
**GEOLOGICAL SURVEY OF CANADA**
**COMMISSION GEOLOGIQUE DU CANADA**

**Open File 3524**

# STRATIGRAPHIC SETTING OF MIDDLE TRIASSIC STRATA IN THE SPIRIT RIVER–RYCROFT AREA OF NORTHWEST ALBERTA

James Dixon

Geological Survey of Canada (Calgary), 3303 - 33 Street N.W.
Calgary, Alberta T2L 2A7

May 2001

**CONTENTS**



**LIST OF FIGURES**

## INTRODUCTION

Oil and gas production from the Spirit River field in northwest Alberta is principally from the Middle Triassic Doig, Halfway and Charlie Lake formations, with the most productive interval in the Halfway Formation. The Spirit River field is located north of Grand Prairie, between townships 77 and 78, ranges 5W6 to 7W6 (Fig. 1). About 234 wells penetrate a significant amount of Triassic strata in the study area (Fig. 1), with quite a few more that penetrate only the top few metres of the Triassic. A large number of cores are available for examination from the Triassic (Fig. 1) but only a few were chosen to be examined in order to characterize the various stratigraphic levels within the interval of interest and to observe variations in the principle reservoir horizon - the Halfway Formation (appendix 1).

Only two publications describe the geology of this field; the most comprehensive is by Aukes and Webb (1986), and a brief abstract by Stevens and Volcko (1991). Aukes and Webb (op. cit.) interpreted the trap to be "the updip edge of an isolated remnant of Doig coquinas and sandstones, created by erosion prior to Charlie Lake deposition". The basis of this interpretation is the correlations they illustrate on cross sections in their figure 9 (their schematic representation of the stratigraphy is illustrated in Fig. 2a). Stevens and Volcko (op. cit.) deal mostly with the reservoir facies.

Alternative correlations are presented here to show that the main trapping mechanism is up-dip pinchout of Doig, Halfway and lowermost Charlie Lake beds against the Coplin unconformity - a Late Triassic event within the Charlie Lake Formation (schematically illustrated in Fig 2b). This is supplemented by Charlie Lake beds being truncated at a pre-Jurassic unconformity - creating a trapping situation for lesser amounts of hydrocarbons in Charlie Lake beds immediately below the pre-Jurassic unconformity.

## STRATIGRAPHY

In the Spirit River area the Triassic is represented by the Lower Triassic Montney Formation, the Middle Triassic Doig and Halfway formations, and the Middle to Upper Triassic Charlie Lake Formation, although few wells penetrate the full succession.

Aukes and Webb (1986) recognised only the Doig and Charlie Lake formations in the Middle Triassic of the Spirit River area. In their interpretation of the stratigraphy, a base-of-Charlie Lake unconformity eroded the Halfway Formation (Fig. 2a). Alternative correlations presented here (Fig. 3) and based on a more regional view of the Middle Triassic, clearly show beds that would normally be considered Halfway Formation in well 16-36-77-10W6, about 20 km west of Spirit River, correlate into the Spirit River area. Strata identified as Halfway Formation would be those Aukes and Web (1986) identified as "an isolated remnant of Doig coquinas and sandstones". The correlations also show that the base of the Halfway Formation in this part of the basin is a significant erosion surface (this is also confirmed in the cores from this interval - see later). This interpretation is similar to other parts of the eastern margin of Triassic deposits, such as in northeast British Columbia, where Clark (1961), Young (1997), Zonneveld et al. (2000), and Dixon (2001) interpret the thin eastern equivalent of the Halfway Formation to rest

unconformably on Doig beds.

Detailed correlations in the Spirit River Field show that the Halfway Formation is a significant but generally thin horizon (Fig. 4). Also, correlations in the lowermost Charlie Lake Formation clearly show a set of readily correlated subparallel units in the west and southwest that are progressively truncated to the northeast by an intra-Charlie Lake unconformity, creating the conditions for the up-dip pinchout of Halfway beds. This unconformity is correlated with the Coplin unconformity (unpublished regional correlations of the author) - a feature first formally identified in northeast British Columbia by Hess (1968) and subsequently recognized as a basin-wide feature (e.g., Davies, 1997). Beds immediately above the unconformity are the Coplin Member, which locally are porous and contain hydrocarbons in the Spirit River area. The Coplin unconformity was not recognised by Aukes and Webb (1986), but it is this feature that creates the trapping situation and not a base-of-Charlie Lake unconformity, which in the interpretation presented here does not exist. Post-Coplin beds are Late Triassic in age (Davies, 1997).

Post-Coplin beds, in turn, are truncated to the northeast by a pre-Jurassic unconformity and the Jurassic Nordegg Formation rests erosionally on various Triassic units.

## STRUCTURE

Figure 5 is a structure contour map on the top of the Coplin Member and shows a southwest dipping succession with minor flexure. There are a number of abrupt deflections in the contours and these are most likely to be small-offset normal faults. Also shown is the subcrop edge of the Halfway Formation. It is apparent from this map that there is no large-scale structural closure, only locally against the small faults. The main trapping mechanism is a stratigraphic trap of the Halfway and Doig beds truncated up-dip at the Coplin unconformity. This up-dip truncation does create local closures against the unconformity due to the trend of the Halfway subcrop being oblique to the trend of the truncation. Northeast of the Halfway subcrop edge the reservoirs are Doig and/or lower Charlie Lake beds, also with up-dip truncation against the Coplin unconformity

## LITHOLOGY AND SEDIMENTOLOGY

Only the broad outlines of the various facies are presented here.

### Doig Formation

The Doig Formation consists of interbedded mudstone, siltstone and very fine to fine grained sandstone with some distinct high-value gamma-ray shales in its lowermost part. In general, the Doig consists of a series of coarsening-upward intervals of varying scales, ranging from a few tens of centimetres to a few metres thick.

Core from the 6-24-77-6W6 well serves to illustrate the facies found in the upper half of the Doig Formation (Figs. 6), along with photographs of Doig facies from comparable stratigraphic levels in well 16-30-77-5W6 (Fig. 7a, b). The lower half of the formation has not been cored. At 6-24-77-6W6 the overall succession coarsens-up but superimposed on this are

several thinner cycles. In general, the cycles, regardless of scale, consist of interbedded to interlaminated mudstone and sandstone in their basal part grading up into thin beds of very fine to fine grained sandstone. Horizontal laminae and current ripple laminae are the predominant sedimentary structures, although many beds are structureless. In a few wells, thin beds of cross bedded sandstone have been noted. Load deformation ranges from mild to severe. Bioturbation structures are lacking in the cores examined from the Doig Formation, although some vertical and horizontal burrows have been noted, and are more common where mudstone beds tends to occur in significant proportions. Locally present are thin dolostone beds, some of which contain bivalve molds.

The upper Doig Formation is interpreted to have been deposited in a lower shoreface setting, primarily below storm wave-base. This is consistent with the facies and the regional setting of the Doig Formation (e.g., Evoy and Moslow, 1995; Evoy, 1997; Moslow and Davies, 1992).

Although the sandstones of the Doig Formation appear to have low porosity there have been significant recoveries of hydrocarbons from these beds and they offer a good secondary target.

**Halfway Formation**

The Halfway Formation rests erosionally on Doig beds (Figs. 8 and 9) and consists of sandstone, coquinal dolomitic sandstone, sandy coquinal dolostone, dolostone and minor amounts of mudstone (Fig. 8). A less common lithology found in the Halfway Formation is dolostone breccia. The dominant lithology in the Halfway succession of the Spirit River area is coquinal sandstone/dolostone. The coquinas are highly porous due to the abundance of vugs and molds of bivalves.

In the16-30-77-5W6 well, the Halfway Formation rests on a dolomitized bed of Doig strata and cracks extend down into the dolostone bed (Fig. 7a). The base of the Halfway Formation contains small clasts derived from the underlying bed. The cracks, which appear to be dessication features, and the dolomitization are interpreted to indicate subaerial exposure and pedogenesis. In other cored wells examined, marine Halfway Formation rest erosionally on marine Doig strata, with no evidence of pedogenesis, or other indicators of subaerial exposure.

The Halfway Formation ranges up to about 10 m thick (Fig. 10), although over much of the study area it is between 4 and 6 m thick. Where drilling density is highest there is a suggestion that Halfway strata have a northeast alignment of thick and thin zones (Fig.10), although this is less apparent where drilling density is low. An unusual setting is seen in the 6-10-78-6W6 well, where the Halfway Formation is represented by a very thin succession (less than 1 m), in an area where the Halfway is generally thicker.

Beds within the Halfway succession range from a few centimetres to over a metre thick, although most are in the 30-60 cm range. Internal stratification is commonly difficult to detect but

where seen it is predominantly horizontal bedding, with locally occurring cross bedding. The coquinas consist of mostly thin-walled bivalve debris in a sandy to dolomitic matrix. Locally there are sandstone beds containing small to large dolomudstone clasts; the clasts commonly similar in lithology to interbedded dolomudstones (e.g., 14-4-78-6W6, Fig.7c). Many beds have a fining-up aspect. The characteristics of these coquinal and clast-bearing beds point to a high-energy, commonly waning-flow, style of deposition, and the presence of abundant bivalves indicate a marine setting

Dolostone breccia is present locally where the Coplin unconformity rests on Halfway strata, such as in the 4-24-77-6W6 and 8-24-77-6W6 wells (Fig. 11b). The disorganized fabric, large range of clast sizes and the presence of coarsely laminated and bands of dolomite within the breccias indicate a pedogenetic origin for these beds, with the complete replacement of the sandy Halfway Formation. This would be consistent with subaerial exposure at the time of unconformity development.

An unusual Halfway succession occurs in the 6-29-77-6W6 well, where the basal unit is a very finely crystalline dolostone overlain by a dolomitic sandstone. In neither lithology is there any indication of a coquina, a facies typical of the Halfway Formation in the Spirit River area. It is possible that the dolostone bed resulted from the complete diagenesis of a coquinal dolostone, however there are no macroscopic indicators to support this conclusion.

The occurrence of Halfway beds above a major unconformity, its marine character and high-energy style of deposition point to an origin as a transgressive interval, probably on an upper shoreface setting. The irregular blanket shape of the deposit, with hints of a northeast trend of thicks and thins, could reflect either the infilling of the unconformity surface, or the depositional topography after transgression. The fact that the beds immediately above the Halfway Formation, in the lowermost Charlie Lake Formation, have a strong tendency to maintain an even thickness over the study area tends to favour the interpretation that the Halfway beds infill the topography on the unconformity.

The abundance of molds and vugs in the Halfway Formation makes it highly porous and permeable, consequently this unit is the most prolific reservoir in the Spirit River-Rycroft area.

**Charlie Lake Formation**

Charlie Lake strata consist of interbedded dolostone, anhydrite, shale, siltstone, and sandstone. The Charlie Lake Formation can be divided into pre-Coplin and post-Coplin successions.

Pre-Coplin beds consist of interbedded dolomitic mudstone, argillaceous dolostone, dolostone, and dolomitic sandstone (Fig. 8). Intraclast-rich dolostone beds are a common component. Thin beds of stromatolitic dolostone are locally present Most of the beds tend to be light to medium grey in colour, although some beds have a yellowish hue and locally, brick-red dolomitic mudstones and brecciated mudstones occur. Nodules and thin beds of anhydrite

commonly occur with the red mudstones.

Most successions of the Coplin Member consist of interbedded dolostone and sandstone, although in some wells only dolostone is present. Coplin beds rest erosionally on strata ranging from the lower Charlie Lake Formation to Doig Formation (Fig. 11). The post-Coplin succession is similar to pre-Coplin strata (Fig. 12), with the exception that there are no red-beds.

Many of the Charlie Lake dolostone and argillaceous dolostone beds have complex diagenetic fabrics, seen as lenticular to diffuse colour changes.

Charlie Lake beds are interpreted to be generally low-energy deposits, dominated mostly by what were carbonate muds, deposited in a sheltered subtidal to peritidal environment. The presence of red-beds and anhydrite in parts of the pre-Coplin succession suggest an intertidal to supratidal setting for these beds. Coplin beds rest on a regionally significant unconformity and are probably marine transgressive beds.

In general, Charlie Lake beds are not particularly porous except where diagenesis below the base-Nordegg unconformity has created vuggy porosity in the dolostones. Minor amounts of porosity are present in some of the thin sandy beds and where fenestral fabrics are present in stromatolitic dolostones.

## CONCLUSIONS

A reinterpretation of the stratigraphic relationships in Middle Triassic Doig, Halfway and Charlie Lake formations of the Spirit River-Rycroft area reveal that the main trapping mechanism is up-dip pinchout of Doig, Halfway and lowermost Charlie Lake beds against the Coplin unconformity. Additional, but less important, traps are created in Charlie Lake beds at the pre-Jurassic unconformity.

This type of trapping situation can be found along a narrow belt close to the Doig-Halfway subcrop edge (Dixon, 1999). A similar style of trap may be present where the Charlie Lake overlaps on to Montney strata, where sandstones of the Montney Formation could be sealed against Charlie Lake beds.. However, this latter situation has a limited geographic distribution, present only between townships 75 and 88 (Dixon, 1999)

## REFERENCES

Aukes, P.G. and Webb, T.K 1986. Triassic Spirit River pool, northwest Alberta. Canadian Society of Petroleum Geologists, 1986 Core Conference, p,3-1 to 3-34.

Clark, D.R. 1961. Primary structures in the Halfway Sand in the Milligan Creek oilfield, British Columbia. Journal of the Alberta Society of Petroleum Geologists, v.9, p.109-130.

Davies, G.R. 1997. The Triassic of the Western Canada Sedimentary Basin: tectonic and stratigraphic framework, paleogeography, paleoclimate and biota. Bulletin of Canadian Petroleum

Geology, v.45, p.434-460.

Dixon, J. 1999. Isopach maps of some Triassic units in the Western Canada Sedimentary Basin. Geological Survey of Canada, Open File 3758 (4 map sheets).

Dixon, J. 2001. Triassic stratigraphy in the subsurface of the Trutch map-sheet (94-G), northeast British Columbia. Central Forelands NATMAP. Geological Survey of Canada, Open File D3464, CD-ROM.

Evoy, R.W. 1997. Lowstand shorefaces in the Middle Triassic Doig Formation: implications for hydrocarbon exploration in Fort St John area, northeastern British Columbia. Bulletin of Canadian Petroleum Geology, v.45, p.537-552.

Evoy, R.W. and Moslow, T.F. 1995. Lithofacies associations and depositional environments in the Middle Triassic Doig Formation, Buick Creek Field, northeastern British Columbia. Bulletin of Canadian Petroleum Geology, v.43, p.461-475.

Moslow, T.F. and Davies, G.R. 1992. Triassic reservoir facies and exploration trends, Western Canada Sedimentary Basin. Canadian Society of Petroleum Geologists, Annual Convention, Short Course No.7, 166p.

Stevens, L.M. and Volcko, M.D. 1991. The Rycroft Halfway C Pool: importance of an accurate and detailed geological model in pool development. Canadian Society of Petroleum Geologists, Annual Convention, Programme and Abstracts, "Opportunities for the Nineties", p.132.

Young, F.G. 1997. An iconoclastic view of mid-Triassic stratigraphy, Umbach-Wargen area, British Columbia. Bulletin of Canadian Petroleum Geology, v.45, p.577-594.

Zonneveld, J-P, Moslow, T.F., and Hubbard, S.M. 2000. (Abstract). Sedimentary and sequence stratigraphic framework of the Middle Triassic in the Trutch map sheet (94-G), British Columbia, outcrop-subsurface correlation and significance for hydrocarbon exploration. GeoCanada 2000 Conference, Calgary, Alberta, p.1-5.

**Appendix 1: List of cores examined in the Spirit River-Rycroft area**

6-18-77-5W6 Core 1: 1386-1396 m
16-30-77-5W6 Core 1: 1382-1400.2 m
6-11-77-6W6 Core 1: 1446-1464 m
6-22-77-6W6 Core 2: 1415-1433.4 m. Core 3: 1433.4-1451.4 m
8-24-77-6W6 Core 1: 1379-1397.2 m. Core 2:1397.2-1415.4 m
14-24-77-6W6 Core 1: 14103-1421 m
6-29-77-6W6 Core 2: 1536-1554.5 m
16-32-77-6W6 Core1: 1457-1475 m
16-3-78-6W6 Core 1: 1406-1424 m
16-4-78-6W6 Core 1: 1418-1435.75 m
6-10-78-6W6 Core 1: 1391-1409.2 m

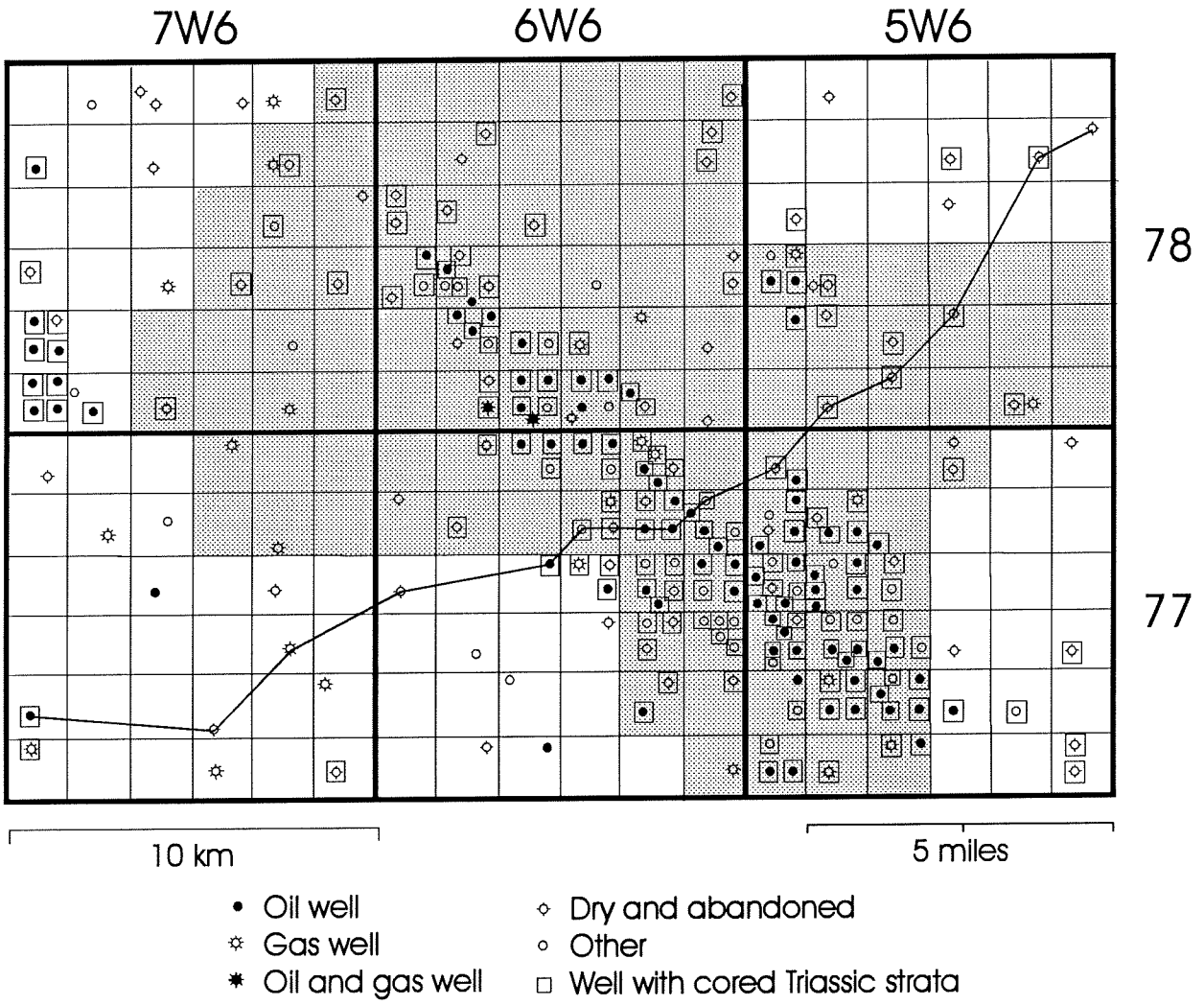



FIGURE 1: Location map of: a) wells penetrating Triassic strata (only those wells with significant penetration are included), b) wells with cored Triassic strata, c) outline of the Spirit River field (from the Alberta Energy Utilities Board), and c) cross section in Figure 4.

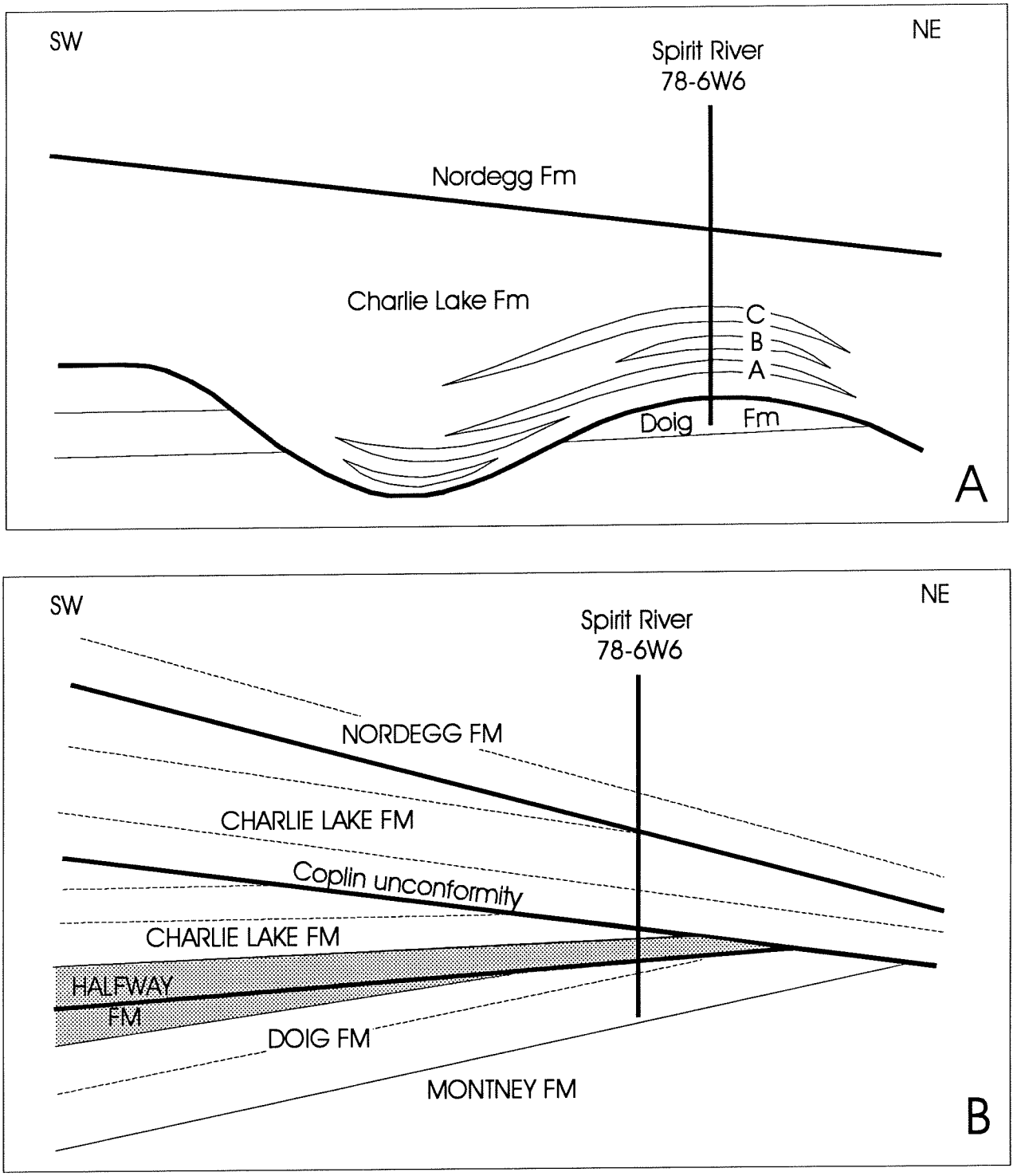



FIGURE 2: Comparison of the schematic representations of the stratigraphic relationships in the Spirit River area: A) Aukes and Webb (1986), B) this report

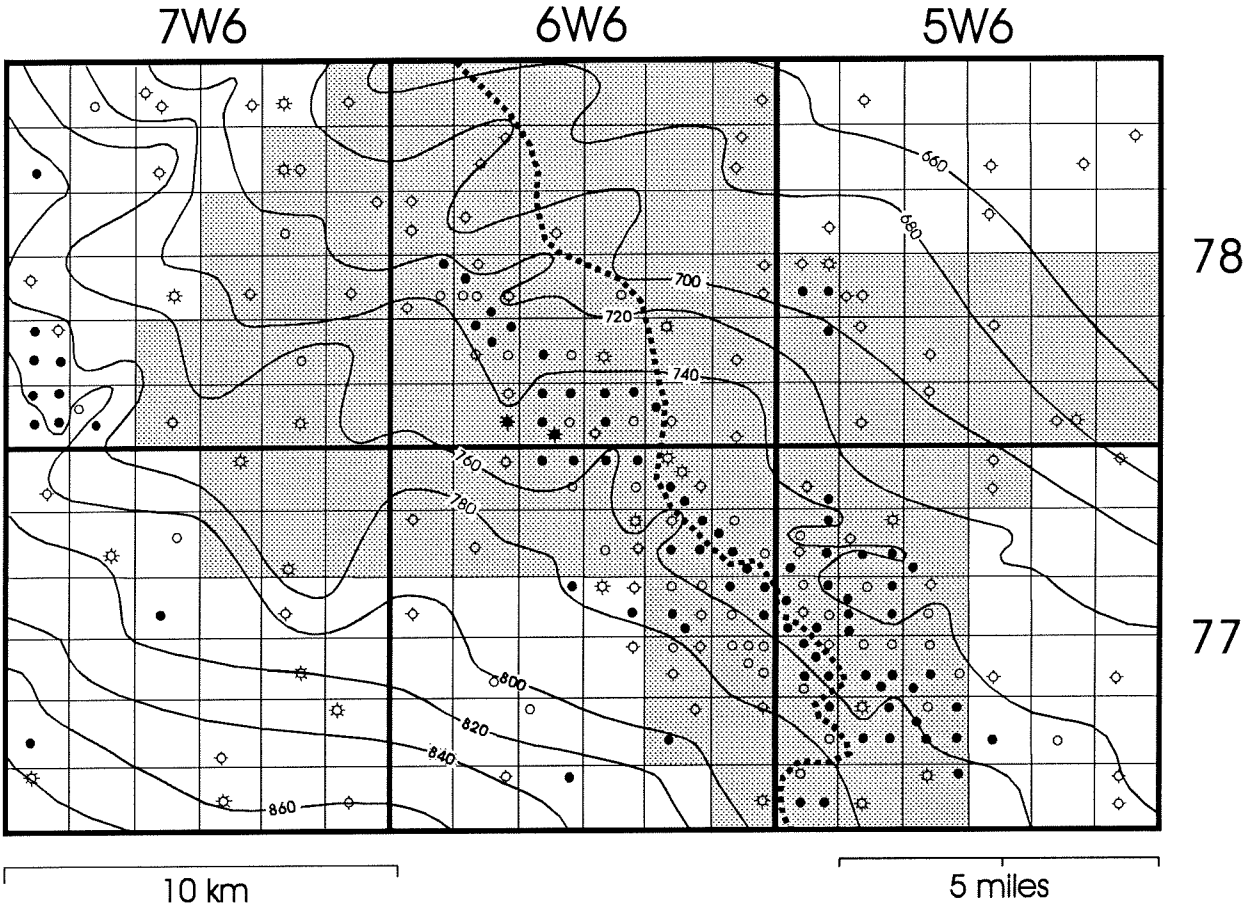



FIGURE 5: Structure contours on the top of the Coplin Member.

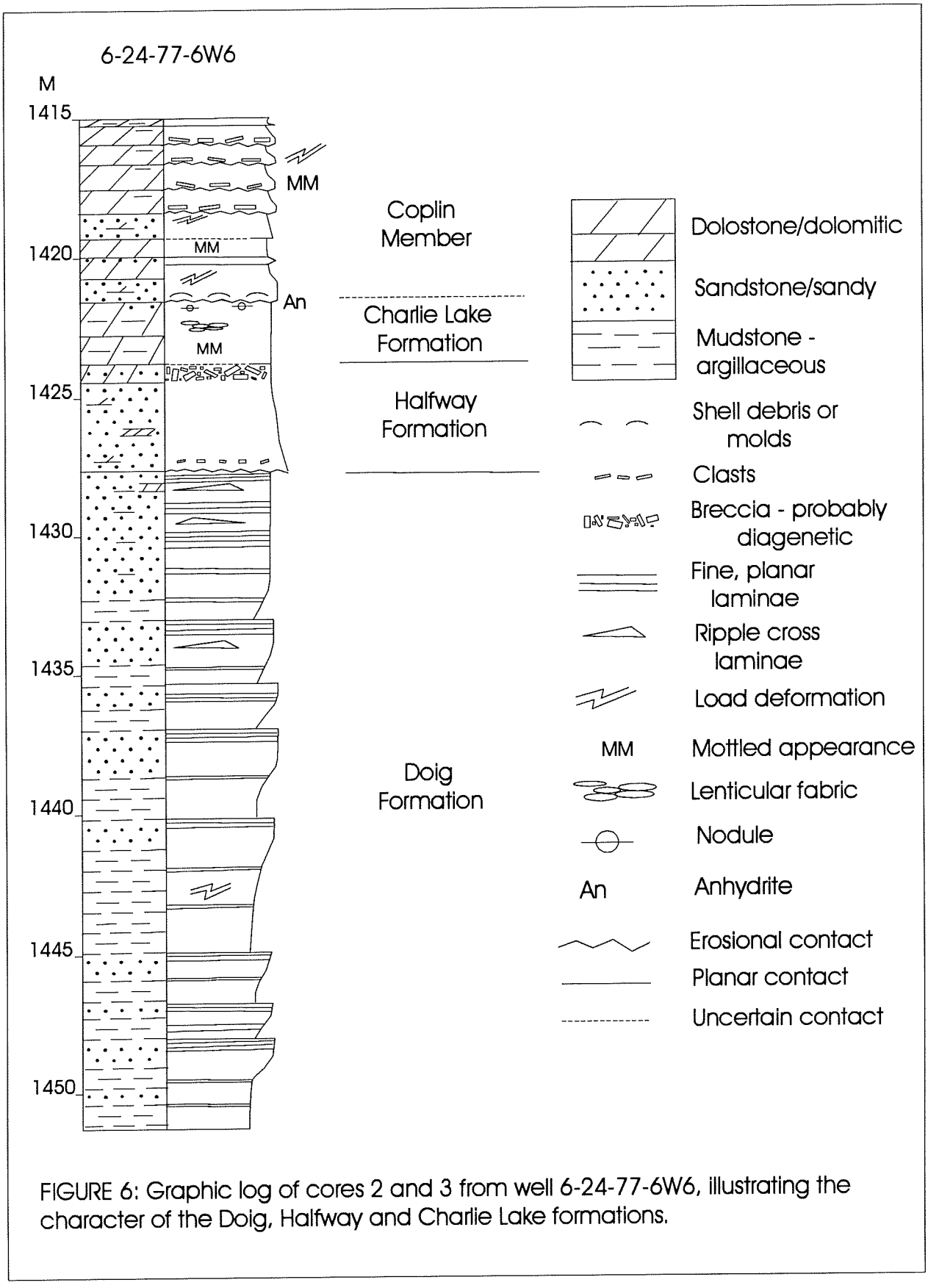
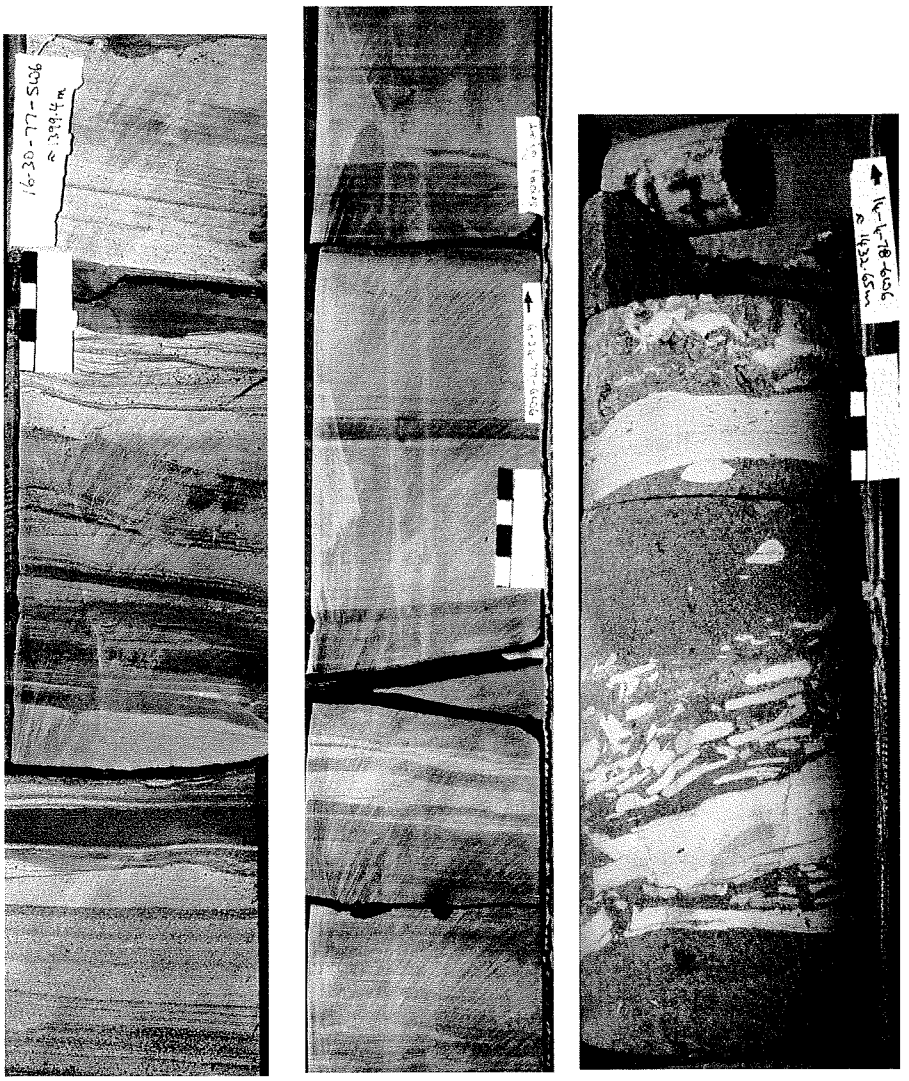



FIGURE 6: Graphic log of cores 2 and 3 from well 6-24-77-6W6, illustrating the character of the Doig, Halfway and Charlie Lake formations.

**Figure 7**
Photographs of core in the Doig and Halfway Formations:
a) Doig Formation from well 16-30-77-5W6: thinly interbedded sandstone and mudstone (ISPG photo 4711-9),
b) Doig Formation from well 16-30-77-5W6: from slighty higher in a coarsening-upward succession than 7a, with thicker beds and less interbedded mudstone (ISPG phot 4711-27),
c) Halfway Formation from well 14-4-78-6W6: beds containing dolomudstone clasts aligned along cross beds (ISPG photo 4711-41).
Bar scale in 1 centimetre increments.



A B C

Figure 7

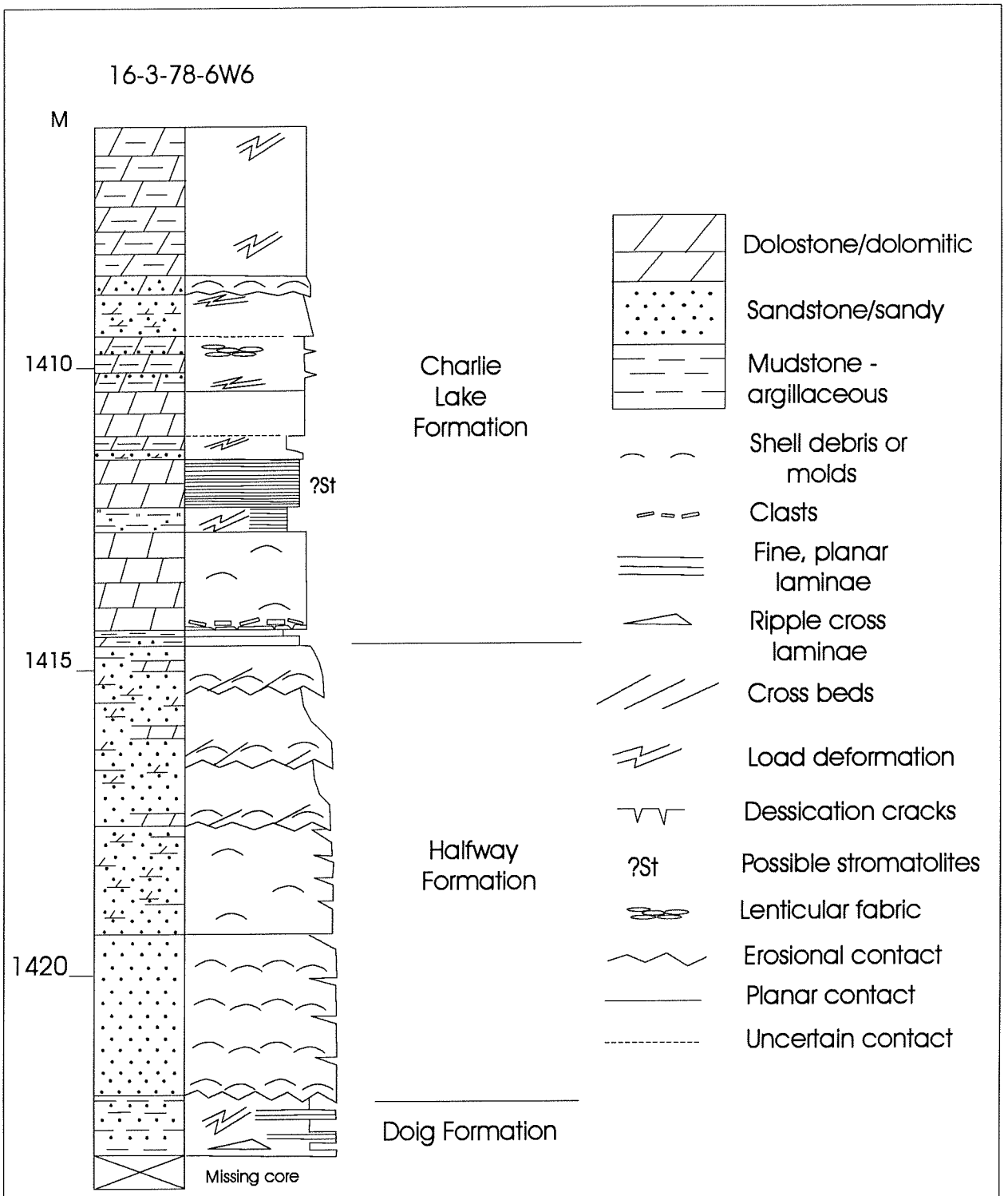
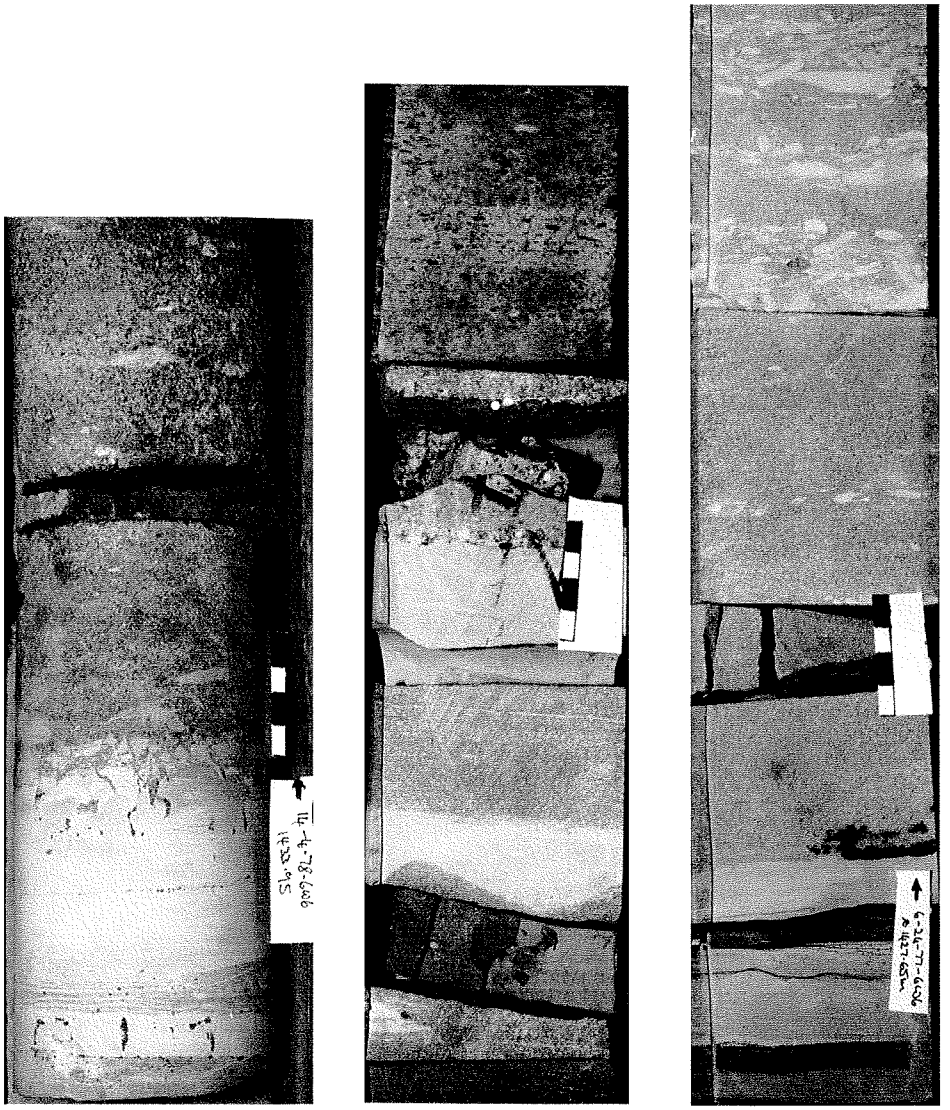



FIGURE 8: Graphic log of core 1 from well 16-3-77-6W6, illustrating the character of the Halfway Formation , and pre-Coplin beds of the lower Charlie Lake Formation

**Figure 9**
Photographs of core intersecting the erosional base of the Halfway Formation:
a) well 14-4-78-6W6 (ISPG photo 4711-44) - at base of bar scale,
b) well 6-18-77-5W6 (ISPG photo 4711-4) - at the bar scale,
c) well 6-24-77-6W6 (ISPG photo 4711-22) - just above the arrow on the well name.
Bar scale in 1 centimetre increments.



A B C

Figure 9

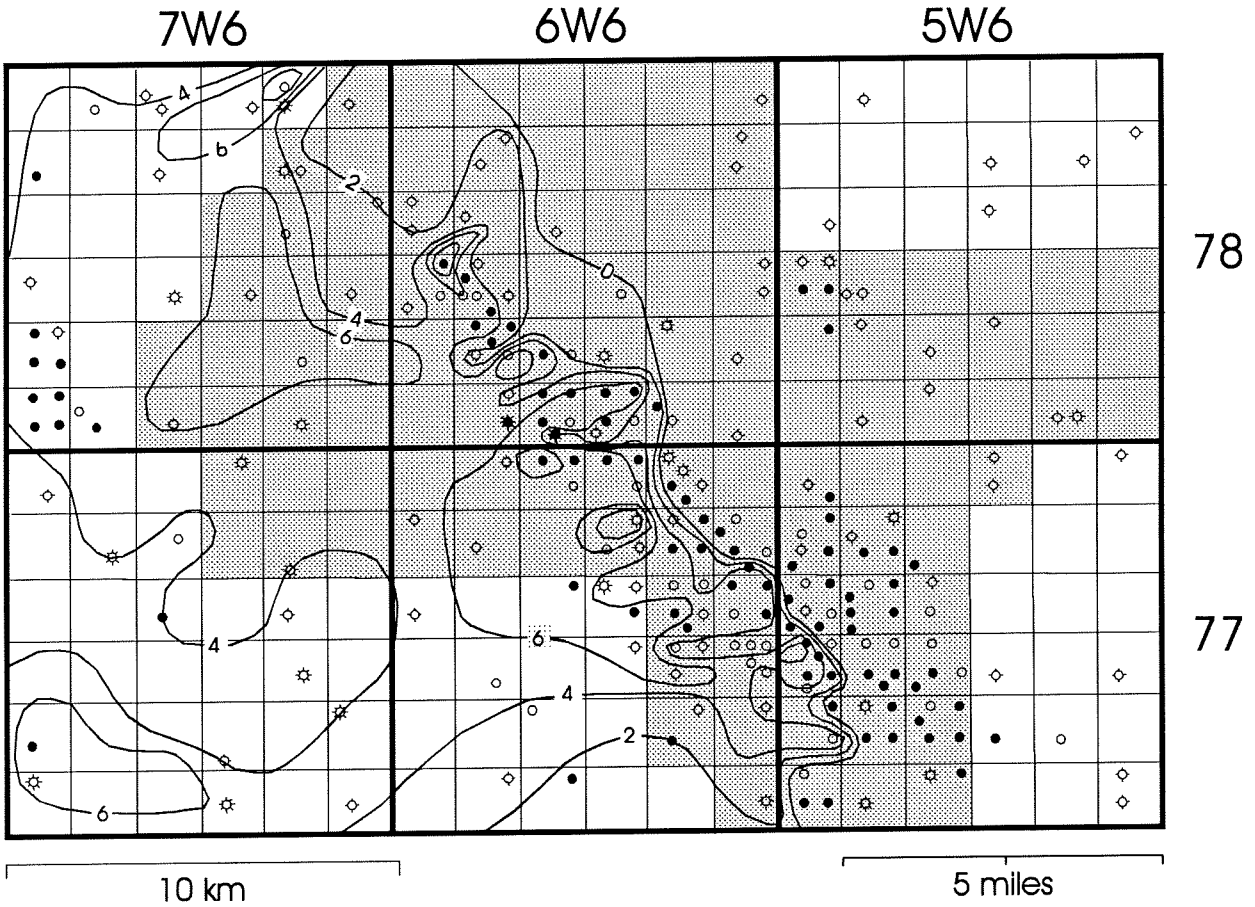
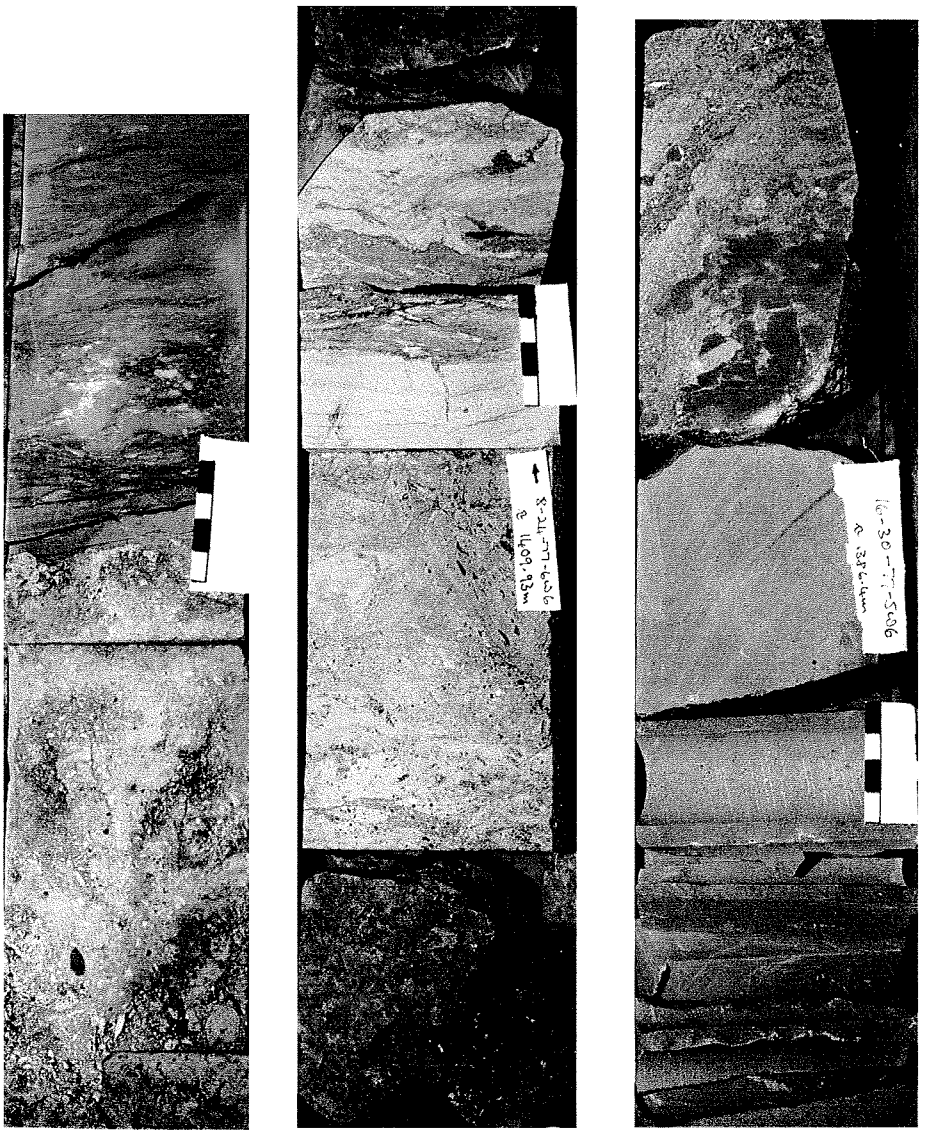



FIGURE 10: Isopach map of the Halfway Formation, Spirit River-Rycroft area.

**Figure 11.**
Photographs of core intersecting the base of the Coplin Member, Charlie Lake Formation:
a) well 6-18-77-5W6: Coplin Member resting on Halfway beds (ISPG photo 4711-6) - at the bar scale,
b) well 8-24-77-6W6: Coplin Member resting on Halfway beds (ISPG photo 4711-28) - dark bed at the top of the photograph is Coplin, resting on diagenetically altered and brecciated Halfway beds (at the bar scale),
c) well 16-30-77-5W6: mottled-looking Coplin Member resting on sandstone of the Doig Formation (ISPG photo 4711-8). Contact is just above the card with the well name.

Bar scales in 1 centimetre increments.



A B C

Figure 11

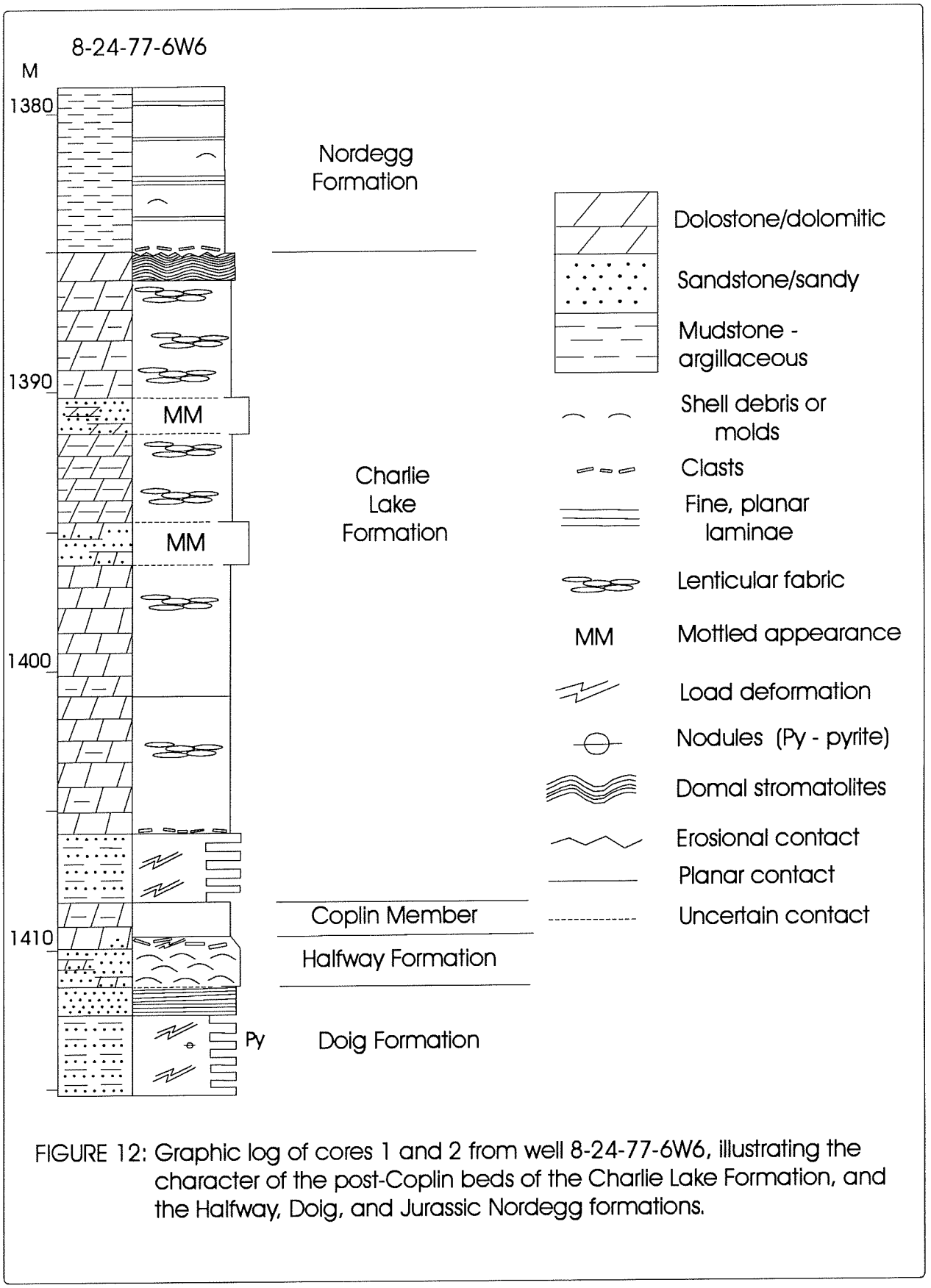



FIGURE 12: Graphic log of cores 1 and 2 from well 8-24-77-6W6, illustrating the character of the post-Coplin beds of the Charlie Lake Formation, and the Halfway, Doig, and Jurassic Nordegg formations.