Chapter 7 - Paleogeographic Evolution of the Cratonic Platform - Cambrian to Triassic

D.M. Kent - University of Regina, Regina

Introduction
The formation of a Paleozoic passive margin on the western side of the North American proto-continent played an integral part in the growth of the western Canada Sedimentary Basin. To consider the entire 4000 km length of this western trailing edge as a nontectonic margin would be an oversimplification, given that at least the United States portion was subjected to intertectonic activities. The end product of this activity was the Antler Orogeny. This event had a significant influence on the late Paleozoic growth of the cratonic margin and platform.

The stratigraphy of the cratonic platform and margin is shown in Figure 7.1, in simplified form. Twelve maps depicting the interpreted paleogeography at selected lithostatigraphic levels illustrate the evolution of the cratonic platform and margin. Each interval is highlighted on the correlation charts accompanying the maps. The maps are a synthesis of the most recent literature on the depositional environments and distribution of facies for the stratigraphic units that they represent. Where there is a conflict of interpretation, the more detailed opinion is accepted; where there is no majority opinion, a compromise is presented. Because this is a synthesis, accuracy in the location of facies boundaries, erosional edges and stratigraphic equivalence is slightly distorted, for improved clarity. On all of the maps, areas of solid color depict the preserved distribution of facies belts, the hachured areas their inferred original extent prior to erosional removal.

Growth of the Western Cratonic Margin
The North American proto-continent was isolated from a Late Proterozoic supercontinent by multi-phase rifting. The rifting created eastern and western continental margins, occurred probably between 625 Ma and 555 Ma.

Prior to the rifting that created the proto-Pacific passive margin, thick sequences of siliciclastics and carbonates belonging to the Purcell (Purcellian) and Belt (Beltian) supergroups were deposited in intracratonic basins, created by early partial rifting (Winston et al., 1984). The thickening of this Upper Proterozoic sequence, some 1500 m, and the presence of basaltic flows at various stratigraphic levels, implies a possible sulfacogen as the site of sedimentation.

Roes et al. (1989) suggested that the rocks of the Windermere Supergroup of Purcell and Belt supergroups were deposited in intracratonic basins, created by early partial rifting (Winston et al., 1984). The thickening of this Upper Proterozoic sequence, some 1500 m, and the presence of basaltic flows at various stratigraphic levels, implies a possible sulfacogen as the site of sedimentation.

Roes et al. (1989) suggested that the rocks of the Windermere Supergroup of Purcell and Belt supergroups were deposited in intracratonic basins, created by early partial rifting (Winston et al., 1984). The thickening of this Upper Proterozoic sequence, some 1500 m, and the presence of basaltic flows at various stratigraphic levels, implies a possible sulfacogen as the site of sedimentation.

The transition from eastern platform siliciclastics to outer shelf carbonates is distinctive because it is marked by an interbedding relation that Aiken (1978) identified as Grand Cycles. He recognized seven Grand Cycles, of which the Plaka is one of the earliest. Each is composed of a basal mudrock and an upper carbonate unit. The cycles are attributed to eustatic sea-level rises and falls and are considered to be excellent examples of fine-grained siliciclas-

Cratonic Margin and Platform
Cambrian-Lower Ordovician Interval
Initial Continental Margin Wedge
A regionally extensive unconformity cutting disconformable, angular and nongenetic unconformations between the Cambrian and the underlying Proterozoic basement on both the cratonic margin and platform, was developed following deposition of the Windermere Supergroup. Rocks of the Cambrian Gog Group probably represent initial growth of the continental margin wedge in the southern part of the Canadian Cordillera (Atkin, 1989). Farther to the north, rocks of similar age appear to have been deposited in a setting where syndepositional block faulting influence

econformity. The Gog rocks are predominantly quartz arenites with minor amounts of mudrocks and carbonates, all totalling 2.2 km in thickness (Atkin, 1989). Siliciclastics, trace and body fossils, and general overall character of these rocks suggests shallow-water deposition (Hein, 1987). Their characters and thicknesses are typical of the rapid thermal subsidence phase of early growth of a passive margin. Readers are referred to Hein and McMechan (this volume, Chapter 6) for a more detailed accounting of the early growth of the continental margin.

The Earliest Cratonic Transgression
Figure 7.2 depicts the inaugural Phanerozoic inundation of the proto- North America continent at the end of Ediacaran Deadwood stratigraphic level. The transgression is typified by a basal orthoquartzitic sandstone and a depositional dip lithofacies gradation (east-to-west) from inner shelf to outer shelf sands through platform mudrocks to outer shelf carbonates. The depositional strike of these lithofacies is subparallel to the northwest trend of the protocontinental margin, except where there is an eastward strike following the inferred paleoshoreline of the Peace River/ Athabasca Arch (Pugh, 1973). South of the arch, outboard deposits from the shelf-edge carbonates are thick, fine-grained siliciclastics, thought to have been laid down in a deep basin. The basin west of the arch, was influenced by an active fault system producing horst and graben features (Atkin, 1989) and a variable lithological character.

The transition from eastern platform siliciclastics to outer shelf carbonates is distinctive because it is marked by an interbedding relation that Aiken (1978) identified as Grand Cycles. He recognized seven Grand Cycles, of which the Plaka is one of the earliest. Each is composed of a basal mudrock and an upper carbonate unit. The cycles are attributed to eustatic sea-level rises and falls and are considered to be excellent examples of fine-grained siliciclas-

The Earliest Cratonic Transgression
Figure 7.2 depicts the inaugural Phanerozoic inundation of the proto- North America continent at the end of Ediacaran Deadwood stratigraphic level. The transgression is typified by a basal orthoquartzitic sandstone and a depositional dip lithofacies gradation (east-to-west) from inner shelf to outer shelf sands through platform mudrocks to outer shelf carbonates. The depositional strike of these lithofacies is subparallel to the northwest trend of the protocontinental margin, except where there is an eastward strike following the inferred paleoshoreline of the Peace River/ Athabasca Arch (Pugh, 1973). South of the arch, outboard deposits from the shelf-edge carbonates are thick, fine-grained siliciclastics, thought to have been laid down in a deep basin. The basin west of the arch, was influenced by an active fault system producing horst and graben features (Atkin, 1989) and a variable lithological character.

The transition from eastern platform siliciclastics to outer shelf carbonates is distinctive because it is marked by an interbedding relation that Aiken (1978) identified as Grand Cycles. He recognized seven Grand Cycles, of which the Plaka is one of the earliest. Each is composed of a basal mudrock and an upper carbonate unit. The cycles are attributed to eustatic sea-level rises and falls and are considered to be excellent examples of fine-grained siliciclas-
Figure 7.6 portrays the fourth subinterval, the time of a shrinking carbonate sea. It is also within this stratigraphic interval that recognizable coral reef structures are identified on the carbonate platform. Bailey (1951) and Stearns (1956) both described reefs from the Cedar Lake Formation of the Interlake area of Manitoba. Jamison (1959) and Kent (1948b) also reported the presence of reef-like rocks in two borehole cores from southwestern Saskatchewan.

In the eastern platform this subinterval is represented by the rocks of the Interlake Formation, which appear to make up a shallow-water carbonate platform. The lower part of the succession is clearly subtidal, but the upper part contains an assemblage of lithological features (Norford et al., this volume, Chapter 9) that have been interpreted as indicators of a range of depositional and diagenetic mechanisms produced by subaerial exposure, vadose alteration (Faul, 1969), and freshwater sedimentation (Magathan, 1967). The shallow-water carbonate platform was obviously a prediction of the end of the carbonate sea on the eastern platform and was followed by a period of exposure lasting some 36 million years.

The western platform may have been covered by carbonate deposits as well, but if so, their extent was significantly restricted by an enlarged Peace River/Attabaska Arch. Evidence of the presence of shelf carbonates on the western platform is found in the Nondina Formation north of the arch (Norford et al., 1966) and in the upper Bearpaw and Tegot further south. The continental margin continued to be a region of turbidity, basins, and embayments in which slope and deep-basin deposits, mainly shales, were laid down. Platformal inner shelf and, on which typical shelf carbonates were deposited, flanked the basins and embayments (Morrow, 1984; Coke and Norford, in press). The break in the depositional record is not as pronounced on much of the craton and does not appear to be present in the continental margin rock record, particularly north of the Peace River/Attabaska Arch, where the succession is continuous from latest Silurian to earliest Devonian (Coke and Norford, in press).

Devonian-Lower Carboniferous Interval

This interval is divided into six subintervals (DM1 to DM6) to facilitate the presentation of specific events in its sedimentary history. The interval presents three contrasting styles of sediment distribution pattern, and five subinterval maps (Figs. 7.7–7.11) are employed to show them, three representing the Devonian and two the Lower Carboniferous.

The embryonic Devonian seaway was confined to a basin flanked by the Peace River Arch, the West Alberta Ridge and the Swift Current Platform in the west and south, the Laurussian hinterland to the north, and the Severn and Sioux arches to the east, extending as far to the southeast as the Transcontinental Arch. The initial inundation of this basin was from the northwest, a distinct contrast from the two previous depositional intervals.

A Coastal Hypersaline Basin - Subinterval DM1

The distribution of the facies in this subinterval is best described by reference to Figure 7.10. The eastern part of the platform was a land surface, and the first Devonian sediments were deposited in a sub-basin lying between the Peace River Arch and Laurussian hinterland, terminated to the southeast at a low ridge of lower Paleozoic rocks commonly known as the Meadow Lake Escarpment.

The transgressive beds are characterized by a basal sandstone, and the remaining sediments in the basin consist of red beds, siltstone, and claystone. Interbedded with these are thick evaporite deposits of anhydrite and halite. Fuzesy (1968) interpreted the evaporites to have extended at least as far as the present erosional edge of Paleozoic rocks in central-western Saskatchewan. Low brine concentration in the halite suggest a possible freshwater influence in the shallow lakes. An outcrop of a limestone, which is probably the equivalent of the ostracodiferous limestone of the Lower Elk Point Subgroup/Meadow Lake Formation, comprising this subinterval, was at least 100 km beyond the present erosional edge.

The coastal basin deposits pass northwesternly into typical carbonate platform sediments situated on what is known as the McDavid Platform. Moore (1989) reported that the oldest Devonian coral/sparite was recognized in the carbonates of the McDavid Platform. Outboard from the carbonate platform are the thin limestone, siliciclastic, deep-basin deposits of the Road River Formation.

Basinal Reefs and Hypersaline Basins - Subinterval DM2

The opening phase of this subinterval is characterized by a marine, carbonate-depositing sea that transgressed the platform through a southeast-trending trough-like depression, the Elk Point Basin, extending from northeast British Columbia to southern North Dakota. Williams (1984) presented several alternatives for the shape of the basin, particularly with regard to the location of the north margin. A slight variation on his alternative “C” is the one employed in Figure 7.7. The sediments of this sea imply relatively normal marine conditions, with a chlorinolite biota dominated by brachiopods and crinoids. This initial phase of sedimentation was one in which rates of subsidence and sedimentation were approximately equal, but it was followed by a time of catch-up deposition when carbonate wedges formed at the margins, while banks and both ecological and stratigraphic expressed as the basin floor (Fig. 7.7). There are probably several hundred reeds in the basin. Moore (1988) identified almost two thousand from the publications he reviewed, and there are another twenty or more in east-central Saskatchewan (Gendzwill and Wilson, 1984). Undoubtedly, there are many others that have not been discovered and an estimate of three hundred would not be out of order.

A sizable barrier reef (Keg River-Pine Point, part of the Pea River barrier complex) developed across the northern end of the basin, extending northeastward from the Peace River Arch to a positive feature on the Laurussian hinterland, beyond the present erosional edge. In addition, there were several broad carbonate banks that may have restricted parts of the basin floor. In fact, Bebout and McKinnon (1973) and Moore (1989) implied that the banks may have been sufficiently extensive to isolate the basin floor into several sub-basins. Most of the bank accumulations appear to have been in northwestern Alberta; however, Wardlaw and Reinson (1971) suggested that there may also have been extensive bank growth in the Saskatchewan area of central Saskatchewan.

Most of the basin edges appear to have been initiated by growth of crinoidal colonies (Langton and Chin, 1968; Martindale and Macdonald, 1990; Kent and Minto, 1991). In the upper part of the interval the composition varies considerably. Those in the proximal end of the Elk Point Basin (northwestern Alberta) appear to be fine-grained reefs dominated by coral/sparite frameworks with coral and stromatoporoid buildups (Langton and Chin, 1968). Those in the basin on the eastern cratonic platform are stratigraphic reefs composed of peloidal- and coccolith algal-rich lime mudstone to wackestone, in the lower parts, with a cliff offordl coral/sparite and red algal (Gendzwill and Wilson, 1987; Martindale and Macdonald, 1990; Kent and Minto, 1991) in the upper 30 m. They take on assorted morphologies, from low-relief, mound-like features through pinnales and pinnae complexes, to flat-topped reefs.
Figure 7.3: Paleogeography of the cratonic platform and margin during subinterval O1. The sandstone/mudrock relation in Manitoba is more complex than can be illustrated on a map, because the sandstones and mudrocks are interbedded and in places there are localized thick accumulations of one rock type or the other (Andrichuk, 1958; Ygrasse, 1971).
Figure 7.4 Paleogeography of the cratonic platform and margin during subinterval OS2. The deposits of the hypersaline basin are dominantly layered anhydrites. Rocks beyond the limits of the hypersaline basin are intensely dolomitized and their origin is not easily determined; however, they are thought to have been shallow marine.
Figure 7.5 Paleogeography of the cratonic platform and margin during subinterval OS3. The environment illustrated as muddy is, in fact, an argillaceous carbonate with some interbedded mudrock.
Figure 7.8 Paleogeography of the cratonic platform and margin during subinteval OS4. Note the locations of reefs in this carbonate sea way.
Figure 7.7 Paleogeography of the cratonic platform and margin during subinfill DM2. Moore (1993) showed the La Crosse sub-basin isolated from both the Black Creek sub-basin and the Saskatchewan sub-basin by extensive carbonate banks. This map depicts a more conservative interpretation. The evaporite infill in the basin includes anhydrite on the basin floor and enclosing the reefs, and halite and potash across the central portion of the Saskatchewan sub-basin.
Figure 7.8 Paleogeography of the cratonic platform and margin during subinterval (DM3). Fine-grained siliciclastics of the basin margin deposits are interpreted as having been sourced in the hinterland to the north and east.
Figure 7.9 Paleogeography of the cratonic platform and margin during subinterval DM4. The outline of reefs on the cratonic margin is based largely on Moore (1986). Palaeoplastic restoration of their positions stems from Mountjoy (1985). The hypersaline basins on the eastern platform have some anhydrite but contain mainly halite. Thicknesses of the evaporites are in the order of 30 m (Kart, 1968b; Dunn, 1976).
Figure 7.16 Paleogeography of the cratonic platform and margin during subinterval DM5. The distribution of Lower Carboniferous lithofacies suggests deposition on a relatively narrow shelf (similar to the coast of the United Arab Emirates of the Persian Gulf), leading to the inferred location of the Lower Carboniferous shoreline and the landward coastal sabkha.
The embayment was covered by shallow-water, sandy carbonates, but the sandy carbonates were restricted to the margins of the embayment and the main carbonate sedimentation took place in the central part.

Moore (1989, 1990) identified the northwestern margin of the entire cratonic platform as a carbonate platform built up by shallow-water, shallow-subtidal carbonates. This platform is further divided into two distinct sub-sections: a carbonate platform with a shallow-water, shallow-subtidal setting and a carbonate platform with a deeper-water, deep-subtidal setting.

This platform is further divided into two distinct sub-sections: a carbonate platform with a shallow-water, shallow-subtidal setting and a carbonate platform with a deeper-water, deep-subtidal setting. The shallow-water, shallow-subtidal carbonate platform is characterized by a series of sub-horizontal layers of lime mud, which are interpreted as the remains of shallow-water, shallow-subtidal carbonates. The deeper-water, deep-subtidal carbonate platform is characterized by a series of sub-vertical layers of lime mud, which are interpreted as the remains of deeper-water, deep-subtidal carbonates.

Moore (1989) also identified the northwestern margin of the entire cratonic platform as a carbonate platform built up by shallow-water, shallow-subtidal carbonates. This platform is further divided into two distinct sub-sections: a carbonate platform with a shallow-water, shallow-subtidal setting and a carbonate platform with a deeper-water, deep-subtidal setting.
Figure 7.12 Palaeogeography of the cratonic platform and margin during the Rundle-Mission Canyon subinterval (DM6). Continental sabkhas inferred.
Figure 7.13 Paleogeography of the cratonic platform and margin during the Permian part of subchron PT1.

CRATONIC PLATFORM
(1987) also delineated a cluster of Waukonsian-type mounds in the lower slope setting of extreme southwestern Saskatchewan. Other mounds on the same subinterval have been found in a comparable palaeohtymetric setting in the Central Montana Trough (Cotter, 1963; Stone, 1970) and the Peace River Embayment (Morgan and Jackson, 1970; Davies et al., 1988).

The rocks on the eastern platform are much like those along the pericratonic margin, consisting of transgressive-regressive cycles of skeletal-collief carbonates (Richards, 1989). However, the nearshore carbonates, silicilastics and evaporites were probably eroded from the eastern platform. Seeds (1990) and Young and Rossenthal (1991) showed that the shelf, slope and basinal rocks comprise sets of parasequences.

In the Rundle-Mission Canyon subinterval the carbonate depositional setting for the Williston Basin was more ramp-like, and although the sequence is marked by transgressive/regressive cycles, there is an overall progradation toward the basin centre with pericratonic carbonates prograding over inner and outer shelf deposits. Figure 7.12 is an attempt to depict this progradation, and the peritidal and shelf facies are shown as having migrated basinward with respect to their postulated position in Figure 7.10. The western platform is marked by a similar progradational shelf sequence but the shelf break is much better defined; the shelf carbonates pass into slope carbonates, which in turn pass into basinal silicilastics in the Prophlet Trough (Richards, 1989).

North of the Peace River Embayment, which was a well defined feature during this subinterval, the depositional setting continued to be one in which fine-grained silicilastic and spilic carbonates accumulated. In latest Early Carboniferous time most of the western margin became dominated by deltaic, coastal plain, and fluvial deposits, as represented by the Matisse assemblage (Richards, 1989).

Upper Carboniferous to Triassic Interval

Demise of Passive Margin Sedimentation - Subintervals PT1 and PT2

The shallowing-upward cycles of the Lower Carboniferous heralded the significant drop in sea-level that is characteristic of the PT interval on the cratonic platform. Continental sedimentation on the eastern platform may have commenced as early as the late Early Carboniferous, as evident from the Poplar Beds of the Madison Group and the Kibby Formation of the Big Snowy Group in southeastern Saskatchewan, which have recognizable continental characteristics (Richards, 1989). At the present time, rocks of the Upper Carboniferous-Permian subinterval have limited distribution in the foothills and Rocky Mountains, probably for two reasons: 1) their deposition was confined to the ancestral continental margin; and 2) according to Henderson (1989) they have been truncated by at least four major unconformities.

Henderson (1989) suggested that the dominance of silicilastics in these strata is related to the drifting of Pangaea into subtrapolical and warm-watertemperature zones where carbonate sedimentation was subdued. Any carbonates that were deposited were formed in a mixed siliciclastic-carbonate setting.

Upper Carboniferous rocks are the most extensively distributed. In their few occurrences, Henderson (1989) recognized shallow- to deepshelf deposits as well as assemblage coastal dunes as seen in the Sletrek Formation of the Spray Lakes and Clearwater formations.

In the Permian rocks (Fig. 7.13), shelf, slope and basin deposits are recognizable (Henderson et al., this volume, Chapter 15), but according to Henderson (1989), with the exception of some nearshore and peritidal carbonates, the remaining rocks appear as though they were deposited below fairweather wave base. They contain a predominance of phosphorite deposits and coarse- and fine-grained clastics. The former are commonly glauconitic. In places the slope sediments are starved deposits, as indicated by abundant phosphatic sediments. Elsewhere, particularly north of the Peace River Embayment, they are covered by turbidites. The basinal rocks, preserved mainly on the eastern side of the Ilebrel (Prophet) Trough, are generally spicular chert, argillaceous limestone, silt- and shale. The nature of the western margin of the trough is speculative, at best. Henderson (1989) suggests that the Cassiar Terrane may have been a subaeulacally exposed part of the rim. In the Barkerville Terrane there is evidence to indicate that the marine setting proximal to the rim had sedimentary deposits and volcanics.

A Late Permian drop in sea level exposed the rocks of that age to erosion, and in places the uppermost Paleozoic strata were completely stripped away. This low sea-level stand also established the initial settling for the Carboniferous sedimentation. Gibson (1954) identified the basin Triassic strata along the ancestral continental margin (Fig. 7.14) as representing deltaic and tidal flat deposits, suggesting a lowstand shoreline. Gibson and Barlow (1989) interpreted the entire Triassic succession along the length of the cratonic margin of that time as comprising at least three transgressive/regressive cycles. Each contains rocks typical of a marine shelf setting ranging from distal deep shelf waters to proximal shoreline (Edwards et al., this volume, Chapter 16). These cycles are characterized by carbonates and fine-grained silicilastics, and the proximal deposits by deltaic, tidal flat and barrier bar silicilastics complexes and in particular卡拉独 evolved carbonate bodies. The sediments that accumulated on the eastern platform during this subinterval reflect the aridity of climatic conditions of that time. They were predominantly redbeds, dominated by mud and silt and characterized by bodies (Cumming, 1956; Burchyn, 1989). Desiccate aridities are also common within the sequence. The deposits generally suggest continental sedimentation, but some of the thin, carbonate facies, lithostratigraphic units have led Burchyn (1980) to invoke marine sedimentation for their origin.

The rifting of Pangaea along the eastern perimeter of the North American province initiated convergence on the western margin. This event terminated the more or less trailing-edge depositional conditions that had prevailed since the proto-continent was formed some 600 million years before, and initiated foreland basin sedimentation.

Summary and Conclusions

Throughout most of the evolutionary history of the cratonic platform, the passive margin prevailed as a site of sediment accumulation. On the platform, an assortment of sediment distribution patterns, related to cycles of transgression and regression, punctuated its history. The inaugural Cambrian inundation was from the west. Following a regression and second transgression, this time from the southeast, the cratonic platform entered into a lengthy phase of carbonate sedimentation (Late Ordovician to Silurian), predominantly on the eastern portion.

The third inundation (Devonian), from the northwest, spread deeply into the interior of the cratonic platform through a southeast-trending embayment. Through time the seaway expanded into a ramp and then to a ree-reeled dominated shelf basin with a broad carbonate-evaporite marginal shelf in the eastern platform. Colli- sion of the western continental margin with the Antler allochthon during the latest Devonian and earlier Carboniferous initiated sedimentation in narrow shelf-to-basin facies belts that followed the depositional strikes of a series of basins and troughs in the western platform and along the passive margin in the west.

In the last phase of the evolution of the cratonic platform (Late Carboniferous-Permian and Triassic), marine sedimentation was again restricted to the passive margin while the platform underwent erosion and continental sedimentation.

In conclusion, the geological history of the cratonic platform can be summarized as two periods of continental margin sedimentation separated by cratonic inundations from the west, southeast, and northwest. The amount of crustal submergence during any one transgression was controlled by an assemblage of, including, the Peace River/Alfahassou, the Severn-Siuslaw, the West Alberta Ridge, Montana, the Sweetgrass-North Battleford and the Central Montana Uplift.

Acknowledgements

I wish to thank Mr. Ken Jones, who did the final line work and colouring of the original maps from which those of this Atlas chapter were copied. Thanks also go to Ruth Berr, Fran Haid, Brian Norford, Doug Paterson, Grant Mossop and Dave Smith for helpful suggestions concerning the formatting of my maps and insights into the geology and paleogeography of their chapters. I acknowledge also the comments of reviewers Mike Cecile, Dave Morrow and Barry Richards.

Last but not least, to my wife Joyce, my deepest appreciation for her patience and encouragement while I sequestered myself for many hours to write this chapter.

References


