Implied basement-tectonic control on deposition of Lower Carboniferous carbonate ramp, southern Cordillera, Canada

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ABSTRACT

The Mount Head embayment is a regional downwarp along the west coast of Lower Carboniferous western Canada that developed by differential subsidence, which we recognize from lithostratigraphic and biostratigraphic patterns. Palinspastic restoration of the Mount Head embayment illustrates that subsidence domains are geometrically coincident with previously identified tectonic elements of the autochthonous basement. Thus, it appears that basement-tectonic elements controlled sediment accommodation and accumulation within the Mount Head embayment. The overall shape of this embayment is probably inherited from the arcuate shape of the Late Proterozoic cratonic rift margin. Within the Mount Head embayment, several northeast-southwest–trending Archean and Proterozoic basement-tectonic elements intersect the autochthonous cratonic margin at high angles. Carboniferous piano-key-like structural reactivation of these tectonic elements produced oriented trends of differential subsidence that partitioned the Mount Head embayment into two subbasins (Crowsnest and Kananaskis depocenters) separated by a more positive area (Highwood high). Moreover, our data imply that Precambrian basement structure noted by others under the Plains and Rocky Mountain fold and thrust belt continued across the Rocky Mountain trench to the west, and that tectonic control on sedimentation noted by others for Precambrian and pre–Middle Devonian rocks extends clearly into overlying Carboniferous deposits.

INTRODUCTION

The Mount Head Formation (Fig. 1), from the Canada–United States border northward to Canmore, Alberta, forms an eastwardly convex and westward-thickening wedge (Fig. 2A). This arcuate geometry outlines a newly recognized Lower Carboniferous oceanic embayment, the Mount Head embayment (Brandley, 1993). Within the Mount Head embayment there are two subbasins, the Kananaskis depocenter in the north, and the Crowsnest depocenter in the south (Fig. 2, A and B). These depocenters are separated by the Highwood high, an area that subsided less and remained largely within shallow-marine to peritidal zones throughout most of its existence (Fig. 2, A and B). Other depositional features within the embayment include isopach anomalies north of lat 50°15′N that trend northeast-southwest, and less-obvious isopach anomalies in the south that trend roughly east-west to northeast (Fig. 2A). Integration of these depositional patterns with biostratigraphic, aeromagnetic, and gravity data, and with regional LITHOPROBE seismic reflection data, reveals that the Mount Head embayment was probably formed by reactivation of underlying Archean and Proterozoic basement-tectonic elements. Basement tectonic control on sedimentation has been identified previously by others, for the Precambrian (Kanasevich et al., 1969) and pre–Middle Devonian (Norris and Price, 1966; Benvenuto and Price, 1979).

METHODS

Geologic observations were recorded on palinspastically restored maps and cross sections and compared to basement-tectonic domains defined on aeromagnetic and gravity maps (Brandley, 1993). The palinspastic base map is modified from Gibson's (1985) map of displacement vectors for Jurassic rocks. The magnitudes of the vectors were altered to reflect displacements at the Mississippian level documented by Bally et al. (1966), Price (1981), and Price and Fermor (1985), university theses, and Geological Survey of Canada maps and sections across the area. Previous cross sections were constructed perpendicular to local strike in this arcuate thrust belt. To conserve mass during palinspastic restoration, all points were restored along the average direction of 260°. Potential field data are from the Geological Survey of Canada.

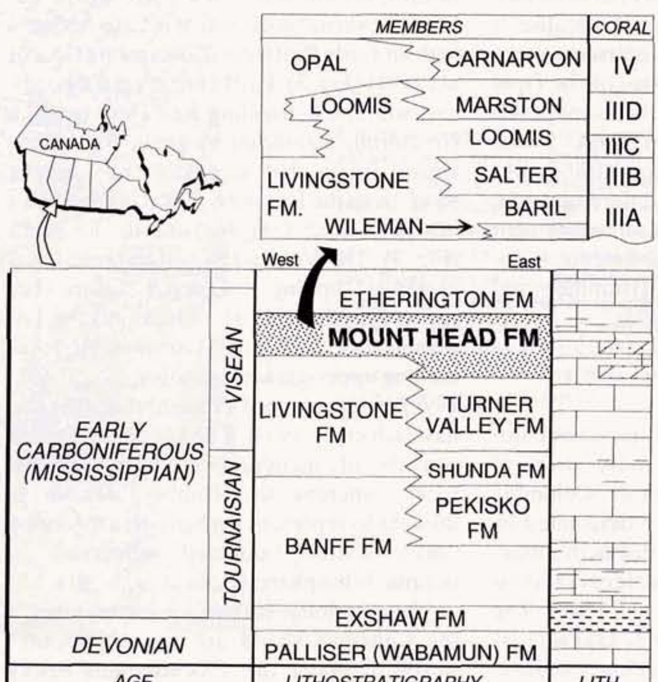

Figure 1. General location, stratigraphic correlation chart, and coral biozones of Lower Carboniferous Mount Head Formation.

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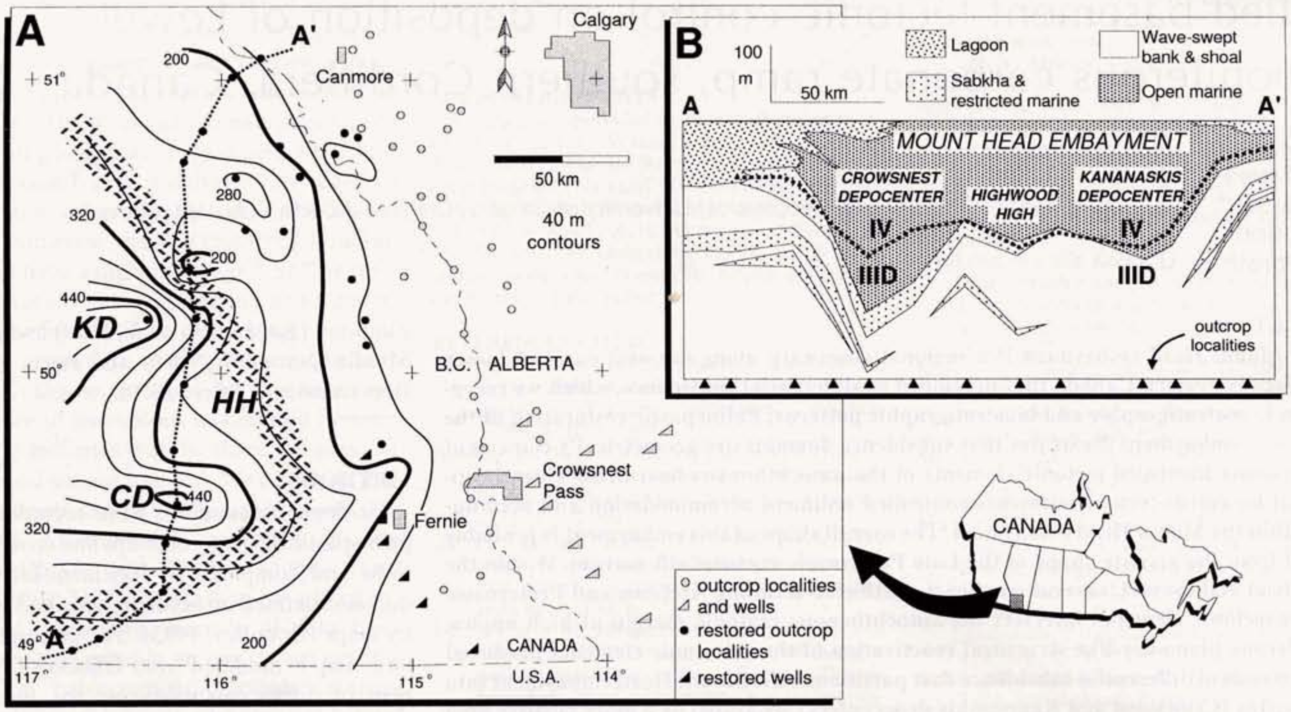

Figure 2. A: Palinspastically restored isopach map of Mount Head Formation showing convex-eastward depositional trend highlighted by shaded band. Isopach trends outline Mount Head embayment, Kananaskis depocenter (KD), Crowsnest depocenter (CD), and Highwood high (HH). Line A-A′ identifies cross section for B. B.C. is British Columbia. B: South-north cross section A-A′ showing thickness and lateral facies variations across KD, HH, CD. Chronostratigraphic IIID/IV coral biozone boundary highlights location, facies variations, and magnitude of differential subsidence within Mount Head embayment.

BIOSTRATIGRAPHY AND SEDIMENTOLOGY

Five coral biozones and subzones occur in the Mount Head Formation (Sando and Bamber, 1985) (Fig. 1). Most biozone boundaries show a strong correlation with lithostratigraphic boundaries (Fig. 1) (Brandley and Krause, 1992a; Brandley, 1993). However, the boundary between biozones IIID and IV is unusual because it crosscuts major lithosomes, intersects a major flooding surface at the base of the Opal Member, and cuts across the Kananaskis and Crowsnest depocenters (Figs. 1 and 2B). This well-delimited chronostratigraphic marker highlights coeval differential subsidence relations that reflect an embayment partitioned into separate sedimentary domains (Fig. 2, A and B) (Brandley and Krause, 1992b; Brandley, 1993).

POTENTIAL-FIELD AND SEISMIC DATA

Archean and Proterozoic basement domains underlie the sedimentary cover of southern Alberta and British Columbia (Figs. 3 and 4). Domains are delineated by geochronologic data and by distinctive magnetic and gravity anomaly patterns (Kanasevich et al., 1969; Ross et al., 1991). The Medicine Hat block (2.61–3.27 Ga) is characterized by northwest-trending magnetic and gravity lineaments, and is truncated on the north by the Vulcan low (2.62 Ga). This low represents a downdropped block and is characterized by low, east-northeast–trending magnetic and gravity values (Figs. 3 and 4). The Vulcan low is bounded to the northwest by the collinear Matzhiwin high (2.58 Ga), which is characterized by a high magnetic signature (Fig. 3). The Matzhiwin high, in turn, is bounded to the north by the colinear Loverna block, which is Late Archean with an Early Proterozoic overprint (Ross et al., 1991) (Fig. 3). Farther north is the northeast-southwest–trending Red Deer trend, a structurally significant magnetic low of unknown origin that separates the Loverna block from the Lacombe (2.30 Ga) and Rimbey (1.79–1.85 Ga) domains to the north (Fig. 3). The Vulcan low is interpreted as a northwest-dipping collisional suture between the Medicine Hat block and the Loverna block, with the Matzhiwin High recording upper-plate magmatism (Ross et al., 1991), or as a buried Precambrian rift (Kanasevich et al., 1969). The Lacombe domain consists of metamorphosed supracrustal rocks, whereas the Rimbey domain is thought to represent a magmatic arc formed during southeast-directed subduction of oceanic lithosphere (Ross et al., 1991).

These regional-scale basement features of the Canadian shield are traceable southwestward under the allochthonous Rocky Mountains (Fig. 3) (Price, 1981, Fig. 3). West of the Rocky Mountain trench, the features lose their distinctive magnetic signatures due to an elevated geothermal gradient and to burial of the craton to depths of 20 km or more where the Curie temperature of magnetite is exceeded (Lewis et al., 1992; Cook et al., 1988). Thus, the short-wavelength magnetic signature west of the Rocky Mountain trench is produced mainly by allochthonous mid-Cretaceous plutons carried above the basement. However, the autochthonous basement elements are inferred to continue to the southwest past the Rocky Mountain trench despite the lack of magnetic signatures (Price, 1981; Ross and Parrish, 1991).

The basement domains are also traceable on the isostatic residual gravity anomaly map into the Rocky Mountains, at which point they are overprinted by a strongly positive, northwest-southeast–trending anomaly (Fig. 4). This anomaly tracks the Rocky Mountains north of 49°30′ and indicates that the topography of the Rocky Mountains is uncompensated (Garland and Tanner, 1957). The anomaly suggests that the Rocky Mountains are supported by a thick, strong, elastic lithosphere that thins to the west (from >200 to 38 km thick) (as suggested by Wu, 1991). Within the Purcell anticlinorium high gravity values reflect basement-involved thrust sheets as interpreted from seismic reflection data (Cook, 1994, per-

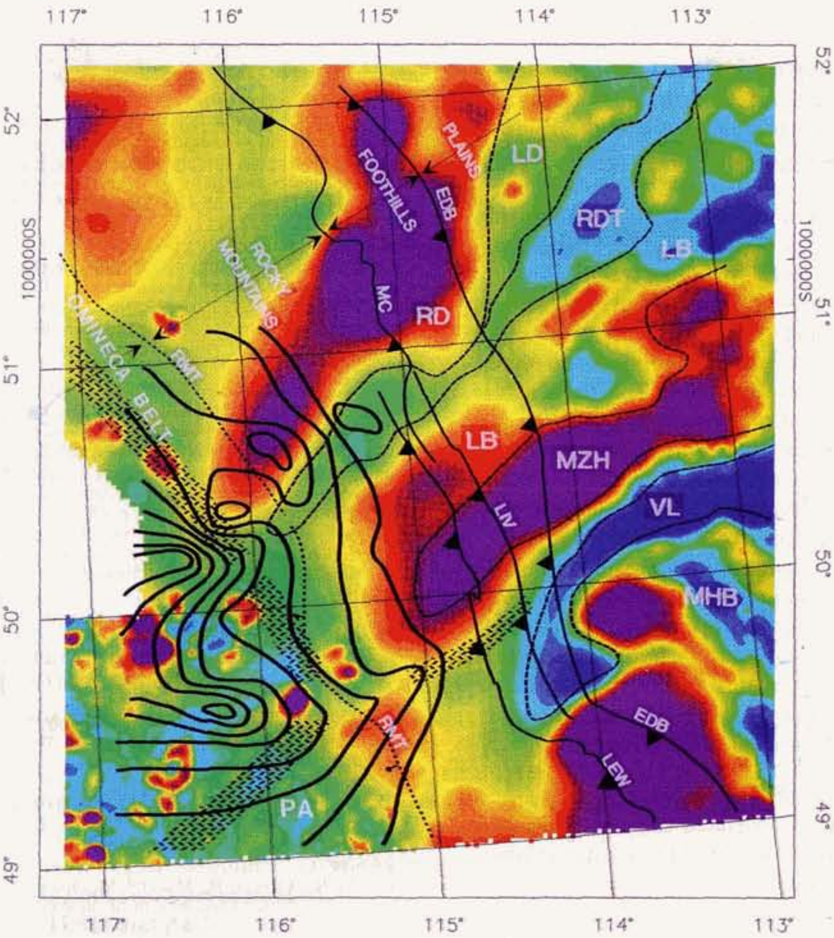

Figure 3. Aeromagnetic map of basement in southern Alberta and British Columbia; palinspastically restored Mount Head Formation isopachs as in Figure 2a are overlain. Basement elements are as follows: MHB, Medicine Hat block; VL, Vulcan low; MZH, Matzhiwin high; LB, Loverna block; RDT, Red Deer trend; LD, Lacombe domain; RD, Rimbey domain. High potential field values are shown in reds and magenta, median values are yellow and green, and low values are blue and purple. Physiographic references include EDB, edge of the deformed belt; MC, McConnell thrust; LIV, Livingstone thrust; LEW, Lewis thrust; RMT, Rocky Mountain trench; OM, Omineca crystalline belt; and PA, Purcell anticlinorium. Patterned bands west of Rocky Mountain trench indicate position on crustal ramp system where cratonic crust is ~21 km thick and thins rapidly to west. Patterned band east of Rocky Mountain trench outlines subsidence trend that passes into Vulcan low. Magnetic anomaly data were gridded at 812 m interval. Equal area contour interval was selected to enhance subtle anomalies near background values, resulting in nonlinear contour interval.

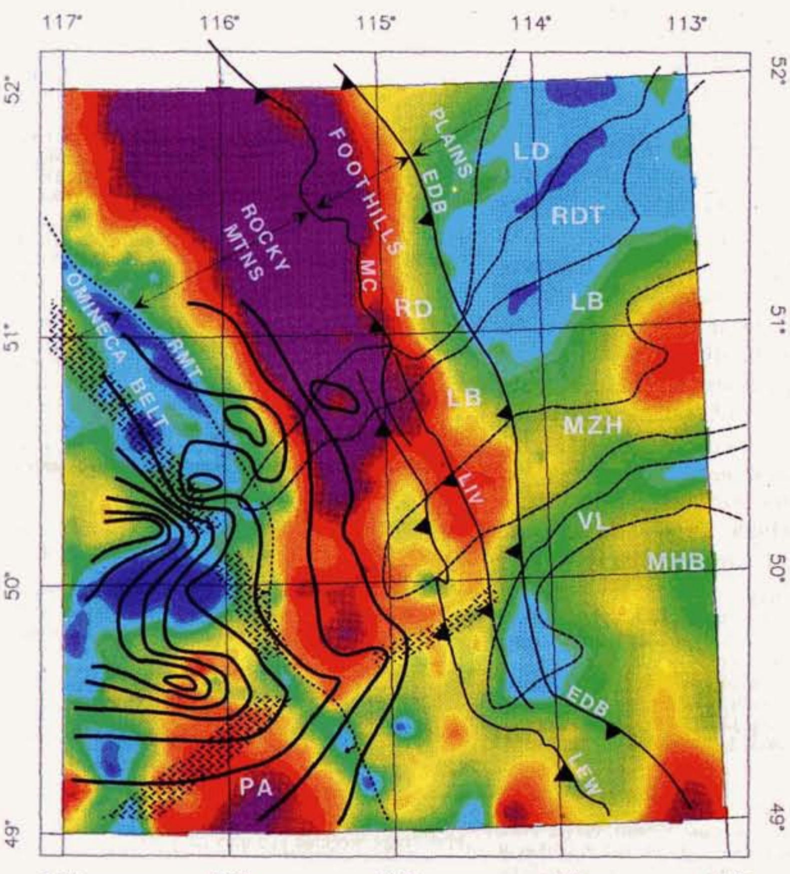

Figure 4. Isostatic residual gravity anomaly map of southern Alberta and British Columbia with aeromagnetic domains, physiographic references, trend of crustal ramp system, Mount Head isopachs, and potential field values as in Figure 3. Large northwest-southeast anomaly dominating central areas of map reflects uncompensated topography of Rocky Mountain front ranges and foothills provinces. Gravity signatures of most of basement elements are obscured under Rocky Mountains. Isostatic residual gravity anomaly data were gridded at 2 km interval. Equal area contour interval was selected to enhance subtle anomalies near background values, resulting in nonlinear contour interval.

sonal commun.). West of the Rocky Mountain trench, low gravity values are caused by the above-mentioned allochthonous plutons.

Along with these basement elements, regional crustal seismic reflection data indicate that the western margin of the North American craton forms a west-facing, eastward-convex, crustal ramp system that developed during the Cordilleran orogeny (Figs. 2A, 3, and 4) (Varsek and Cook, 1994). The crustal ramp system marks a transition from thick cratonic crust in the east (about 30 km) to thin cratonic crust in the west. The geometry and position of the crustal ramp system appear to be inherited from the Late Proterozoic rift margin of North America, as described by Hansen et al. (1993).

DISCUSSION

On a regional scale, the arcuate trend of the Mount Head embayment approximates the trend of the northwest-southeast–trending gravity high that marks the westward change from thick to thin lithosphere. Furthermore, the zone of increased subsidence within the palinspastically restored Mount Head embayment is approximately spatially coincident with the arcuate cratonic margin and crustal ramp system (Figs. 2A, 3, and 4). Thus, we propose that increased subsidence on the west side of the crustal ramp system controlled the overall shape of the Mount Head embayment, and regional lithofacies and biostratigraphic trends within it (Fig. 2B). Differential subsidence across the crustal ramp system appears to be related to an east-west decrease in lithosphere and crustal thickness and strength: i.e., thin, weaker lithosphere and crust on the west side of the ramp may have subsided more than thicker lithosphere and crust to the east. If so, the thick, strong lithosphere and crust east of the ramp would have provided an effective edge that controlled the shape of the Mount Head embayment.

Within the Mount Head embayment the northern northeast-southwest–trending isopach anomalies, including the Kananaskis depocenter, line up with the approximate projection of the Red Deer trend–Rimbey domain boundary as it passes beneath the Rocky Mountains (Figs. 2, 3, and 4). The trend of the Loverna block projects to the southwest into the Highwood high (Figs. 2 and 3). The east-west trend of the Crowsnest depocenter swings to the northeast, in an eastward direction, and lines up with the trend of the Vulcan low (Figs. 3 and 4). From these relations we propose that differential subsidence along and across Archean and Proterozoic basement structural elements influenced accommodation, depositional geometry, lithofacies relations, and biostratigraphic trends within the Mount Head embayment (Fig. 2).

The northern, northeast-southwest–trending isopach anomalies and the Kananaskis depocenter were likely produced by generally increased rates of subsidence along the Red Deer trend–Rimbey domain boundary (Figs. 2 and 3). The Highwood high (Fig. 2) was formed by generally lower rates of subsidence along the Loverna block. Southern isopach anomalies were produced by increased subsidence along a path that lines up with the Vulcan low. This trend may be the westward continuation of the Vulcan low, or may be some other basement element that passes into the Vulcan low to the east (Price, 1981). Subsidence patterns indicate that the basement domains are separated by discontinuities that allowed the domains to move relative to each other, much like piano keys oriented at a high angle to the crustal ramp system. Subsidence appears to be greatest where the discontinuities intersect the thinned crust and lithosphere of the crustal ramp system.

CONCLUSIONS

Crustal-scale, basement-tectonic elements in the southwest corner of the Western Canada sedimentary basin appear to have controlled the development of the Mount Head embayment, a 250-km-wide regional downwarp along the western margin of Early Carboniferous North America. The overall shape and westward-thickening geometry of the Mount Head embayment correspond with a zone of thinned crust and lithosphere, and are probably inherited from the Late Proterozoic rift margin of North America. Within the Mount Head embayment, subsidence domains (the Kananaskis and Crowsnest depocenters and the intervening Highwood high) intersect the rift margin at high angles. These subsidence and sedimentation domains appear to have formed by differential piano-key-like movement along and across the basement-tectonic elements. In the Western Canada sedimentary basin, basement-tectonic elements display a long history of reactivation and control on accommodation that includes the Late Proterozoic to pre-Middle Devonian, and, as we have shown, the Early Carboniferous.

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