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REGIONAL CORRELATIONS IN THE LOWER TRIASSIC MONTNEY FORMATION OF WESTERN CANADA

James Dixon

Geological Survey of Canada (Calgary)
3303-33rd St NW
Calgary, Alberta
T2L 2A7

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

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INTRODUCTION

The Montney Formation is a Lower Triassic unit present in the subsurface of west-central Alberta and northeastern British Columbia. It is a predominantly siliciclastic unit with local accumulations of coquinal carbonate beds.

Montney strata were formally defined from the subsurface occurrence of Triassic strata in western Canada by Armitage (1962), in the Texaco NFA Buick Creek 6-26-87-21W6 well of northeast British Columbia, between log depths 5625 ft and 6500 ft (1714.5 and 1981.2 m respectively). In the type section, the Montney rests unconformably on Permian strata and is abruptly overlain by the Triassic Doig Formation. Together, the Montney and Doig formations comprise the Daiber Group (Armitage, op. cit.). Both the upper and lower boundaries of the Montney Formation are well defined lithologically and by geophysical log signatures. In the case of the Doig-Montney contact, the lower beds of the Doig Formation are shale or siltstone characterized by an abundance of phosphatic pellets and/or phosphatized grains, resting abruptly on a siltstone or argillaceous sandstone of the Montney Formation. At the depth indicated by Armitage (op. cit.; i.e., 5625 ft) the log response is not distinct, whereas at 5614 ft the gamma-ray log deflects rapidly to a high gamma-ray count and is a very distinct horizon. Above this depth, the lowermost Doig beds have a strong radioactive signature (commonly referred to as the phosphatic zone), whereas the underlying Montney beds are less radioactive. This strong gamma-ray log signature is correlatable throughout the subsurface and can be used to approximate the Doig-Montney contact (e.g., the regional cross sections in Edwards et al., 1994). At the base of the Montney Formation shale to silty shale commonly rests abruptly on carbonate (of either the Carboniferous or Permian) imparting a very abrupt shift in the traces of most log types.

Although strata equivalent to the Montney in outcrop have been given a variety of names (see Davies et al., 1997, for a brief review) generally it has proven difficult to correlate the named outcrop units into the subsurface. Barss et al. (1964) suggested that the uppermost beds of the Montney Formation correlated with Manko's (1960) Black Shale member of the Sulphur Mountain Formation. However, as argued by Dixon (2000), this correlation is incorrect, the Black Shale member is almost certainly equivalent to the basal Doig Formation. Attempts at a consistent internal lithostratigraphic subdivision of the subsurface Montney Formation have been presented by Davies et al. (1997) and Dixon (2000).

Much of the detailed work done on Triassic stratigraphy in the subsurface of Western Canada Sedimentary Basin has tended to be local to subregional in extent. The objective of this paper is to present a basin-wide perspective of the Montney Formation by using seven regional cross sections to illustrate the internal stratigraphy (Figs. 1 to 8). Other cross sections, located between the ones illustrated in this manuscript, were compiled by the author but for the sake of brevity are not illustrated here. The correlations were used primarily to identify large-scale transgressive-regressive sequences within the Montney Formation.

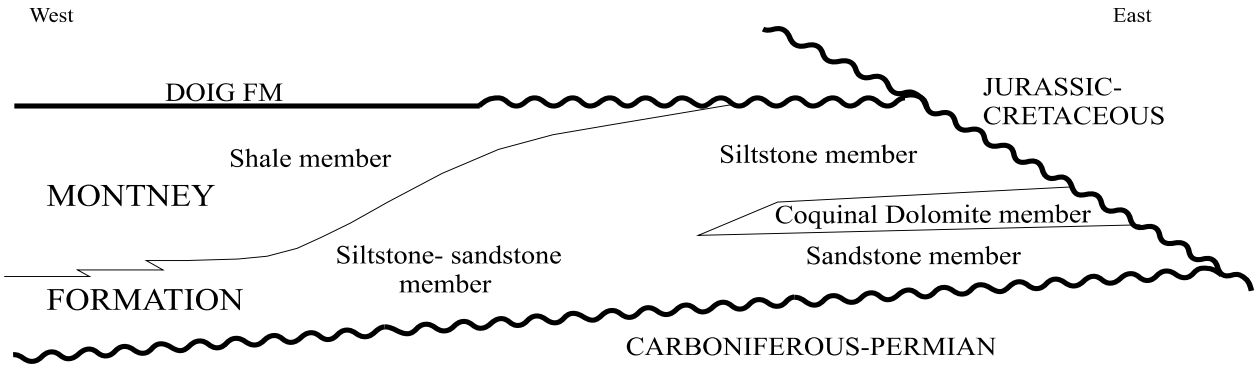

Figure 9: Schematic representation of the lithostratigraphic subdivisions in the Montney Formation (after Dixon, 2000).

STRATIGRAPHY

Introduction

Montney strata consist of interbedded shale, siltstone and sandstone, commonly arranged in a series of stacked transgressive-regressive cycles. Locally developed shelly sandstone and coquinal carbonate beds are present, especially in its eastern occurrence. There is one exceptionally thick coquinal dolostone that is readily mapped in the eastern areas of Montney subcrop and acts as a reservoir in a number of hydrocarbon pools (e.g., Sturgeon Lake and Kaybob South fields). The dominant lithology in the Montney Formation is shale and silty shale, with significant, but subordinate, amounts of sandstone. Sandstone beds are generally very fine to fine grained with locally developed coarser grained sandstone beds.

Lithostratigraphy

With the exception of Barss et al.'s (1964) correlation of the outcropping Black Shale member to the uppermost beds of the Montney Formation the latter remained undivided until Davies et al. (1997) proposed informal subdivisions, using a thick coquinal dolostone unit as a means to subdivide the succession into three members. The lithostratigraphic subdivisions of Davies et al. (1997) are based on only a part of the Montney's occurrence, that area bounded between townships 70 to 86, from range 22W5 to 12W6, in west-central Alberta. Here they divide the Montney into three members, the lower, middle and upper. The middle unit is a distinct coquinal dolostone (their Coquinal Dolomite Middle member) that occurs over a limited east-west extent and a more extensive north-south distribution (see fig. 1 in Davies et al., 1997, and fig. 2 in Dixon, 1999). West of the occurrence of the coquinal dolomite the Upper member rests directly on the Lower member. To the east of the coquinal dolomite, Jurassic strata unconformably rests on the Lower member.

Dixon (2000) presented a fivefold lithostratigraphic subdivision of the Montney Formation which is applicable on a basin-wide scale (Fig. 9). As well as the subregional nature of the Davies et al. (1997) scheme, Dixon (2000) noted that they used some sequence

stratigraphic principles, as well as lithostratigraphic principles, in their definition of members, adding to the difficulty of identifying the Davies et al. subdivisions basin-wide. Dixon's (op. cit.) scheme uses the same criteria as Davies et al. (op. cit.) in the eastern area of occurrence, where the coquinal unit allows for a threefold subdivision, but west of where the coquinal unit changes facies, the equivalent strata can only be subdivided into two members. The informal members of Dixon (op. cit.; Fig. 9) were given lithological descriptors, i.e., Sandstone, Coquinal Dolomite, Siltstone, Siltstone-Sandstone and Shale members (Fig. 9).

Sequence Analysis

Basin-wide sequence analysis of the Montney Formation has been limited in scope, with Davies et al. (1997) discussing the significance of their correlations in terms of sequence analysis, albeit on a scale that is not basin encompassing. The regional cross sections (Figs. 2 to 8) reveal a number of anomalous correlations and stratigraphic relationships that are best explained by regional unconformities and/or transgressive surfaces. The principal correlations are of flooding surfaces associated with transgressive-regressive sequences of varying scales, or distinct log-markers. Erosional surfaces are inferred where truncation is the most reasonable explanation of anomalous correlations or stratigraphic relationships. In some instances the existence of the interpreted erosional surfaces can be shown if core is available, for example the erosional nature of the base of the Coquinal Dolomite member (Davies et al., 1997; Davies and Sherwin, 1997). However, there is a lack of core that cuts through most of the interpreted unconformities and/or erosional transgressive surfaces, making it difficult to confirm their existence or to characterize them.

Based on the regional correlations five extensive, major transgressive-regressive sequences can be identified within the Montney Formation (Figs. 2 to 8). Most of the identified erosional surfaces appear to be transgressive surfaces, there being little evidence of subaerial exposure or for the presence of non-marine strata. The erosion surface at the base of the Coquinal Dolomite member is a major unconformity and may be locally a subaerial exposure surface modified by transgression, although Davies and Sherwin (1997) preferred to identify it as a regressive surface of erosion. They also argued for local subaerial exposure at the top of the Coquinal Dolomite member.

Whereas Davies et al. (1997) show a succession of prograding and aggrading transgressive-regressive cycles up to the base of the Coquinal Dolomite member without any major internal truncations I have identified a significant erosional surface within this interval (Figs. 2 and 5). This erosional surface defines the top of the first sequence. The erosional surface is itself truncated, both eastward and westward, by a younger erosional surface, that at the base of the Coquinal Dolomite member and its equivalent surface to the west. The erosion surface at the base of the Coquinal Dolomite member, and its lateral equivalent, defines the upper boundary of the second sequence. Because upper strata of the second sequence are extensively eroded, the sequence has a limited areal distribution, both east-west (see Fig. 2) and north-south; preserved only in the east-central part of the basin.

Correlation of the erosion surface at the base of the Coquinal Dolomite member westward into non-coquinal beds is critical to understanding the distribution of a particularly sandy interval in the lower Montney Formation. Davies et al. (1997) also recognized the importance of this erosional surface, but, as is apparent from the cross sections presented herein (Figs.2 to 4), I correlate the erosion surface westward to a stratigraphic level below that of Davies et al. (1997). As correlated, this sequence boundary is widespread and can be identified throughout most of the basin, even in "basinal" settings. An isopach map of stratal thickness between the base-of-Triassic and the unconformity at the base of the Coquinal Dolomite member (or its equivalent marine erosional surface) can be used to indicate the approximate paleotopography at the time of the unconformity (Fig.11). This shows a platform area in the east and southeast grading westward into a scalloped slope, in turn grading into a large area of very low-slope gradients. The remnant of a platform is preserved in the northern subcrop area. This type of topographic expression would be consistent with the development of an unconformity at or near a paleoshoreline as the relative sea-level dropped, creating a "nick point" in the shelf. Accommodation space would be shifted seaward and deposition within this space as sea-level gradually rose created the third sequence. Even at its steepest this erosion surface has a very low slope, for example there is a drop of only 75 m over a distance of 17 km in the southern platform. One other aspect of the erosion surface at the base of sequence 3 that needs some explanation is the apparent basinward truncation of strata, as well as landward truncation. A reasonable explanation for this geometry would be either to have sequences 1 and 2 folded into a broad, but very shallow syncline or tilt these strata landward (to the east), prior to deposition of sequence 3; or possibly a combination of broad, shallow folding and fault-tilt. Folding and/or tilting, plus base-level drop, could produce basinward truncation of strata. This would be consistent with the truncation geometry and the fact that the base of the Coquinal Dolomite member is a major regional unconformity within the Montney succession. A similar, but less pronounced basinward truncation is seen at the base of sequence 2, and it too could be explained by minor tectonic tilting or folding.

Strata of the third sequence onlap this major unconformity. Internal correlations within this third sequence point to a complex depositional history, details of which still need to be resolved. However, this complexity could, in part, account for some of the multiple events recorded in the Coquinal Dolomite member (Davies and Sherwin, 1997), which appears to correlate with much of this interval.

A regionally correlatable erosion surface at the base of a distinct sandstone-rich interval defines the top of the third sequence and the base of the fourth. This sandy interval is equivalent to Davies et al.'s (1997) "turbidite-lowstand/transgressive wedge". Unlike Davies et al. (op. cit.) I do not correlate the erosion surface at the base of these sandstones with that at the base of the Coquinal Dolomite member, rather it is stratigraphically higher, correlating to strata above the coquinal dolomite (Figs. 3 and 4). Strata of the fourth sequence are relatively thick, compared with the older sequences, and consist of a series of prograding and aggrading cycles. Major internal discontinuities are not readily identified. This succession corresponds, in large part, to the Siltstone member of the Montney Formation. Apart from the basal sandstone-rich interval,

the fourth sequence is lacking in thick sandy intervals, being composed mostly of shale and siltstone with thin sandstone interbeds.

The fifth, and uppermost sequence, in the Montney Formation corresponds mostly to the Shale member. A basal unconformity/erosional surface is difficult to identify, there being only minor indications of truncation. However, the strong gamma-ray response that defines the basal contact for much of the Shale member is interpreted to be a flooding surface and an unconformity and/or transgressive surface underlies the flooding surface. Based on log correlations the unconformity/transgressive surface appears to be very close to the flooding surface and on the cross sections the basal erosional surface is interpreted to underlie a thin silty or sandy unit immediately below the high-gamma-count shale of the flooding surface. No cores have been cut across this boundary. Although the distinct gamma-ray response of the flooding surface is correlatable over much of the basin, in the westernmost wells (i.e., within the foothills) this stratigraphic level becomes more difficult to correlate due to the presence of organic-rich, high-gamma-count shales in subjacent beds of sequence 4. The upper boundary of the fifth sequence is the contact with the Doig Formation, which also is a closely spaced unconformity/transgressive surface and flooding surface. However, the Doig-Montney contact can be shown to truncate significant amounts of strata on a basin-wide scale. The thickest part of the fifth sequence shows a significant westward shift compared with the lower four Montney sequences (Figs. 5 and 6).

Age of the Sequences

When compared with the units identified and dated by Davies et al. (1997, fig. 5 and table 1) the following ages for the sequences are suggested:
Sequence 1: Griesbachian
Sequence 2: ?Griesbachian-Dienerian
Sequence 3: Dienerian-Smithian (contains the Coquinal Dolomite member)
Sequence 4: Smithian-Spathian
Sequence 5: Spathian
These ages are necessarily broad because of the poor biostratigraphic control within the Lower Triassic succession of the subsurface.

DEPOSITIONAL HISTORY

In general, the five sequences identified in the Montney Formation offlap westward to northwestward. Internally, each sequence contains minor transgressive-regressive cycles that also offlap westward to northwestward, each cycle tending to thin basinward. Sequences 1 to3 are thinner and more sand-prone than sequences 4 and 5. Correlations indicate that the major unconformity at the base of sequence 3 truncates underlying strata both basinward and landward, suggesting that erosion resulted from minor tectonic warping of older strata.

Sequence 1

Sequence 1 strata consist of a series of prograding to aggrading depositional cycles of shoreline and/or deltaic strata (Miall, 1976; Davies et al., 1997). Because of post-Triassic erosion the eastern subcrop rarely preserves the most proximal facies, the bulk of the preserved

sediments represent middle and lower shoreface, and offshore depositional environments. Some units act as hydrocarbon reservoirs, such as at the Ring-Border, Fox Creek and Flood fields.

Sequence 2

A significant drop in base-level shifted deposition slightly westward relative to that of sequence 1. Strata of sequence 2 also consist of prograding to aggrading successions of offshore to shoreline sediments. These strata could be potential reservoirs, similar to those in sequence 1, although of more limited extent due to subsequent erosion. The end of sequence 2 deposition may have been the result of tectonic tilting, or minor folding, accompanied by base-level fall.

Sequence 3

A major drop in base-level and westward shift in the facies belts marks the beginning of sequence 3. Subsequent deposition resulted in two very distinct facies assemblages, the Coquinal Dolomite member and a sandy facies. The coquinal dolomite developed on an eastern platform as a series of storm accumulated shelly deposits (Davies and Sherwin, 1997), whereas the marine sandy beds onlap the sequence's basal unconformity west of the coquinal beds. The best developed sandy beds occur where the basal unconformity is steepest, close to the western margin of the coquinal dolomite, becoming siltier and shalier to the west. As previously indicated, correlations within these sandy beds indicate a complex sedimentary history with possible internal discontinuities, in part reflected by the complex internal stratigraphy of the laterally equivalent (in part) Coquinal Dolomite member (Davies and Sherwin, 1997).

The coquinal dolomite is locally a very porous and permeable unit and acts as a hydrocarbon reservoir, such as at Sturgeon Lake or Kaybob. To date only a few hydrocarbon pools are known from the sandy facies, for example at Gordondale (Montney A and B pools) and possibly the West Eagle pool. The potential of these sandy beds remains to be tested.

Sequence 4

By the end of sequence 3, deposition had shifted eastward again but further uplift and/or base-level drop caused westward regression and truncation. The initial deposits of sequence 4 represent transgressive beds and form a widespread carpet of sandy beds of varying thickness and quality. These beds are equivalent to Davies et al.'s (1997) "turbidite-lowstand/transgressive wedge". Although the description of these basal beds as "turbidites" (Moslow and Davies, 1997; Davies et al., 1997) may be stretching the definition (see Shanmugan, 1997, for example), it is apparent that they do have many of the attributes of sediment gravity-flow deposits, as well as storm deposits. The widespread distribution of these basal beds points to deposition as a thin apron of sediments rather than as discrete, small submarine fans, although the thickest and best developed sandstones tend to be in a more proximal position relative to the presumed slope break. Also, the low gradient of the slope indicates a ramp-like setting with a minor slope break rather than a distinct shelf-slope break.

As transgression progressed eastward the basal beds became thinner and less prominent. Transgression must have moved the shoreline a considerable distance eastward because the

preserved sedimentary succession appears to be devoid of nearshore deposits. Presumably the shoreline sediments were eroded below the pre-Jurassic unconformity. Sequence 4 is much thicker than preceding deposits and consists of prograding and aggrading deposits that formed a wide shelf area. Western occurrences of sequence 4 contain zones rich in radioactive shales which could be organic-rich and potential source rocks. The thicker nature of sequence 4 is interpreted to reflect greater subsidence and sediment supply than was the case during deposition of sequences 1 through 3.

Hydrocarbons are present in the basal beds at Valhalla and Sexsmith, for example, but the remainder of the sequence is poor in reservoir quality beds. However, locally well developed sandstones at the top of sequence 4 have recovered hydrocarbons at Gordondale.

Sequence 5

Another major westward shift in deposition marks the beginning of sequence 5. This sequence is characterized by a dearth of coarse clastics and an abundance of radioactive shales, especially in more basinward locations. Correlation of these shales suggests that deposition progressed as a series of onlapping events onto a paleo-shelf margin or ramp-margin created during base-level drop at the end of sequence 4. The lack of significant coarse clastics suggests a very low-relief hinterland that supplied low quantities of coarse sediment.

No hydrocarbon discoveries are known from this sequence. However, the abundance of radioactive shales could be indicative of potential source rocks. Its thickest development in the more deeply buried western part of the basin probably places the strata within the mature to past-mature organic maturity zones, indicating a gas-prone potential (Reidiger, 1997).

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