Preliminary Mapping and Field Reconnaissance of the Lower to Upper Cretaceous (Middle Albian to Lower Turonian) Stratigraphy - Northeastern Alberta

Athabasca Gold Project
Alberta Geological Survey

Darrell Cotterill
Parallax Resources Ltd.

Habtemicael Berhane
Alberta Geological Survey

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Introduction

As far as non-renewable resources are concerned, northeastern Alberta is known best for its enormous bitumen reserves contained within the Lower Cretaceous Mannville Group. The petroleum industry's principle interest continues to be the development of the oil sands within the McMurray Formation. Recent exploration by the mineral industry, in the region, has identified other sedimentary units that may potentially contain economic deposits of precious metals such as gold, silver and platinum. Initial exploration programs focussed on Devonian carbonates that directly underlie the Cretaceous McMurray Formation. Anomalously high, isolated occurrences of gold were reported by several companies near Fort MacKay (Figure 1), a town situated along the Athabasca River, about 60 km north of Fort McMurray. Here, carbonate members of the Waterways Formation crop out along the Athabasca River and the tributaries that feed it. Speculation on the existence of economically recoverable gold and other metals from the Devonian carbonates prompted the leasing of large tracks of land in northeastern Alberta. As exploration programs expanded to other areas, additional sedimentary units were evaluated for their metallic potential.

This expansion led to a second stratigraphic target within the Upper Cretaceous succession. Most exploration activity has now shifted for the time being to Cretaceous units in the Birch Mountains, situated about 130 km northwest of Fort McMurray (Figure 1). Most tributaries, presently draining the northeast flank of the mountains, incise into Upper Cretaceous units. Stream sediment samples taken from the McIvor River valley, the most prominent drainage feature, revealed anomalous concentrations of sulphides. Very fine grains of pristine gold were also recovered and are thought to be locally derived. Gold collected, thus far, is believed to come from within the Labiche Formation, a thick succession of strata comprised dominantly of mudstone interbedded with thin siltstones and sandstones. Little geological documentation exists for the Labiche Formation as well as other Cretaceous strata in the area that bound this unit. Results from field reconnaissance sampling, over the past two summers, have

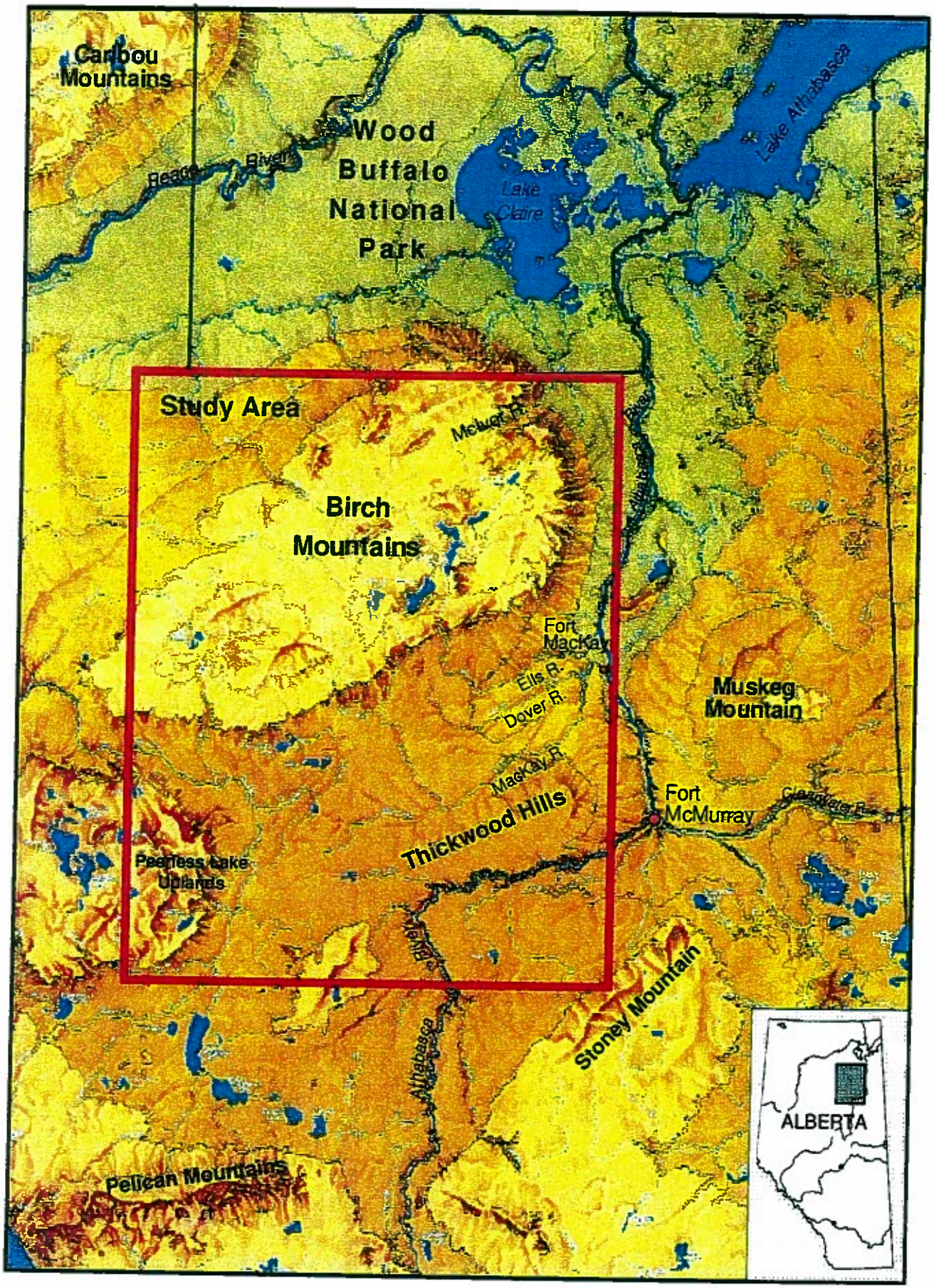

Figure 1. Physiographic map of northeastern Alberta

identified several geochemical anomalies. Some of these targets may be drilled next summer (1996).

Purpose and Scope of Study

First, the principle purpose of this report is to provide a stratigraphic framework outlining the Cretaceous interval from the base of the Joli Fou Formation upwards through to the Second White Speckled Shale (Middle Albian to Turonian). This stratigraphic framework is required to assist the mineral industry with their current investigations and promote future exploration programs in the area.

Second, the existing bedrock map produced by Green et al. (1970) requires updating. New borehole data, combined with ongoing field activities indicate that several Cretaceous units presented on the map require modification. To properly revise the bedrock geology of the region it was necessary to expand the initial study area to the south where exposed Cretaceous units are better defined. Because no core exists for the interval of interest the study has relied mainly on subsurface geophysical well log data and field data gathered from the Birch Mountains during the past summer. Nearly 1400 wells throughout the region, and over 30 surficial exposures (primarily from the Birch Mountains) were used to characterize the stratigraphic interval.

Physiography

The study area encompasses Townships 84 to 104, Ranges 11W4 to 2W5 (Figures 1 and 2). The region is bounded to the north by Wood Buffalo National Park and to the east by the Athabasca River. Northeast Alberta, commonly called the Athabasca region, can be divided into three geographic regions based upon bedrock geology and prominent topographic features (Figure 1). These include the Canadian Shield

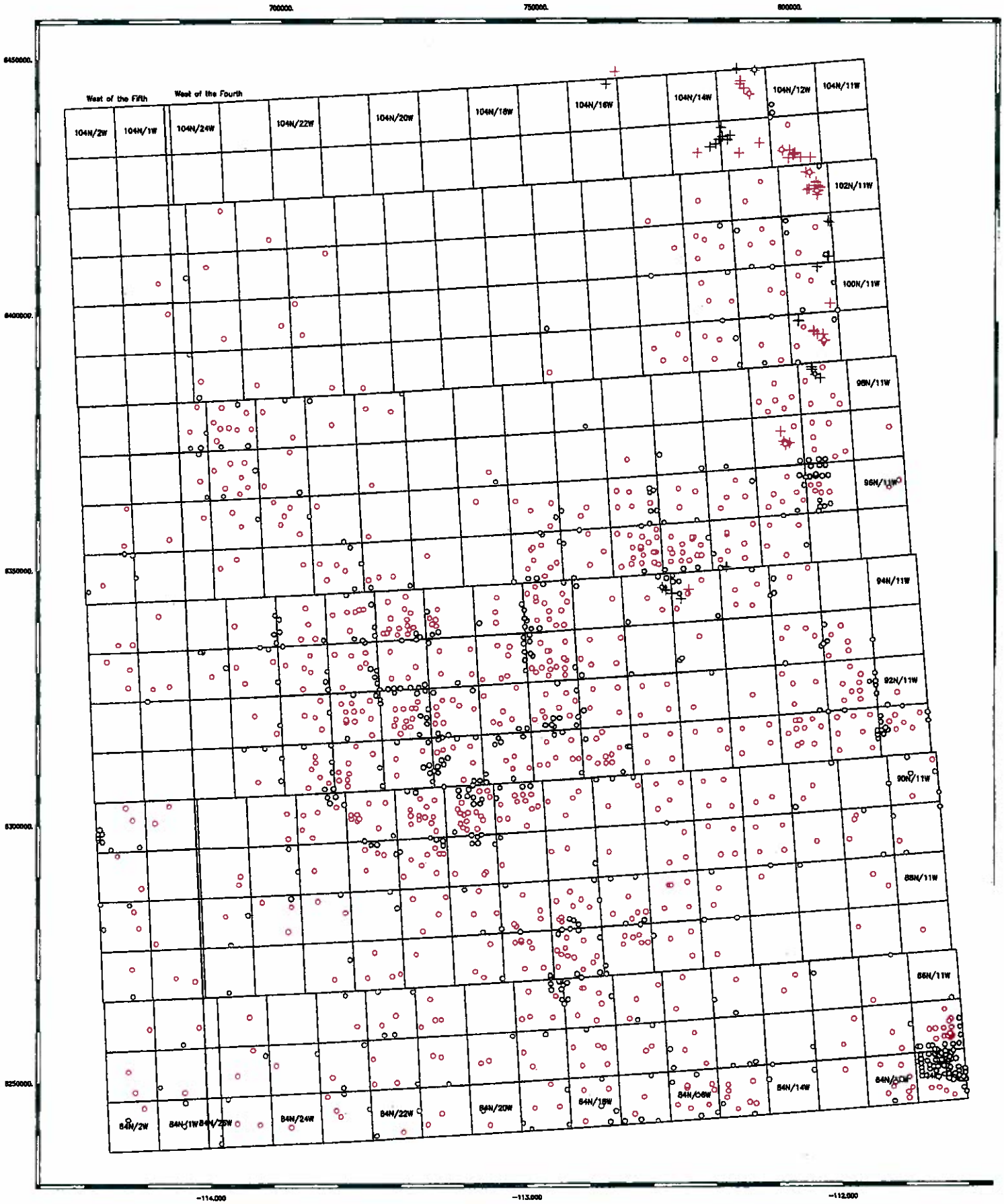

Figure 2. Data distribution within the study area.

(o represent well locations, + represent outcrop locations)

(located east of the study area), the lowlands juxtaposed to the major drainage systems and the dissected highlands that ascend from the plains to the west, south and east of the Athabasca River drainage basin (Hamilton and Mellon, 1973). Within the study area the lowlands and plains, each with their associated drainage networks, surround three highlands. These highlands include the Birch Mountains, the Thickwood Hills and another topographic high, herein called the Peerless Lake Uplands (Figure 1). A series of perched lakes are present on both the Birch Mountains and the Peerless Lake Uplands. Most of tributary networks that dissect and drain the three highlands eventually empty into either the Athabasca, Wabasca or Peace river drainage basins. The Birch Mountains, the most pronounced topographic feature, forms a plateau-like, northeast trending high that rises up to 500 m above the surrounding plains. The Birch Mountains comprise thick, glacially sculpted Cretaceous bedrock. Some locally thick Quaternary intervals have also been identified, but are poorly understood.

Geologic Setting

The region preserves a variably thick succession of Cretaceous strata that unconformably rests upon a wedge of westerly dipping Devonian strata dominated by carbonates and shales founded on the Precambrian basement. Differential erosion of variably shaly, Devonian units subcropping at the unconformity surface combined, with the effects of a southwesterly migrating salt dissolution scarp has significantly effected the initial sediment distribution and structural evolution of the overlying Cretaceous strata, particularly the Lower Cretaceous interval.

A pronounced topographic feature evident on the eastern border of the study area consists of a long, linear depression. The Athabasca River currently occupies this low north of Fort McMurray (Figure 1). Here, Athabasca valley is a surface expression of the Prairie Evaporite Formation dissolution edge, a subsurface escarpment within the

Devonian Elk Point Group. Collapse, deformation and preferential erosion of the weakened overlying Devonian and Cretaceous strata reflect the deep seated processes along the salt scarp. This north-northwest trending regional feature extends through the entire area and continues far to the south. The scarp is the result of long term salt dissolution from the Prairie Evaporite Formation by infiltrating meteoric waters and possibly to a lesser extent by unsaturated formation brines. The dissolution and removal of large volumes of salt resulted in the undermining, deformation and eventual collapse of the overlying Waterways Formation. Continued salt dissolution throughout the Cretaceous period not only modified the sediment dispersal of the lowermost formations, but also is responsible for some of the structural attributes of the overlying succession proximal to the escarpment.

The Lower Cretaceous Mannville Group, consisting of the McMurray, Clearwater and Grand Rapids formations, is an unconformity bound succession often made up of a thick, variably shaly sand at the base overlain by thick mudstone, siltstone and fine grained sandstone intervals. Overlying the Mannville succession are the Lower Cretaceous Joli Fou and Pelican formations (Figures 3 and 4). Thick shales and mudstones of the Labiche Formation blanket the Pelican Formation. The Labiche Formation spans the Lower and Upper Cretaceous boundary, and the Base of Fish Scales, a horizon within the Labiche succession, marks this division. The Second White Speckled Shale is also a distinctive marker horizon within the Labiche Formation.

Equivalent stratigraphic units of the Joli Fou, Pelican and Labiche formations are well documented in other parts of the basin. Leckie and Smith (1992) provide a summary of the depositional cycles within the Jurassic and Cretaceous sedimentary successions of the foreland basin. These cycles coincide with distinct tectonic events emanating from the rising cordillera to the west. The summary furnishes a link between the poorly understood stratigraphy in northeastern Alberta and the well-documented Cretaceous successions elsewhere in the province.

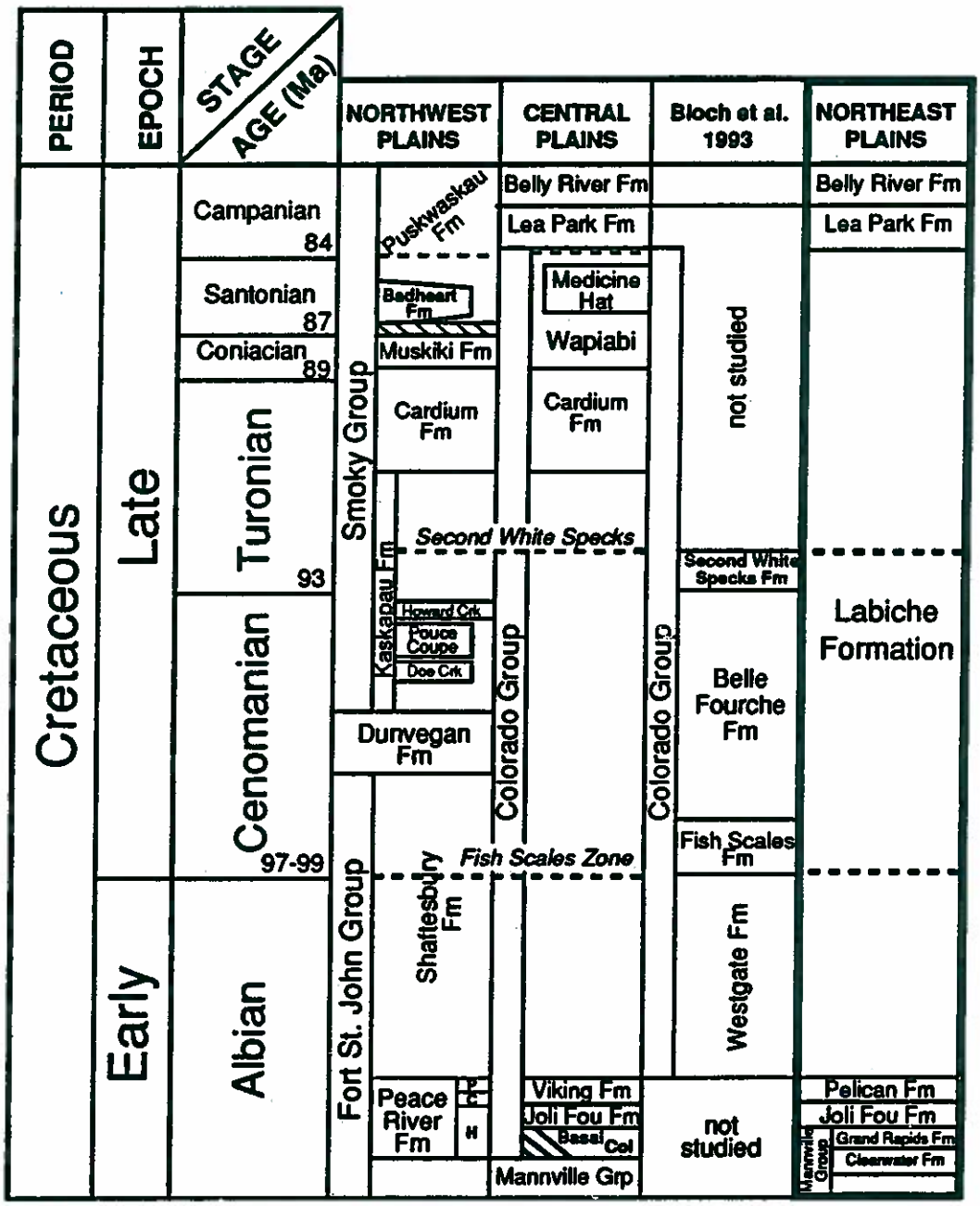

Figure 3. Cretaceous nomenclature for northeast Alberta and stratigraphic equivalents elsewhere in the Western Canada Sedimentary Basin (modified after Bloch et al., 1993). Subdivision of Peace River Formation: P = Paddy Member, C = Cadotte Member and H = Harmon Member.

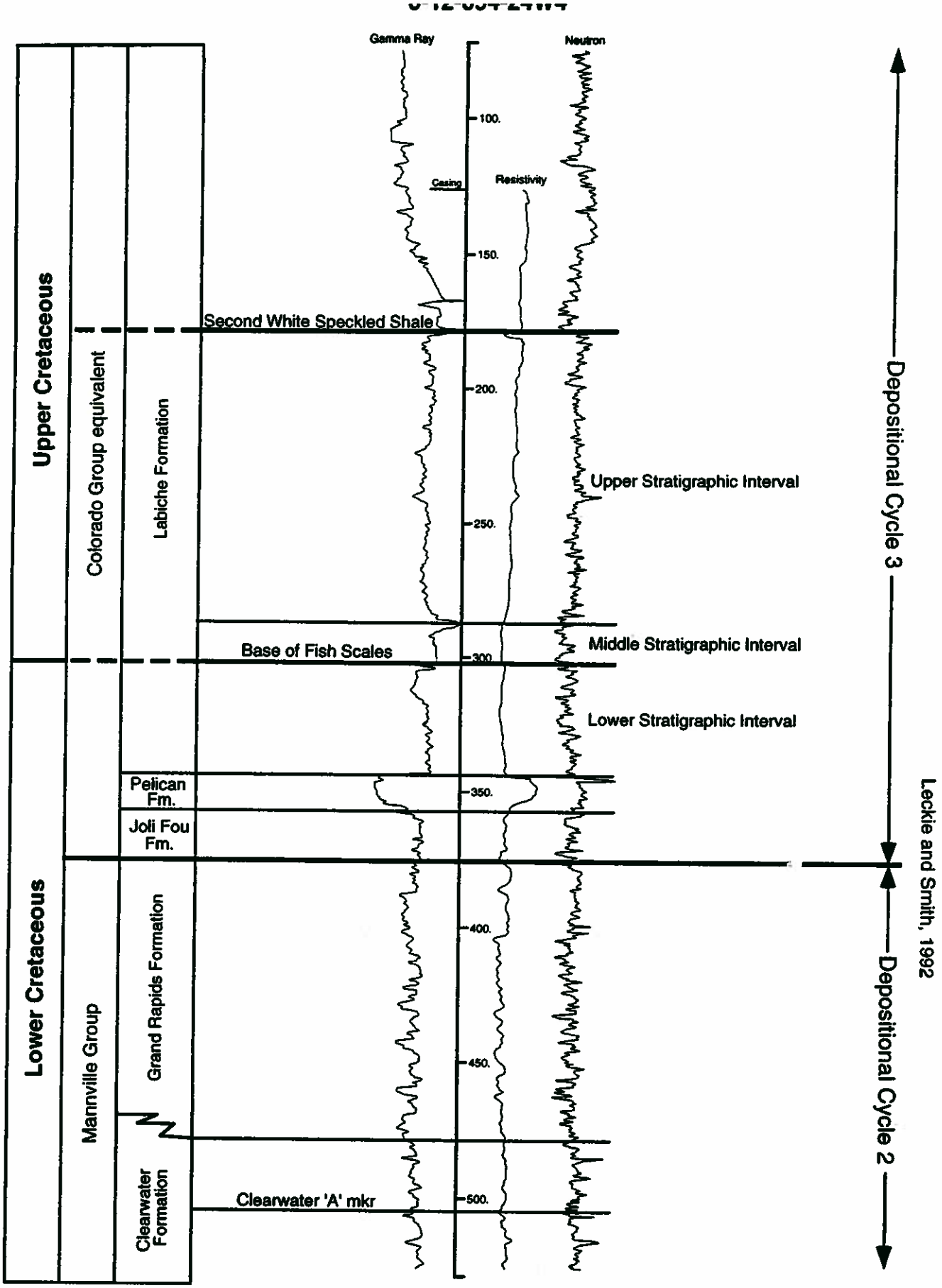

Figure 4. Reference well 6-12-94-24W4

The geological history of the Jurassic and Cretaceous sedimentary series in the foreland basin can be defined in terms of five depositional cycles. Each cycle, of differing age represents strata bound by either major unconformities or changes in lithology. Cretaceous formations in northeastern Alberta are incorporated into cycles two and three (Figure 4). Elsewhere in the basin Cycle two encompasses the Cadomin Formation/Dina Member to the top of the Mannville Group. In the Athabasca area Cycle two is made up of the McMurray, Clearwater and Grand Rapids formations. Cycle three is defined as the sedimentary succession from the base of the Joli Fou Formation/Paddy Member to the top of the Wapiabi Formation/Colorado Group. The Joli Fou, Pelican and Labiche formations make up Cycle three in northeastern Alberta.

Cycle two, within the foreland basin, is thickest (> 600 m) in east-central B.C. (Leckie and Smith, 1992) and thins progressively to less than 200 m in the subsurface, east of where the succession begins to crop out in northeastern Alberta. Cycle three is again thickest in east-central B.C. (>1150 m) and progressively thins to the east along a northwest-southeast strike. Within the study area much of Cycle three has been removed by post-Cretaceous erosion. The thickest (> 400 m) preserved remnants of Cycle three (Figure 5) are located in the Birch mountains. Cretaceous units are exposed best along the Athabasca, MacKay, Dover and Ells rivers and within the incised tributaries that drain the northeast rim of the Birch Mountains.

Stratigraphic Framework

The sedimentary package from the base of the Lower Cretaceous Joli Fou Formation upwards through to the Upper Cretaceous Second White Speckled Shale (SWSS) is comprised dominantly of mudstones interspersed with thin sandstones and siltstones. The thickness of the stratigraphic interval is highly variable due primarily to post-Cretaceous erosional events in the region. The succession thins erosionally into the lowlands and associated drainage network where the stratigraphic units incrementally

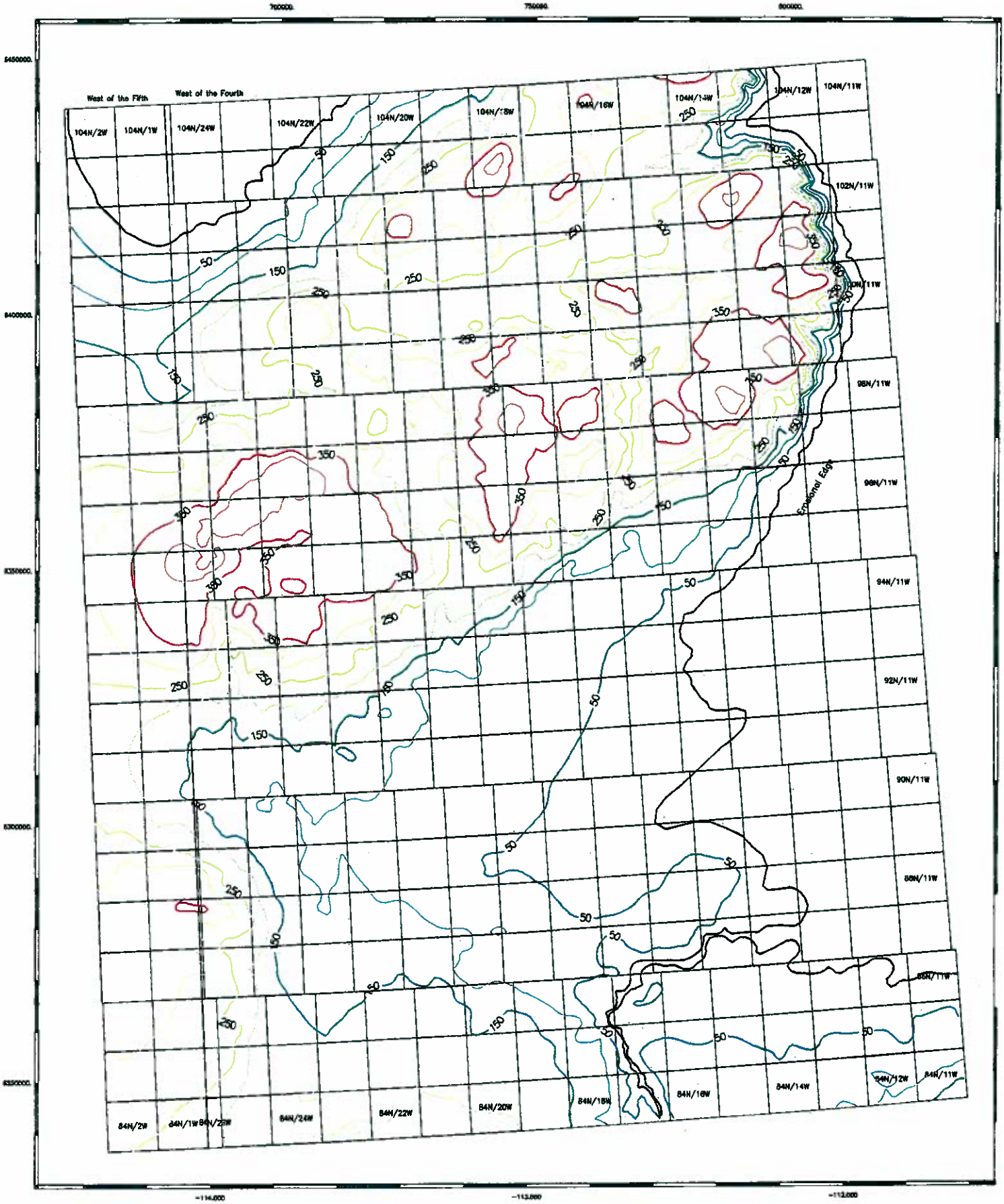

Figure 5. Top of the Mannville Group to the Second White Speckled Shale isopach

crop out at the surface.

The unconformity bound Cretaceous succession from the top of the Mannville Group to the top of the eroded Labiche Formation (Colorado Group equivalent), in the region, was deposited in the eastern portion of the Western Canada Foreland Basin during a time when relative global sea levels were generally high and rising. Within this period several major, but short lived sea level falls occurred. Sedimentation took place during a tectonically active time in the basin particularly in the western portion of the basin adjacent to the cordilleran fold-thrust belt.

Noncalcareous shales and minor sandstones of the Joli Fou Formation reflect the initial marine transgression over top of the Mannville Group in northeast Alberta. Joli Fou strata reflect the first connection between the southern Gulf of Mexico sea and the northern Arctic sea (Leckie et al., 1994).

Several relative sea level drops may have occurred during the deposition of the sand-rich Pelican Formation. Research on stratigraphically equivalent units in the northwest plains (Paddy-Cadotte succession) and the central plains (Viking Formation) suggest evidence for multiple sea level drops (Leckie et al., 1994).

In the northeast reestablishment of sea level rise blanketed the region with shales of the lower Labiche Formation. To the west, stratigraphically equivalent shales of the Shaftesbury Formation transgressed the Paddy Member of the Peace River Formation. The Base of Fish Scales horizon is thought to reflect a second connection of the two seas once again forming the extensive Cretaceous Interior Seaway.

To the west, along the disturbed belt, a relative lowering of sea combined with tectonic uplift resulted in the deposition of the Dunvegan Formation, a succession comprised of a series progradational clastic-rich cycles. The sand-rich portion of these depositional cycles never reached northeast Alberta, but the distal edge of the clastic wedge is

likely represented by shales within the lower portion of the Labiche Formation, just above the Base of Fish Scales.

A third, basin wide transgression resulted in the deposition of the Second White Speckled Shale within the Labiche Formation. Further transgressive and regressive events important to the development of the Western Canada Sedimentary Basin are not well represented in northeastern Alberta due to post-Cretaceous erosional events that have removed much of the Upper Cretaceous strata.

The entire erosionally thinned interval is founded disconformably on the underlying Mannville Group. The Grand Rapids Formation is the uppermost succession of the Mannville Group. This unit is, in turn, underlain by the Clearwater Formation. With the exception of the lowermost unit described in this report (upper portion of the Clearwater Formation) the Cretaceous succession progressively crops out at the surface from east to west within the study area. Successive post-Cretaceous erosional edges were derived using computer mapping software. Each structural surface was subtracted from the ground surface. A zero edge was extrapolated where like elevations on the two theoretical surfaces intersect. The erosional edges were then refined using surficial bedrock exposures where possible.

Clearwater Formation (Lower Cretaceous-Mannville Group)

The Clearwater Formation, in northeastern Alberta, unconformably overlies bitumen-rich sands of the McMurray Formation. Stratigraphically equivalents include Bluesky Formation and the lower part of the Spirit River Formation in the Peace River area (Glass, 1990). Although the Clearwater Formation lies well below the interval of interest it does contain significant marker horizons that are present throughout the study area. The Clearwater 'A' marker (Wightman et al., 1995 and Petroleum Geoscience Section, 1993) is the lowermost surface correlated throughout the region.

The surface is characterized by a thin (~2 m), low resistivity, dark grey to black shale (Figures 6, 7 and 8; in pockets). The marker is laterally extensive, stratigraphically flat and serves as good lower datum upon which to begin building the successively younger Cretaceous succession.

Within the study area, the Clearwater Formation comprises mudstones interbedded with thin, often glauconitic sandstones and siltstones. Concretion bearing horizons are prevalent. At the base of the succession is a variably thick, often sand dominated unit called the Wabiskaw Member (Badgley, 1952). Far to the south, in the Cold Lake area, the Clearwater Formation consists of massive, glauconitic, salt and pepper sands and interbedded mudstones and is suggested to have been deposited within a deltaic system (Wightman and Berezniuk, 1985). The shaly succession within the study area likely represents the off shore component to these shoreline deposits.

Elevations on the Clearwater 'A' surface rise over 150 m from west to east (Figure 9). The prominent ridge, in the southeast, closely resembles and may be a propagation of the Beaverhill Lake Spur, a large, north-northeast trending topographic high on the sub-Cretaceous unconformity (Cotterill and Hamilton, 1995 and Wightman et al., 1995). East of the high, limited well control suggests the surface drops sharply. This structural roll over has also been documented in units lower within the Cretaceous succession. The depression marks the location of the deep seated scarp, a feature resulting from salt dissolution within the Devonian Prairie Evaporite Formation previously described.

Grand Rapids Formation (Lower Cretaceous-Mannville Group)

The Grand Rapids, the uppermost formation of the Mannville Group, conformably overlies and laterally interfingers with the Clearwater Formation (Kramers and Prost, 1986). The sedimentary succession is stratigraphically equivalent to the upper part of

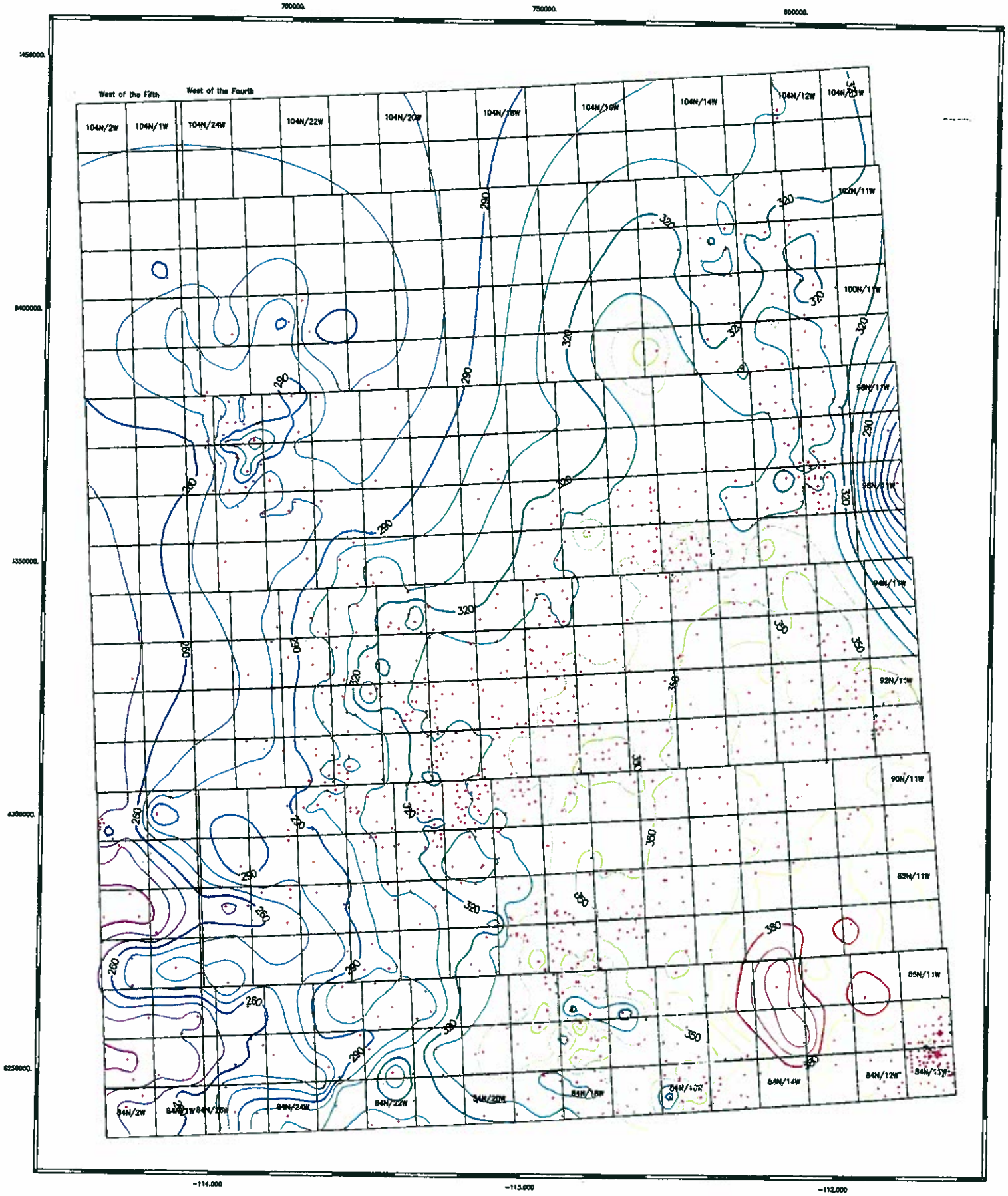

Figure 9. Structure on the Clearwater 'A' marker

the Spirit River Formation and the lower part of the Peace River Formation (Glass, 1990).

In the south, the Grand Rapids Formation consists of up to three thick sand bodies separated by thin siltstones and mudstones (Figure 7). These units form a shingle-like geometry in which each successively younger sand body progressively pinches out further to the north (Kramers and Prost, 1986). Elsewhere the succession is comprised of interbedded, very fine grained sandstones, siltstones and mudstones with occasional isolated, clean sandstones up to 10 m thick. Portions of the three southerly sand bodies of the Grand Rapids succession crop out at Brule Rapids, Grand Rapids and Pte. La Biche along the Athabasca River in the southern part of the study area (Figure 1). Locally, the top Grand Rapids Formation has been incised into by overlying units.

Elevations on the top of the Grand Rapids Formation are very similar to the Clearwater Formation. The surface rises from west to east to a height of over 490 m (Figure 10). In the east, approaching the Athabasca drainage area, the succession has been progressively eroded to a zero edge. The top of the Grand Rapids Formation is overlain by the Joli Fou Formation, marking the contact between Cycles two and three as defined by Leckie and Smith (1992).

Joli Fou Formation (Lower Cretaceous)

The contact between the Grand Rapids Formation and the Joli Fou Formation is sharp and disconformable. Relief at the contact appears subtle on the top of the Grand Rapids Formation except for localized incisions emanating from an erosional surface at the top of the Joli Fou succession (Figure 8).

The type section for the Joli Fou Formation is about 33 m thick and is located

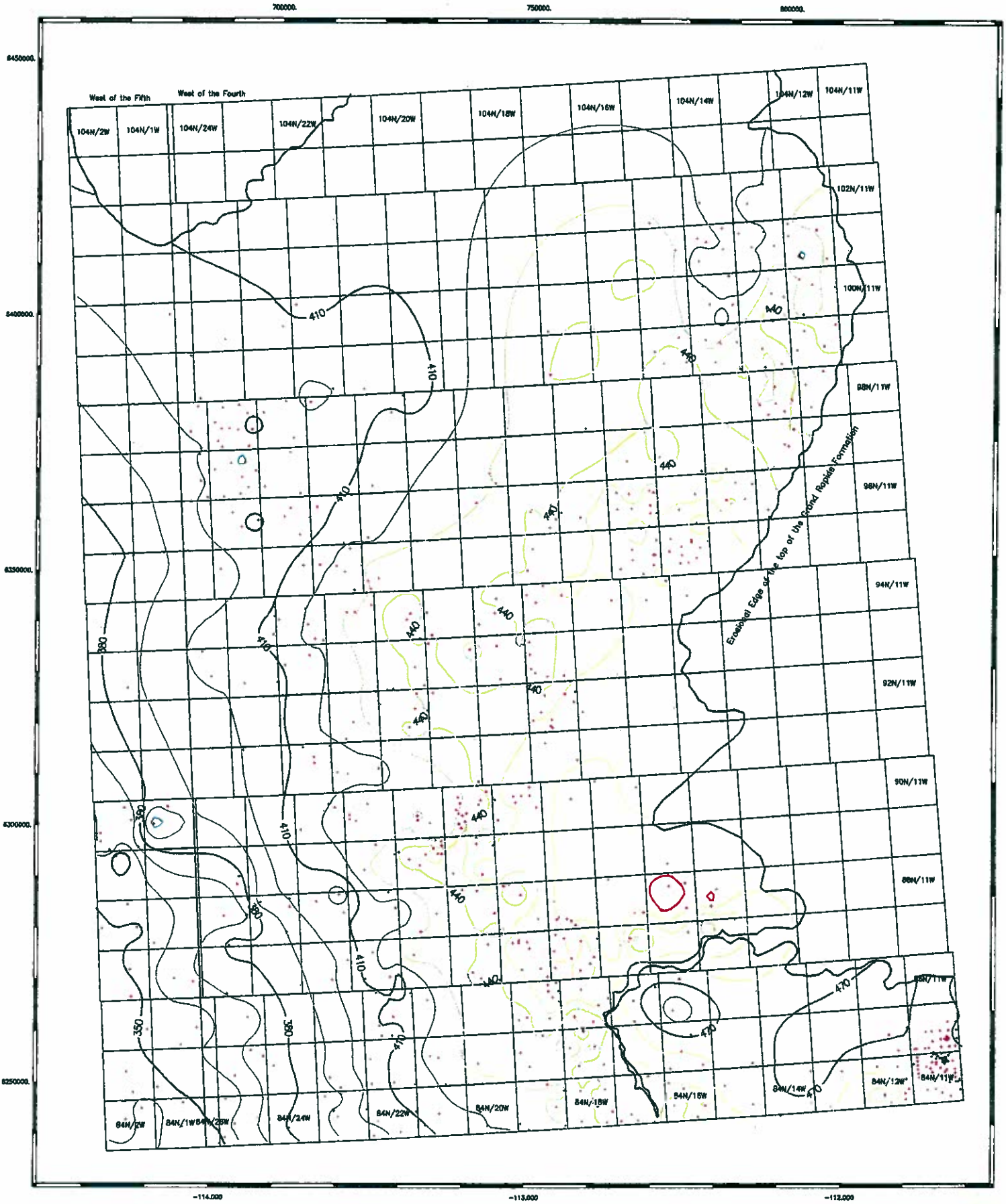

Figure 10. Structure on top of the Grand Rapids Formation

(T82 R17W4) along the Athabasca River between Pelican Rapids and 8 km downstream from Joli Fou Rapids (Figure 1). The Joli Fou Formation is made up of dark grey, noncalcareous shale. Very thin bedded lenses of fine to medium grained sandstone are common. Accessories include calcite, siderite, pyrite, bentonite and nodular phosphorite (Glass, 1990).

In the Birch Mountains the Joli Fou Formation ranges from 0 to over 30 m thick (Figure 8). The unit is thin along the southern margin of the Birch Mountains where the top of the Grand Rapids Formation is structurally elevated. In the subsurface the variable thickness of the Joli Fou Formation can most often be attributed to the erosional contact with the overlying Pelican Formation. Localized incision into the Joli Fou Formation and the subsequent filling of these lows with sands of the Pelican Formation is evident in the area, particularly along the southeast flank of the Birch Mountains. In some cases the Joli Fou succession has been totally removed by the erosion surface (Figure 8).

Structurally the top of the eroded Joli Fou succession is similar to, but more variable locally than the Grand Rapids Formation (Figure 11). This variability in relief, although subtle, likely highlights the topography typical of an erosion surface.

Pelican Formation (Lower Cretaceous)

The Pelican Formation disconformably overlies the Joli Fou Formation. The erosion surface separating the two formations displays significant relief in some places, particularly in the Birch Mountains. McConnell (1893) first assigned the name Pelican to an interval of strata comprising two distinct lithologies, a sand and an underlying shale. The two units were later appointed formation status that designated the sand as the Pelican Formation and the underlying shale as the Joli Fou Formation (Wickenden, 1949). Stratigraphically the Pelican Formation is equivalent to the Viking Formation of

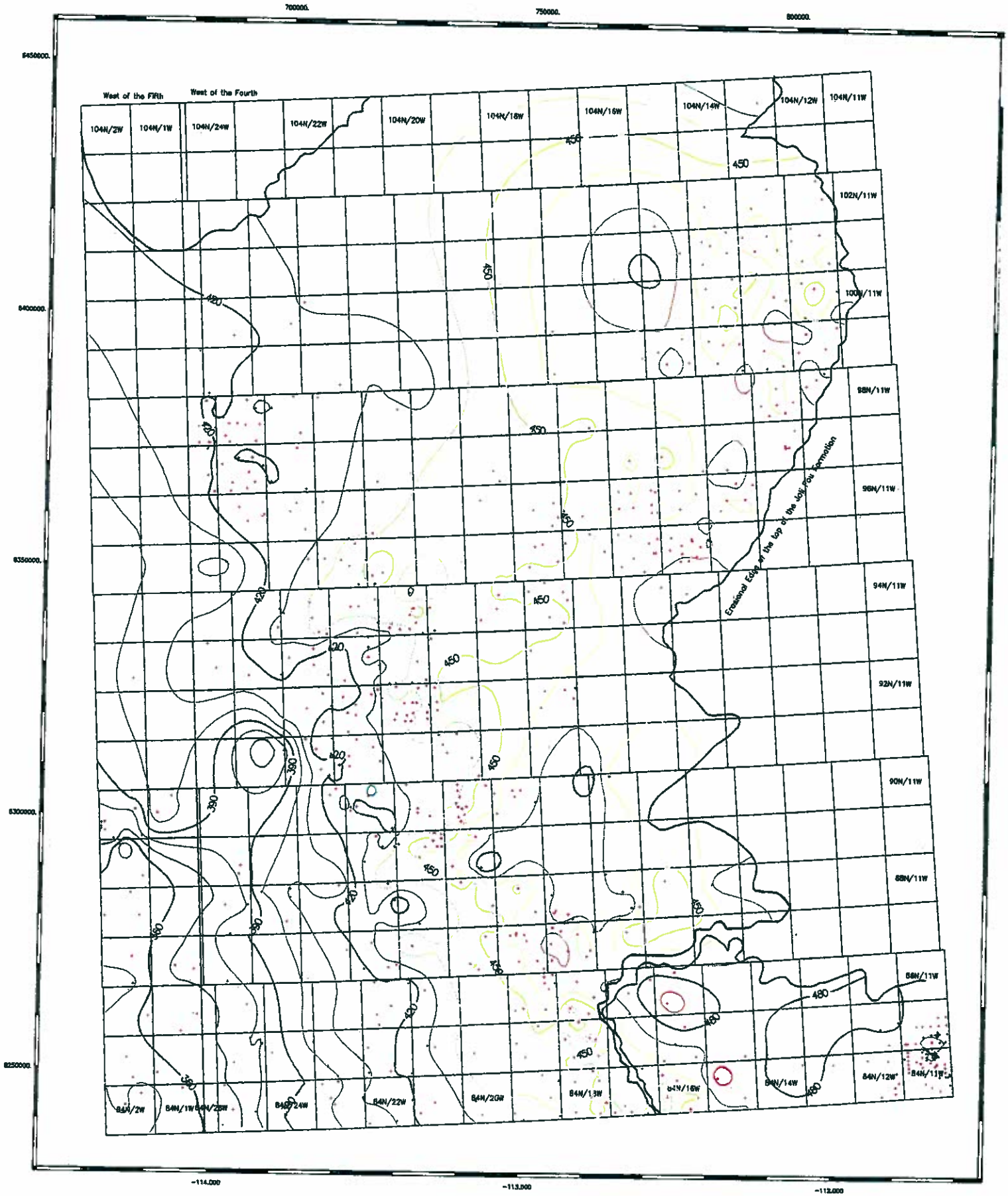

Figure 11. Structure on top of the Joli Fou Formation

central and southern Alberta and to the Paddy Member of the Peace River Formation in northwestern Alberta (Figure 3).

The type section for the Pelican Formation is situated at the mouth of the Pelican River (T79, R17W4) about 40 km south of the study area. Here, the formation is described as a coarsening upward succession comprised of relatively well washed, variably shaly, fine to medium grained, glauconitic sandstone. Interbeds of siltstone, dark grey noncalcareous mudstone, pebbly sandstone and conglomerate also characterize the interval. Shaly portions are commonly bioturbated. Conglomeratic layers near the top of the succession contain chert pebbles. Coalified plant debris is locally abundant (Glass, 1990).

The bedrock map, of northeastern Alberta, published by Green et al. (1970) indicates that the Pelican Formation pinches out near the Athabasca River in the southern part of the study area (T88, R15-18W4). Subsurface mapping and field investigations conducted during the past summer indicate the formation continues far to the north into the Birch Mountains, where the unit crops out at several locations along the northeast scarp of the highlands (T98-104, R12-13W4).

In the Birch Mountains, the lithology and character of the Pelican Formation differs significantly from the previous description. Surficial exposures of the Pelican Formation along the rim of the Birch Mountains are comprised generally of thick, unconsolidated, light beige to white, very quartzose, medium grained sand with minor mudstone bearing zones. Along Greystone Creek, a tributary to the McIvor River, the succession is characterized by several intervals of bidirectional, planar to tabular cross bedded, very clean sand with subordinate parallel bedded horizons. Individual bed sets range from 20 cm to 2 m thick (Appendix A-1). Some units are locally bioturbated. Accessories include devitrified chert, rare coalified wood fragments and minor pyrite. In the subsurface, the gamma ray profile displays the lower half of the Pelican Formation as a gradual upward coarsening succession while the upper portion tends

to have a blocky geometry (Figures 6, 7 and 8).

A contact separating the lower and upper units of the Pelican Formation is correlatable throughout most of the region (Figure 6). The nature of the contact is not known, but the surface appears to have considerable relief in some areas. The unconformable surface at the base of the Pelican Formation displays even more relief and accounts for most of the thickness variability throughout the area. Geophysical well logs indicate, in some localized areas, that the erosion surface incises deeply into the Joli Fou Formation and sometimes downcuts into the top of Grand Rapids Formation. (Figure 8).

The thickness of the Pelican Formation is extremely variable throughout the study area (Figures 6, 8 and 12). The formation is thickest (> 55 m) along an arcuate northeast trend coincident with the southern and northeastern flanks of the Birch Mountains. A surficial exposure, in the extreme northeast corner of the study area, exceeds 75 m thick. The anomalously thick sand may reflect continued subsidence of the Cretaceous succession caused by the migrating salt solution edge that now sits just to the west of the northeast scarp of the Birch Mountains. Elsewhere, with the exception of localized thickening, the Pelican Formation thins to about 25 m on either side of the arcuate feature. In the extreme southeast, the unit does become shale prone with a thin, clean sand at the base and the top.

The top of the Pelican Formation rises from the southwest along a northwest strike (Figure 13). In the northern half of the study area the surface shifts gradually to a north-northeast strike, forming a broad low that roughly follows the axis of the Birch Mountains. The Pelican Formation is conformably overlain by the Labiche Formation.

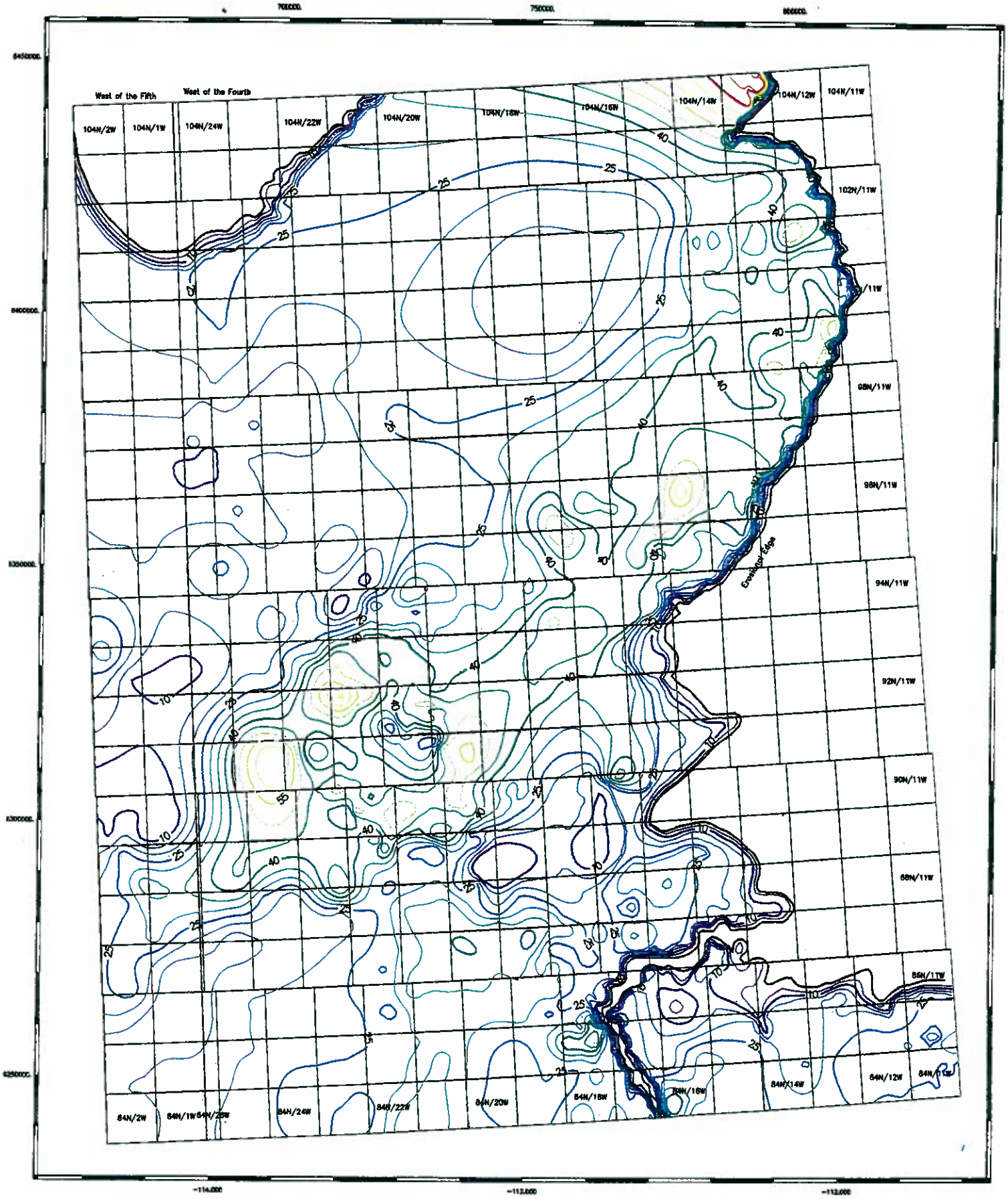

Figure 12. Pelican Formation isopach

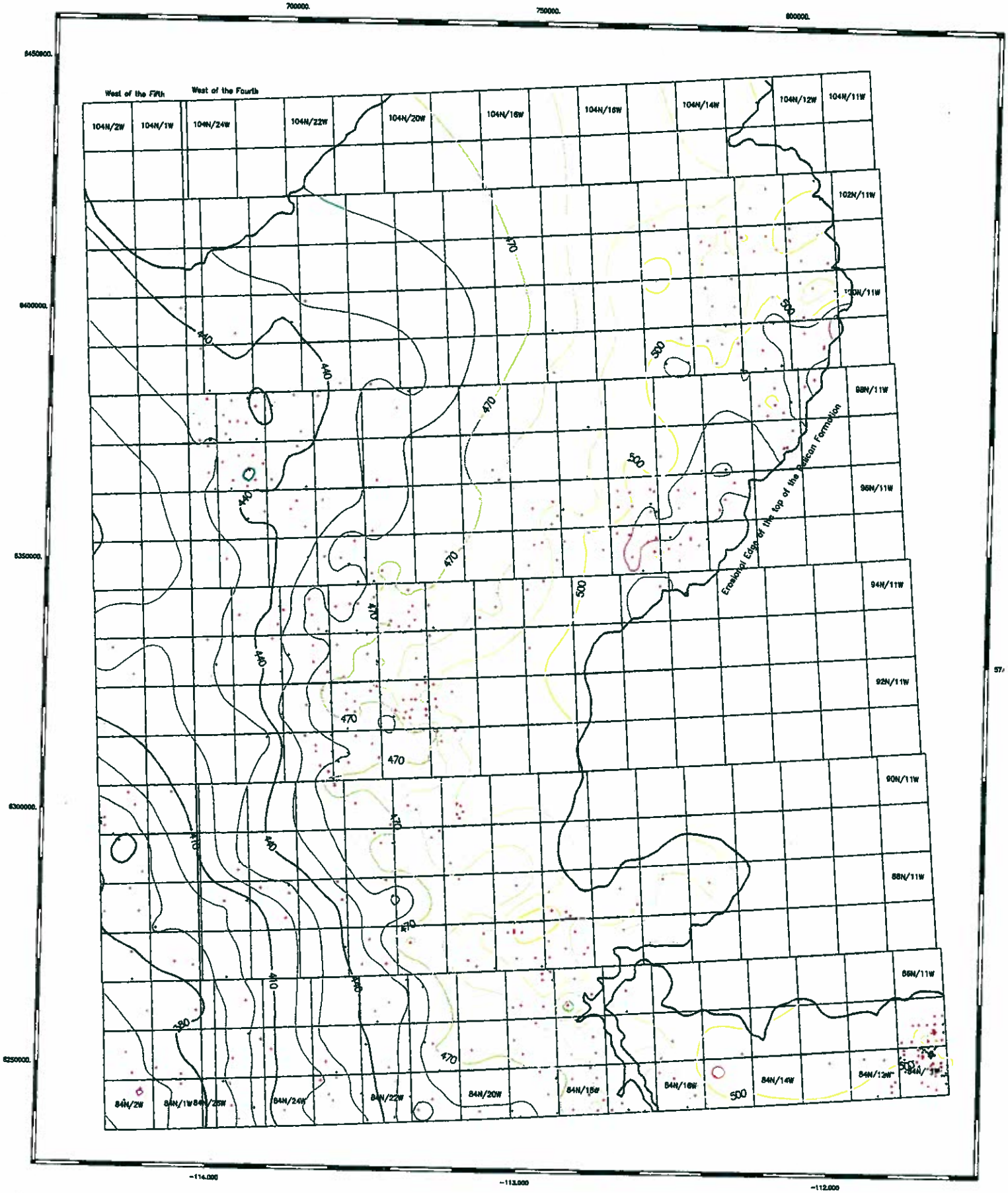

Figure 13. Structure on top of the Pelican Formation

Labiche Formation (Lower and Upper Cretaceous)

In the subsurface thick shales and mudstones of the Labiche Formation blanket the Pelican Formation throughout the study area. The Labiche succession contains three important marker horizons often used as Cretaceous stratigraphic datums in many parts of the Western Canada Sedimentary Basin. These markers include the First and Second White Speckled Shales and the Base of Fish Scales (BFS). Within the study area only the latter two are preserved, as post-Cretaceous erosional events have removed much of the interval (Figure 4). The preserved succession is stratigraphically equivalent to the Shaftesbury, Dunvegan and Kaskapau formations of northwestern Alberta (Figure 3). Quaternary sediments unconformably cap the succession. Within this section the stratigraphic interval from the top of the Second White Speckled Shale (SWSS) to the top of the Pelican Formation is mapped. Although there is some stratigraphic control above the SWSS marker well control is sparse. In the Birch Mountains the mapped interval attains a thickness of over 190 m in the southwest.

The Labiche Formation is made up of dark grey and brown shales near the top (Figure 4). The shales darken and become increasingly siliceous down section. Two important markers, an upper horizon consisting of coccolithic debris (SWSS) and a lower horizon consisting of concentrated fish remains (BFS), serve to subdivide an otherwise monotonous shale and mudstone package. Other lithologies include accumulations of calcarenite (mainly *Inoceramus* prisms) and pyritic concretions (Glass, 1990). In this report the Labiche succession has been informally subdivided into three mappable units; the lower stratigraphic interval, the middle stratigraphic interval and the upper stratigraphic interval (Figure 4). The units are separated by the two prominent, internal markers (BFS and SWSS).

Lower stratigraphic Interval: Pelican Formation to the Base of Fish Scales (Lower Cretaceous)

The interval from the top of the Pelican Formation to the BFS is stratigraphically equivalent to the Westgate Formation in central and southern Alberta (Bloch et al., 1993) and the lower part of the Shaftesbury Formation of the northwest plains (Figure 3). The base of the succession conformably overlies the sand-dominated Pelican Formation and the upper contact marks the Base of Fish Scales, a highly radioactive, organic carbon-rich zone prominent throughout much of the foreland basin.

The interval contains bioturbated, silty, often sulphurous, rusty weathering shale that grades upwards into lightly bioturbated, thin bedded to laminated argillaceous siltstone. Fish debris is abundant at the top. On geophysical well logs the interval (Figure 4) is shown as a radioactive shale overlain by an often equally thick, blocky siltstone capped by the highly radioactive marker horizon (BFS). Shales and mudstones of the lower unit thin gradually from southwest to northeast whereas the upper siltstone unit thickens (Figure 6).

The interval is thickest in the northwest (> 55 m) and thins to less than 25 m to the southeast (Figure 14). The upper surface (BFS marker) closely resembles the structural topography on the Pelican Formation, rising uniformly out of the basin from the southwest (Figure 15).

Middle Stratigraphic Interval: Base of Fish Scales to the top of radioactive zone (Upper Cretaceous, Albian-Cenomanian boundary)

The stratigraphic interval from the BFS marker upwards through to the top of a very radioactive shale is roughly equivalent to the Fish Scales Formation proposed by Block et al. 1993. The Base of Fish Scales has also been termed "Fish Scales

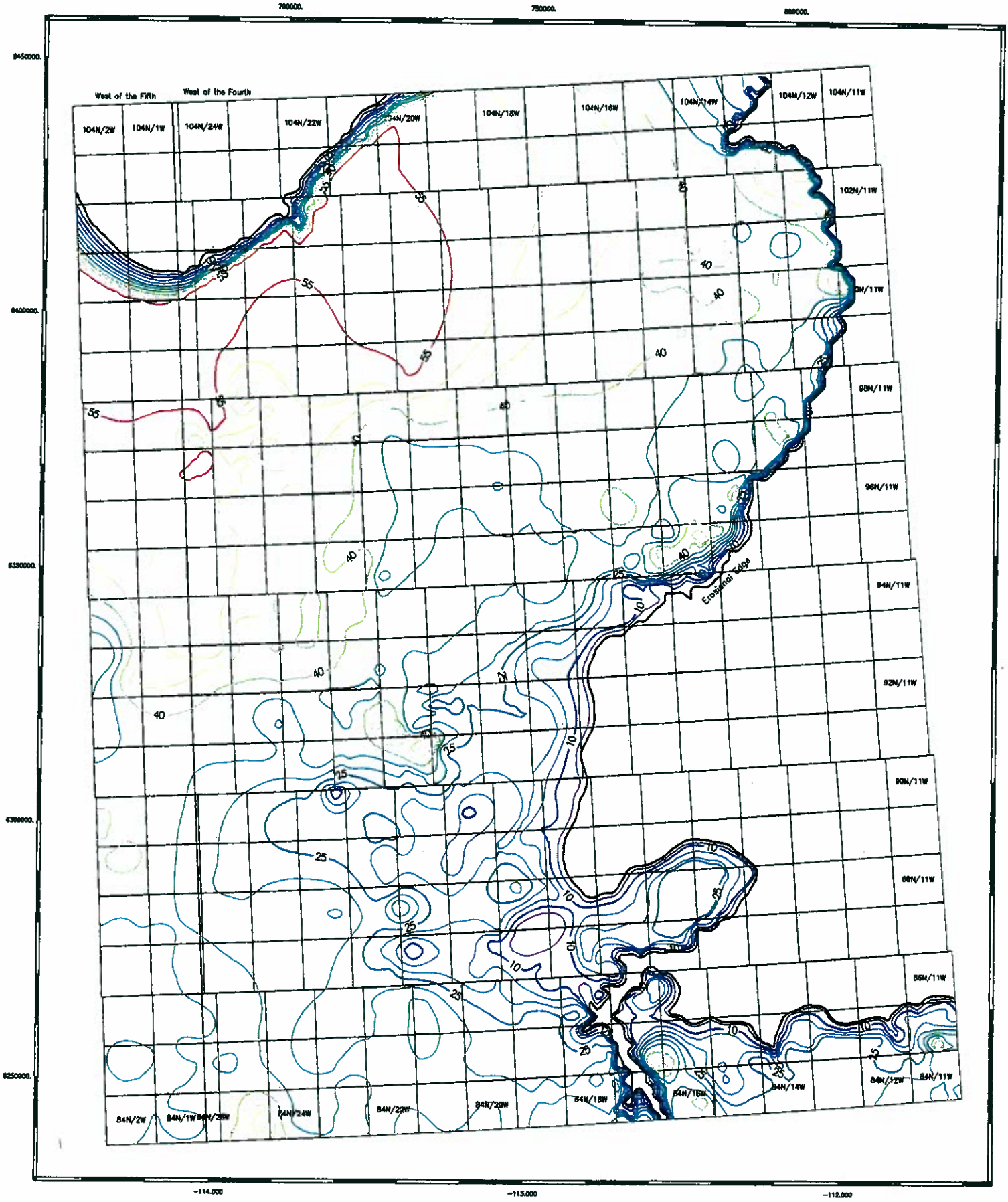

Figure 14. Lower Stratigraphic Interval, Pelican Formation to Base Fish Scales isopach

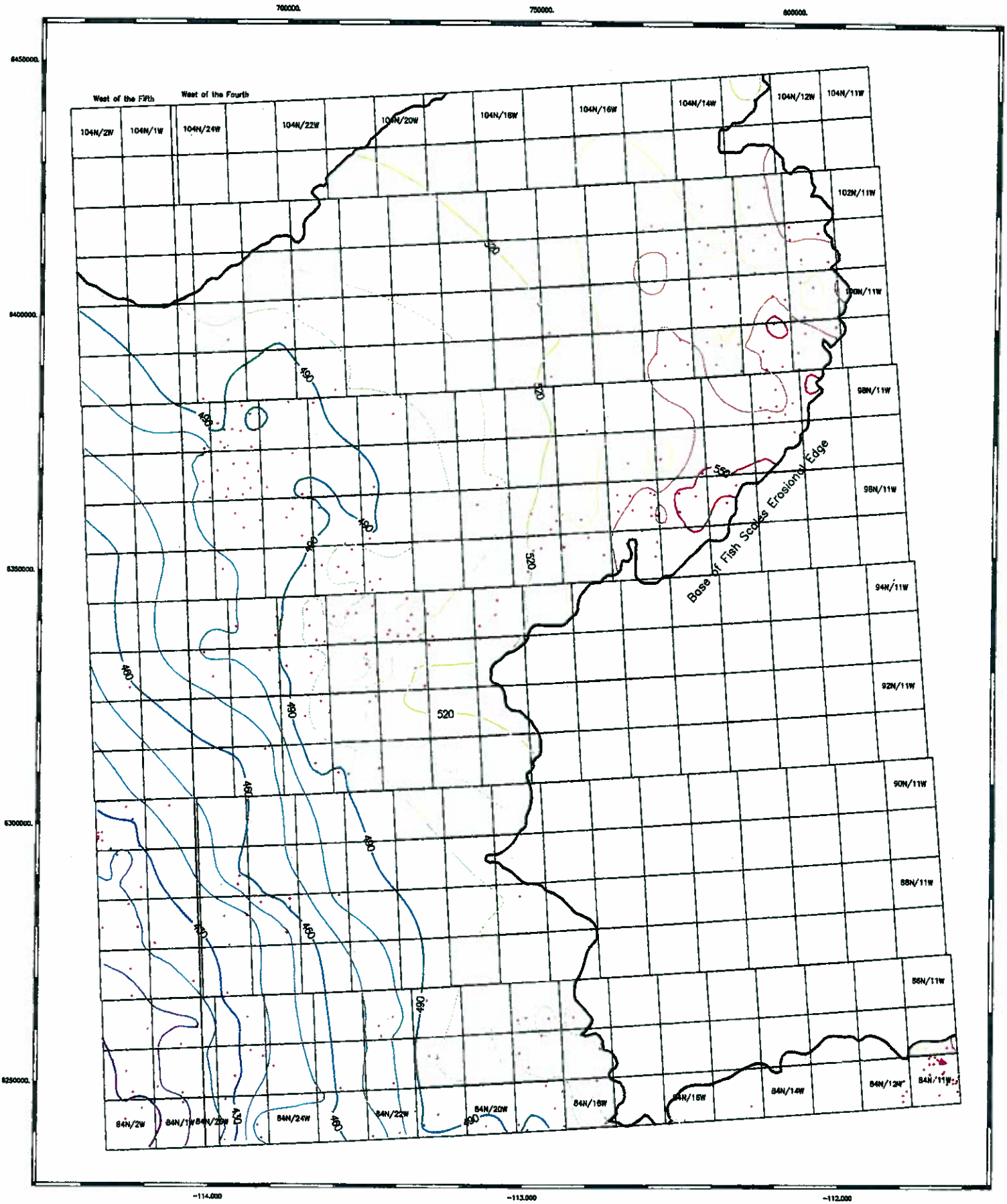

Figure 15. Structure on the Base of Fish Scales

Sandstone", "Fish Scale Zone", and "Fish Scale Marker Bed" (Leckie et al., 1992). The Base of Fish Scales denotes a regional paraconformity (Stelck et al., 1958). In the Peace River area the Base of Fish Scales (Fish Scale Marker Bed) marker sharply overlies shales of the lower Shaftesbury Formation (Leckie et al., 1992). A prominent, interbedded siltstone and sandstone bed containing abundant skeletal fish remains (bone bed) marks the surface. A contact, possibly representing a similar boundary, is found at an outcrop (Appendix A-2) on Greystone Creek in the Birch Mountains. The knife sharp contact is marked by a 20 cm thick sandy siltstone containing fish debris that abruptly overlies silty, rusty weathering shale.

Above the contact the succession consists of wave-rippled, lightly bioturbated, very thin, lenticular bedded argillaceous siltstone, some very fine grained sandstone and shale. Fish debris is common. Thin sandstones are rarely bioturbated, noncalcareous and often contain very thin wisps of mud. The interval contains varying amounts of pyrite.

The highly radioactive interval is variable thick throughout the area, but is generally thickest (~16 m) in the northwest and thins to the south and northeast (Figure 16). The unit crops out at several locations along the northeast scarp of the Birch Mountains, proximal to the McIvor River.

Current exploration activities in Birch Mountains are focussing on this interval. The succession contains abundant sulphides, primarily in the form of pyrite. Very fine grains of gold have also been recovered from some surficial exposures.

Upper Stratigraphic Interval: Top of radioactive interval to the Second White Speckled Shale (Upper Cretaceous)

A gamma ray profile from the top of the radioactive unit to the SWSS indicates a thick

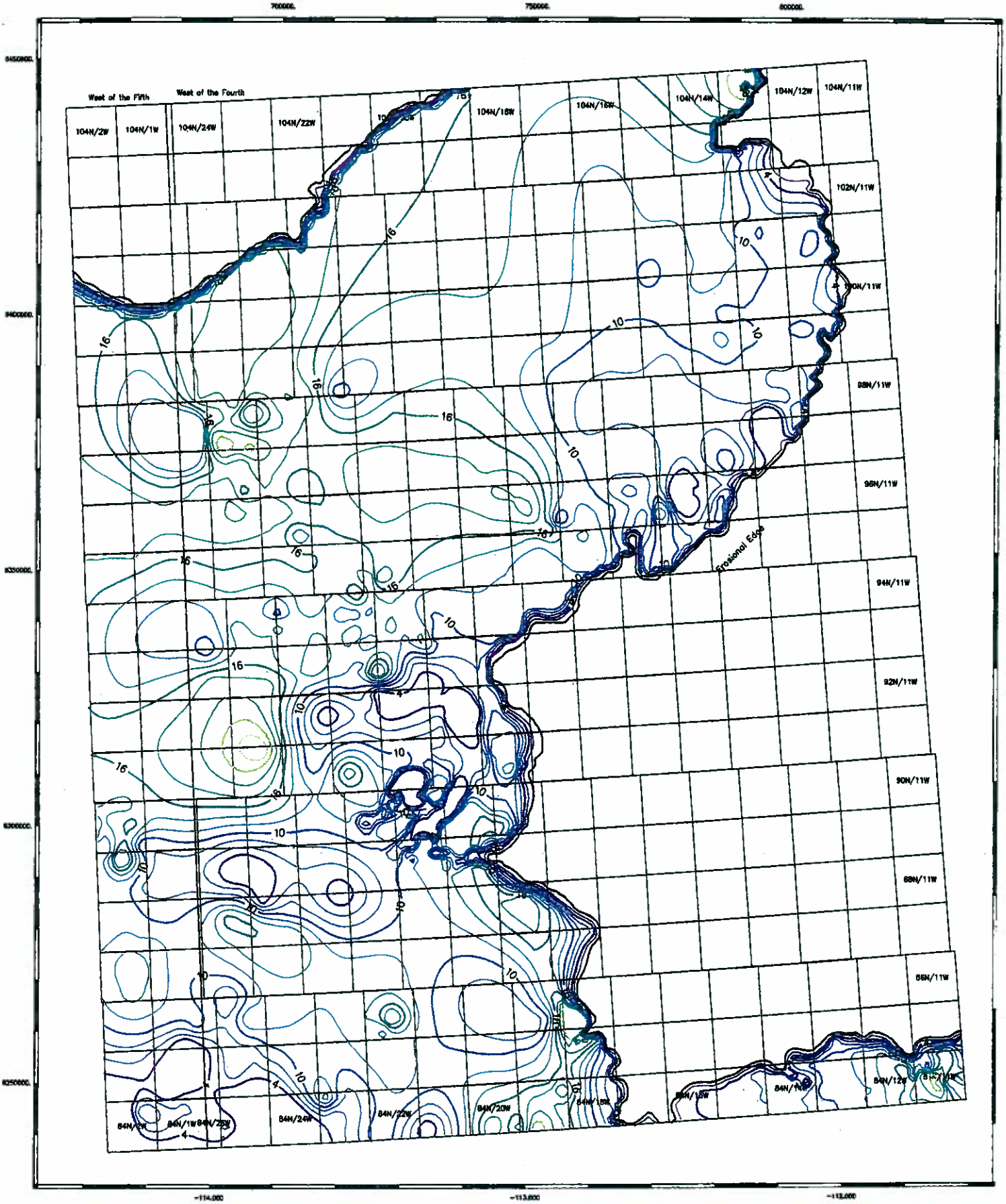

Figure 16. Middle Stratigraphic Interval, Base of Fish Scales to the top of the radioactive interval isopach

succession of mudstones and siltstones except for rare, discontinuous, often blocky sandstones (Figures 6 and 8). Stratigraphic equivalents include the upper part of the Shaftesbury Formation, the Dunvegan Formation and the lower portion of the Kaskapau Formation of the northwest plains of Alberta (Figure 3). The succession is also equivalent to the Belle Fourche Formation of central and southern Alberta (Bloch et al., 1993). The contact between the underlying unit and this interval was not found during preliminary field investigations in the Birch mountains. Several isolated exposures of the succession were located, but all were of limited vertical extent. Elsewhere in the basin the contact is described as transitional and contains several thin bentonite beds (Bloch et al., 1993).

The SWSS (top of the interval) is described as regularly laminated, mainly calcareous shale and mudstone intercalated with shaly chalk and skeletal calcarenite. Subordinate accessories include bentonite, fish debris, concretionary layers of calcite, siderite and nodular phosphorite. Thin siltstones and sandstone occur locally. The shale and mudstones often contain white to light bluish grey coccolithic debris. Skeletal calcarenites are often composed of *Inoceramus* prisms and foraminiferal tests (Glass, 1990).

In the subsurface the remainder of the stratigraphic interval ranges from thick, monotonous mudstones and siltstones to a succession vaguely subdivided into two or three coarsening upward cycles that likely grade from shale at the base to coarse silt or very fine grained sand at the top. A few wells show anomalously thick, blocky to upward coarsening, discontinuous sand bodies at various stratigraphic levels. Limited exposures at the surface, along the northeast rim of the Birch Mountains, consist of rusty weathering, calcareous to non calcareous shale containing one or more thin (< 1 m) resistive, coarse sand beds. The sand beds are generally made up of chert and quartz, are often calcareous and locally contain abundant pyrite. These beds also include rare to moderate concentrations of skeletal fish debris. Very thin, single to multiple bentonite beds were found at some exposures.

The entire interval, where preserved, attains thicknesses of over 110 m in the Birch Mountains (Figure 17). The succession has some variability in thickness, but thinning on the isopach map generally reflects post-Cretaceous erosion that has stripped back the sedimentary package. Sparse well control prohibits accurately defining the top of the SWSS, but the surface generally maintains the structural trends observed by the underlying units (Figure 18).

Selected intervals within the succession contain notable amounts of pyrite. Drill cuttings from 11-9-96-17W4 contain 25-60% pyrite from a depth interval of 150 to 175 m. Samples above and below the sulphide enriched zone average about 5% pyrite.

Cretaceous Exposures in the Birch Mountains

The northeast rim of the Birch Mountains reveals numerous Lower and Upper Cretaceous exposures (Figure 2). Because the succession is dominated by thick shales and mudstones many of the sections are severely slumped making them unusable for detailed stratigraphic work. The best exposures include the interval from the Pelican Formation through to the Base of Fish Scales.

Sands of the Pelican Formation crop out best along the incised, glacially modified McIvor River valley and the tributaries that feed it. Along Greystone Creek, a tributary to the McIvor River, clean, white Pelican sands attain thicknesses of greater than 70 m (Appendix A-1). Although the exposed sands are unconsolidated, sedimentary structures are remarkably preserved. Structures are dominated by planar and tabular cross bed sets.

In the same region the interval from the top of the Pelican Formation to the Base of Fish Scales also crops out (equivalent to the Westgate Formation; Bloch et al., 1993).

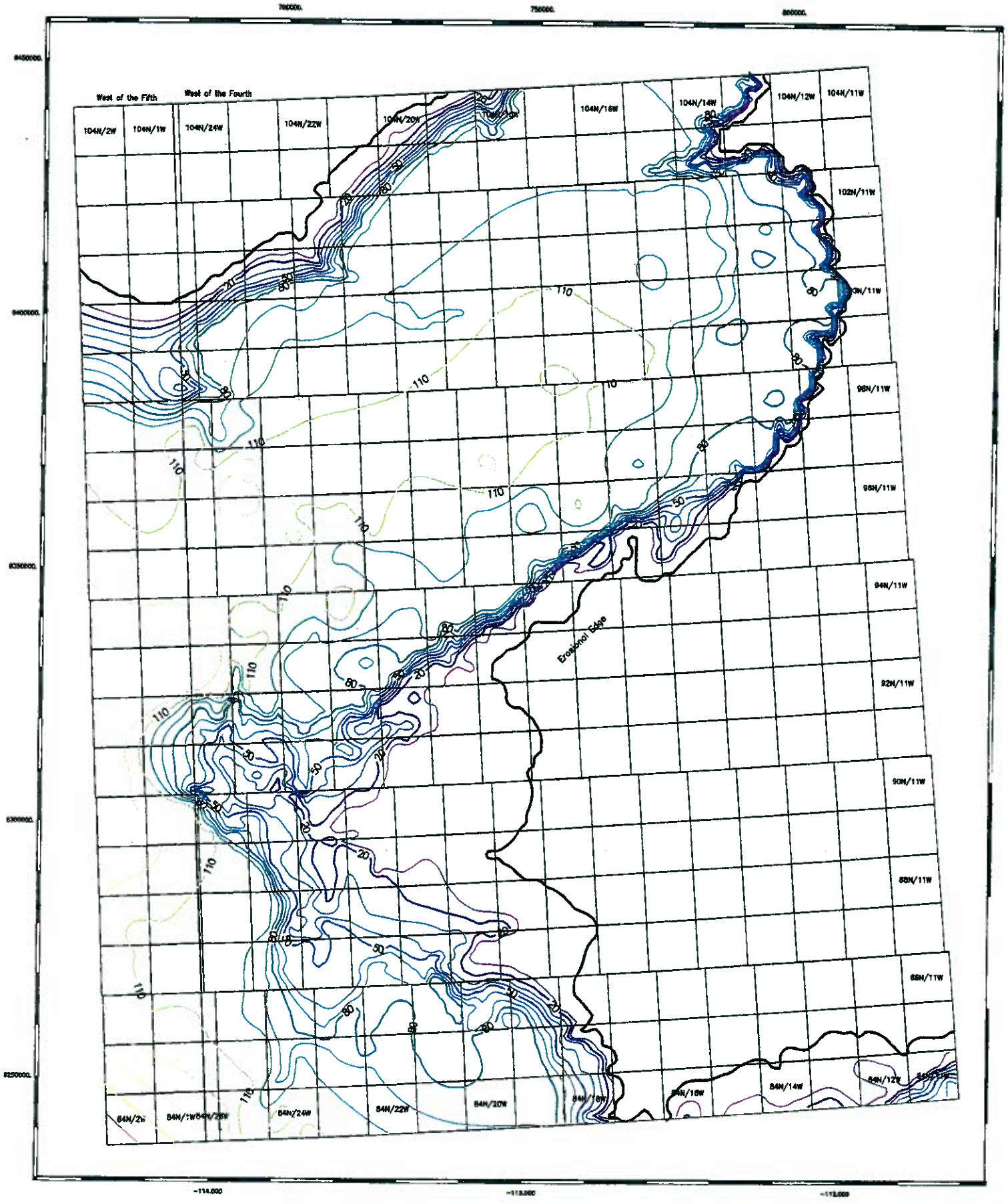

Figure 17. Upper Stratigraphic Interval, top of the radioactive interval to the Second White Speckled Shale isopach. Note that Base of Fish Scale Erosional Edge is used.

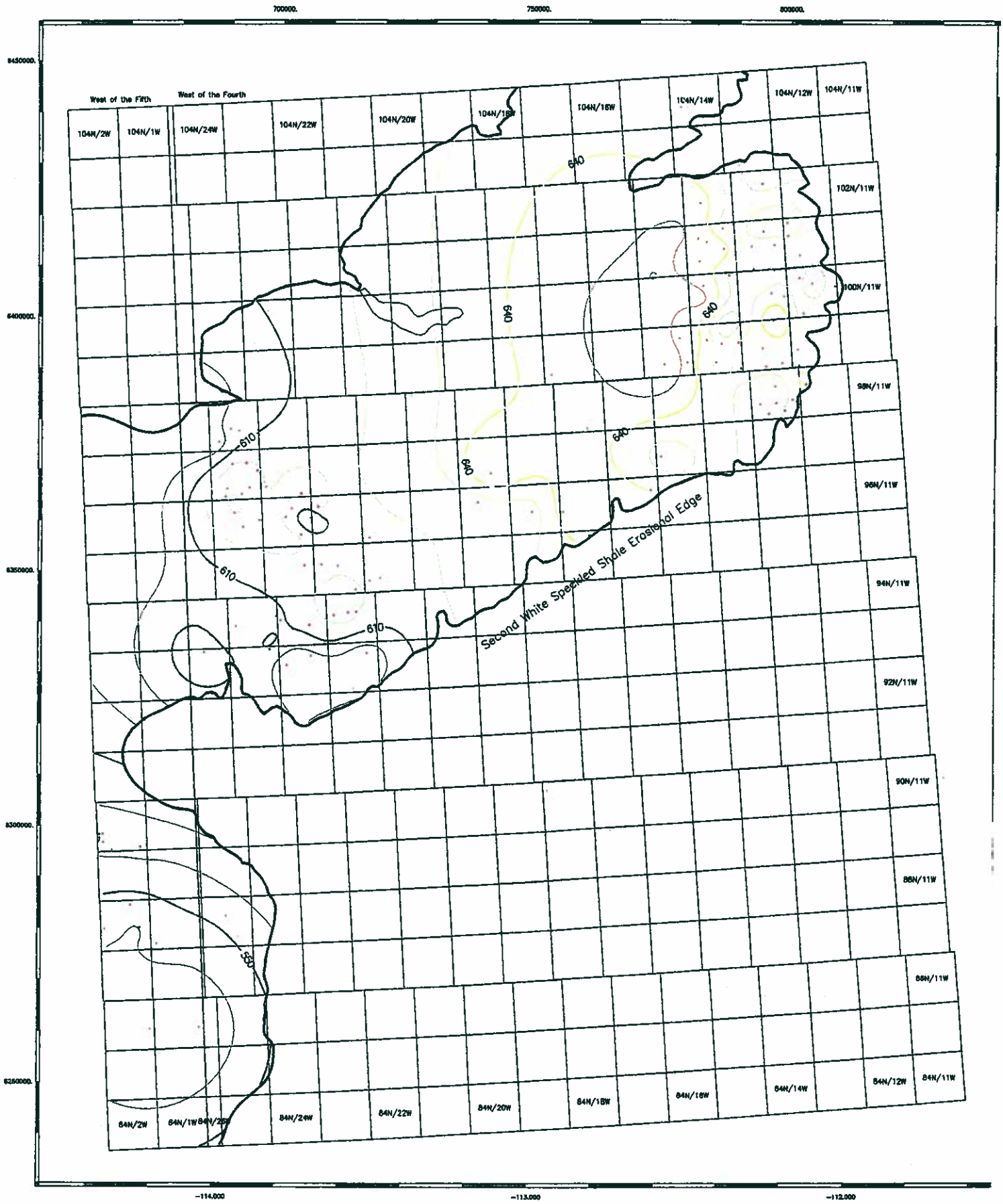

Figure 18. Structure on the Second White Speckled Shale

The interval is often slumped and talus covered, so continuous, lengthy sections are rare (Appendix A-2). Dark grey, monotonous, often sulphurous shales and mudstones characterize this interval. The thin, but distinctive radioactive horizon above the Base of Fish Scales marker is well exposed in a few sections proximal to the McIvor River valley. Measured elevations from many of the sections (using an altimeter and surface topography maps) tie in closely with nearby subsurface control.

Several exposures, of limited vertical extent, situated within other tributaries around the rim of the highlands, are comprised of mudstones with thin (< 50 cm) medium to coarse grained, somewhat resistant sand beds often containing abundant skeletal fish remains. Some of these sands contain abundant sulphides. Thin, individual to multiple bentonite beds are present in a few of the sections. Elevation data indicate that these units are stratigraphically positioned near the Second White Speckled Shale.

These fossiliferous bone beds may serve as important stratigraphic markers within the often featureless mudstone/shale package identified from the SWSS to the top of the radioactive interval. The thick succession requires additional stratigraphic work to further constrain these beds. Current mineral exploration activities have targeted these particular units.

Cretaceous sections are also exposed along the Asphalt, Buckton and Tar rivers, located along the northeast flank of the Birch Mountains. Additional field investigation is key to further refining the Cretaceous stratigraphy in the region.

Overlying Cretaceous Bedrock (above SWSS) and Quaternary Cover

Stratigraphic control above the SWSS is poor throughout most of the region. Post-

Cretaceous erosion has removed most of the strata above the SWSS except for isolated regions in the Birch Mountains and in the southwest corner of the study area. Typically, geophysical logs were not run within the upper portions of many of the drill holes, and if they were, the interval was often cased which severely dampens or obliterates the log response.

Glaciation has significantly modified some regions of the study area, particularly the Birch Mountains. Distinct, remarkably straight glacial flutes trend southwest down the axis of the Birch Mountains. One well (7-6-100-17W4) in the mountains intersects a deep (150 m) Quaternary valley that incises into the Labiche Formation, bottoming out within about 40 m of the BFS marker. Quaternary sediments within the valley include unconsolidated, well-rounded, medium to coarse grained quartz, black chert and other exotic igneous and metamorphic rock fragments. Cretaceous skeletal debris such as *Inoceramus* prisms are also common. The drilling cuttings also contain notable quantities of pyrite grains in the form of (up to 50% in some samples) agglomerated framboids and individual, pristine grains displaying well-developed crystal faces. The orientation of the valley is purely speculative at this time as only one well bore has penetrated the succession. A topographic low extending from the axis of the McIvor River turns abruptly to the north-northwest from a previous southwest trend. The incised valley intersected by the drill hole may be linked in some way to the McIvor valley. Quaternary sediments are well exposed along the southwesterly reaches of the u-shaped McIvor River valley. Here, unconsolidated coarse grained Quaternary sediments directly overlie eroded sands of the Pelican Formation. Sand and gravel filled Quaternary valley complexes have been identified in other parts of the study area (Horne and Seve, 1991), but the paleodrainage network and extent of these features is poorly understood.

Summary

Northeastern Alberta preserves a variably thick succession of Cretaceous strata unconformably bound at the base by eroded Devonian carbonates and at the top by relatively thin, coarse grained Quaternary siliciclastics. Post-Cretaceous erosion has removed large portions of the sedimentary succession throughout the area. The sedimentary package can be broadly divided into two successions, the Mannville Group (lower interval) and strata equivalent to the Colorado Group (upper interval) comprised of the Joli Fou, Pelican and Labiche formations. Thick shales and mudstones of the Labiche Formation can be subdivided into mappable units based upon two regional markers, the Base of Fish Scales and the Second White Speckled Shale.

Post-Cretaceous erosion has created a series of backstepping erosional edges which define the boundaries of the Cretaceous units at the surface. Subsurface data acquired from nearly 1400 wells combined with Cretaceous exposures from the Birch Mountains were used to characterize the mapped intervals.

Noncalcareous shales of the Joli Fou Formation are unconformably overlain by thick, clean sands of the Pelican Formation. The erosional contact, in places, incises deeply into the Joli Fou Formation and sometimes bottoms out into the top of the Mannville Group. Pelican sands, that generally infill the erosional lows, are thickest along the southern and northeast flank of the Birch Mountains. Thick shales and mudstones of the Labiche Formation conformably overlie the Pelican Formation.

Field investigations, in the Birch Mountains, over the past two summers have identified anomalous concentrations of sulphides within the interval from the Base of Fish Scales marker to the Second White Speckled Shale. Very fine grains of gold have also been recovered from stream sediment samples and are believed to be derived locally from the Cretaceous bedrock. Comprehensive geochemical sampling conducted by a mineral exploration company has identified several targets that may

be drilled as soon as this summer. Sulphide-rich beds, found within tributaries that drain the northeast scarp of the highlands, require further work to position them accurately within the Labiche succession.

Conclusions

1) The interval from the top of the Lower Cretaceous Mannville Group (Grand Rapids Formation) to the Upper Cretaceous Second White Speckled Shale is a thick succession of shale, mudstones and siltstones except for the Pelican Formation that is comprised dominantly of thick, clean, very quartzose sand. A previously published bedrock map of the region suggested that the Pelican Formation pinches out in the southern part of the study area. Subsurface correlation and field work show the formation to be far more extensive than earlier mapped. The unit is particularly interesting in the Birch Mountains where the thick sands infill erosional lows on the Joli Fou Formation. A second correlatable stratigraphic pick, within the Pelican Formation, also shows significant relief and may also be an erosional surface, but additional work is required to define the nature of the contact.

2) Extensive post-Cretaceous erosional events have stripped back much of the Cretaceous strata in northeastern Alberta. A series of, computer derived, erosional edges have been generated to outline better the present configuration of these deposits at the surface. The edges were refined using well and outcrop data.

3) Despite extensive slumping of many of the shale prone units, some excellent exposures of the Cretaceous formations are present along the northeast rim of the Birch Mountains, particularly the interval from Pelican Formation and to the Base of Fish Scales marker.

4) Significant amounts of sulphide, primarily in the form of pyrite, and notable amounts of very fine grained gold have been recovered from the interval between the Base of Fish Scale marker and the Second White Speckled Shale. It appears, at this time, that the majority of the sulphides and gold retrieved from stream sediment and bedrock sampling is derived from somewhere above the highly radioactive zone (above the BFS). Drill cuttings from a couple of wells in the Birch Mountains suggest the same

stratigraphic interval.

5) Additional geological studies are required to position, stratigraphically, the fossiliferous, sulphide-rich sandstone beds that are present below the Second White Speckled Shale. Exploration activities have targeted several geochemical anomalies in the Birch Mountains. These proposed sites along with a possible stratigraphic test hole, jointly funded by the Alberta Geological Survey and the Geological Survey of Canada, may be drilled as soon as this summer (1996). Drill hole data gathered from these sites should isolate the sandstone beds within the thick, shale and mudstone prone interval.

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Appendix A - Cretaceous Exposures in the Birch Mountains

A-1. 95-DL-05

A-2. 95-DL-06

95-DL-05 Greystone Creek
UTM 6432762N 0437864E

Date logged: August 30, 1995

Logged by: Dale Leckie (GSC), Darrell Cotterill (AGS)

Datum elevation: 488.00 m

Remarks: Very thick, quartose sands of the Pelican Formation
capped by sulphurous, dark grey mudstones of the Westgate Formation
Greystone Creek-Northwest trending tributary to the McIvor River(Birch Mountains)

LEGEND

LITHOLOGY

SAND/SANDSTONE | SHALE/MUDSTONE | clay/claystone | matrix supported | SILT/SILTSTONE

CONTACTS

Sharp | Bioturbated

Sample taken

PHYSICAL STRUCTURES

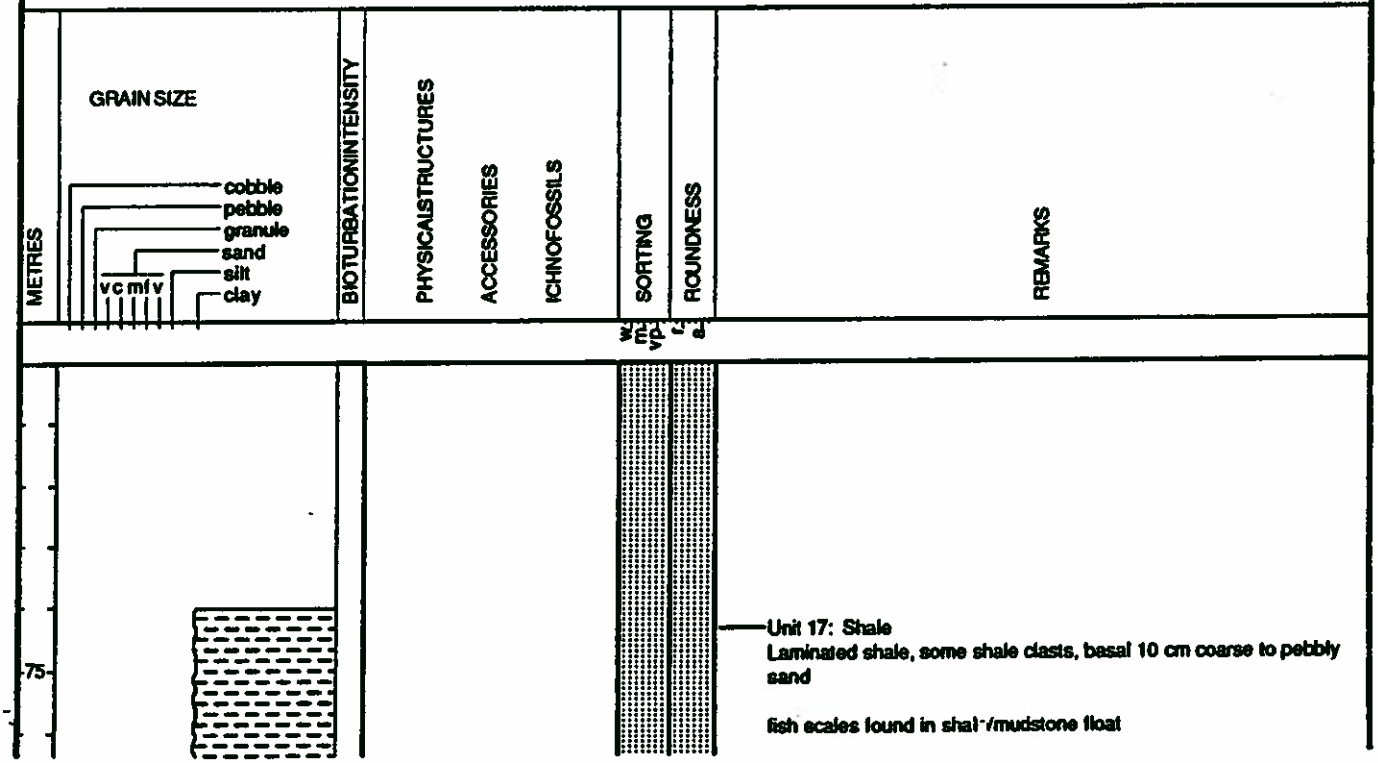
Current Ripples | Trough Cross-strat. | Oscillatory Ripples
Planar Tabular Bedding | High Angle Tabular Bedding | Low Angle Tabular Bedding
Flaser Bedding | Lenticular Bedding | Reactivation Surface
Double Mud Drapes

LITHOLOGIC ACCESSORIES

Sand Lamina | Shale Lamina | Pebbles/Granules
Sid - Siderite | Cherty | Py - Pyrite
Rip Up Clasts | Coal Fragments | Mc - Micaceous

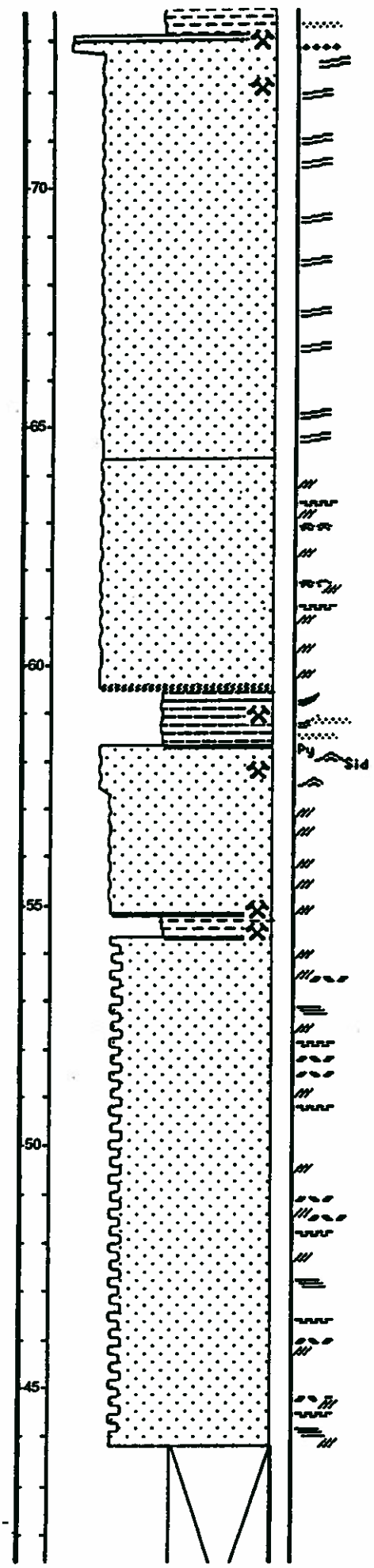
ICHNOFOSSILS

Skolithos | Planolites | Palaeophycus
Arenicolites | Trichichnus



Unit 17: Shale
Laminated shale, some shale clasts, basal 10 cm coarse to pebbly sand

fish scales found in shale/mudstone float



Contact: Westgate/Pelican formations

Unit 16: Well sorted, cross bedded sand
Coarse grained sand, well sorted and rounded, dominantly low angle cross bedding (10 to 70 cm), pebble layer at top

Unit 15: Cross bedded sand
Coarse grained, cross beddded sand, bed sets from 70 cm to 2 m with some subordinate sets 10 cm thick, minor mudstone, some mud drapes
Dominant flow 290 to 285 degrees, subordinate flow 80 to 85 degrees

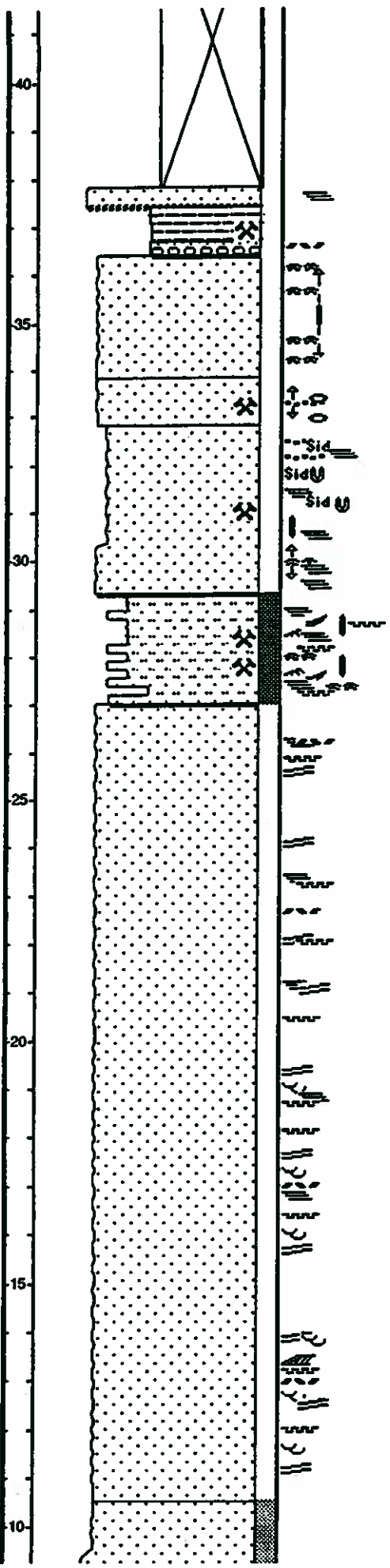
Unit 14: Claystone
Claystone with thin stringers of sand, becomes sandy and lightly bioturbated at top

Unit 13: Cross bedded limonitic sand
Medium grained, limonitic sand, large bidirectional cross beds (50-60 cm), small channel at base
Upper meter is comprised of coarse grained, wave rippled, sideritic and limonitic sand that becomes increasingly sulfurous towards the contact with the overlying unit, top 50 cm contains pyrite lenses
Limonitic at the base

Unit 12: Shale
Thin (0.5 to 3 cm), parallel bedded, alternating grey and black shale

Unit 11: Sand with thin shale interbeds
Medium grained sand, thin planar-tabular cross bedding (10-20 cm), parallel laminated intervals, shale clasts and chips (3-20 cm)
Discontinuous, bioturbated shale beds (up to 3 cm)

Unit 10: covered interval



Unit 9: Limonitic sand
Bright yellow, coarse grained

Unit 8: Claystone.
Thinly interbedded (5 cm), alternating beds of dark grey and grey claystone, upper surface bioturbated

Unit 7: Shale clast zone, resistant and bioturbated

Unit 6: Burrowed sand
White, medium grained, bioturbated, contains mud drapes

Abundant vertical Skolithos burrows up to 30 cm long

Unit 5: Organic rich sand
Black, medium grained sand, lenses and pockets of organic matter

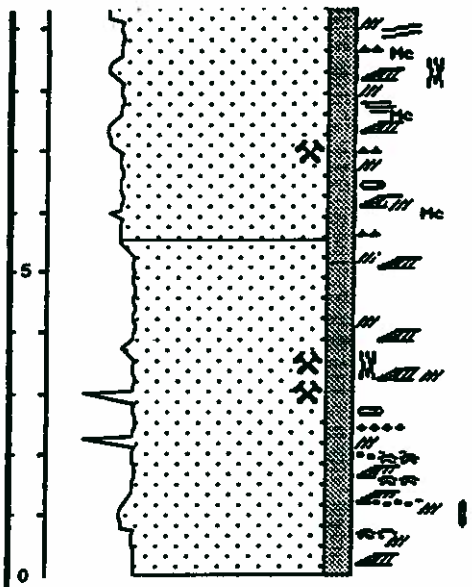
Unit 4: Siderite cemented, fine grained sand
Dominantly parallel laminated, fine grained sand.
Basal meter medium grained, contains mud drapes
Top of unit is siderite cemented and carbonaceous

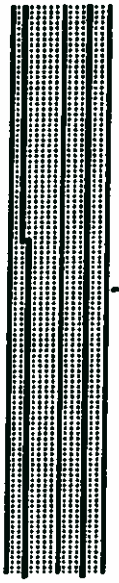
Skolithos and Arenicolites (mud lined and sand filled)

Unit 3.5: Thinly interbedded sand, silt and mud
Parallel bedded sand (5-15 cm), some ripples, mud drapes and flasers, sand filled vertical burrows, minor Glossifungites

Unit 3: Cross bedded, unconsolidated sand.
Trough cross bedded and parallel bedded sands (20-60 cm), dominant northerly trending bed sets, subordinate south trending bed sets, dispersed mud layers, broad shallow scours, shale clast(up to 3 cm) horizons (some as channel fill)

Unit 2: Unconsolidated, white sand





Medium to coarse grained sand, decimeter to 1 m thick cross beds sets, mica and devitrified chert, individual beds well sorted, abundant channel forms up to 2 m thick (cut and fill), abundant parallel lamination
Less mud than underlying unit

Rare Trichichnus and Planolites (sand filled)

Unit 1: White, unconsolidated, very quartzose sand (95% upper fine to medium grained, 5% granules)
Dominant bidirectional, planar tabular cross bedding (up to 60 cm), double mud drapes in lower part of section, sigmoids, some localized channels up to 1.5 m deep, abundant cut and fill, some clay chips and localized wood debri
Some cross bed sets show lateral variation from sand forsets grading to mud forsets, semi regular spacing every 20-35 cm)

Mud lined Skolithos (low diversity, locally abundant), rare Trichichnus and Planolites

95-DL-06 Greystone Creek
UTM 6434008N 0436830E

Date logged: August 30, 1995

Logged by: Dale Leckie (GSC), Darrell Cotterill (AGS)

Remarks: Top Pelican Formation to the Base of Fish Scales
Greystone Creek-Tributary to the McIvor River (Birch Mountains)

LEGEND

LITHOLOGY

SAND/SANDSTONE
sandy silt
clayey silt
silty shale
sandy shale

CONTACTS

Sharp

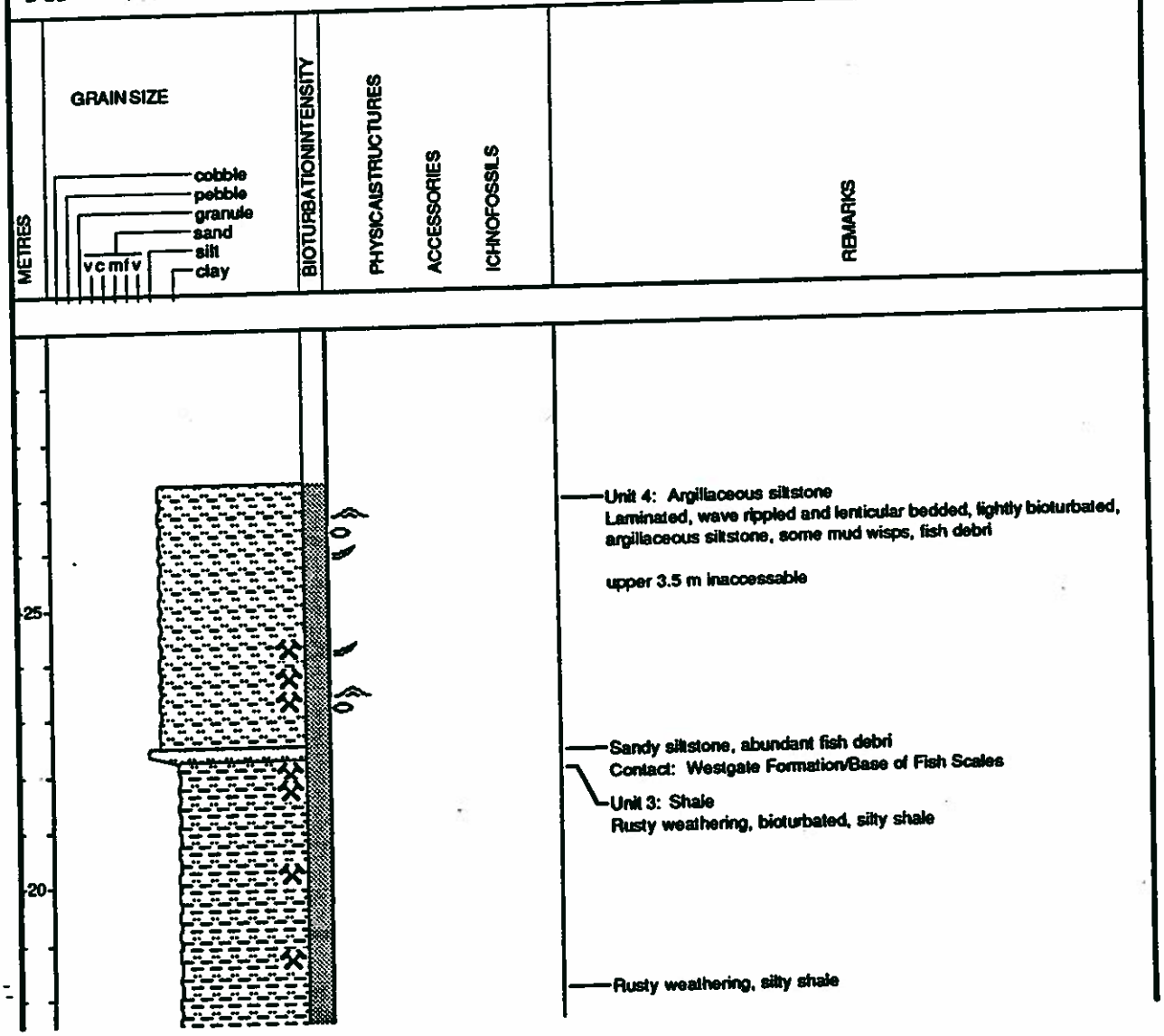
sample taken

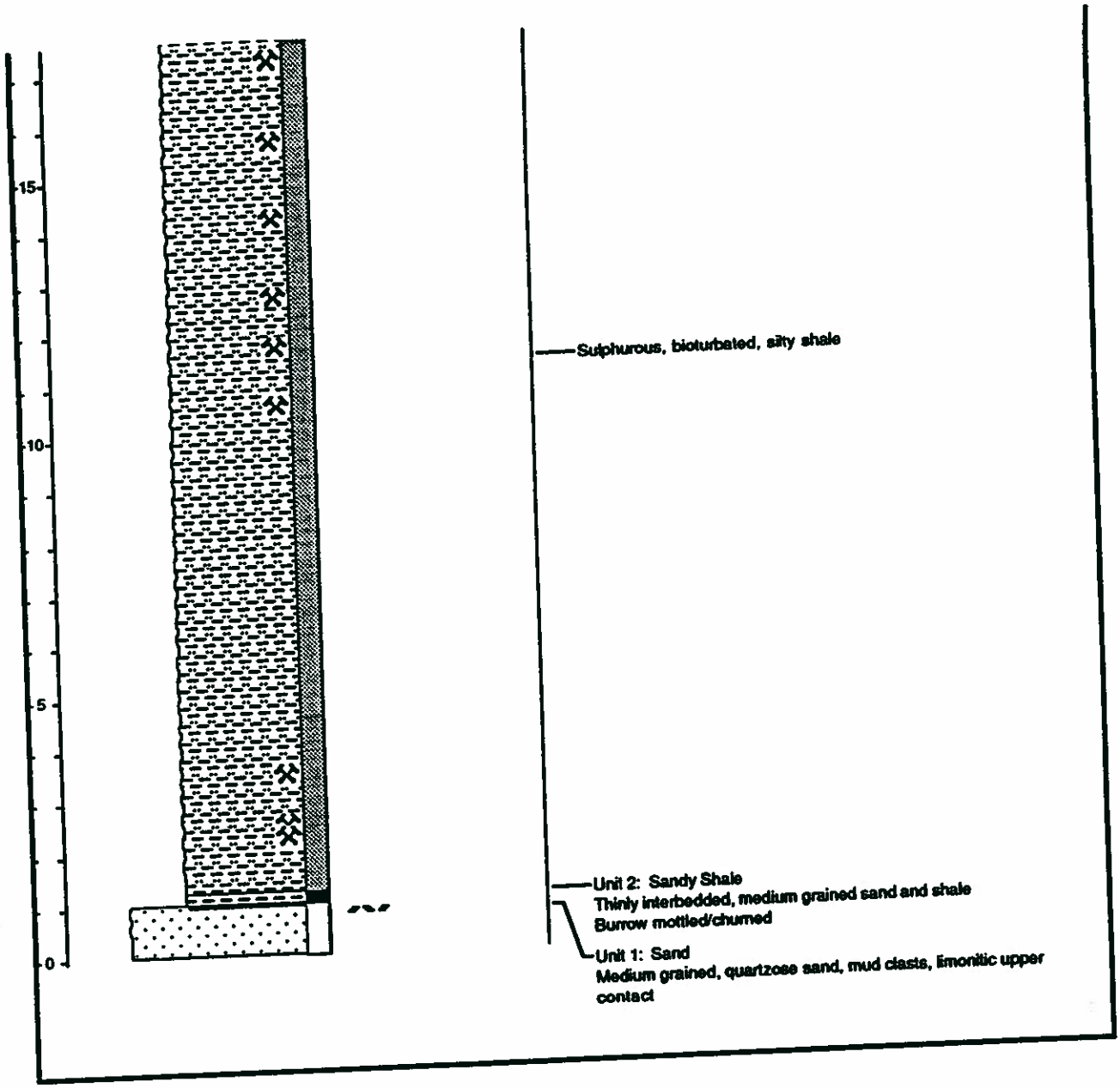
PHYSICAL STRUCTURES

Oscillatory Ripples
Flaser Bedding
Lenticular Bedding

LITHOLOGIC ACCESSORIES

Rip Up Clasts




15
10
5
0
Sulphurous, bioturbated, silty shale
Unit 2: Sandy Shale
Thinly interbedded, medium grained sand and shale
Burrow mottled/churned
Unit 1: Sand
Medium grained, quartzose sand, mud clasts, limonitic upper contact

Birch Mountain Structural Cross Section A-A'

Horizontal Scale = 1:100,000 Vertical Exaggeration = 100X

A

A'

Upper Cretaceous

Lower Cretaceous

Mannville Group

Labiche Group equivalent Formation

Colorado Group

Grand Rapids Formation

Clearwater Formation

Second White Speckled Shale

Base of Fish Scales

Pelican Fm

Joli Fou Fm.

Clearwater 'A' mkr

10-11-093-02W5
K.B. 637.3m

10-15-093-25W4
K.B. 677.6m

6-12-094-24W4
K.B. 798.3m

10-23-095-23W4
K.B. 781.5m

10-6-096-21W4
K.B. 822.4m

10-10-097-19W4
K.B. 787.0m

7-3-098-17W4
K.B. 777.2m

12-12-099-15W4
K.B. 744.3m

9-35-100-14W4
K.B. 726.6m

7-8-101-12W4
K.B. 817.6m

Gamma

Resistivity

Neutron

Second White Speckled Shale

Base of Fish Scales

Pelican

Joli Fou

Grand Rapids

Clearwater "A" Marker

Elevation (m)

700

600

500

400

300

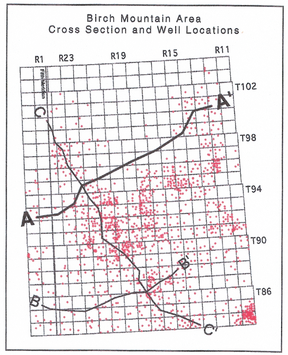
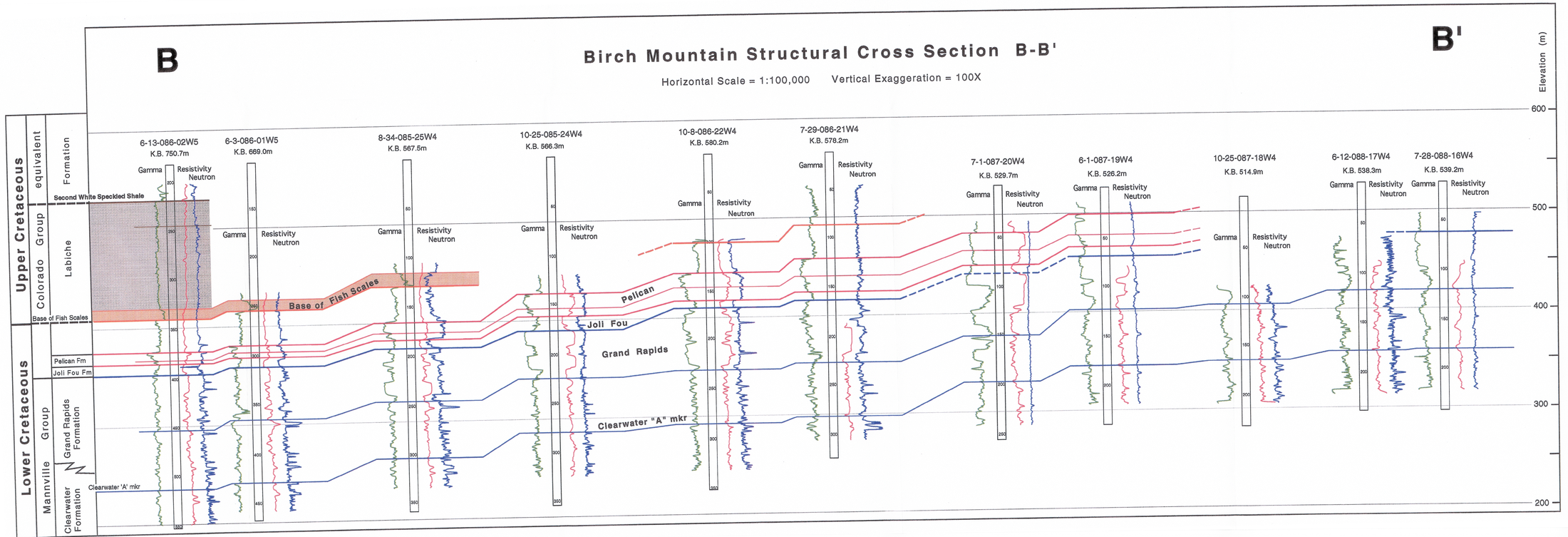


Figure: 6


B
Birch Mountain Structural Cross Section B-B'
Horizontal Scale = 1:100,000 Vertical Exaggeration = 100X
B'
Elevation (m)
600
500
400
300
200
Upper Cretaceous
Colorado Group equivalent Formation
Labiche
Second White Speckled Shale
Base of Fish Scales
Lower Cretaceous
Mannville Group
Pelican Fm
Joli Fou Fm
Grand Rapids Formation
Clearwater Formation
Clearwater 'A' mkr
6-13-086-02W5
K.B. 750.7m
6-3-086-01W5
K.B. 669.0m
8-34-085-25W4
K.B. 567.5m
10-25-085-24W4
K.B. 566.3m
10-8-086-22W4
K.B. 580.2m
7-29-086-21W4
K.B. 578.2m
7-1-087-20W4
K.B. 529.7m
6-1-087-19W4
K.B. 526.2m
10-25-087-18W4
K.B. 514.9m
6-12-088-17W4
K.B. 538.3m
7-28-088-16W4
K.B. 539.2m
Gamma
Resistivity
Neutron
Base of Fish Scales
Pelican
Joli Fou
Grand Rapids
Clearwater "A" mkr

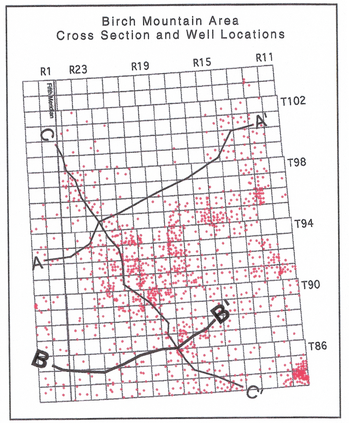

Birch Mountain Area
Cross Section and Well Locations
R1
R23
R19
R15
R11
T102
T98
T94
T90
T86
A
A'
B
B'
C
C'

Figure: 7

Birch Mountain Structural Cross Section C-C'

Horizontal Scale = 1:100,000 Vertical Exaggeration = 100X

C

C'

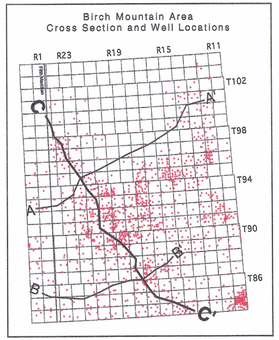


Figure: 8

Upper Cretaceous
Group equivalent
Formation

Lower Cretaceous
Colorado Group
Labiche
Pelican Fm
Joli Fou Fm
Mannville Group
Grand Rapids Formation
Clearwater Formation
'A' marker

Second White Speckled Shale

Base of Fish Scales

Pelican

Joli Fou

Grand Rapids

Clearwater "A" mkr

11-25-100-01W5
K.B. 523.0m

11-36-099-25W4
K.B. 603.6m

6-6-099-24W4
K.B. 595.8m

11-16-098-24W4
K.B. 734.2m

6-11-097-24W4
K.B. 823.5m

10-23-095-23W4
K.B. 781.5m

7-19-094-22W4
K.B. 750.7m

11-26-093-22W4
K.B. 683.8m

6-36-092-22W4
K.B. 610.3m

11-13-091-22W4
K.B. 535.4m

16-5-090-20W4
K.B. 524.4m

7-28-088-19W4
K.B. 521.7m

13-33-087-19W4
K.B. 533.7m

6-1-087-19W4
K.B. 526.2m

6-8-086-18W4
K.B. 536.8m

6-23-085-18W4
K.B. 538.6 m

7-6-085-16W4
K.B. 514.5 m

6-11-084-15W4
K.B. 551.4m

Gamma
Resistivity
Neutron

Elevation (m)
600
500
400
300

700000.

750000.

800000.

6450000.

6400000.

6350000.

6300000.

6250000.

58.000

57.000

West of the Fifth

West of the Fourth

104N/2W

104N/1W

104N/24W

104N/22W

104N/20W

104N/18W

104N/16W

104N/14W

104N/12W

104N/11W

102N/11W

98N/11W

96N/11W

94N/11W

92N/11W

90N/11W

88N/11W

86N/11W

84N/2W

84N/1W

84N/26W

84N/24W

84N/22W

84N/20W

84N/18W

84N/16W

84N/14W

84N/12W

84N/11W

McIvor

Birch River

Erosional Edge

Ells Rivers

Dover River

MacKay River

Wabasca River

Athabasca River

10

20

25

40

55

−114.000

−113.000

−112.000

Alberta Geological Survey		
Athabasca Gold Project Isopach Map Pelican Fm. to the Base of Fish Scales		
Figure 14		2/6/97
	Scale 1:500000.	

Scale 1:500000.

10. 0. 10. 20. 30. 40. 50. miles

10. 0. 10. 20. 30. 40. 50. kilometers

700000. 750000. 800000.

6450000. 6400000. 6350000. 6300000. 6250000.

58.000 57.000

West of the Fifth West of the Fourth

104N/2W 104N/1W 104N/24W 104N/22W 104N/20W 104N/18W 104N/16W 104N/14W 104N/12W 104N/11W

102N/11W 100N/11W 98N/11W 96N/11W 94N/11W 92N/11W 90N/11W 88N/11W 86N/11W

84N/2W 84N/1W 84N/26W 84N/24W 84N/22W 84N/20W 84N/18W 84N/16W 84N/14W 84N/12W 84N/11W

Birch River

McIvor River

Base of Fish Scales Erosional Edge

Ells River

Dover River

MacKay River

Wabasca River

Athabasca River

460 490 520 550

−114.000 −113.000 −112.000

Alberta Geological Survey

Athabasca Gold Project
Structure Map
Base of Fish Scales

Figure 15		2/6/97
	Scale 1:500000.	

Scale 1:500000.

10. 0. 10. 20. 30. 40. 50. miles

10. 0. 10. 20. 30. 40. 50. kilometers

West of the Fifth

West of the Fourth

104N/2W | 104N/1W | 104N/24W | 104N/22W | 104N/20W | 104N/18W | 104N/16W | 104N/14W | 104N/12W | 104N/11W

102N/11W

100N/11W

98N/11W

96N/11W

94N/11W

92N/11W

90N/11W

88N/11W

86N/11W

84N/2W | 84N/1W | 84N/26W | 84N/24W | 84N/22W | 84N/20W | 84N/18W | 84N/16W | 84N/14W | 84N/12W | 84N/11W

Birch River

Ells River

Dover River

Erosional Edge

MacKay River

Athabasca River

Wabasca River

20 50 80 110

6450000. 6400000. 6350000. 6300000. 6250000.

58.000 57.000

−114.000 −113.000 −112.000

Alberta Geological Survey		
Athabasca Gold Project Isopach Map Top of radioactive interval to the SWSS		
Figure 17		2/6/97
	Scale 1:500000.	

Scale 1:500000.

10. 0. 10. 20. 30. 40. 50. miles

10. 0. 10. 20. 30. 40. 50. kilometers

700000.

750000.

800000.

West of the Fifth

West of the Fourth

104N/2W | 104N/1W | 104N/24W | 104N/22W | 104N/20W | 104N/18W | 104N/16W | 104N/14W | 104N/12W | 104N/11W

102N/11W

100N/11W

98N/11W

96N/11W

94N/11W

92N/11W

90N/11W

88N/11W

86N/11W

84N/2W | 84N/1W | 84N/26W | 84N/24W | 84N/22W | 84N/20W | 84N/18W | 84N/16W | 84N/14W | 84N/12W | 84N/11W

Mclvor River

Birch River

Second White Speckled Shale Erosional Edge

Ells River

Dover River

MacKay River

Wabasca River

Athabasca River

640

610

550

6450000.

6400000.

6350000.

6300000.

6250000.

58.000

57.000

-114.000

-113.000

-112.000

Alberta Geological Survey		
Athabasca Gold Project Structure Map Second White Speckled Shale		
Figure 18		2/6/96
	Scale 1:500000.	

Scale 1:500000.

10. 0. 10. 20. 30. 40. 50. miles

10. 0. 10. 20. 30. 40. 50. kilometers