root and Liard basins are parts of an extensive, long-lived, down-on-the-west hinge line which was active throughout most of Paleozoic and, possibly, Mesozoic time. The Redstone Arch was also a long-lived feature, active throughout Early Paleozoic into, at least, Middle Devonian time; there is no younger rock record preserved over the arch.

The northern and southern limits of the Root Basin are less clear cut. At the north end is the Keele Arch, a feature that first became positive in latest Silurian or earliest Devonian time; previously the Root Basin was part of a more extensive north-south trending downwarp known as the Mackenzie Trough (Williams, 1989). The South Nahanni River serves as a convenient but arbitrary southern boundary. Lower and middle Paleozoic strata are exposed north of the river, upper Paleozoic and Mesozoic strata within the Liard Basin south of the river (Fig. 2). The down-on-the-south flexure causing this change may be mainly a Mesozoic phenomenon.

When the Root Basin originated is unknown. The Proterozoic history is entirely unknown. The Keele Arch and, probably, the northern end of the Root Basin, were strongly negative through Early and Middle Cambrian time, but no strata of this age outcrop or have been reached by the drill within the basin. The Late Cambrian-Early Ordovician Franklin Mountain – Broken Skull Formations are known to floor the basin and to cover most of the flanking arches. The basin was probably negative at this time but there is insufficient thickness control to be sure. Our knowledge of the tectonic sag begins with the Middle Ordovician Sunblood Formation which is present in the southern part of the basin but is missing in the north and over the flanking arches, at least in part due to pre-Late Ordovician erosion. The main differential warping occurred through the Silurian and Early Devonian time. Evidence for late Paleozoic down warping is circumstantial, deduced by analogy with the Liard Basin.

ROOT BASIN FORMATIONS AS ORIGINALLY DEFINED

The stratigraphic framework of the Root Basin was established during Operation 'Mackenzie', this operation extended west to longitude 126°W, hence covered most of the Root Basin but not its western limb (Fig. 1). New formation names introduced during this operation include the Headless, Landry, Manetoe, Arnica, Sombre, Delorme and Whittaker (Douglas and Norris, 1960, 1961, 1963). These authors recognized that some of these units were time-equivalent variants of each other however most formations were considered to be widespread, blanket-type deposits. Subsequent mapping, as well as the drilling of several deep holes (Fig. 3) has shown that the stratigraphy is more complex than originally anticipated and that the existing nomenclature is inadequate. In the southern part of the basin several changes have been introduced by Morrow and Cook (1987) including several new names: Vera, Cadillac, Root River and Corridor (Figs. 4, 5). Knowledge of the basin is still too sketchy to suggest further changes at this time, however, the reader should be warned that Root Basin nomenclature is fraught with imprecision.

In this chapter formations are briefly described, as far as is practical, by quotations from the original reports. Formation names appear on Figure 4, age ranges, in part based on subsequent refinements, are shown on Figure 5.

Proterozoic. Within the Root Basin as defined on Figure 1 Proterozoic rocks are exposed in three culminations high on the western flank (~62°30', 63° and 63°30'N near 126°W, Fig. 2). It is a moot point whether these areas should be classed as Root Basin or Redstone Arch. These exposures are shallow water clastics and carbonates of the Mackenzie Mountains supergroup (0.77 to 1.26 Ga). Farther west, forming the Redstone Plateau (Fig. 2) are thick deposits of the Windermere supergroup (0.57 to 0.77 Ga). Probable Windermere equivalents, mostly fine grained clastics, occur in the southwest corner of the map-area and in a small outcrop within the Liard Basin on Beaver River (~60°25'N, 125°50'W, Fig. 2). East of the Root Basin Proterozoic sedimentary rocks outcrop in the core of the McConnell Range and have been penetrated by many wells; these are thought to be equivalents of the Hornby Bay Group (1.2 to 1.85Ga) by Meijer Drees (1975) and Aitken and Pugh (1984).

Broken Skull Formation. This name was introduced by Gabrielse et al. (1973) for a thick sequence of dominantly carbonate strata of Late Cambrian to Early Ordovician age that occur west of the Redstone Arch. Along the eastern limb of the arch unfossiliferous strata above Proterozoic quartzite and below the Whittaker Formation were provisionally assigned to the Broken Skull Formation by Gabrielse et al. (1973). They are described as follows (*ibid.*, p. 47): "The lower recessive beds, more than 200 feet thick, consists of orange and brown weathering shaly dolomites, variably sandy, interbedded with red and green dolomitic shales... The upper 500 feet of strata is fine grained, orange and grey weathering, thin- to medium-bedded dolomites, variably sandy. Salt casts are present locally". Beds of hematitic, crossbedded sandstone at the base of the formation occur locally.

Douglas and Norris (1960, 1961, 1963) did not identify rocks of this age in the central Root Basin. Correlative strata east of the basin are known as the Franklin Mountain Formation.

Sunblood Formation. From the core of Whittaker anticline (Whittaker Range section, Fig. 3) the Sunblood Formation was described as follows (Douglas and Norris, 1961, p. 6): The upper 260 feet consists of grey-weathering, fine grained, dark grey limestones and calcareous shales containing Middle Ordovician fossils. Malachite, azurite and goethite occur 70 feet above the base of the unit. The underlying part, 680 feet thick, is composed of interbedded reddish-orange- to brown-weathering, brownish grey, fine- to medium-grained, medium- to thin-bedded, sandy or silty limestones; fine-grained dolomites; and calcareous to dolomitic sandstones. Copper minerals occur 650 feet above the base. These beds and those lower in the section were found to be unfossiliferous. Underlying strata comprise 335 feet of fine grained grey limestone that is thin- to medium- and thick-bedded and forms a low cliff. These are underlain by the lowest beds exposed which consist of 340 feet of arenaceous dolomites – light grey, fine- to medium-grained and brown-weathering; interbedded with sandstones – dark grey, medium-grained and grey-weathering.

Whittaker Formation. The Whittaker Formation (Douglas and Norris, 1961, p. 7) is described as characteristically grey weathering in contrast to the light colours, sometimes brilliant, of the overlying Delorme Formation. A threefold division was recognized, obvious in the southern part of the basin, less so in the north. The lower division consists of dark grey to grey, fine to medium grained, thin bedded limestone with Late Ordovician brachiopods. The middle unit is mostly massive, resistant, light and dark grey, medium grained dolomite, partly porous and vuggy, variably cherty, with Late Ordovician and Early Silurian corals. The upper unit, in the south, consists of dark grey to black, argillaceous, fine grained, platy limestone with thin interbeds of siltstone near the base; Early Silurian graptolites occur in the limestones. Farther north (Douglas and Norris, 1963, p. 12) the formation is mostly dolomite; some platy limestones occur in the upper and lower units.

Concerning the formation in the belt transitional from the Root Basin to the Redstone Arch, Gabrielse et al. (1973, p. 59) generalize as follows: ". . . well bedded, commonly cherty, dark grey weathering dolomite and light grey to grey weathering dolomite and limestone". A basal limestone member occurs locally but the threefold division seen in the type area (Whittaker Range) is not evident.

Southwest of the Redstone Arch, near the transition to the shaly Road River facies, in the upper part of the Whittaker Formation there are lenses of ". . . light grey, massive, medium- to coarse-grained, vuggy and porous reefoid dolomite. . . Where they occur the thickness of the Whittaker Formation increases greatly" (*ibid.*, p. 59). Such reefoid lenses have not been reported from the Whittaker Formation within the Root Basin.

Delorme Formation. In the central Root Basin the Delorme Formation (Douglas and Norris, 1961, p. 10) is described as characteristically recessive, slope forming and talus covered. Weathering colours are alternating buff or brown, locally with yellowish, orange or reddish tones. At the type section (Pastel Creek, Fig. 7) the basal 152 m consist of interbedded dark grey shale and black, argillaceous limestones or dolomites with Silurian fossils. The middle unit (609 may consists of light grey, fine, medium or coarse grained dolomite, in part massive and resistant, sparsely porous and vuggy; the upper 213 m of this middle unit is silty and contains

Silurian-Devonian fossils. The uppermost unit (229 m), mainly covered, contains dark grey, cryptograined, thin bedded limestone. To the south at the Whittaker Range section the middle unit is not recognizable, the equivalent is described as dark grey, cryptograined, variably silty and sandy limestone that weathers orange. In the northern part of the basin the Delorme Formation is described as light to medium grey, cryptograined, in part silty, platy dolomite and limestone; fine bioclastic debris occurs in the upper part (Douglas and Norris, 1963, p. 13).

In the central part of the basin the Delorme Formation is overlain by the brecciated carbonates of the Camsell Formation, thus the upper Delorme contact is mappable westward into the area studied by Gabrielse et al. (1973) (west of 126°W). However the Camsell breccia is not present over the Redstone Arch nor in the area south of the arch, equivalent strata consist of unbrecciated carbonates, mostly dolomite. This pre-Sombre section has been mapped either as Delorme-Camsell undivided (unbrecciated) or as the Delorme Formation. The section is described as "...relatively uniform, laminated, fine grained, locally sandy, buff weathering dolomite. . ." East of the arch the section becomes more shaly and platy (*ibid.*, p. 72).

Camsell Formation. The Camsell Formation of the northern part of the Root Basin is described as follows (Douglas and Norris, 1963, p. 13): "...composed mainly of limestone and dolomite commonly brecciated, either devoid of bedding or massive to thickly bedded. It weathers characteristically light grey, with interbeds of buff, yellow and orange. The limestone is light grey, cryptograined, varying to medium grained, and weathering light or dark grey. The dolomite, which is minor, is fine to coarse grained. Breccia fragments vary in size from a few inches to several feet, being angular to subrounded. The matrix is mainly calcite – fine- to medium-grained, partly forming a fine stockwork – and towards the top it includes large salt casts".

At the south end of the basin the formation thins and changes to "...alternating thick-bedded, fine-grained, medium-grey-weathering, recessive limestone and shaly, fine-grained, orange-weathering, recessive limestone; the colour banding is its most striking characteristic" (Douglas and Norris, 19961, p. 11).

On the western flank of the basin, as previously mentioned, typical Camsell strata are absent; if equivalents are present they have been mapped with the Delorme dolomite. Southwest of the basin, south of the Redstone Arch, strata believed to be Camsell equivalent are described as ".... very fine grained dark grey dolomites, variably calcareous and silty" (Gabrielse et al., 1973, p. 75).

Sombre Formation. The Sombre Formation of the Root Basin consists almost entirely of dolomite, minor limestone. It is over 1000 m thick in the south, thinning to zero in the north; this thinning was provisionally attributed to sub-Arnica erosion. A section said to be typical consists of light brownish grey, fine grained, in part silty, laminated, thin bedded dolomite and medium grey, fine grained, granular, thin to medium bedded dolomite; these weather to give a light and medium or dark grey banded appearance (Douglas and Norris, 1961, p. 14). In more northern exposure (Douglas and Norris, 1963, p. 14) some beds are finely brecciated and, locally, the basal beds are sandy and interbedded with thin calcareous sandstones.

In the western part of the basin, and over the Redstone Arch the dolomite is similar but apparently contains more dark grey dolomite in the lower part. The upper part produces a "characteristic silver grey weathering talus". Where thin, in the northwestern part of the basin and over the Redstone Arch, the Arnica and Sombre dolomites usually connot be differentiated (Gabrielse et al., 1973, p. 76).

Arnica Formation. In central Root Basin the Arnica is " . . .dark grey to black dolomite – cryptograined to fine grained, granular to finely porous and vuggy, variably fetid . . .The rocks are massive, but medium and dark grey colour-alternations impart a distinctive bedded and banded appearance" (Douglas and Norris, 1963, p. 16). The weathering characteristics seem to be the main criterion for distinguishing the Arnica from Sombre dolomites. Concerning the area flanking the Redstone Arch Gabrielse et al. (1973, p. 77) state "In contrast to the underlying strata of the Sombre Formation the Arnica assemblage is generally thinner bedded, darker weathering, and shows a much more conspicuous striping or banding".

Manetoe Formation. In some parts of the Root Basin and surrounding areas the Arnica Formation is overlain by a thin unit of massive, coarse crystalline dolomite. Locally this unit is porous and cavernous. This unit will be discussed later.

Bear Rock Formation. In the northern part of the Root Basin the Arnica dolomite grades northward into the Bear Rock Formation. This unit is described (Douglas and Norris, 1963, p.17) as massive breccia layers between layers of unbrecciated dolomite or limestone. "The breccia consists mainly of angular fragments and lumps of fine-grained, dark grey limestone and fine- to medium grained, brownish grey dolomite in calcite or granular limestone matrix".

Funeral Formation. In the south-central part of the Root Basin strata homotaxial with the upper part of the Arnica Formation consist of argillaceous limestones and shales of the Funeral Formation. These beds (Douglas and Norris, 1961, p. 17) are

"...limestone – dark grey, fine-grained, mainly platy to thinly bedded, but also partly silty, argillaceous and finely laminated, and breaking down to a buff-weathering platy talus. Some medium-bedded, medium- to coarse-grained fossiliferous limestones occur near the top". The Funeral shaly strata were thought to grade laterally into the upper part of the Arnica, the Manetoe and to the Landry Formations.

Landry Formation. In the northern Root Basin (Douglas and Norris, 1963, p. 18). "The characteristic lithology of the Landry Formation is limestone – cryptocrystalline to finely crystalline, dark to light grey, weathering light to medium grey, and generally medium bedded. The lower contact is transitional with the Arnica Formation, the basal limestones being partly dolomitized...". Farther south where the Funeral Formation is present Landry limestones intertongue with and, in some areas, overlie the Funeral Formation (Douglas and Norris, 1961, p.18).

Headless Formation. The Headless Formation (Douglas and Norris, 1963, p. 18) "...consists of grey to dark grey argillaceous limestone – fine-grained, thinly bedded, variably biogenic and fossiliferous – interbedded with greyish brown calcareous shale..." The Headless shaly strata intertongues with the overlying Nahanni limestones. The base of the Headless was tentatively considered to be a disconformity (Douglas and Norris, 1961, p. 19). Along the western edge of the Root Basin the Headless is described as ".... buff-brown weathering, fine-grained, nodular, argillaceous limestones ....Relatively resistant units are silty and in some places lenses and pods of dark grey limestone are enclosed in silt" (Gabrielse et al., 1973, p. 86). These authors also note that "In contrast to the underlying Middle Devonian formations the Headless is of relatively uniform lithology throughout the region" (i.e., over both arch and basin).

Nahanni Formation. In the original definition (Hage, 1945) the Nahanni Formation included strata now assigned to the Headless Formation. The revised Nahanni Formation is uniform in character throughout the Root Basin. It is "... an alternation of light-grey-weathering, recessive and resistant units. The resistant units are medium to thickly bedded limestone, varying from cryptocrystalline to medium-grained, and are coralliferous and fossiliferous; thicker fossiliferous beds are more prevalent in the middle part. The recessive units are covered or consist of thinly bedded to rubbly, dark grey, cryptocrystalline to fine grained limestones, generally more argillaceous toward the base of the formation" (Douglas and Norris, 1963, p. 19).

Horn River Formation. The Horn River Formation consists of platy to fissile, dark grey to black shale and hard black, non-calcareous mudstone. Near the contact with the Nahanni Formation the shales are calcareous and contain thin limestone interbeds (Douglas and Norris, 1963, p. 20. Gabrielse et al. (1973, p. 92) noted a similar situation at the base of equivalent shales on the Redstone Arch.

Upper Devonian strata. Upper Devonian strata are thick and widespread in the eastern part of the Root Basin – that part known as the Mackenzie Plain. They consist, almost entirely of fine grained marine clastics including shale, siltstone and minor sandstone, thin coquinas occur locally. Desciptions are given in Douglas and Norris (1963, p. 21 to 23). In the western Root Basin these strata are confined to narrow patches in the cores of synclines. For descriptions, see Gabrielse et al. (1973, p. 93; also *ibid.,* part II, section 49).

Of special interest is a thin limestone that occurs in the eastern part of the basin about 750 m above the Nahanni Formation. This limestone is described as patches of limestone reef (Douglas and Norris, 1963, p. 22), "The southwesternmost reef.... consists of more than 40 feet of strongly biogenic and stromatopoidal limestone – light grey and varying to brownish grey and yellowish grey, mainly medium grained and massive-bedded. These beds are underlain by 40 feet of weathered flaggy sandstones, partly covered, and thence by 30 feet of stromatoporoidal limestone – partly biogenic, grey to pink, massive-bedded and partly porous".

Post-Devonian strata. The northern end of the Root Basin is truncated by pre- Late Cretaceous erosion, Cretaceous rocks are restricted to this northern area (Fig. 2). For a description, see Yorath and Cook (1981) or Williams (1989).

South of the South Nahanni River (the arbitrary southern limit of the Root Basin) Carboniferous, Permian, Triassic and Lower and Upper Cretaceous strata are thick and extensively exposed. Descriptions are provided by Douglas and Norris (1959, 1961), Richards (1983), Stott (1982).

DEVELOPMENTS IN CONCEPTS, CORRELATION AND NOMENCLATURE

Since the early reports on the surface geology of the Root Basin were published (mainly Douglas and Norris, 1960, 1961, 1963) there have been several developments, these will be reviewed in this chapter.

Lower and Middle Cambrian

A study of the Fort Norman area, which included the Keele Arch, led to the following hypothesis:

> Throughout early Paleozoic time a north-south system of grabens occupied the belt now known as the Mackenzie Plain and extended north-northeasterly toward the Colville Hills, this tectonic element is known as the

Mackenzie Trough. Downwarping of this trough, which included the Root Basin, continued through Cambrian into, at least, Middle Ordovician time. Through Late Silurian into Middle Devonian time a segment of this belt was uplifted to form the Keele Arch. Early and pre-Devonian erosion cut deeply into Cambrian strata. South of the Keele Arch the Root Basin continued to subside (Williams, 1989).

It can be anticipated, therefore, that at least the northern end of the Root Basin contains thick (over 1 km) Lower and Middle Cambrian sediments including a basal sandstone (Mount Clark Formation), a marine shale (Mount Cap Formation) and salt (Saline River Formation). Also there must have been some sort of barrier within or near the southern end of the Root Basin to isolate the open sea of the Selwyn Basin from the inland saline sea, either a tectonic sill or a massive carbonate bank (Williams, 1987).

Pre-Whittaker strata, central Root Basin

Comparison of cross-section Figure 11 with Figure 7 will show several correlation and nomenclature refinments in Whittaker and pre-Whittaker strata.

Sandy dolomite at the base of the Whittaker Range section and similar rocks farther north have been identified as Broken Skull Formation (Upper Cambrian-Lower Ordovician) by Ludvigsen (1975). Fossils were not seen in the sections of Figure 11 but were found in nearby exposures (*ibid.*, p. 666).

The Sunblood Formation, as reinterpreted by Ludvigsen, is only 306 m thick at Whittaker Range. The Sunblood is a shallow water shelf carbonate (Morrow and Cook, 1987).

Revised Whittaker Formation

At the type section, (Whittaker Range, Fig. 11), the top of the Whittaker Formation has been revised downward to the top of the former middle member. The shaly strata of the former upper Whittaker have been assigned to a tongue of the Road River Formation (Morrow and Cook, 1987; Ludvigsen, 1975). This revision reflects the fact that the shale-out of the Whittaker shelf carbonates is a gradual, dischronous phemonenon, and that the carbonate/'shale' contact shifts down-section from northeast to southwest (see Figure 2 of Ludvigsen, 1978). According to Ludvigsen (1975) the carbonates of the revised Whittaker were deposited in water of shallow to intermediate depths.

Mitchell and Sweet (1989) have demonstrated that the base of the Whittaker is also diachronous, becoming much younger on the flanks of the Redstone Arch (*ibid.*, Fig. 5). The same situation probably exists to the east, however control is not as precise.

Deep water strata, central Root Basin

The Road River tongue, Figure 11, includes shaly strata formerly included in the uppermost Whittaker and lowermost Delorme Formation. There are examples of graded beds and the unit is possibly a turbidite deposit (Morrow and Cook, 1987, p. 189).

The remainder of the original Delorme Formation of Whittaker Range has been renamed the Cadillac and Vera formations by Morrow and Cook (1987). The Cadillac formation is described as silty dolomite and argillaceous limestone with several resistant ribs of breccia or skeletal wackestone; these ribs are subaqueous mass flow deposits (*ibid.*, p. 39). The Vera Formation (*ibid.*, p. 188) is recessive, thin bedded, argillaceous limestone and silty dolomite with layers of bioclastic debris.

The Vera strata were probably deposited in "an upper slope position below wave base but in the phoitic zone" (*ibid.*, p. 44).

In summary there is, within the central or deepest part of the Root Basin, a tongue of deep water clastic-rich carbonates and shale with affinities with the Road River Formation (or Group) of the Selwyn Basin. The Cadillac Formation differs from typical Road River strata in being more silty. The Vera Formation represents a shallowing-upward phase of Road River sedimentation and grades into the overlying evaporitic Camsell Formation. The northward extent of this deep water tongue can not yet be established; available descriptions do not permit an appraisal of the depositional environment. The age of this deep water tongue ranges from Early Silurian (Road River Formation, Fig. 11) to earliest Devonian (Vera Formation, Figs. 4, 5).

Root River Formation

The middle part of the former Delorme Formation at its type section on Pastel Creek (Fig. 7) has been renamed the Root River Formation by Morrow and Cook (1987); the type section of this new formation is also at Pastel Creek (Fig. 11). It is described (*ibid.*, p. 189) as resistant, light grey to cream coloured, thick bedded dolomite, in part biostromal and sucrosic. Crinoids, silicified corals and large timerellid-type brachiopods are abundant. The age is, tentatively, Silurian, (possibly Wenlock-Ludlow) (*ibid.*, p.31). This unit is also found at two isolated occurrences southeast of the type section and at one occurrence to the west (*ibid.*, p.34). Morrow and Cook postulate that a Root River carbonate bank may have existed as a belt fringing the deep water tongue in the central Root Basin, prograding over shaly strata toward the basin's centre in certain areas (*ibid.*, p. 32). For the most part, however, the deeper water Cadillac sediments that are homotaxial with the Root River carbonate are believed to postdate the bank (*ibid.*, p. 34). The above postulate is similar to the observed lenses of reefoid dolomite in the upper Whittaker near the Whittaker/Road River facies boundary on the flank of the Selwyn Basin (Gabrielse et al., 1973, p. 59); available paleontological control permits the concept that the two phenomena could be related.

Prairie Creek Embayment

This feature was named by Morrow (1978) and described in detail by Morrow and Cook (1987). The name applies to a northward jutting reentrant about 30 km in length in the facies front between Lower Devonian shelf sediments on the north and east and the Road River or basinal facies on the south and west (Fig. 6). This is the most intensively studied area of the Root Basin, with over 30 measured sections within an area 60 x 60 km. This study demonstrates how dramatic facies and thickness changes may be over short distances.

Shelf sediments rimming the embayment

All of the map units of the Root Basin above the Delorme Formation (in its original sense, or above the Vera Formation in the revised nomenclature) are present up to the rim of the embayment and exhibit the same or similar gross lithologies or weathering characteristics. The greatest change is in the Camsell Formation which, as noted by Douglas and Norris (1961, p. 11) changes facies southward to mostly non-brecciated carbonates. Morrow and Cook (1987) named this facies the Corridor Member of the Camsell Formation (this so-called member equates with the entire Camsell brecciated unit, and should be of formational rank). The Corridor overlies the Vera Formation (upper member of the original Delorme) and is overlain by the Sombre and Arnica dolomites.

The report on the Prairie Creek embayment makes it obvious that the names Arnica, Sombre and Corridor (Camsell) are all parts of a single depositional unit.

They are all relatively shallow water sediments, ranging from shallow subtidal to intertidal. There are five endmember lithotopes, at least three lithotopes are present in each formation in cyclic repititions of layers from about 1 to 10 m thick:

Type A, dark subtidal dolomite – medium to dark brownish grey, weathers dark grey, often sucrosic and slightly vuggy; sparsly to abundantly fossiliferous or biostromal. These dark layers have erosional basal contacts but grade upward to dolomite type B.

Type B, bleached shoal dolomite – light grey to white, light weathering; intertidal features include fenestral fabric, pelletal or intraclastic texture, algal laminations, shrinkage cracks and mudchip breccias.

Type C, terreginous rich layers – light grey, yellowish or brownish orange, laminated, platy, silty dolomite; occasional layers of fine, rarely medium grained quartz sandstone.

Type D, penecontemporaneous dolomite breccia – chaotic, unsorted, angular clasts of dolomicrite from a few centimetres to a few metres in size, floating in a dolomicrite matrix.

Type E, probable solution breccia – fragments of dolomite incompletely cemented by white coarse crystalline dolomite, often encrusted by quartz crystals.

The corridor Member (Camsell Formation) contains all five lithofacies but is characterized by its' terrigenous rich layers (Type C). At the northern apex of the embayment the clastics are coarser and the carbonates are incompletely dolomitized.

The Sombre and Arnica formations consist mainly of alternating layers of dark subtidal (Type A) and light intertidal (Type B) dolomite. In the Arnica Formation the alternating dark and light weathering colours of these units create a distinctive banded appearance. In the Sombre Formation some of the subtidal layers appear to have been bleached, persumably by oxygenated ground waters during the succeeding shoaling, thus the banded weathering pattern is less pronounced. Layers of penecontemporaneous breccia (Type D) are common and solution breccia (Type E) are rare in the Arnica and Sombre formations. Terrigenous rich layers (Type C) occur in the basal Sombre Formation.

The Arnica and Sombre formations are largely coeval (Morrow and Cook, p. 55 and Figs. 9, 11, 58). The shallow shoal facies (Sombre) predominates near the embayment, the subtidal (Arnica) facies distant from the embayment (This seems to be the reverse of what would be expected, could the embayment be a submarine canyon cut by post-Arnica/Sombre erosion?). The subtidal facies is more abundant in the upper part of the Arnica/Sombre couplet with, in some areas, thick biostromal rocks containing corals, stromatactis, crinoids (including two-holers), amphiporids and brachiopods (*ibid.*, p. 69).

Not only are the Sombre and Arnica formations largely coeval but also the Sombre and Corridor are, at least to some extent, coeval. The Corridor to Sombre contact is gradational both vertically and laterally; "on the west side of the Prairie Creek embayment the Corridor Member passes laterally westward into the Sombre Formation" (*ibid.*, p. 50).

Basinal sediments of the embayment

North of the 60th parallel there extends, for more than 1000 km, a relatively narrow shelf-to-basin transition belt flanking the east sides of the Selwyn Basin and Richardson Trough. Complexity of the mountain structures combined with the recessive nature of the basinal strata conspire to keep the nature of the transition relatively obscure. The Prairie Creek Embayment is a notable exception. Although exposures are far from satisfactory Morrow and Cook (1987) have elucidated the nature of the transition in considerable detail.

In the Richardson Trough and Selwyn Basin Upper Cambrian to Middle Devonian argillaceous limestone, shales, and debris flows are generally undivided and mapped as the Road River Formation (or Group). In the Prairie Creek area basinal strata (which in this area range from Lower Silurian to Middle Devonian) are now subdivided, from base to top into: the Road River Formation or tongue (argillaceous limestone and shale), the Cadillac Formation (mainly shaly siltstone with many turbiditic layers), the basinal Arnica Formation (carbonate debris flows in a shaly matrix), and the Funeral Formation (argillaceous limestone and shale) (Fig. 4). Of the above units only the Basinal Arnica and the upper part of the Cadillac Formation are confined to the narrow indentation in the Corridor/Sombre/Arnica bank called the Prairie Creek Embayment. The others – the Root River tongue, the lower part of the Corridor Formation, the Vera and the Funeral formations all have a wider distribution within the southern part of the Root Basin (Figs. 4, 6).

Flanking the narrow Prairie Creek Embayment are fan-like lobes of resedimentated carbonates derived from the carbonate bank. On the west flank these are fine grained and are mapped and the Detrital Member of the Sombre Formation. On the east flank are thick layers of carbonate breccia which are mapped as the Megabreccia Member of the Cadillac Formation.

Funeral Shale Embayment

The Arnica, Landry and Headless (basal Hume) formations are very widespread, covering not only the Root Basin but the flanking arches and beyond. Within the south-central part of the Root Basin the interval between the Headless and Arnica formations, normally occupied by a thin shallow water Landry limestone, 'opens up' and is occupied by a much thicker interval of fairly deep water deposits known as the Funeral Formation.

The shape of the Funeral Shale embayment shown on Figure 6 is derived from maps of Douglas and Norris (1973a, b; 1974a, b) modified by data from Brady and Wissner (1961), and Gorveatt (1972). The latter (unpublished) report contains the most detailed stratigraphic analysis that is currently available. The eastern and northern limits of the embayment are reasonably well constrained; the western limit is poorly constrained because much of the post-Arnica section has been eroded from this mountainous area. The 'island' in the west-central part of the embayment corresponds with a part of the Manetoe Range (see Fig. 81, Morrow and Cook, 1987).

The Funeral Formation is nearly 700 m thick in the centre of the embayment. Where thick it consists of dark pyritic shale, silty shale, and silty and shaly limestone. The strata are fissile and platy. The carbonate to shale or silt ratio varies rapidly, both vertically and laterally. In general the carbonate percentage increases upwards and laterally toward the embayment edges. Several mass flow or turbidite deposits were noted by Morrow and Cook (1987, p. 74). The sparse macrofauna of inarticulate brachiopods, gastropods (Gorveatt, 1972, p. 19), tentaculitids and dwarfed ostracodes (Braun, 1978, p. 269) suggest an environment hostile to benthic fauna, probably deep and oxygen poor. In the two wells that drilled through the Funeral section (Ram Plateau N-44 and N. Nahanni N-42) there is a basal zone, several tens of metres thick, that in lithology and gamma log response resembles the Horn River or Canol Formations (i.e., known petroleum source rocks).

Relationship of Funeral Formation to contiguous strata

Floor of the embayment

The floor of the emabyment consists of typical Arnica dolomite, i.e. relatively shallow water deposits, and the contact is described as abrupt but conformable. In some areas the uppermost Arnica beds consist of dolomite breccia in a dark argillaceous matrix (e.g., Section 35, Morrow and Cook, 1987, p. 175; or the cores of Ram Plateau N-44 and N. Nahanni N-42), or what seems to be a mass flow deposit (Section WR-20 of Gorveatt, 1972). In other words, the Arnica/Funeral transition appears to represent a rapid drowning event, the initial deep water deposits consist of transported debris from the undrowned Arnica banks surrounding the embayment – a deposit similar too, perhaps in part contemporaneous with, the basinal Arnica Formation of Morrow and Cook (1987). The radioactive Canol-type shales referred to above possibly represent a long period of nearly sediment-starved conditions before the main influx of basin fill which constitutes the bulk of the Funeral Formation.

Edges of the embayment

The relationship of the Funeral Formation to homotaxial strata around the rim of the embayment shows considerable variation and is still somewhat controversial. Of central importance here is the meaning of the term 'Manetoe'.

Manetoe dolomite. Figure 12 displays the evolution in thinking concerning that term, and in the nature of the eastern rim of the embayment. When originally introduced by Douglas and Norris (1961) the term applied to a thin (±50 m) but widespread unit of dolomite, much of it coarse crystalline, that was conceived to be time-significant unit equivalent to the Landry limestone as well as part of the Funeral shale. In places along the eastern rim of the embayment the Manetoe facies is unusually thick (about 150 m) and, in certain exposures, the interface between coarse crystalline Manetoe dolomite and Funeral argillaceous limestone is abrupt and nearly vertical. Brady and Wissner (1961) interpretated this relationship as being a recrystallized reef front, the Landry limestone represented the back-reef facies. The interpretation of Noble and Ferguson (1971) was similar; many geologists consider the Landry limestones east of the embayment to be nothing more than the final, semi-restricted phase of the Arnica carbonate bank, which in many areas happens to be undolomitized.

The idea that the coarse crystalline dolomite (in which none of the original sedimentary texture remains) was originally a reef was undoubtedly influenced by the then-prevailing views on the geology of the Pine Point mining area. There, a coarse dolomite (Presqu'ile Formation) was believed to be the reef core and homotaxial limestone (Sulphur Point Formation) a back-reef facies (Norris, 1965). It is now known that the coarse crystalline dolomite in the Pine Point area is a late diagenetic facies with no direct relationship to any particular sedimentary facies or time-rock unit (Skall, 1975). The Manetoe dolomite appears to be a similar phenomenon (Morrow and Cook, 1987). This white, secondary dolomite may be found in the upper part of the Arnica, in the Landry, Headless and Nahanni Formations. It is most common in the Landry Formation and its' thickest development occurs in discontinuous strips around the edge of the Funeral shale embayment. A thin Manetoe-like layer also occurs at the Arnica/Funeral contact along the eatern margin of the Selwyn Basin where it has been mapped as the Grizzley Bear Formation (Gabrielse et al., 1973; Douglas and Norris, 1974d). The much-photographed so-called Ram River Reef, with it's near vertical but jagged interface with the Funeral Formation (Brady and Wissner, 1961, Figs. 34, 35; Noble and Ferguson, 1971, Fig. 9) is probably a metasomatic front.

Eastern rim. Along the eastern rim of the embayment the upper Arnica beds (homotaxial with the Funeral strata, are dolomitized crinoid banks (Gorveatt, 1972; Morrow and Cook (1987), in part these banks have been 'Manetoeized'. The steepness of this bank edge is uncertain. As previously mentioned the Manetoe/Funeral contact, variously estimated at between 30° and vertical, is probably a metasomatic front. Nevertheless several closely spaced sections indicate a slope of the crinoid bank/Funeral shale interface in the order of 5° to 10° (e.g., see Figure 70, Morrow and Cook, 1987).

Douglas and Norris (1961) thought that the Funeral shales were equivalent in age, and interbedded with, the upper part of the Arnica as well as the Manetoe Formations. Morrow and Cook (1987) contend that the Funeral strata are entirely younger than homotaxial Arnica strata, and are time-equivalents of the Landry Formation. Note that if the Landry limestones east of the embayment are nothing more than undolomized patches of uppermost Arnica (an interpretation I favor) both interpretations are true.

Northern limit. Sections studied by Gorveatt (1972) suggest that the northern segment of the rim is essentially the same as the eastern rim, with several occurrences of massive crinoidal dolomite in the upper Arnica. These are homotaxial with Funeral shale and overlain by Landry limestones which are more shaly than strata mapped as the Landry Formation farther east.

North of the limit of the embayment as drawn on Figure 6, Douglas and Norris (1973b) mapped the Funeral Formation to nearly 64° N. According to Gorveatt (1972, p. 22) this unit consists of shaly pelletal limestone, a lithology transitional between typical Funeral and typical Landry formations (see Meijer Drees, 1980, p. 16 for a core description of these so-called Funeral beds).

Western rim. Most of the western rim of the embayment has been destroyed by erosion. The few exposures that remain suggest that the pre-Headless beds, prior to dolomitization, consisted of interbedded fossiliferous limestone and dark grey shale. Where dolomitized these beds have been mapped as the Arnica Formation or, if altered to medium to coarse crystalline dolomite, the Manetoe Formation

(Glacier Lake map of Gabrielse et al., 1973, or Root River map of Douglas and Norris, 1974b). Where not dolomitized they have been mapped as the Landry Formation. However these are not the typical pelletal, sparsly fossiliferous Landry limestones but contain abundant bioclastic debris: corals, bryozoa, brachiopods and crinoids, including two-holers (see section 40 of Gabrielse, 1967, Part II, p. 219; note that on the Glacier Lake map, this interval is mapped as the Arnica Formation). Shaly intervals apparently occur at several horizons and may be up to 100 m thick; Gorveatt (1972) likened these intervals to the Prongs Creek Formation of Norris (1967), see Gorveatt's section FF'.

Southwestern opening. To the south and southwest there is no carbonate rim and the Funeral Formation merges with the shaly Road River strata of the Selwyn Basin. The carbonate 'island' shown on Figure 6 (~125°W, 61°45'N) is based on sections in Gorveatt (1972) and Brady and Wissner (1961). These authors also show a narrow carbonate peninsula extending northwest from this 'island'; their interpretation is probably based on the presence of Manetoe-type dolomite at the top of the Arnica Formation. However, the Funeral Formation is thick in this area, and the Manetoe-type dolomite belongs to the pre-Funeral Grizzley Bear Formation (see map 1376A, Virginia Falls area, (Douglas and Norris, 1974d). Southeast from the Manetoe 'island' the entrance to the Funeral shale embayment appears to have been partially silled (see Figure 23, p. 38 of Morrow and Cook, 1987 but note that the caption that belongs with the figure appears on p. 71). As will be discussed later, this sill appears right to have been a tectonic phenomenon.

The Upper Contact

The Funeral Formation may be overlain by either the Landry or Headless Formations. The former contact is transitional or diachronous. The Funeral-

Headless contact is usually gradational and somewhat arbitrary (Gorveatt, 1972, p. 19), marked by a change upwards from non-fossiliferous to abundantly fossiliferous strata. In one much-photographed cliff exposure there appears to be a slight bedding discordance at the contact. This was interpreted as an erosional break by Brady and Wissner (1962, Fig. 24). According to Morrow and Cook (1987, p. 74 and Fig. 71) the change denotes upward-shallowing of the depositional slope.

Shelf to basin correlation

Basin to shelf correlation, as indicated on Figure 4, is documented by paleontological control in the cases of the Broken Skull to Franklin Mountain and Whittaker to Mound Kindle Formation (Ludvigsen, 1975) and also by mappable continuity in the case of the Nahanni/Headless to Hume Formation (Tassonyi, 1969; Meijer Drees, 1980). The brecciated dolomite mapped as the Bear Rock Formation of the northern Root Basin should, on the basis of stratigraphic position, correlate with the subsurface Bear Rock anhydrite and dolomite of the eastern plains, however this is by no means certain.

A pre-Bear Rock tongue of fossiliferous dolomite (Arnica Platform dolomite) was tentatively correlated with an intra-Bear Rock dolomite in the Great Bear Lake area which, also tentatively was correlated with the Ernestina Lake Formation of northern Alberta (Williams, 1975). This correlation was based only on an hypothesis – a presumed transgressive pulse (eustatic?) within an otherwise monotonous evaporitic succession. There is, as yet, no paleontological test of this idea. The pre- 'Ernestina Lake' anhydritic strata of the Great Bear Lake area, which are rich in terrigenous clastics, were named the Tsetso Formation by Meijer Drees (1975) and correlated with the Camsell Formation; in this case no paleontological test is possible.

The Ebbutt break, or disconformity at the top of the Lower Chinchaga anhydrite (Law, 1971) has usually been correlated with the base of the Headless Formation. This may be approximately correct although the Landry to Headless contact in the Root Basin is obviously a transgressive pulse whereas the Ebbutt break represents a regression. It is possible that the Ebbutt break represents a significant hiatus with considerable erosion (see cross-section, map 2, of Williams, 1981a); during the shelf area hiatus the Landry and Funeral Formations (a regressive suite) were being depositied in the Root Basin. Again, paleontological control for this hypothesis is lacking.

DISCUSSION OF CROSS-SECTIONS, FIGURES 8, 9, 10

Longitudinal cross-section, Figure 8

This cross-section along the eastern side of the Root Basin (Fig. 6) is based primarily on subsurface data. The northernmost well (B-30) is actually located near the crest of the Keele Arch; only 15 km northeast of this well the entire sequence of strata featured by the cross-section is missing and Upper Cretaceous beds lie directly on Middle Cambrian shale. This cross-section extends south of the Root Basin (which ends in the vicinity of Mattson Creek #1) into the Liard Basin. Both Beavercrow K-02 and E Grayling d-95-F lie on the western flank of the Liard Basin.

The length of the cross-section is over 500 km, yet the overall Nahanni to (?) Mt. Kindle thickness (~. 2.5 km) changes very little.

This apparent consistency may be deceptive. The axis of the Liard Basin lies between Mattson Creek #1 and K-02, the deepest drilling in the axial area (Pointed Mountain) penetrates only into the upper part of the section (Nahanni equivallent). There probably is a fault-repeat in the K-02 well, both lithology and gamma logs indicate such a possibility. The Dahadinni I-70 well encountered an anomalous thickness of the Arnica/Bear Rock interval (1470 m vs. 800 m in G-70) and of the

Camsell evaporites (2060$^+$m vs 1460 m in G-70). If these intervals are not overthickened by faults, as shown, this well indicates a very deep hole in the Root Basin. However, faulting probably is present, three large thrust faults are mapped at the surface along this segment of the Dahadinni structure (Map 1374A, Douglas and Norris, 1973b).

The following discussion is based on what can be learned from well samples and mechanical logs, beginning with the most correlatable units.

North from Mattson Creek #1 the Nahanni/Headless/Landry package is fairly uniform in lithology, consisting mainly of limestone and shaly limestone. Thin beds of marly limestone or limy shale occur throughout but are most abundant in the Headless Formation. Bioclastic layers are common in the Nahanni and Headless but are rare in the Landry, the latter are dominated by ostracods. Many of the shaly markers within this package can be traced over long distances on gamma-sonic logs (see Figure 4 of Meijer Drees, 1980). The contact with the Arnica Formation is placed at the highest abundance of dolomite, this is a transitional contact that does not coincide with any obvious log marker.

In the Liard Basin, in contrast, facies changes within the Nahanni/Headless package may be profound over short distances. The Landry Formation is not recognizable in Mattson Creek #1 nor in any wells farther south. There are a few thin radioactive kicks through what may be the Headless equivalent but correlation is tentative. Most, rarely all, of the Nahanni/Headless equivalent may be dolomitized, as it is in K-02. Layers of coarse crystalline dolomite (Manetoe facies) may occur at various levels. The reservoir of the Pointed Mountain gas field is an example where dolomitization extends to the top of the Nahanni Formation.

The Arnica Formation consists of alternating light coloured micro to fine crystalline dolomite and darker dolomite which may be up to medium crystalline. The only fossil material identifable in samples are crinoid stems which occur in traces in the Arnica platform dolomite and in abundance in Beavercrow K-02; the crinoid banks flanking the Funeral shale tongue are projected from outcrops in the vicinity (Gorveatt, 1972; Bradly and Wissner, 1961), such banks have not been drilled in this vicinity. The Arnica platform dolomite is only recognizable where it underlies the Bear Rock evaporites, which is limited to the northern end of the Root Basin. The Bear Rock consists of anhydrite and light coloured micro to fine crystalline dolomite. There are no well log markers within the Arnica/Bear Rock package that can be traced throughout the Root or Liard Basins.

The terms 'Sombre', 'Camsell' and Corridor' as employed on the cross-section are facies terms denoting strata that are primarily light coloured dolomite, anhydrite or anhydritic dolomite respectively. All three facies are characteristically silty and sandy to some degree, sometimes highly so with, scattered throughout, thin layers of siltstone or sandstone. The contact between this package and the overlying Arnica is only obvious on well logs or samples where the Camsell anhydrites are present. The Arnica-Sombre contact is not obvious by any criterion – it is a subtle change, downward, from predominently fine to medium crystalline dolomite with an occasional relict fossil trace to fine or microcrystalline dolomite. The presence or absence of quartz sand grains does not seem to be significant, however, sand is more common in the Sombre facies.

Within the Sombre/Camsell/Corridor package [or Delorme Group (informal)] there are several tentative well log markers. Markers a and b are at the top of a modest shift in the gamma log response, an increase downward in the abundance of thin radioactive interbeds. Marker b also corresponds with an increase downward in the amount of sand and silt. Marker c is the base of a pronounced radioactive zone about 30 m thick. This layer consists of very silty, shaly dolomite and, in Mattson Creek #1 and K-02, with the highest abundance of sand. Marker d also is the base of a radioactive zone similar to but thicker than Marker c. A core was cut from near the top of this marker d zone (Core 14, 8201′-8229′, Mattson Creek #1); it consists of dark, argillaceous, laminated, dolomitic siltstone with quartz sand grains, up to coarse, scattered or in laminae. The core shows fining-upward graded beddding, truncated at the top of the cycle, some mild soft-sediment deformation, and suggestions of trails on some bedding planes. The contrast of this marker d zone with the evaporitic dolomites above and below suggests a possibly significant drowning event.

The top of the Mt. Kindle (? or Root River Formation) is marked by an abrupt change, obvious on well logs and samples, from silty, fine to microcrystalline slightly anhydritic dolomite above to fairly dark coloured fine to medium crystalline, non-silty dolomite or siliceous dolomite with traces of chert. A core from the Mattson Creek well yielded *Cystihalysites* sp. and ?*Paleofavosites* sp. (identified by B.S. Norford, Report 53-BSN-1973). These fossils indicate a Silurian age but do not permit a positive identification as Mt. Kindle or Whittaker Formation; this unit could conceivably be the Root River Formation (age uncertain but probably Silurian).

In most company reports or well cards the interval labelled Corridor facies on Figure 8 is usually identified as the Delorme Formation. Morrow and Cook (1987, p. 182) picked the Corridor Member between 7050′ and 8370′ in Mattson Creek #1; the unit from 8370′ to 9480′ was tentatively called the Root River Formation. The description of the Corridor Member in the Prairie Creek Embayment area, and its relationship to the Sombre dolomite and the Camsell breccias (Morrow and Cook, 1987) appears to fit with the Corridor facies as shown on Figure 8. If so, what remains of the Delorme Formation (as originally defined), i.e., the pre-Corridor (Camsell) to Whittaker (Mt. Kindle) section? Perhaps the deepest wells yet drilled in the Root Basin have not reached the Mt. Kindle Formation.

Transverse cross-sections, Figures 9 and 10

These cross-sections illustrate the high degree of variability in thickness and facies and emphasize correlation and nomenclatural difficulties. Aside from the Nahanni/Headless couplet and the top of the Whittaker/Mt. Kindle formations there are no basin-wide markers. A certain degree of nomenclatural anarchy is inevitable at this time. Formation names are applied as they are in the published filed sections; correlation lines are merely suggestions, dashed where highly uncertain. Several down-to-basin faults are shown, these are conceptual, and do not necessarily exist (see drawing with no vertical exaggeration at the bottom of Fig. 10). However, as will be discussed later, there is evidence for at least one such fault at the south end of the Root Basin.

The Nahanni/Headless couplet thickens westward at rates which remain fairly constant over arches and basin alike. The post-Whittaker-pre-Headless interval, in contrast, varies from under one kilometre over the arches to over three kilometres in the basin; this was, obviously, a time of marked tectonic differentiation (see also Fig. 21).

As was noted previously, the unit identified as the Mt. Kindle Formation in the subsurface might actually be the Root River Formation; if so, the correlation of W. Wrigley G-70 is wrong on Figures 9 and 10, and the post Whittaker section in the eastern side of the Root Basin would be much greater than shown. The subsurface unit tentatively identified as the Root River Formation by Morow and Cook (1987) is between 10 075 feet and 11 068 feet in the G-70 well (Fig. 8); in comparison with the Pastel Creek section (Fig. 9) this correlation appears reasonable. However, the drowning event recorded by marker d, Figure 8, is at 10 075 feet in G-70; it is tempting to correlate this with the Root/Vera contact, which, also must record a deepening event.

There is little change in thickness between section M366-40 and the Pastel Creek section (Fig. 9); this casts doubt on the concept that an extention of the Redstone Arch passes between these sections (the Sombre Salient of Morrow and Cook, 1987).

Strata identified as the Camsell Formation by Gabrielse et al. (1973) in M366-40 (Fig. 9) are little different from the rocks above or below (*ibid.*, Part II, p. 220). *Striatopora* sp. and *Favosites* sp., collected from this interval, suggest a Silurian age; correlation with the Root River Formation is tenable.

Aside from the tops of the Hume and Mt. Kindle (Whittaker) formations there are no reliable correlation ties between the Root Basin and the eastern shelf (Blackwater E11, Fig. 9; Fish Lake G-60, Fig. 10). If the tentative tie at the level of the Arnica platform dolomite is correct (Williams, 1975), most of the tectonic differentiation that created the Root Basin occurred before Arnica time (Morrow in press).

THE CASE FOR SYNDEPOSITIONAL FAULTING, SOUTHERN ROOT BASIN

The cartoon cross-sections Figures 13 to 16, were drawn to test the concept that block faulting occurred in the area of the Prairie Creek Embayment. Pre-Headless strata are lumped into three broad categories: 1) shallow water – Corridor (Camsell), Root River, Sombre, Arnica and 'Landry' formations; 2) deep water – Road River, Cadillac, Sombre Detrital and basinal Arnica formations and 3) transitional – Vera Formation. Thicknesses are from measured sections of Morrow and Cook (1987).

For Figures 13 to 15 datum is the base of the Headless Formation. The change from Funeral to Headless deposition, as previously discussed, marks a shallowing-upward phenomenon; where the Headless overlies the carbonate bank the contact marks a deepening-upward phenomenon. This contradiction makes it doubtful that the base of the Headless Formation represents a level datum, however, it is the only available marker that is reasonably well constrained in time. It has therefore been assumed that the base of the Headless probably corresponds within ± 100 m to sea level at that time, which is early Middle Devonian (Early Eifelian).

Manetoe Range, Arnica Range and Tundra Ridge cross-sections (Figs. 13, 14) are north-south slices, each confined to a single Laramide thrust sheet; only data from above the thrust faults are plotted. The north to south facies change evident in the Manetoe and Arnica Range slices is part of the main facies front that bounds the Selwyn Basin, i.e., this change is not confined to the Prairie Creek Embayment. The Prairie Creek Embayment cross-section Fig. 14, also trends north-south, and is situated between the Manetoe Range and Tundra Ridge thrust slices (Fig. 6).

The transverse cross-section (Fig. 15) provides the strongest evidence for syndepositional faulting. Assuming that the datum does approximate sea level in early Headless time the cross-section represents the geometry at that time. As was first observed by Morrow (1978, p. 361) the deep water strata are "markedly thinner than the surrounding contemporaneous shallow water shelf carbonates". During deposition of the basinal strata (Late Silurian-Early Devonian) there must have been considerable bathymetric relief at the sediment/water interface, possibly several hundred metres, between shelf and basin. By Headless time this relief no longer existed.

Post-Headless compaction of the basinal strata to about half their original thickness would produce the observed geometry. Although the basinal strata are shaly, the predominent constituents are quartz silt, carbonate debris and carbonate mud (see descriptions of the Cadillac Formation, Morow and Cook, 1987). Time represented by the basinal deposits spans Late Silurian and most of Early Devonian. Surely most of these rocks would have undergone most of their compaction long before Headless time. Differential compaction seems inadequate to explain tbe geometry, differential subsidence must have been involved. The block underlying the Prairie Creek Embayment, by Headless time, had been uplifted relative to the adjacent blocks by about a kilometre.

Pre-Laramide faults have been mapped in this area, one example is the Gate Fault (Map 1378A), Douglas and Norris, 1974d). This fault was discussed by Cook (1977). It can be mapped for over 50 km along a north-northeast trend. It can be interpreted as a post-Devonian-pre-Laramide right lateral wrench fault on which west-side-up reverse movement has been superimposed by Laramide compression. Its' surface manifestations terminate abruptly against the north-northwest trending Tundra fault, an east dipping Laramide thrust (Fig. 81 of Morrow and Cook, 1987). The trace of the Gate Fault lies between sections 15 and 22 (Fig. 15). The fact that the main development of the spectacular Cadillac megabreccias occurs in this area suggests faulting in Late Silurian-Early Devonian time (see Morow and Cook, 1987, p. 51, "seismic disturbances"). Other faults shown on Figures 13, 15 are merely conceptual, there are no obvious surface manifestations. There are, however, other north-northeast lineaments farther north in the Root Basin, some of which are plotted on Fig. 1; one of the best documented is the Spirit Fault (Map 1374A, and Map 1376A, Douglas and Norris, 1973b, 1974b).

Figure 16 is a hypothetical history of movement of the Prairie Creek fault block. In Early Silurian time deep water conditions were widespread. A tongue of Road River shaly strata extended into the southern part of the Root Basin (Fig. 6) well beyond the extent of the cross-section. The Vera Formation was also deposited over a wide area in fairly deep water; the Vera records a shallowing-upward process that led to the establishment of the succeeding carbonate bank. The Vera is not recognizable within the Prairie Creek Embayment, nor are there any other indicators there of a shallowing event. It is probable, therefore, that the basement block underlying the Prairie Creek Embayment was differentially negative in Vera time (Lochkovian) and earlier time.

Intuitively one would expect that the embayment remained negative relative to adjacent blocks during Cadillac and basinal Arnica deposition, perhaps it did, but not necessarily. There must have been a reversal, a transformation from graben to horst at some time between Vera and Headless time (Lochkovian to Eifelian, 5 to 10 m.y.). The transformation could have occurred at any time during that interval and the embayment, although subsiding at a slower rate than the adjacent blocks, remained a bathymetric deep. Such conditions seem to have prevailed at times in parts of the Richardson Trough (Williams, 1988, Fig. 17, p. 7)

In summary, the case for Late Silurian – Early Devonian movement across the Gate Fault is persuavie: a mappable surface trace, the Cadillac megabreccia, and a pronounced change of thickness and facies of contemporaneous rocks. No convincing case for other ancient faults in the area can be made, however it seems reasonable that some did exist.

RELATIONSHIP OF LIARD AND ROOT BASINS

The Liard Basin was named by Gabrielse (1967). As the term was used by Torrie (1973) it denotes an area of maximum preserved basin fill, the centre of which lies just south of the 60th parallel. Unlike the Root Basin, where the youngest preserved strata are Upper Devonian, the Liard Basin contains Carboniferous, Permian, Triassic, Lower and Upper Cretaceous strata. A convenient but arbitrary boundary between the Root and Liard Basins is the northern limit of these post-Devonian sediments (Fig. 2).

The eastern limits of the Liard and Root Basins is a hinge line (a marked increase in the rate of east to west thickening) that follows a northerly trend. This hinge, active throughout most, if not all, of Paleozoic time, coincides with the western flanks of the Tathlina, Liard and McConnell Arches (Fig. 1 and Fig. 21). Laramide structures that coincide with the hinge line include the Bovie Fault and the Nahanni, Camsell and McConnell Ranges (Fig. 2). The continuity, in space and time, of this hinge belt is the main indication that the Liard and Root Basins are genetically related.

The distribution of Permo-Carboniferous strata (Fig. 2) tends to give the impression that the Liard Basin was a late Paleozoic depocentre with a somewhat elliptical outline, an entity distinct from the Root Basin. B.C. Richards (pers. comm., 1989) has the impression, but lacks sufficient control to be sure, that both the Flett and Mattson formations show signs of south to north shallowing; in other words, paleoshorelines may indeed have lain somewhere near but north of the present limit of outcrop. However, Figures 17 and 18 give a different impression.

Fig. 17 shows isopachs of late Paleozoic strata, taken from Map 5 of Williams (1981). There are hazards in assuming that these isopachs accurately reflect the subsidence pattern: the top of the package is the sub-Mesozoic erosion surface; there is at least one major unconformity within the package (Pennsylvanian hiatus); and the basal marker (Exshaw Formation) is a deep water fondoform whose recognition in the westernmost wells is difficult. However, even given these uncertainties, the isopachs suggest a linear downwarp trending north-northwesterly toward the Root Basin. The fact that the shale-out belt of the Flett limestone trends in the same direction (Williams, 1986b) adds weight to the isopach evidence.

The isopachs of Fig. 18, base of Exshaw to the top of the Middle Devonian carbonate (assumed to be the Nahanni Formation) show a similar northerly trend. As for Fig. 17, the uncertainty concerning the Exshaw pick casts doubt on the westernmost thickness values. However, the north-northwesterly trends of the shale-out lines of the Kakisa, Jean Marie and Jean Marie-like limestones support the concept of one major trough combining the Root and Liard Basins through Upper Devonian and Late Paleozoic time.

In the Liard Basin there is virtually no data on the Middle Devonian or earlier subsidence history. Wells in the central, presumably deepest, part of the basin penetrate a dolomite presumed to be the Nahanni Formation. The maximum penetration of this dolomite is 712 m, base not reached (N. Beaver River I-27). If all of this dolomite is Nahanni equivalent it would be an unusually thick section (see Figure 8). However, this dolomite probably includes equivalents of the Headless, Landry and Arnica formations.

In summary, the Root Basin was strongly negative through much of early Paleozoic time but its late Paleozoic and Mesozoic history is unknown. The Liard Basin was strongly negative through Late Devonian time to, at least, early Mesozoic time but its earlier history is unknown. The one definite comon feature that links the two basins is the hinge line that forms their eastern edges.

PETROLEUM POTENTIAL

The Root Basin lies entirely within the disturbed belt (Figs. 1, 2). The western half of the basin lies within the Mackenzie Mountains, all potential reservoir horizons are exposed in the major ranges; this mountainous belt has no petroleum potential. Along the eastern margin of the basin the Nahanni, Camsell and McConnell Ranges of the Franklin Mountains also bring the reservoir rocks to the surface. In between these mountain systems lies the Mackenzie Plain where the structural deformation is more subdued and, except for a few major folds, Upper Devonian clastics (cap rocks) form the surface (Fig. 2). At the base of this clastic sequence are the bituminous Horn River shales. The Mackenzie Plain does have potential for petroleum.

Omitting the wells north of 64°N, which can be considered as part of the Keele Arch, only 13 wells have been drilled in the prospective area north of the South Nahanni River (~20 000 km^2) Of these 13 wells (Chart 2):

- all but one penetrated at least as deep as the Arnica or Bear Rock formations;
- only one well (W. Wrigley G-70) drilled through the entire Devonian section, this well reached the (?) Mt. Kindle Formation;
- at least some porosity in Devonian carbonates was indicated by drill stem tests or lost circulation in all but one well (Dahadinni D-65);
- out of a total of seventeen drill stem tests, eleven yielded water, three water cut mud, and three only mud. The latter tests were of the Funeral or Bear Rock formations. There were no shows.
- water salinities ranged from 340 to 38 000 p.p.m., most in the low range; (?) Mt. Kindle water (from a partial misrun) was 20 000 p.p.m.;
- two wells are located on large faulted anticlines, six are on mapped anticlines. The reasons for the other locations are not apparent from the surface geology.

The above results point to two important conclusions: 1) There will be some porosity within the carbonate package virtually everywhere in the Mackenzie Plain; the highest good porosity is most likely to be within the Arnica Formation. Every closed structure is a potential trap for petroleum. 2) As would be expected, given the topographic setting, water salinities indicate a vigorous hydrodynamic regime with deep penetration by meteoric waters. Only exceptional traps will have escaped being flushed. This second point does not totally condem the area because somewhat similar conditions prevail in the gas rich Liard Basin (see Snowdon, 1977, p. 15, re. Beaver River gas field).

Source rocks. The Horn River Formation (± 100 m thick) contains several layers of bituminous shale. The Horn River contains equivalents of the Canol and Bluefish shales which, in the Norman Wells and Keele Arch areas, are good oil souce rocks (Snowdon et al., 1987; Feinstein et al., 1988a). Similar looking shales occur in the basal part of the Funeral Formation. The Road River basinal strata could also contain source rocks, neither the Road River nor Funeral strata of this area have been adequately analysed for organic carbon content.

Maturation. At the southern end of the Root Basin conodonts from the Nahanni, Headless, Funeral and Arnica formations show Colour Alteration Indices of five (D.W. Morrow, pers. comm., 1989). At the northern end of the Root Basin vitrinite reflectance values from Horn River and adjacent strata range from 1.36 to over 3% Ro, increasing from north to south (Feinstein et al., 1988b). It can be anticipated, therefore, that the entire Root Basin section below the Horn River Formation has been heated well beyond the oil window; only dry gas can be expected.

However, that generalization is not entirely safe. Over the Keele Arch, at the northern end of the Root Basin, rather large changes in maturity can occur over short distances. For example, between Tate J-65 and Stewart B-30, a distance of 10 km, the vitrinite reflectance from Horn River samples changes from 0.58 to 1.34% Ro (Feinstein et al., 1988b). The reason for this high gradient is unknown but it is surely somehow related to the tectonic history of the Keele Arch. As discussed later, other Keel Arch-like features may lie hidden below other parts of the Mackenzie Plain; there is potential for surprises.

Structure. The Mackenzie Plain is a broad synclinorium with several sinuous, en-echelon folds (Douglas and Norris, 1973a, b; 1974a, b, c, d). The east flank of the synclinorium is formed by the gentle west dips (~10°) of the ranges of the Franklin Mountains. The western flank is more variable, being either steep dip slopes (~45°E) or west dipping thrust faults at the eastern limit of the Mackenzie Mountains.

The surficial structures of the Mackenzie Plain as well as the mountains are products of Laramide (Late Cretaceous-early Tertiary) compression. Older, deeper seated structures are probably present. A set of north-northeasterly trending wrench faults (probably dextral) can be anticipated. Mappable examples of such faults are the Gates and Liard faults south of the Root Basin, and the Brackett Fault north of the basin (Fig. 1). The presence of such faults beneath the Mackenzie Plain is suggested by the sinuous, en echelon pattern of the surface folds. The Gate Fault, as has been shown, was probably active in Late Silurian-Early Devonian time. The Brackett Fault appears to have been active, intermittently, since Cambrian time (Williams, 1989). In early Paleozoic time the Keele Arch and Root Basin were consanguineous parts of a linear tectonic feature known as the Mackenzie Trough. Uplift of the arch, and consequent deep erosion were pre-Bear Rock phenomena. Although there are no known clues, there could be Keele Arch-like structures below Upper Devonian cover elsewhere beneath the Mackenzie Plain. In summary, the surface structures of the Mackenzie Plain do not necessairly accurately reflect deeper structures, especially below the Arnica Formation. Also, if there are any Keele Arch-aged uplifts, they may have been deeply eroded prior to Bear Rock or Arnica deposition.

There is a cryptic structure at the same location as the isolated post-Hume reef on Root River (62°58' 125°15'W). Brady and Wissner (1967) noted "....a brecciated unit, which includes limestone and dolomite blocks, red and green shales, gypsum and fragments of specular halmatite, appears to be the expression of an evaporite plug..." Other geologists who have seen this structure (but not published), have noted black coaly shale, brecciated shale and it's crater-like outline. Possible explanations for this feature include a steam vent, Cambrian shale or salt diaper or a Camsell salt diaper. The association of this feature with the anomalous reef, and Spirit Fault is intriguing.

Reservoir rocks. The most widespread and promising reservoir is the Arnica carbonate bank (Fig. 19), especially where it and immediately overlying strata have been partly recrystallized to the Manetoe facies (Fig. 20).

The most interesting possibility for combined stratigraphic-structural traps occurs along the eastern rim of the Funeral shale embayment (Figs. 6, 12). Shaly Funeral strata, which probably contain petroleum source rocks, are in contact with crinoidal dolomite. These dolomites are in part altered to the coarse crystalline Manetoe facies and in outcrop exhibit good reservoir character. Much of this rim carbonate is exposed at the surface; however, a segment at least 60 km long lies in the subsurface beneath at least one kilometre of Upper Devonian shale. To date there has been no test of this play although Ram Plateau N-44 and Nahanni N-42 were drilled near the bank but within the shale embayment.

There are several horizons where porosity may occur, in no case is it possible to predict the reservoir quality. These are listed from youngest to oldest:

1) Jean Marie-like limestones (one or more?) and associated sandstones within the upper part of the Imperial Formation occur in the northeastern part of the Root Basin (Fig. 18); it is unlikely that these will occur deep enough to constitute an exploration target.
2) Kee Scarp reefs of the Norman Wells area developed over the top of a thick lobe of Hare Indian shale. A similar Hare Indian shale lobe juts southward into the northern part of the Root Basin (see Figure 14, Williams, 1989). Kee Scarp reefs could be present on the top or on the flanks of this shale lobe.
3) A post-Hume reef (the Root River reef) outcrops in the Mackenzie Mountains near the centre of the Root Basin. It occurs on the southeast side of the Spirit Fault near 63°N, 125°W (Fig. 1). It is impossible to predict where others might occur (see Williams 1986a).

4) The Nahanni and Headless formations are usually not porous, and can be considered as cap rocks. However, occasionally, especially at the south end of the basin, they may be dolomitized. In such cases they will be continuous with the Arnica reservoir. In Tate J-65, near the crest of the Keele Arch, the upper part of the Hume Formation is porous dolomite; a drill stem test yielded water with a trace of oil. The significance of this nearby unique occurrence, and the possible relationship to growth faults of the area, is unresolved.
5) Manetoe 'Island', Figure 6, is shown as an isolated carbonate bank within the Funeral shale embayment. This picture is a reinterpretation of data including measured sections of Gorveatt (1972), Brady and Wissner (1961), Morrow and Cook (1987) and geological maps 1376A and 1378A (Douglas and Norris, 1974b, d). If true, and if there are otehr such islands farther east, the situation presents a favorable reservoir target. The dolomite is richly crinoidal and the upper part has been altered to the Manetoe facies. The bank is surrounded by Funeral shale and overlain (? unconformably) by the Headless Formation (cap rocks).
6) The (?) Silurian Root River Formation may provide a target similar to but deeper than the rim of the Funeral shale embayment. It has been postulated (Morrow and Cook, 1987) that this carbonate, which is in part reefal, may rim the Road River – Cadillac deep water tongue (Fig. 6). This play is entirely hypothetical, however, thick reefoid lenses are known to fringe the Selwyn Basin within the upper part of the Whittaker Formation along the eastern margin of the Selwyn Basin (Gabrielse et al., 1973). Within the limits of paleontological control these could be the same age as the Root River Formation.
7) The Whittaker – Mt. Kindle carbonate will floor the entire Root Basin; there may be local sandstones.

8) The Sunblood carbonate will be present in the southern part of the basin (Fig. 13, Williams, 1989); there may be local sandstones.
9) A Middle Cambrian carbonate barrier may have extended across the southern part of the Root Basin isolating the inland salt basin (Saline River Formation) from normal marine circulation in the Selwyn Basin (Williams, 1987, p. 29).
10) A thick (± 100 m) basal Cambrian sandstone (Mount Clark Formation) is probably present in the northern part of the Root Basin (see *ibid.*, Map 2). Its presence in the southern part of the basin is questionable.

Of the foregoing, all horizons below the Arnica Formation are high risk, high cost targets. Even if reservoir beds are found, there is a high probability that, because of fractures, there will be reservoir continuity up-section to the Arnica Formation. Of course if a Cambrian salt layer is present, as is probable in the northern part of the basin, the basal Cambrian reservoir would be isolated.

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CHART 1

List of wells plotted on Figure 3

95B, 60°N-61°N, 122°W-124°W

B-76	Arrowhead
D-29	Liard
E-54	Big Arrow
H-13	East Flett
J-72	Bovie Lake
L-20	Nahanni Butte
M-05	Arrowhead
M-78	Bovie Lake
N-02	Arrowhead
N-19	Flett
P-24	Pointed Mountain
Bovie Lake	#1

Pointed Mountain Field: A-55, F-38, G-62, K-45, L-68, O-46 and P-53

95C, 60°N-61°N, 124°W-126°W

B-16	Beavercrow
C-30	La Biche
F-08	La Biche
K-02	Beavercrow
L-60	Merril
O-67	Kotaneelee
P-50	Kotaneelee

Kotaneelee Field: E-37, I-48, H-38 and N. Beaver River I-27

Beaver River Field: G-01

95G, 61°N-62°N, 122°W-124°W

N-44	Ram Plateau

Mattson Creek#1

95J and K, 62°N-63°N, 122°W-126°W

A-50	Carlson Lake
I-60	Root River
J-66	Dahadinni
M-69	Iverson Lake
N-42	Nahanni

95N, 63°N-64°N, 124°W-126°W

A-12	Johnson
D-65	Dahadinni
G-51	Silvan Plateau
G-70	W. Wrigley
I-46	Cloverleaf
I-70	Dahadinni
M-43A	Dahadinni

96C, 64°N-65°N, 124°W-126°W

A-28	Keele South
*B-30	Stewart
I-01	Keele River
*J-65	Tate
K-29	Red Dog
*L-04	Keele River
*N-62	Keele
P-78	Redstone
Redstone	#1

*Note, these wells are located on the south end of the Keele Arch.

95O, 63°N-64°N, 122°W-126°W

E-11	Blackwater
G-60	Fish Lake
I-54	Wrigley

CHART 2

Root Basin wells

Well Name	Total Depth (m) in (formation)		D.S.T. of	Rec. (m)	p.p.m.	Surface structure	GSC Map
Carlson Lake A-50	2437	Corridor	Arnica Arnica	359 W 168 W	2310 1568	Carlson anticline	1375A
Cloverleaf I-46	3450	APD	Imperial Bear Rock	405 WCM 1070 FW	22,000	English Chief syncline	1374A
Dahadini D-65	2438	Bear Rock	Nil	-	-	Johnson syncline	1374A
Dahadinni I-70	3054	Camsell	Several LC zones Arnica & Camsell		-	Dahadinni Range	1374A
Dahadinni J-66	1850	Camsell	LC in Sombre	-	-	Iverson Range	1376A
Dahadinni M-43A	3132	APD	Imperial Bear Rock	183 M, 9W 610 M, 2037 W	340 38,000	Cloverleaf Ridge anticline	1374A
Iverson Lake M-69	1768	Arnica	Arnica	195 W	518	English Chief anticline	1376A
Johnson A-12	1227	Landry	Nahanni LC in Nahanni	440 M & W (partial misrun)	34,400	flank of Wrigley anticline	1374A
North Nahanni N-42	1343	Arnica	Funeral Arnica	47 M 995 W	- 1568	Nil	1376A
Ram Plateau N-44	776	Arnica	Nahanni Arnica	122 W 104 WCM	2246	Ram fault	1377A
Silvan Plateau G-51	2118	Bear Rock	Bear Rock 9 M LC in Bear Rock		-	anticline	1374A
West Wrigley G-70	3734	(?) Mt. Kindle	Arnica (?) Mt. Kindle	269 W & M 139 WCM (partial misrun)	7200 20,000	anticline	1374A
Wrigley I-54	1969	Camsell	Bear Rock APD	282 M 594 M, 539 F W	-	Wrigley anticline	1373A

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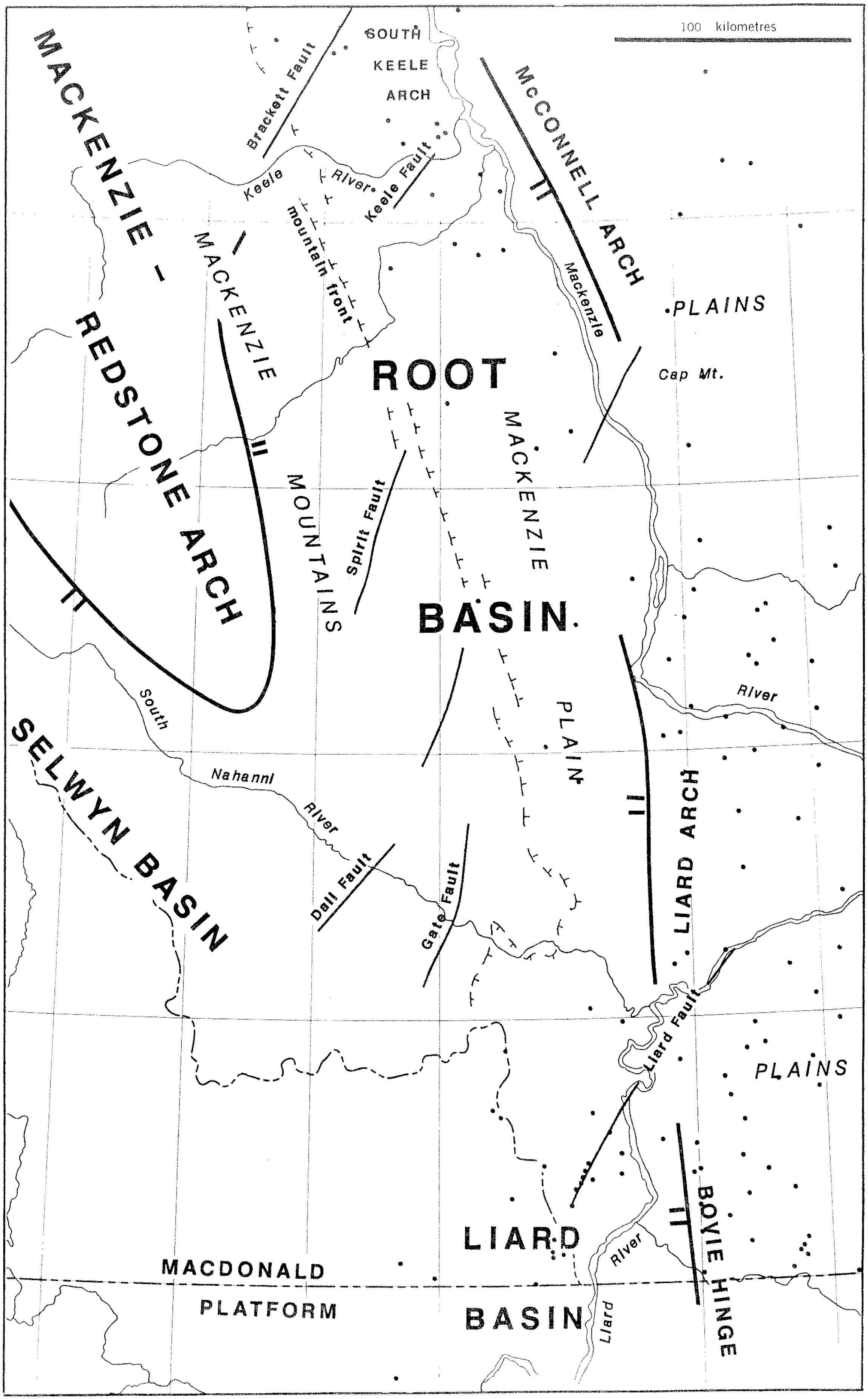
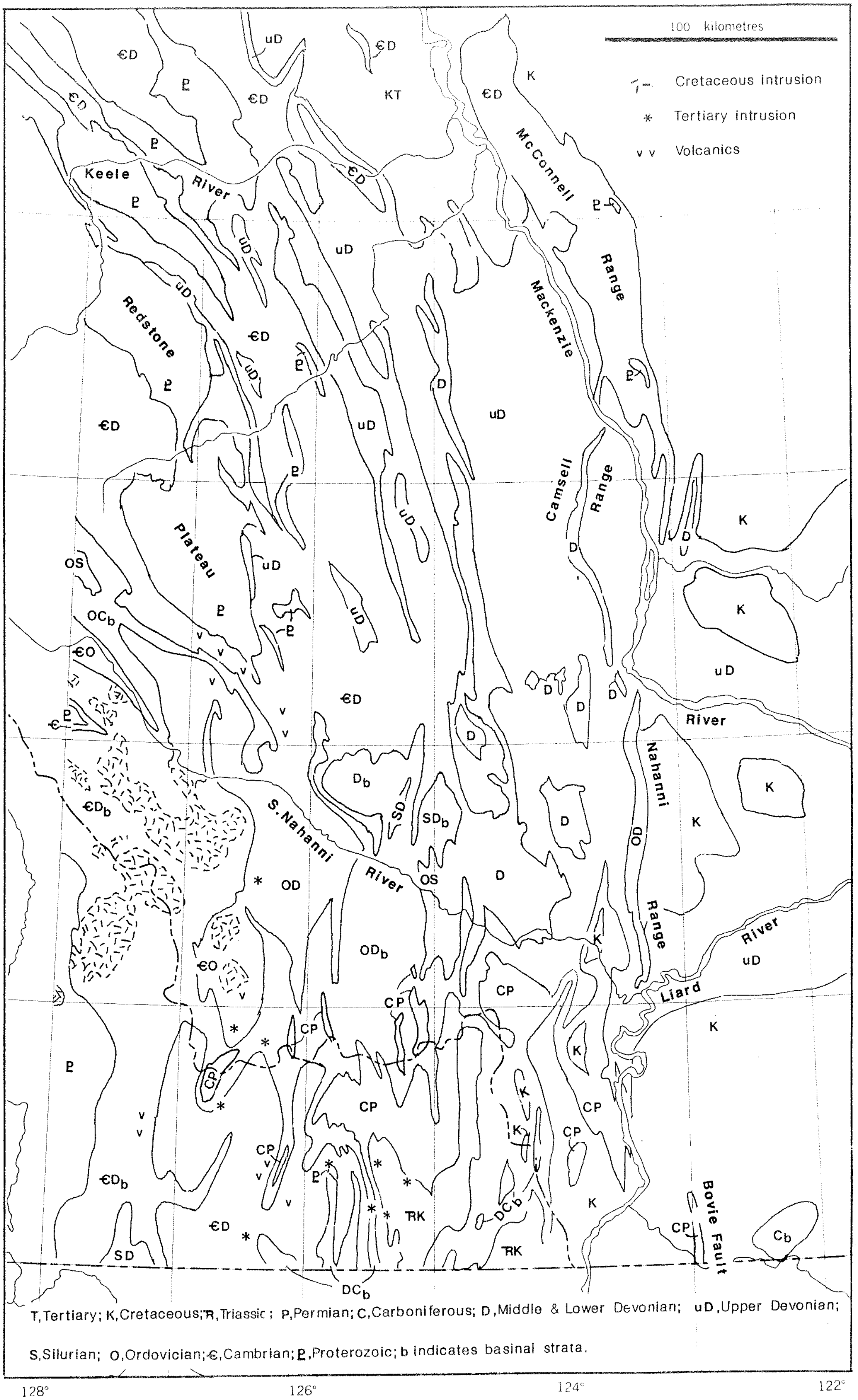
water, W; mud, M; cut, C; fresh, F; Arnica platform dolomite, APD; lost circulation, LC.

Figure 1



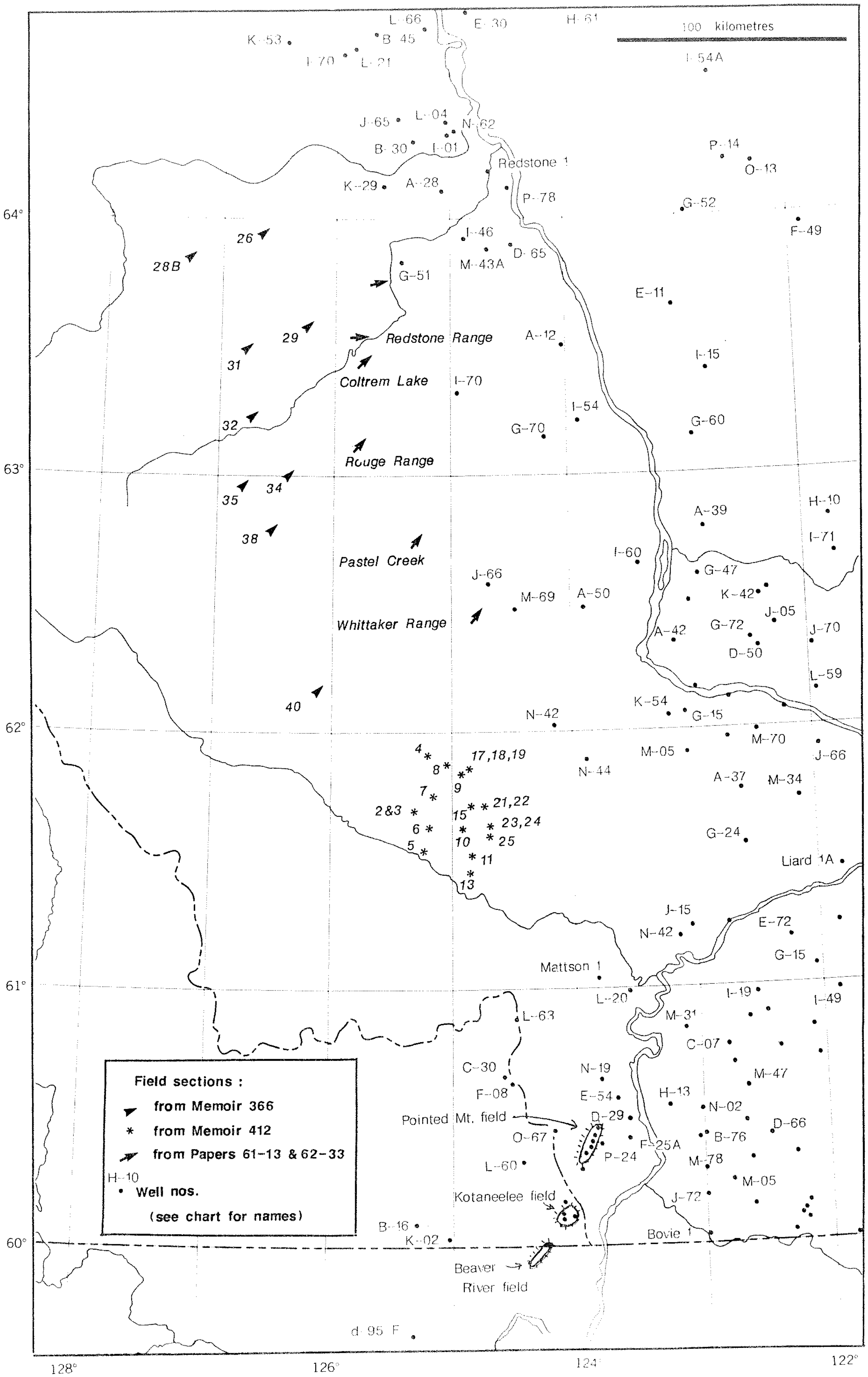
Root Basin and adjacent tectonic elements.

Figure 2



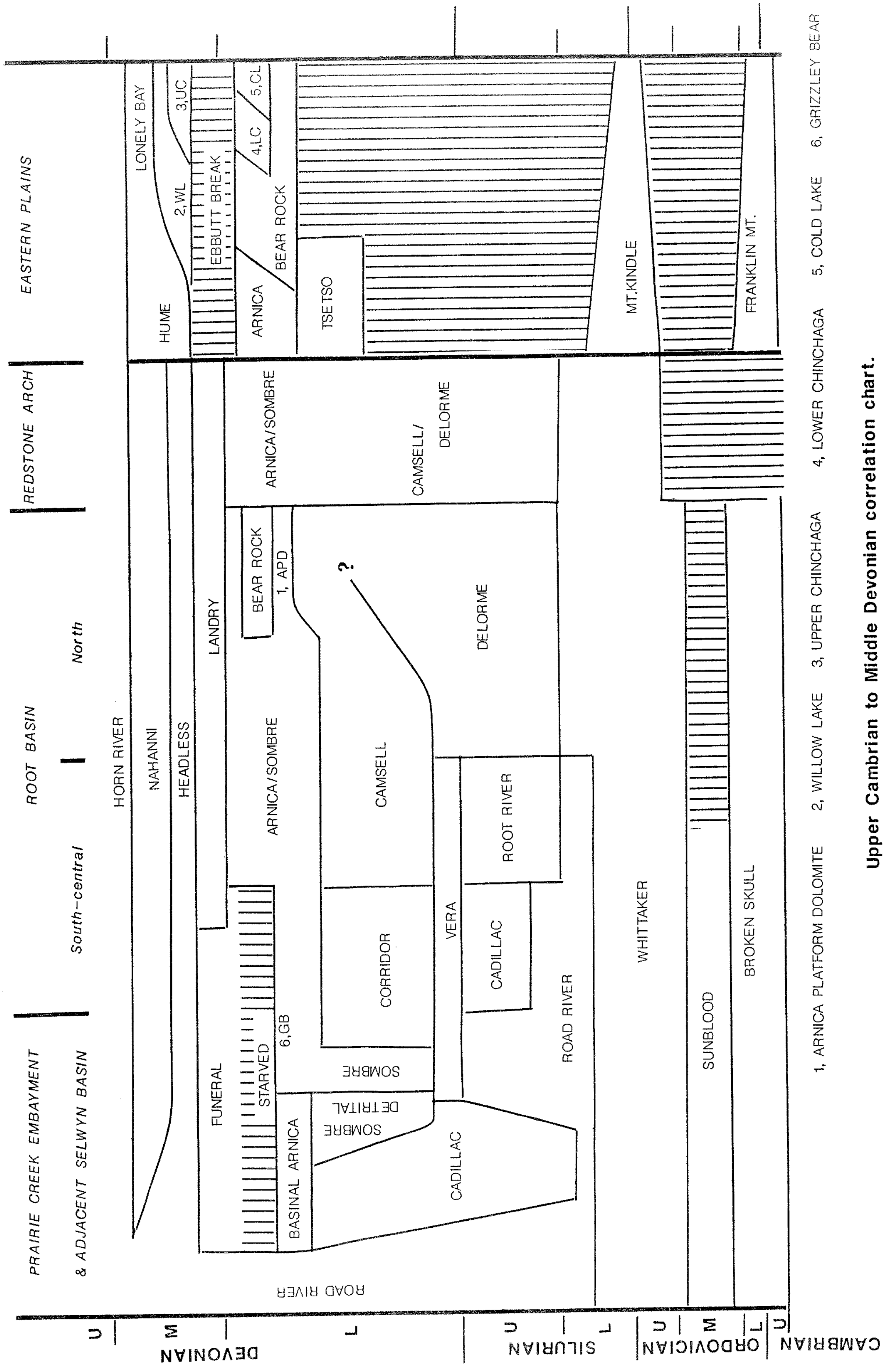
Surface geology.

Figure 3



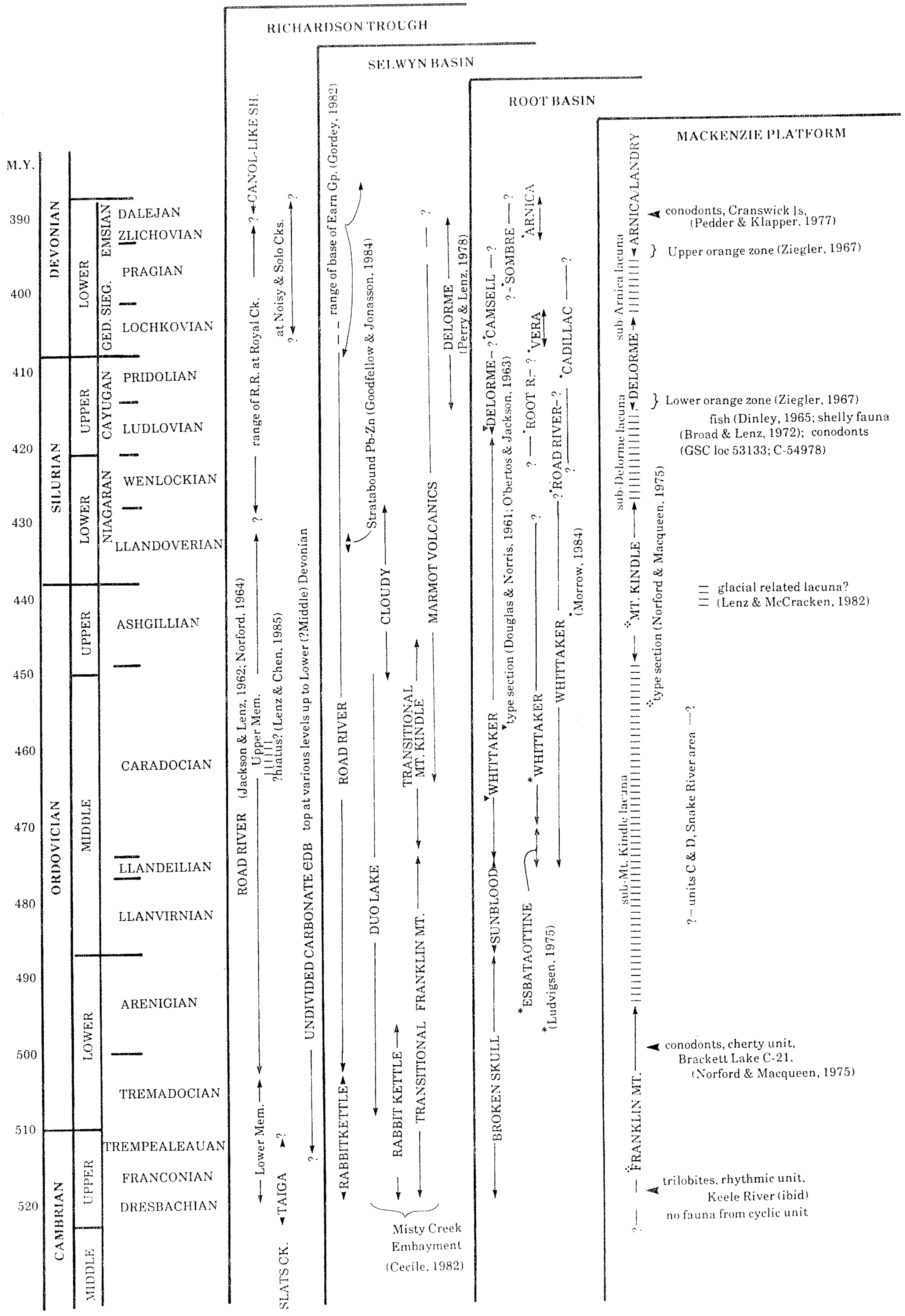
Locations, wells and field sections.

Figure 4



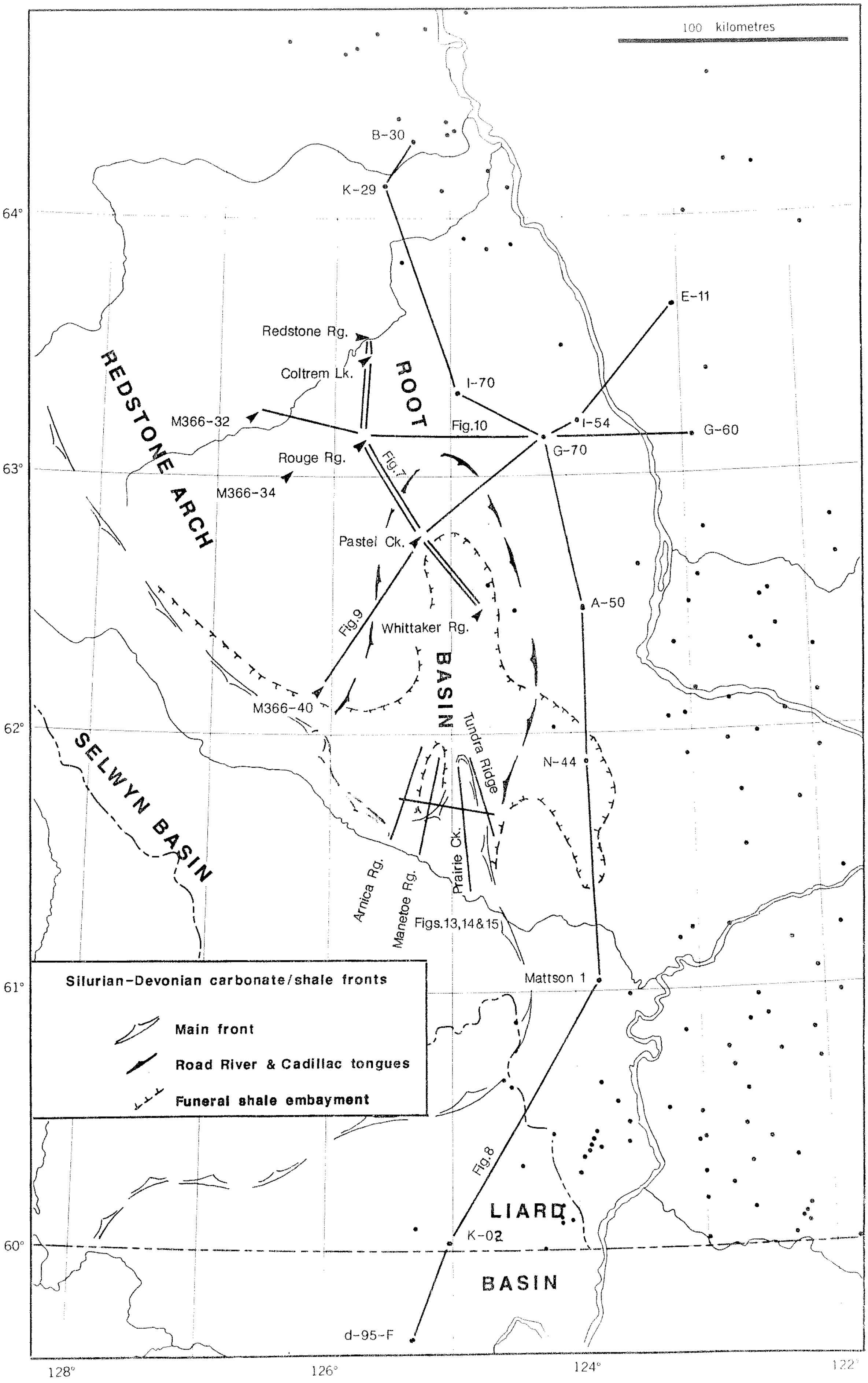
Upper Cambrian to Middle Devonian correlation chart.

Figure 5



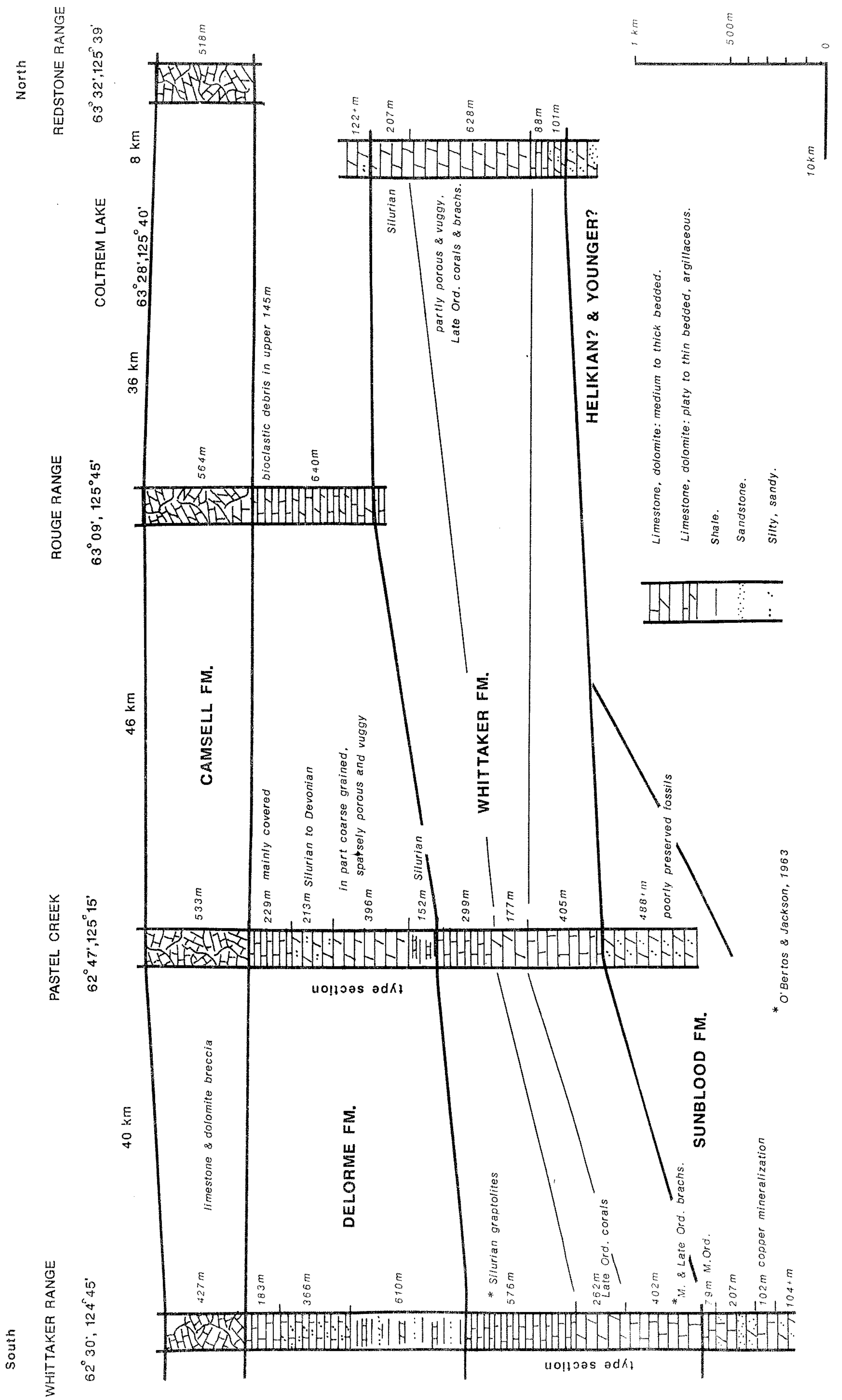
Age ranges of Upper Cambrian to Middle Devonian formations

Figure 6



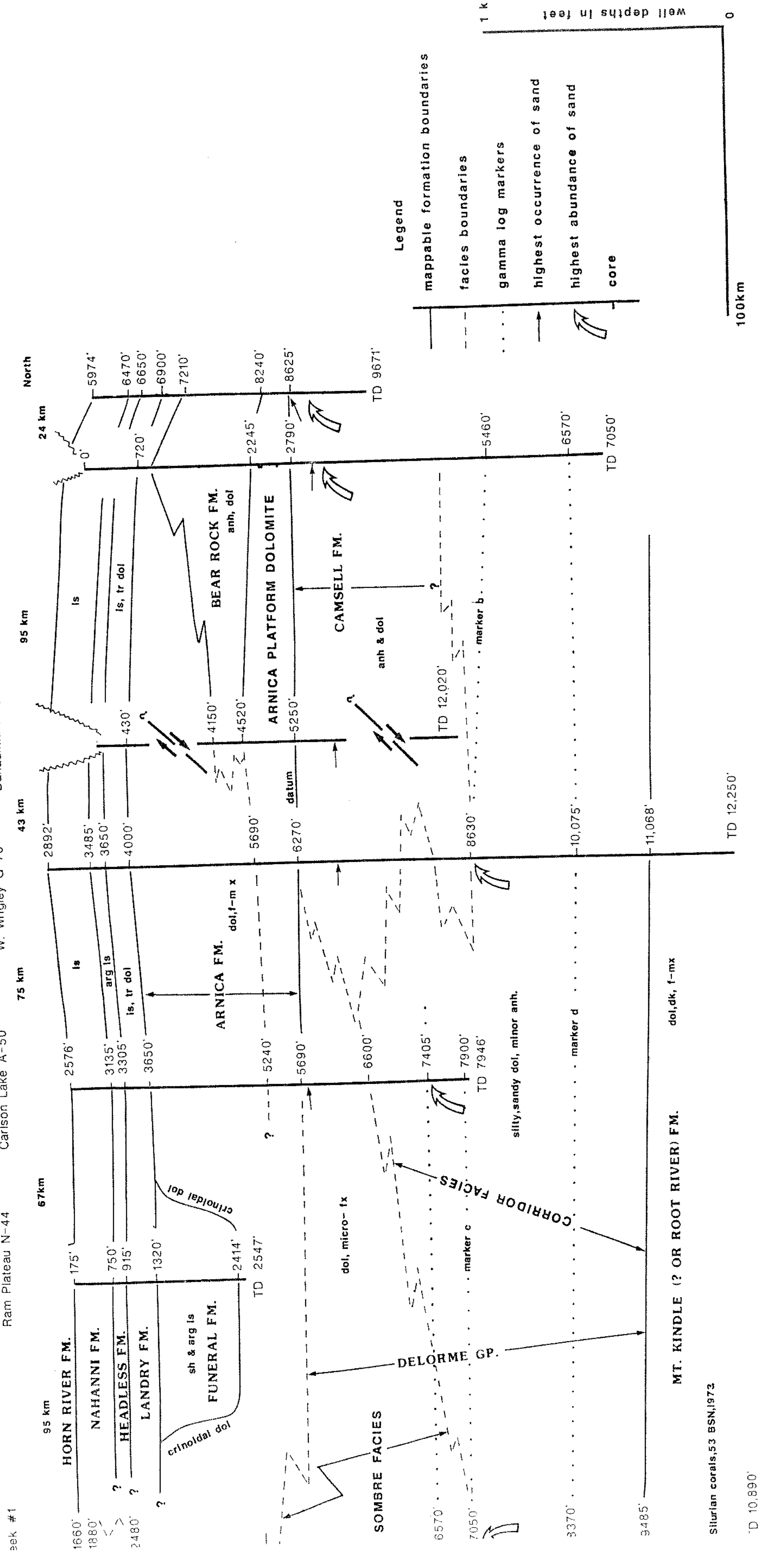
Index map for cross-sections.

Figure 7



Whittaker and Delorme Formations as defined by Douglas and Norris, 1961 & 1963.

Figure 8
(part)



Longitudinal cross-section, Keele Arch to N.E.B.C.

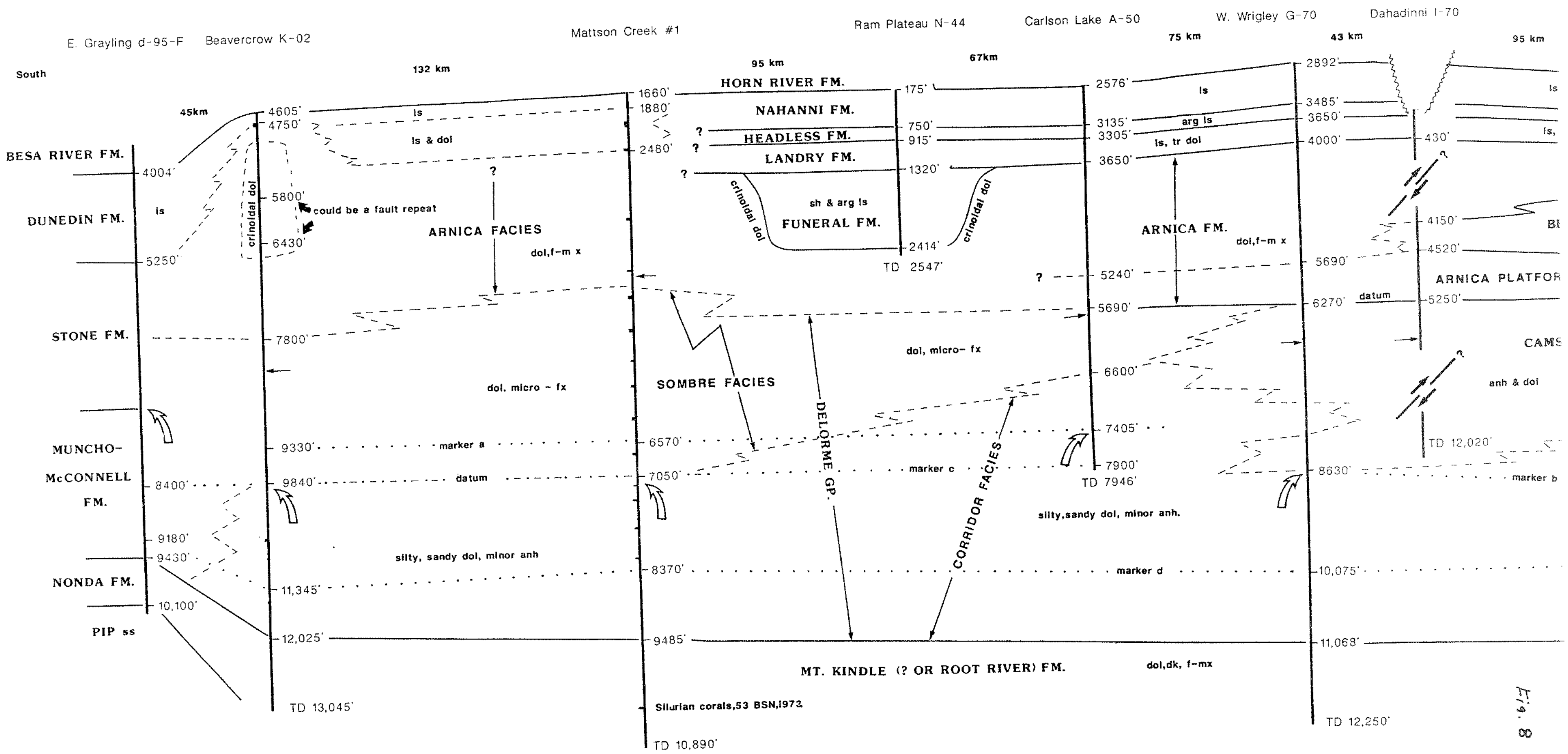
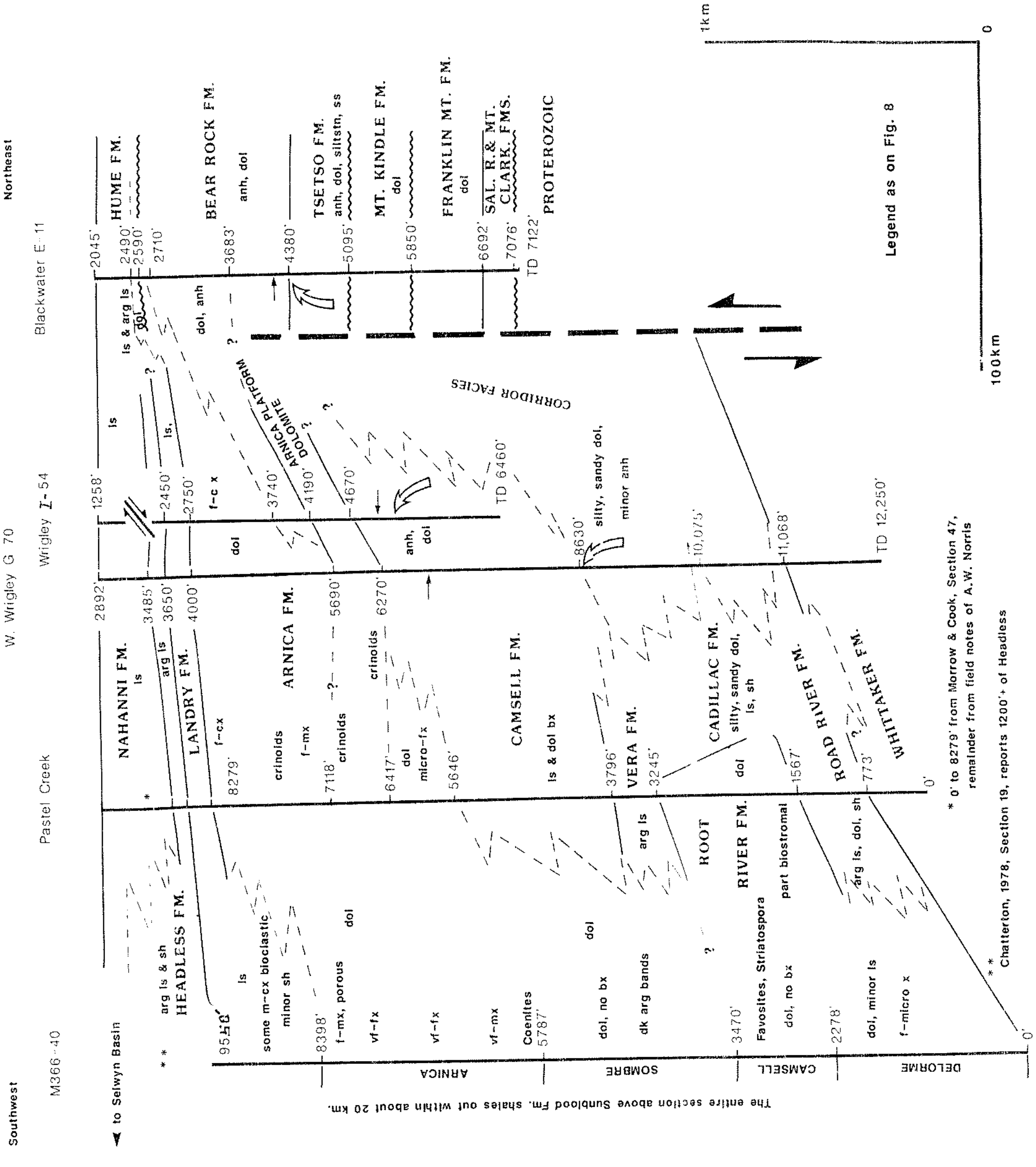

South
E. Grayling d-95-F
Beavercrow K-02
Mattson Creek #1
Ram Plateau N-44
Carlson Lake A-50
W. Wrigley G-70
Dahadinni I-70
45km
132 km
95 km
67km
75 km
43 km
95 km
BESA RIVER FM.
DUNEDIN FM.
STONE FM.
MUNCHO-McCONNELL FM.
NONDA FM.
PIP ss
4004'
ls
5250'
8400'
9180'
9430'
10,100'
4605'
4750'
crinoidal dol
5800'
could be a fault repeat
6430'
7800'
9330'
9840'
11,345'
12,025'
TD 13,045'
ls
ls & dol
?
ARNICA FACIES
dol,f-m x
dol. micro - fx
marker a
datum
silty, sandy dol, minor anh
1660'
1880'
2480'
6570'
7050'
8370'
9485'
Silurian corals,53 BSN,1972
TD 10,890'
HORN RIVER FM.
NAHANNI FM.
HEADLESS FM.
LANDRY FM.
?
?
?
crinoidal dol
sh & arg ls
FUNERAL FM.
175'
750'
915'
1320'
2414'
TD 2547'
crinoidal dol
SOMBRE FACIES
DELORME GP.
CORRIDOR FACIES
dol, micro- fx
marker c
MT. KINDLE (? OR ROOT RIVER) FM.
2576'
3135'
3305'
3650'
?
5240'
5690'
6600'
7405'
7900'
TD 7946'
ls
arg ls
ls, tr dol
ARNICA FM.
dol,f-m x
silty,sandy dol, minor anh.
marker d
dol,dk, f-mx
2892'
3485'
3650'
4000'
5690'
6270'
8630'
10,075'
11,068'
TD 12,250'
datum
430'
4150'
4520'
5250'
?
?
TD 12,020'
ARNICA PLATFOR
BE
CAMS
anh & dol
ls
ls,
marker b

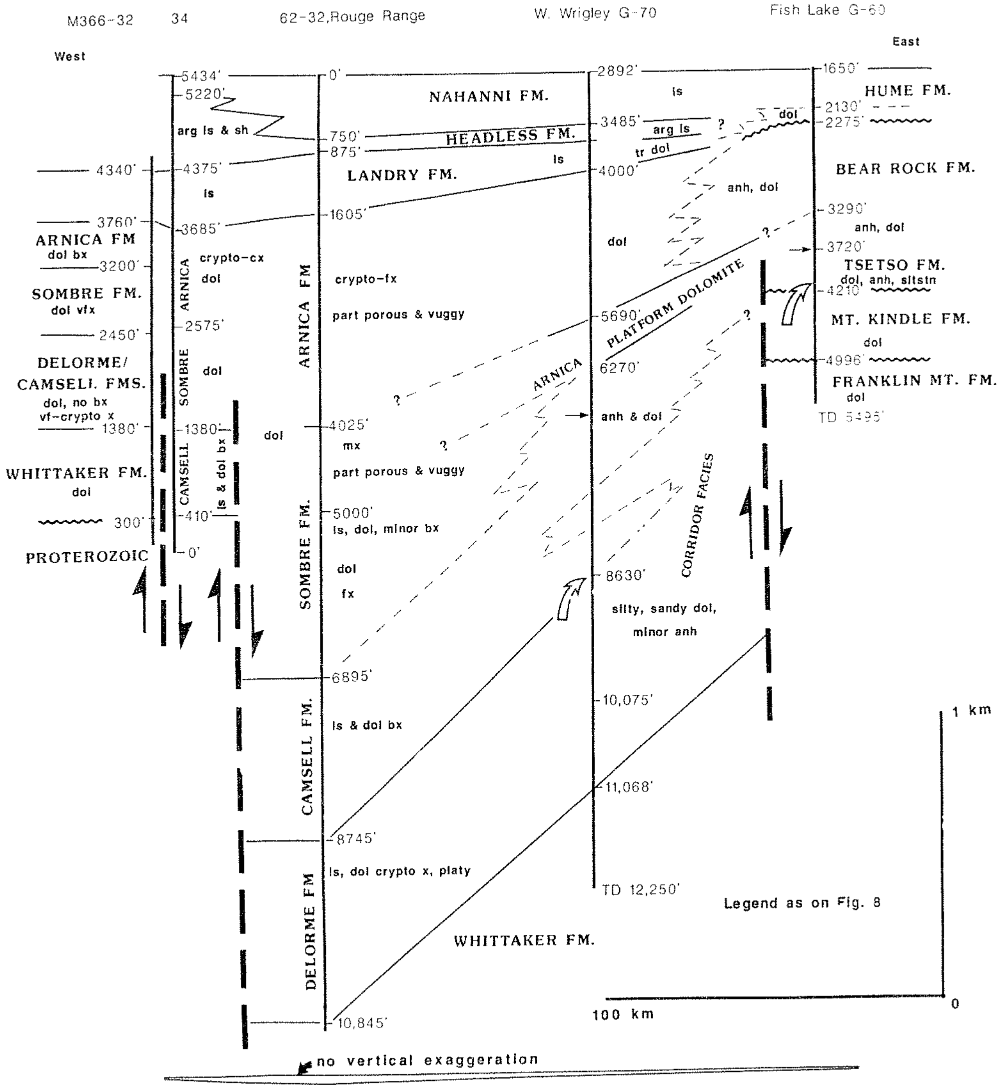
Fig. 8 cont.

Figure 9



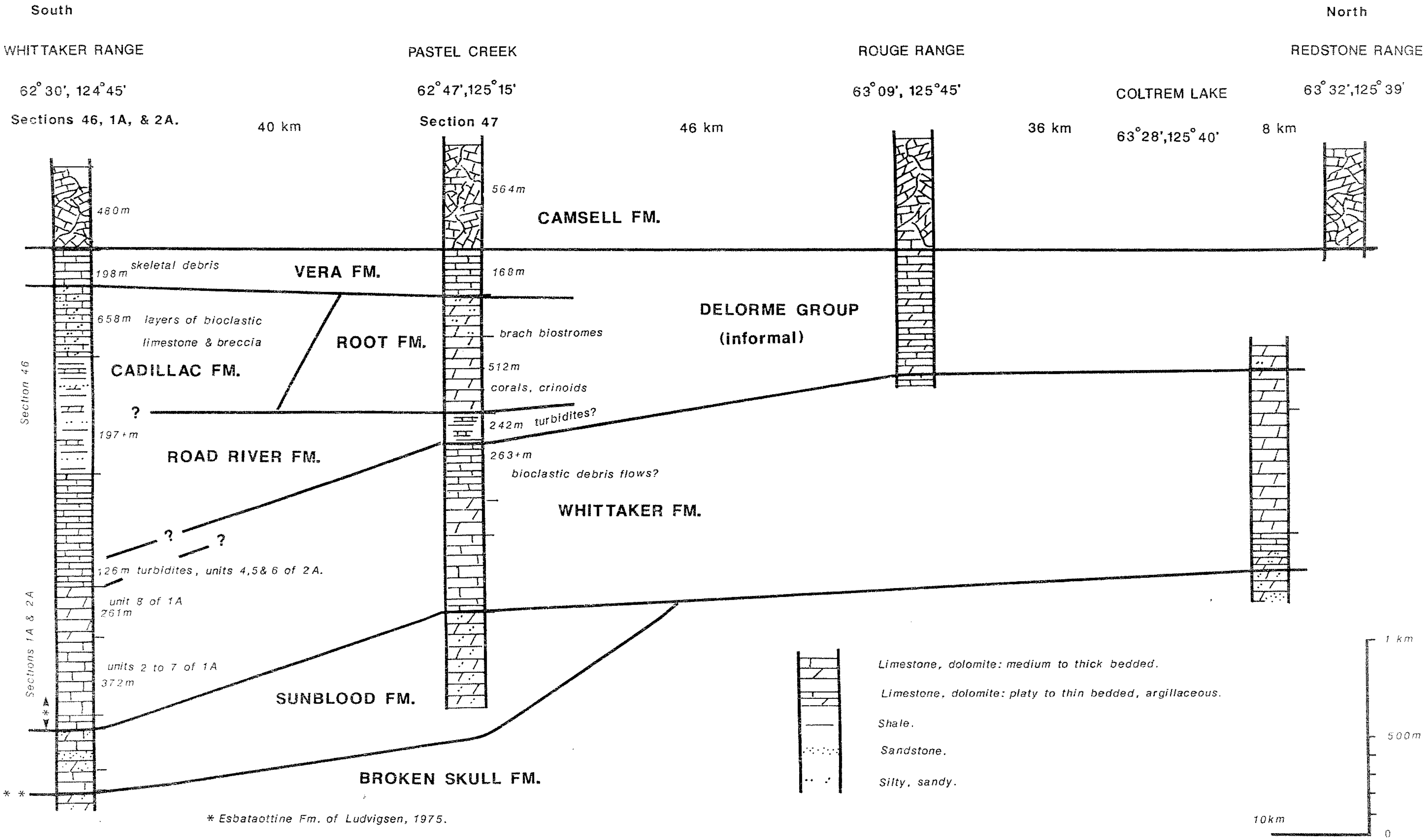
Transverse cross-section, M366-40 to E-11.

Figure 10



Transverse cross-section, M366-32 to G-60.

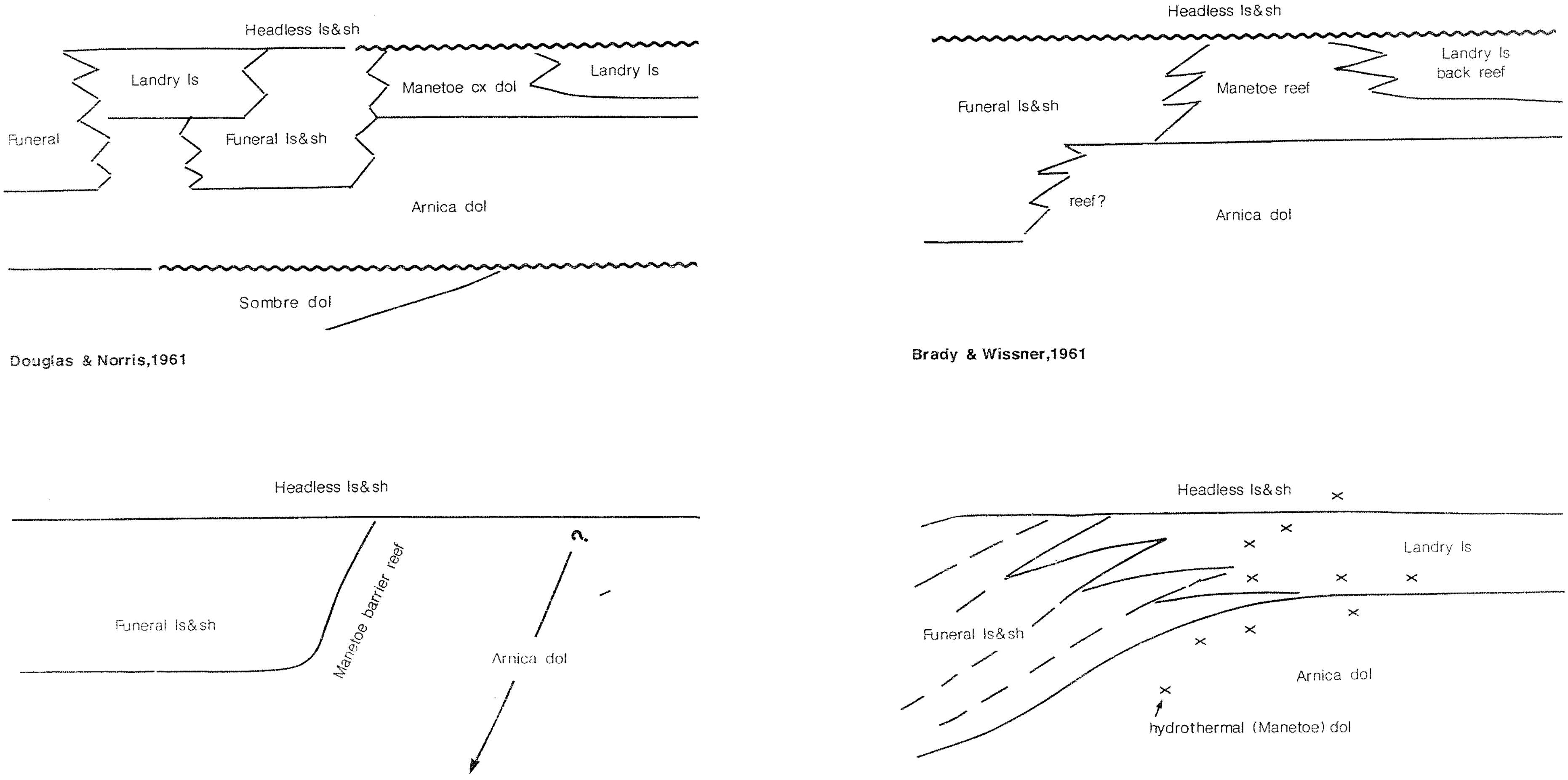
Figure 11



* Esbataottine Fm. of Ludvigsen, 1975.

* * Contact as picked by Ludvigsen, 1975.

Root Basin nomenclature as revised by Morrow and Cook, 1987, superimposed on measured sections of Douglas and Norris.



Douglas & Norris,1961

Brady & Wissner,1961

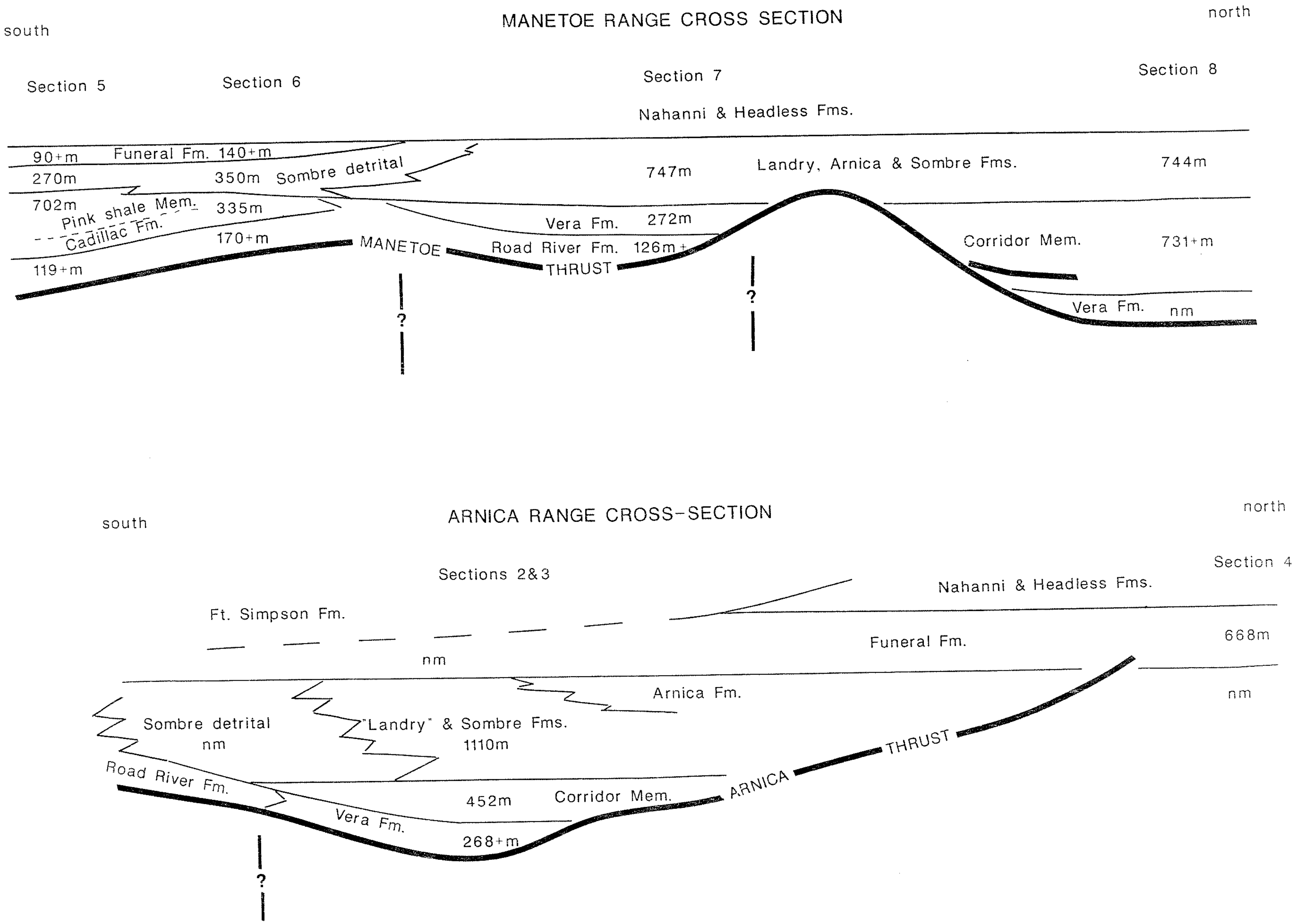
Noble & Ferguson,1971

Morrow & Cook,1987

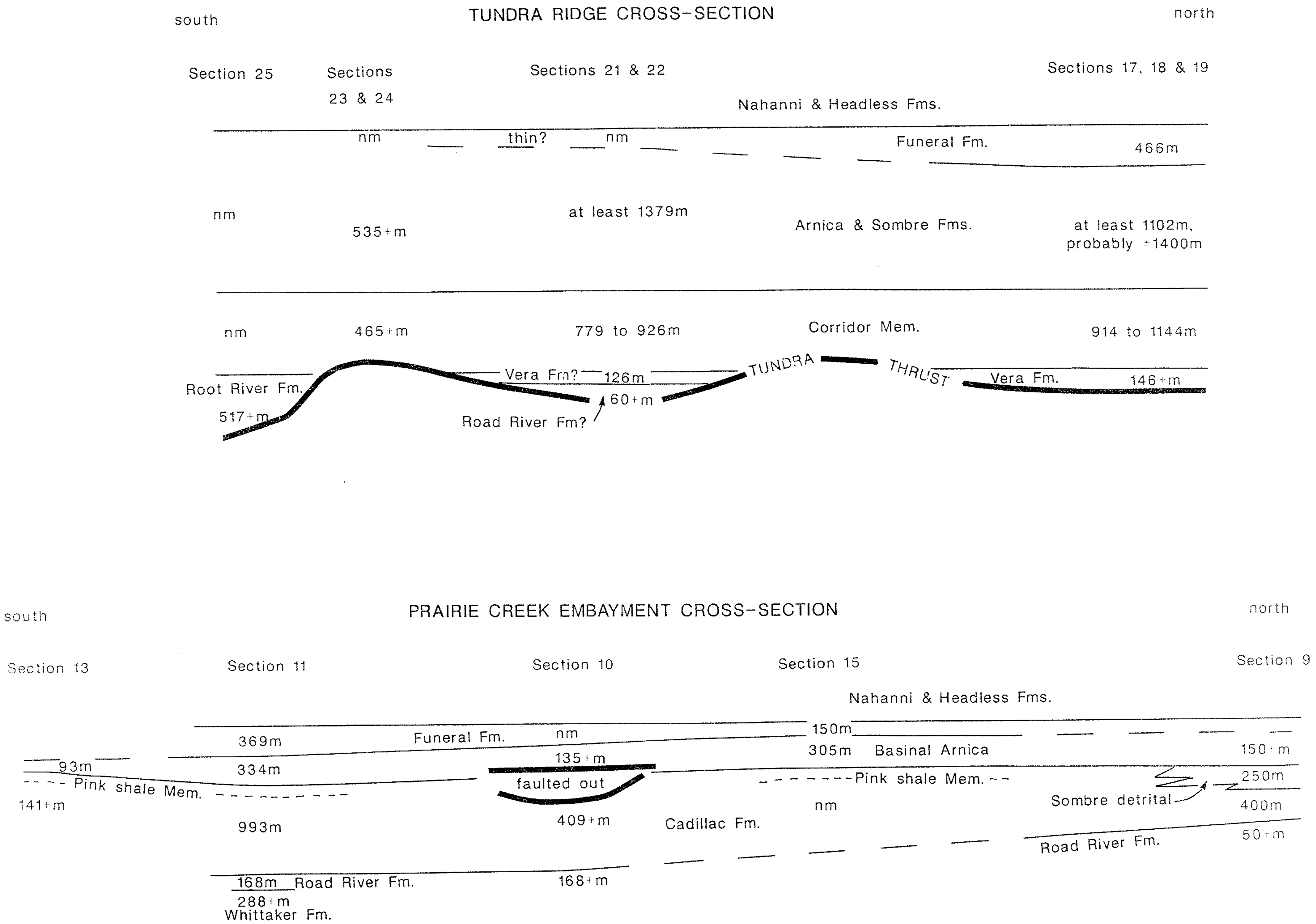
Evolution of concepts, Manetoe dolomite.

Figure 12

Figure 13

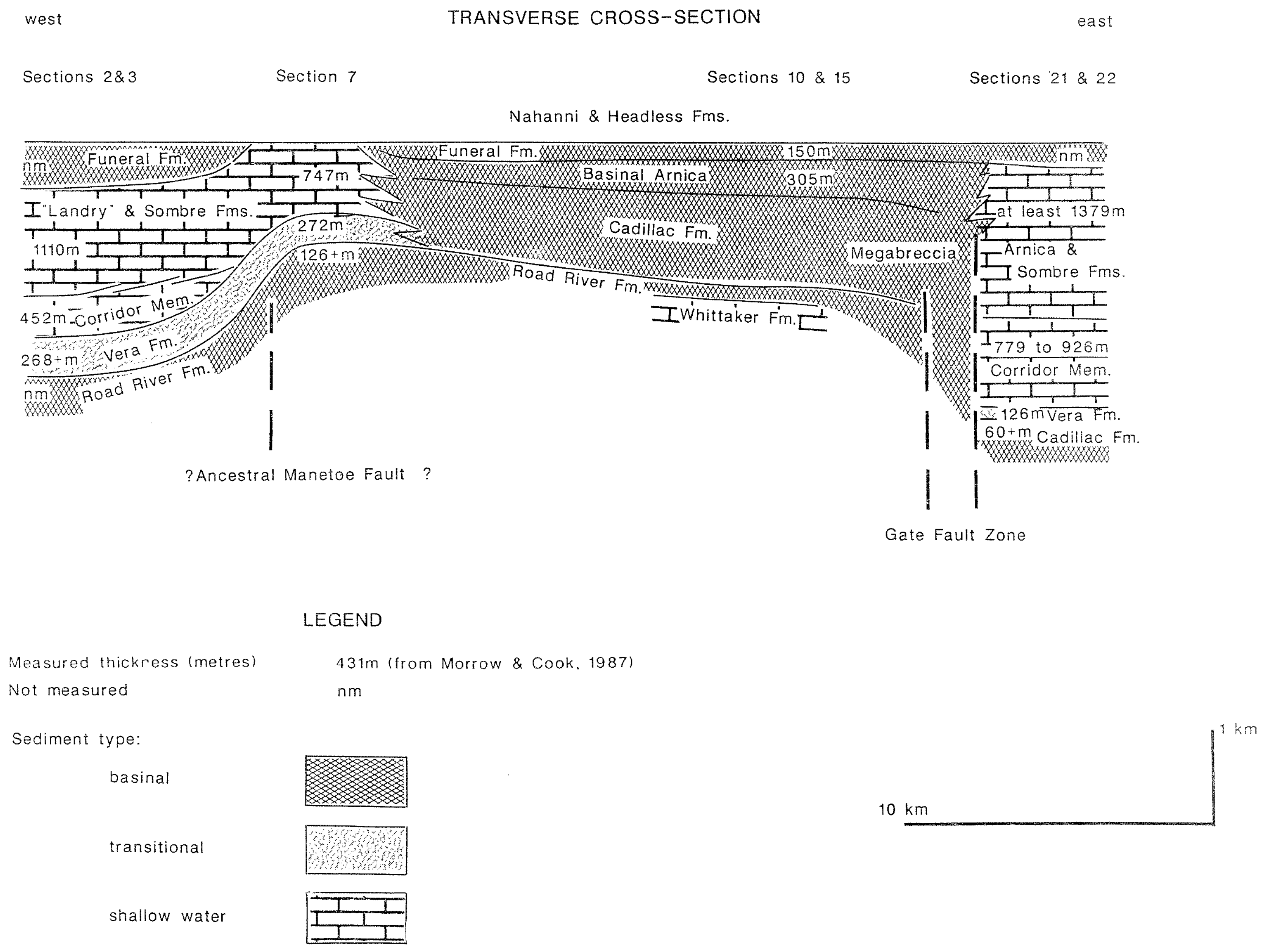


Cross-sections along Arnica and Manetoe Ranges.



Cross-sections along Prairie Creek Embayment and Tundra Ridge

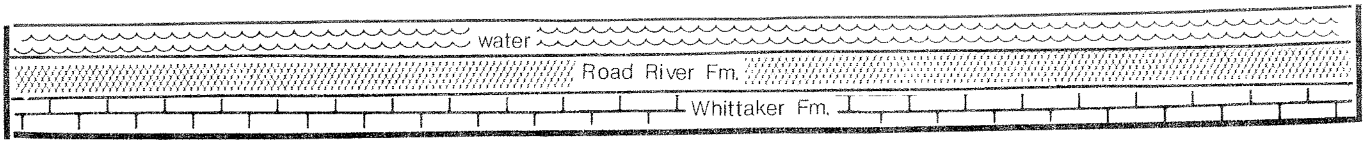
Figure 14



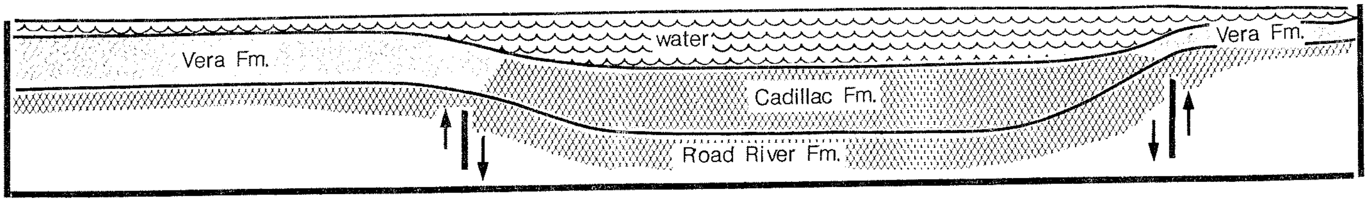
Transverse cross-section through Prairie Creek Embayment.

Figure 15

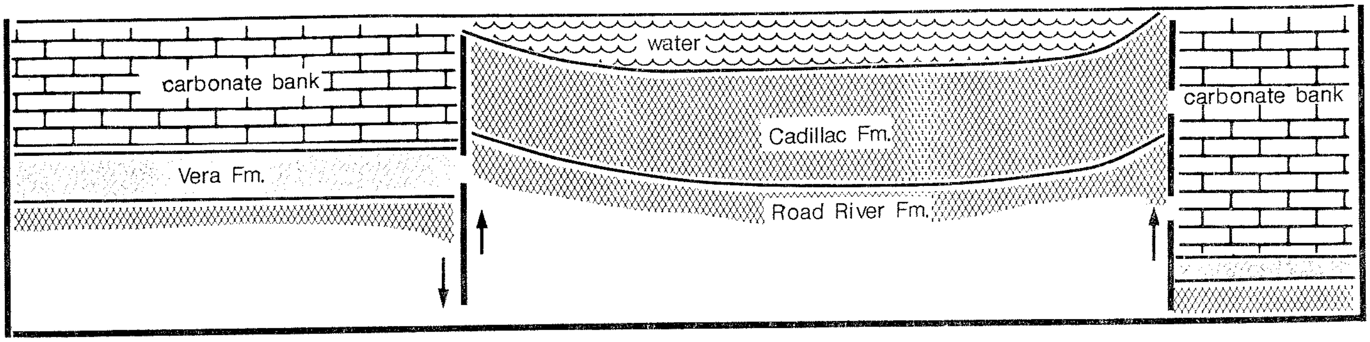
Figure 16



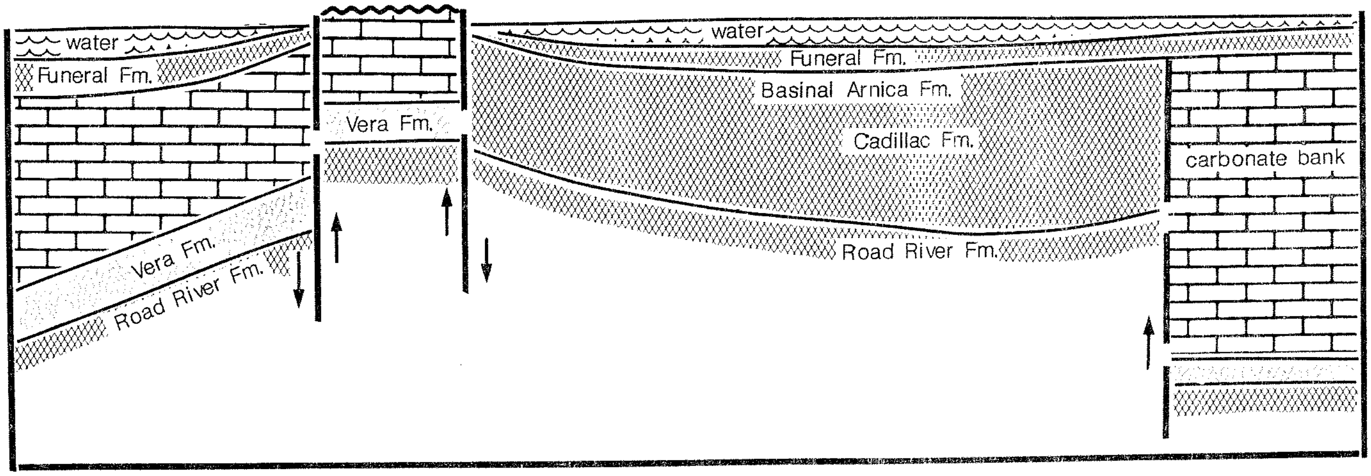
Early Silurian (late Road River time)



Earliest Devonian (Vera time)



Early Devonian (mid-Arnica time)



Early Middle Devonian (late Funeral time)

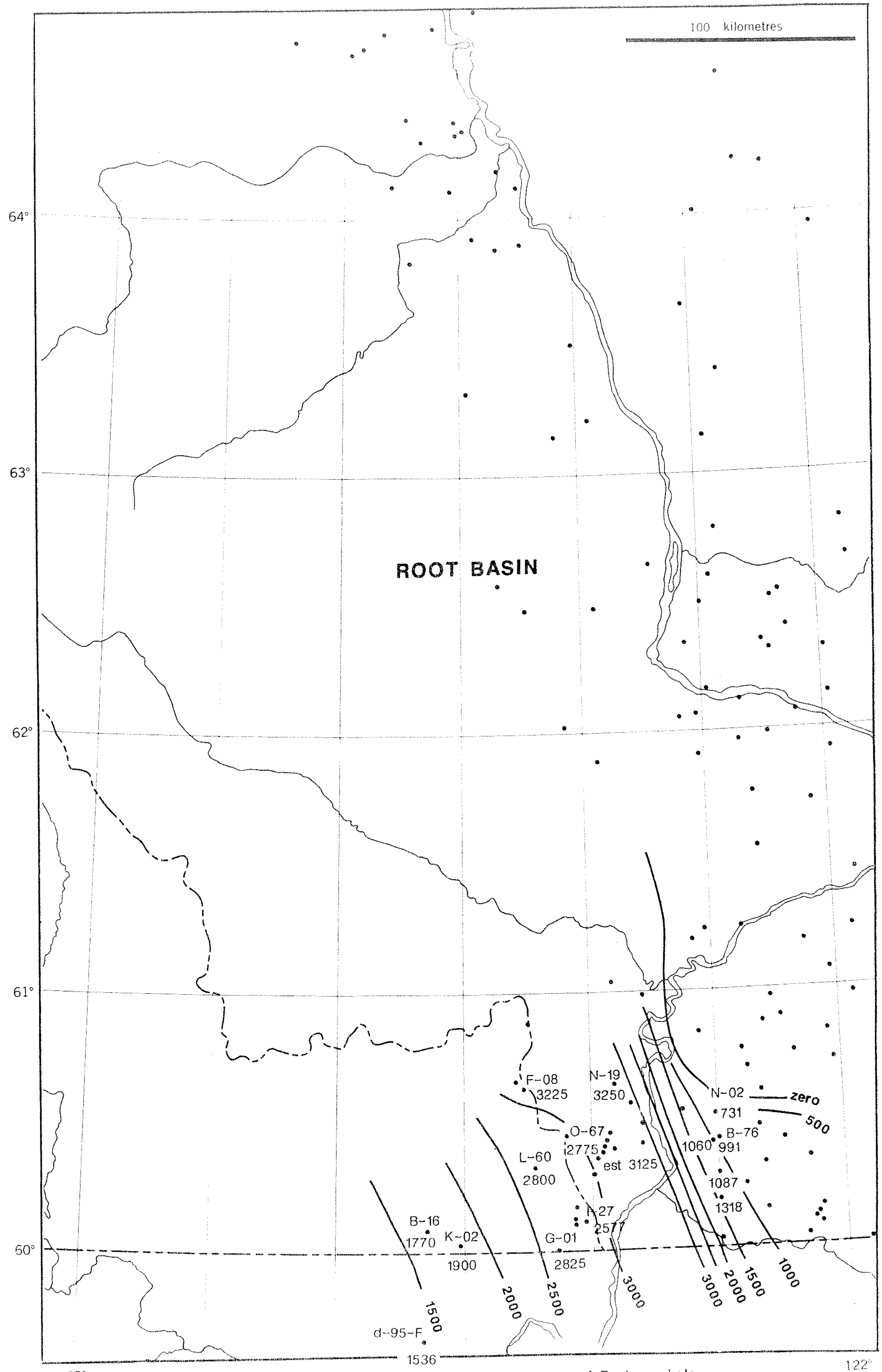
1 km

10 km

Legend on Fig.15

Time and motion study. Prairie Creek Embayment.

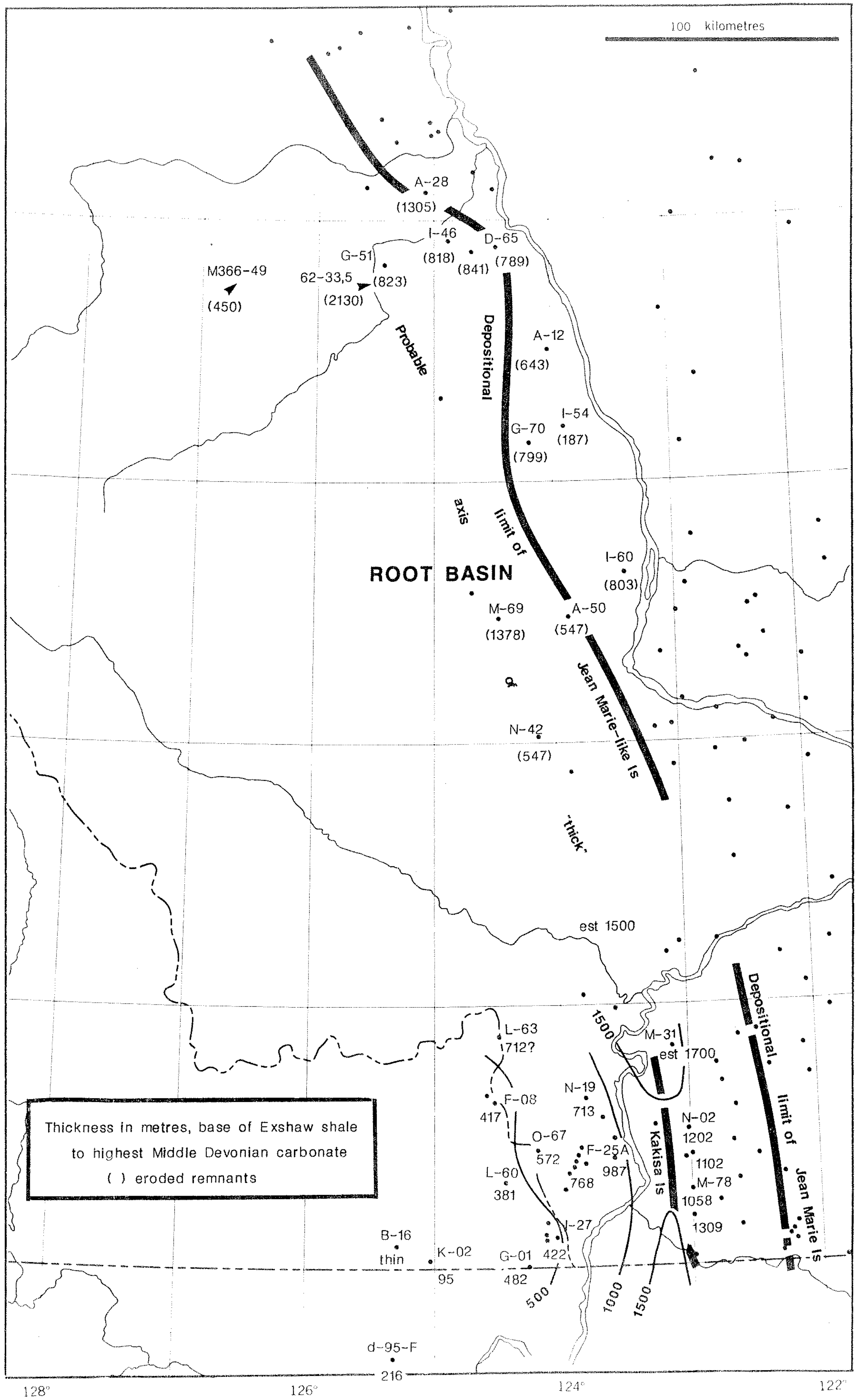
Figure 17



Thickness in metres, top of Paleozoic to base of Exshaw shale

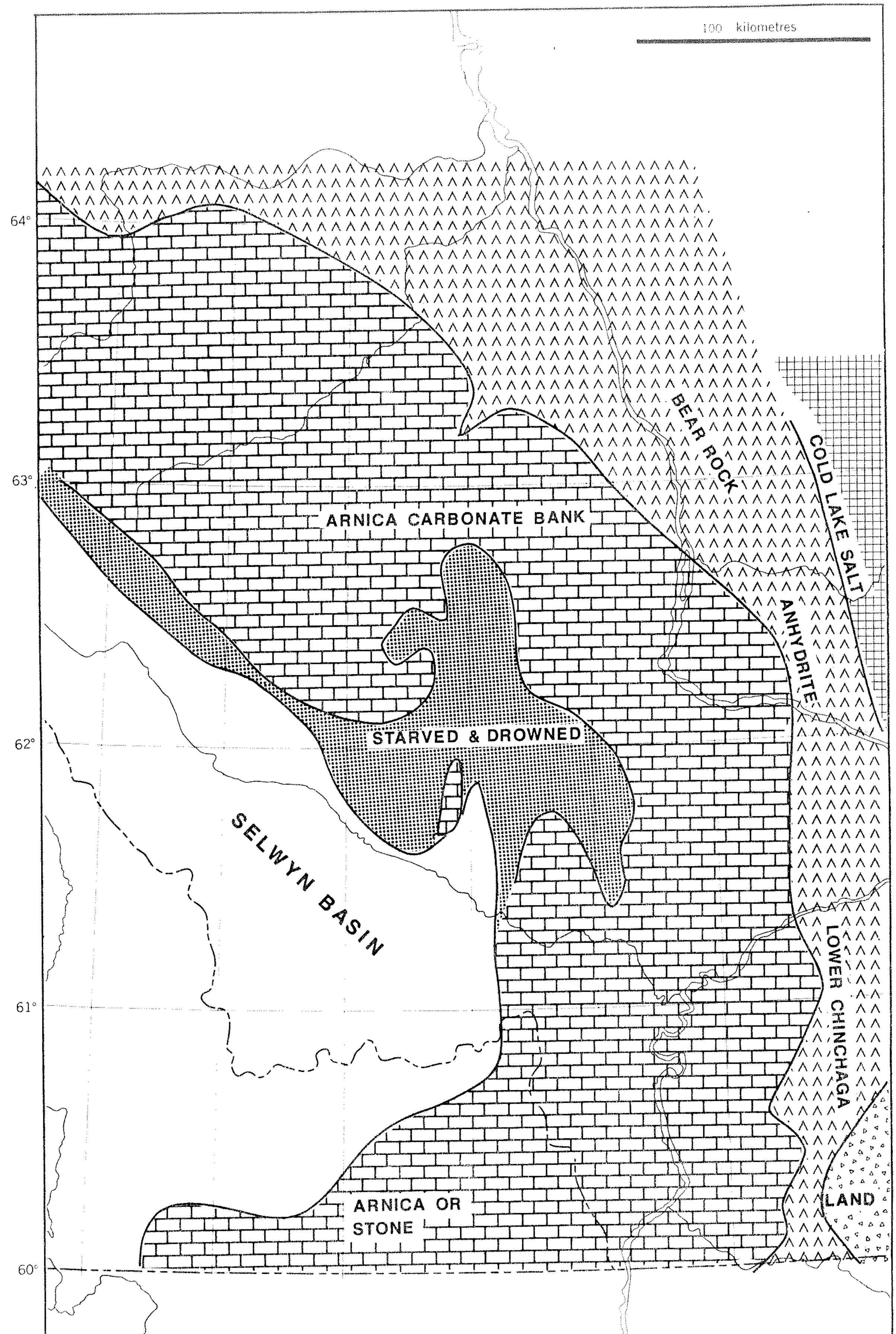
Late Paleozoic Isopach map

Figure 18



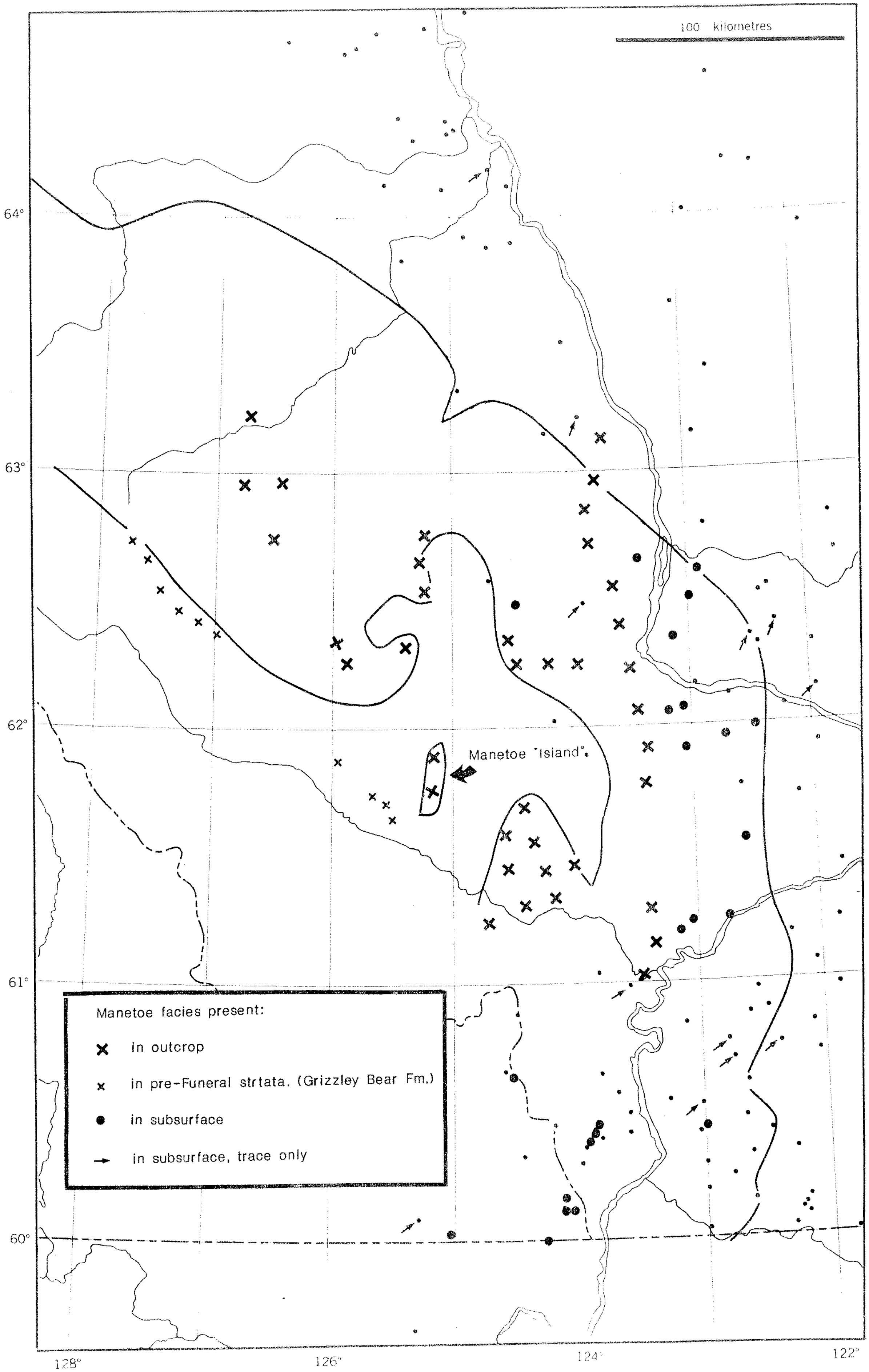
Upper Devonian isopachs and facies trends.

Figure 19



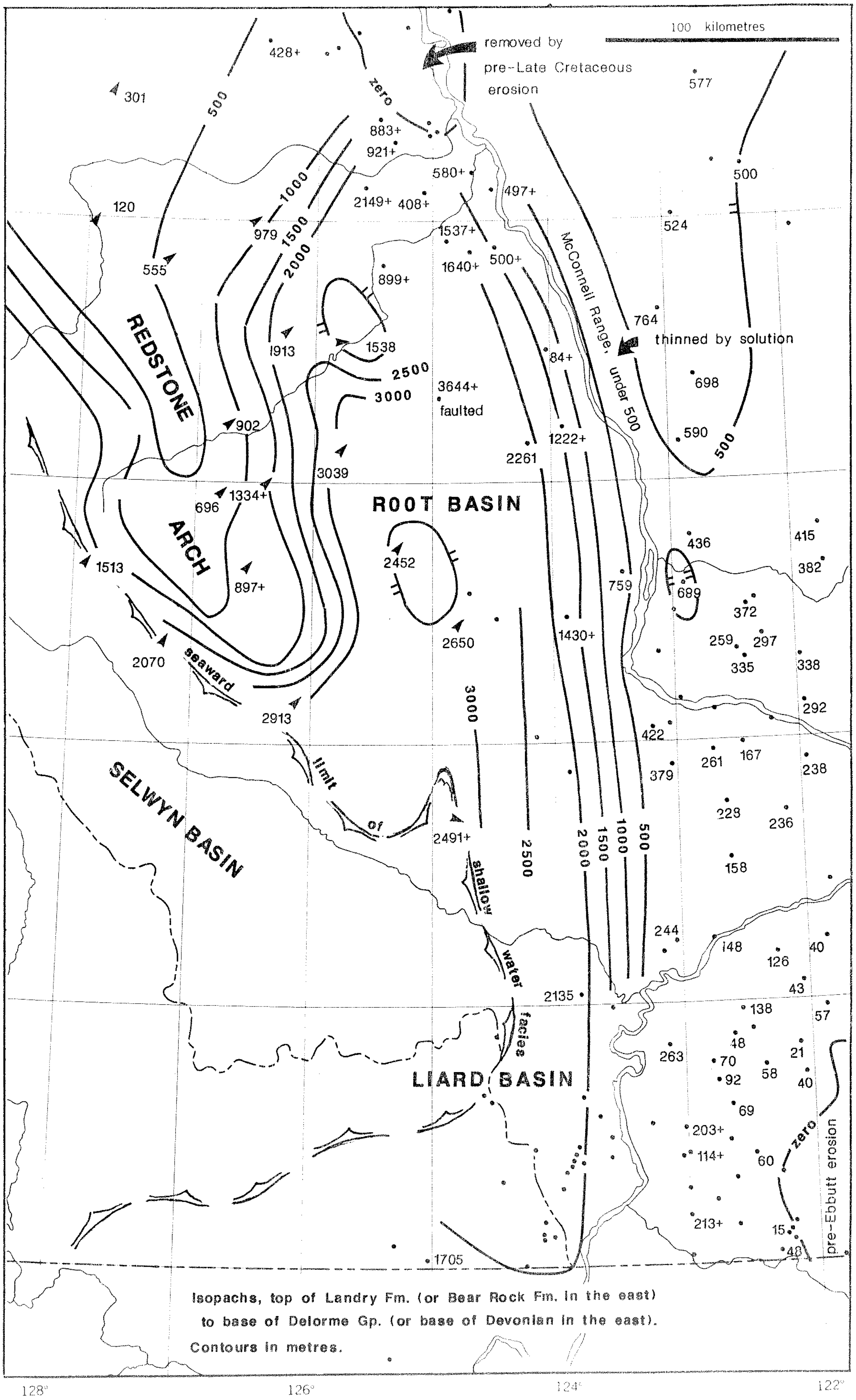
Paleoenvironments, late Arnica time.

Figure 20



Distribution of Manetoe (coarse crystalline) dolomite facies.

Figure 21



Isopachs, top of Landry Fm. (or Bear Rock Fm. in the east) to base of Delorme Gp. (or base of Devonian in the east).
Contours in metres.