Structural and Intrinsic Fluvial Controls on the Geomorphology of an Integrated, Incised-Valley Network in the Lower Cretaceous of Southern Alberta, Canada

By

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Introduction

Detailed regional stratigraphic analysis by Zaitlin et al. (2002) shows that the Lower Cretaceous Basal Quartz (BQ) is composed of at least four unconformity-bounded, incised-valley systems (Figure 1); namely, (from oldest to youngest):

1. A-sands
2. Horsefly
3. Bantry-Alderson-Taber (BAT)
4. Ellerslie

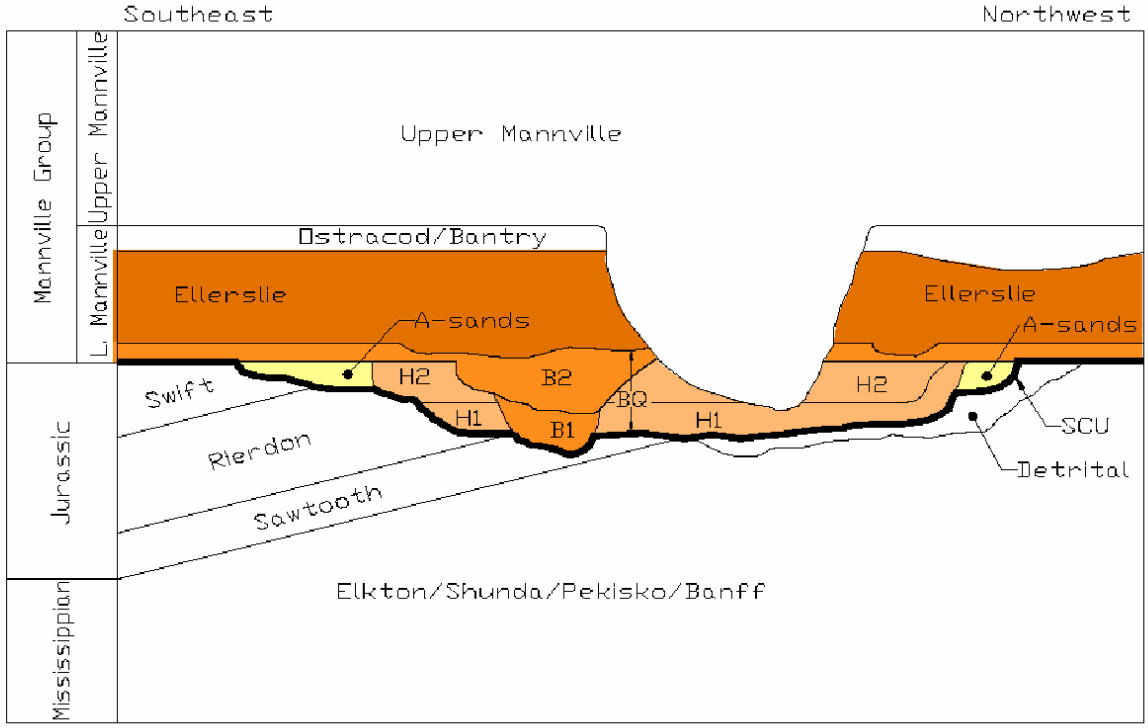

Figure 1: Schematic representation of the stratigraphic succession in the study area. SCU: sub-Cretaceous unconformity (heavy line). BQ deposits include the units that lie between the SCU and the base of the Ellerslie. The thickness of the BQ ranges from 0 to 70 m. The mean breath of the Horsefly valley is 20 km in the study area, while that of the BAT (B1 + B2) is approximately 8 km.

This study describes the distribution of the valley-filling BAT unit in south-central Alberta, Canada (Townships 7-18; Ranges 11-25W4) (Figures 2 and 3) and provides a comprehensive description of the palaeogeography of the sequence, including the complex assemblage of trunk and tributary valleys. A detailed analysis of the controls on the development of the planform geometry of the valley network is also given.

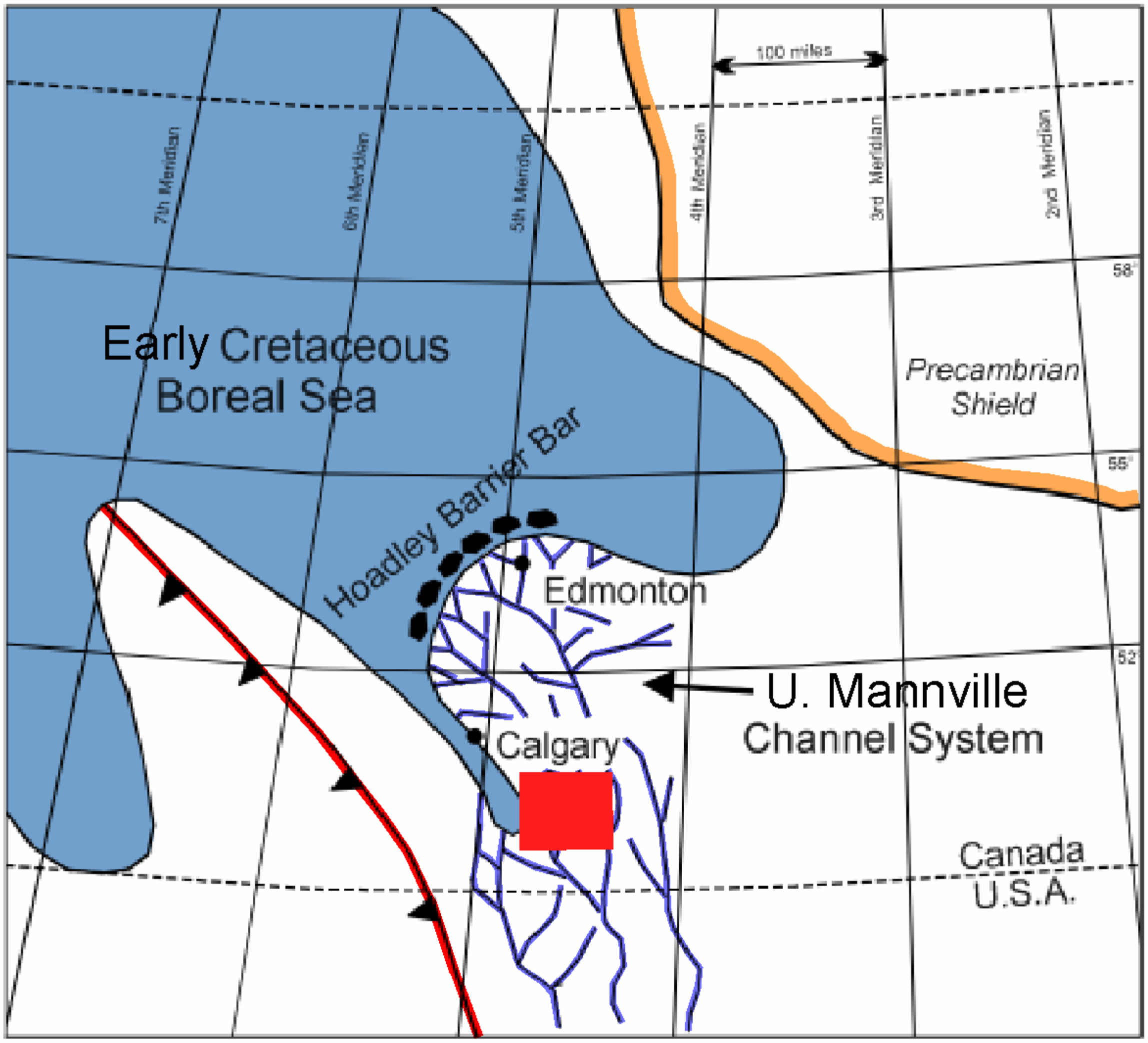

Figure 2. Index map, showing location of study area in Southern Alberta and general palaeogeography during deposition of Lower Cretaceous sandstones of the region. After Peijs-van Hilten et al. (1998).

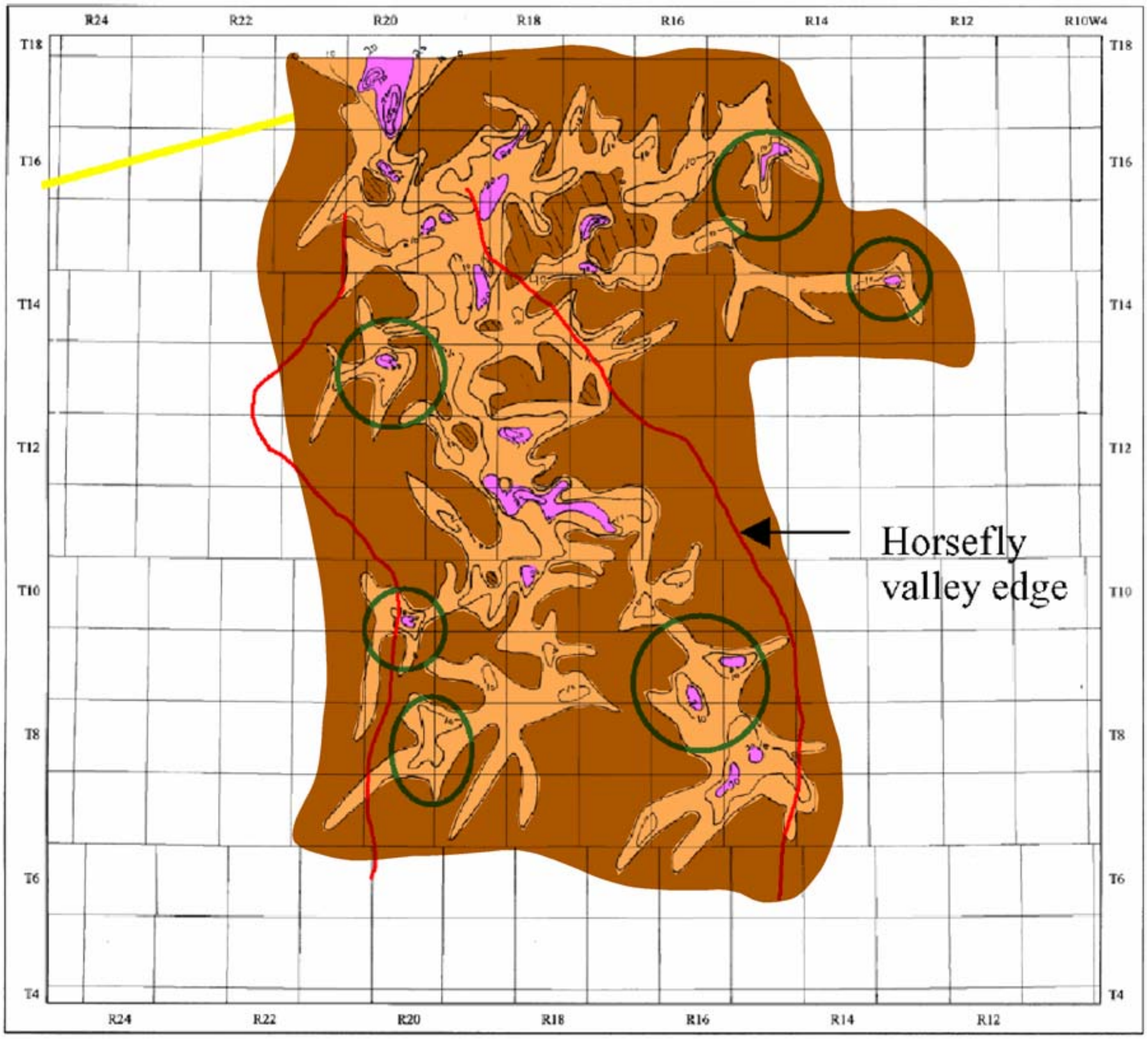

Figure 3: Isopach map (black lines) showing the palaeomorphology of the BAT incised-valley fills. Note the presence of thicker deposits at the junctions of tributaries (green circles). The yellow line indicates the approximate location of the Vulcan structure. Isopach interval = 10 m.

In the study area, the BAT consists of a narrow, deeply incised valley fill. Twelve facies, ranging from conglomerates and sandstones to mudstones, have been recognized and have, in turn, been grouped into five facies associations. They are:

1. Fluvial channel sandstones
2. Tidal-fluvial channel sandstones and mudstones
3. Overbank sandstones and mudstones
4. River-dominated delta-front sandstones and mudstones (estuarine bayhead delta)
5. Interdistributary-bay and estuarine central-basin mudstones.

Within the BAT valley fill, the deposits begin with meandering-fluvial conglomerates and sandstones that are overlain by tidal-fluvial sandstones, and estuarine sandstones and mudstones in a transgressive succession.

Controls on Planform Palaeogeography

An isopach map of the BAT unit (Figure 3) shows the presence of a north-south-oriented trunk valley that passes headward (southward) into a set of dendritic tributaries. A single large tributary, which has a trellis pattern, is present in the north-east part of the study area. Four primary processes control this planform geometry:

1. Underlying geology
2. Palaeoclimate
3. Duration of incision
4. Inherent fluvial processes

The durability of the underlying substrate has a considerable control on the palaeogeometry of the fluvial systems. The BAT system has a dendritic pattern where it is incised into relatively soft, uniform, and unfractured Horsefly and Rierdon substrata, but has a trellis pattern where incised into well-lithified and fractured Mississippian carbonates.

During deposition of the BAT channel sands, climatic conditions were relatively humid. This is implied by the presence of abundant coalified wood fragments and substantial, but shallow rooting, indicative of a high water table, and the absence of mature palaeosols. The vegetated overbank deposits of the BAT may have restricted lateral erosion (excision) during BAT time, leading to the development of a meandering fluvial style and, thus, of deep, laterally confined valleys. This situation contrasts markedly with that in the underlying Horsefly unit (Figure 1), which is characterised by a dry climate (as indicated by mature, red palaeosols, braided fluvial deposits, scarcity of carbonaceous matter, and common evidence of atmospheric exposure), which led to the development of a broad, flat-floored valley.

Alternatively, the differences in the widths of the two valley systems may be due to differences in the duration of incision (Schumm and Ethridge, 1994). The Horsefly valley may have formed during a longer LST than that of the BAT. As a result, the former valley network had a longer time to excise, resulting in a wider valley. The BAT valley fill is much narrower perhaps because of less time for valley widening. Ultimately, both the duration of valley formation and the change in climate may have influenced the differences in valley shape.

The dramatic narrowing of the BAT valley at the northern edge of the study area (in Township 16, Range 20; Figure 3), the deep incision of the underlying strata at this location, and the east-west direction of the large tributary in the northeast quadrant of the study area all suggest that there was strong structural control on the BAT rivers. Indeed, these features are coincident with the Vulcan structure (Figure 3), which is an aeromagnetic and gravity low associated with an amagmatic shear zone of Precambrian age that appears to have been a structurally weak zone with subsequent periodic reactivation (Ross et al., 1990). We believe that this feature was reactivated and uplifted slightly during valley formation, in response to orogenic activity to the west. This uplift caused the BAT river to incise more deeply, creating a water gap. It also controlled the location of the large easterly tributary, causing it to have long tributaries on the down-dropped block to the south and short tributaries on the uplifted block to the north.

The focusing on hydraulic energy led to the development of deep tributary-junction scours (TJS) at the confluence of tributaries with the trunk valley (Figure 3). The sediments filling these scours are up to five times thicker than immediately adjacent deposits and consist of well-sorted sands that are coarser than the adjacent valley-fill deposits. These localized thicks might be misidentified as the fills of karst holes, but their close association with tributary junctions and their presence in areas where the Rierdon Shale is the underlying bedrock makes a karst origin highly unlikely. Additionally, the Rierdon Shale is anomalously thin directly beneath the overlying sandstone thick, suggesting erosion by younger channels and not dissolution of the underlying Mississippian carbonates. These TJSs represent ideal sites for hydrocarbon reservoirs (assuming the existence of a suitable source and trapping configuration). If a TJS is identified along a channel/valley trend, one may suspect the presence of a tributary channel/valley at that location. Alternatively, if two channels/valleys, upon projection, appear to converge, one may want to explore for a possible hydrocarbon-bearing TJS at their confluence.

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