Regional-scale allostratigraphy of the Cardium Formation in subsurface and outcrop, southern Alberta and northern Montana: evidence for high-frequency relative sea-level change

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Summary

Allostratigraphic correlation of the Cardium Formation in the subsurface and outcrop of southern Alberta provides a framework in which facies and stratal geometries are examined. Facies mapping within an allostratigraphic framework indicates two major relative sea-level falls, punctuated by a major transgression. Higher-frequency relative sea-level changes superimposed on this long-term trend have a magnitude of ~12 m and a frequency of ~250 k.y., and are regional in extent; these relative sea-level changes are best explained in terms of glacioeustasy.

Introduction

The Cardium Formation has been well studied because it hosts major oil and gas reserves. However, south of approximately the latitude of Calgary, where sandstone and conglomerate facies are much less abundant, regional-scale stratigraphy and facies analysis has been largely neglected since Stott (1963) established a lithostratigraphic framework in outcrop. The allostratigraphic framework for the Cardium Formation (Plint *et al*., 1986) has only been correlated into 4 outcrops south of Ram River (Township 36; Plint *et al*., 1988), and has not been correlated south of Township 27 in subsurface (Wadsworth and Walker, 1991). The present study is a regional analysis of facies and allostratigraphy in both outcrop and subsurface in southern Alberta and northern Montana.

Methods

In the Cardium allostratigraphic framework of Plint *et al*. (1986), allomembers are bounded by regionally extensive erosion ('E') and transgressive ('T') surfaces. Ten regional transgressive surfaces—3 of which have not previously been recognized—were correlated throughout a grid of >1200 well logs between Townships 1 and 36, and between the Rocky Mountain Foothills in the west and Range 8W4 in the east. Correlations were extended into 23 outcrop sections along the Rocky Mountain Foothills, and into 2 outcrop sections in the Sweetgrass Hills of northern Montana. Eleven cores, in both shoreline proximal and distal locations, were also examined. Mapping of facies and paleogeography in three dimensions and within an allostratigraphic framework allowed for interpretation of depositional controls, including tectonics, eustasy, and sediment supply.

Results

The lack of clinoform geometry in the Cardium Formation indicates deposition within the mud accommodation envelope (inferred to lie at ~70 m depth in the Western Interior Seaway; Plint, submitted). The presence of wave-formed sedimentary structures in thin beds of very fine-grained sandstone, ~250 km from coeval shoreface facies, indicates that the entire study area was, at times,

within effective wave-base for very fine-grained sand (inferred to lie at ~40 m depth in the Western Interior Seaway; Plint, submitted).

Facies distribution and stratal geometry of allomembers indicates that deposition of the Cardium Formation was characterized by two long-term relative sea-level falls (culminating in the E5 and E7 surfaces respectively), separated by a major transgression (the Niobrara transgression, represented by the upper Raven River and Dismal Rat members). Higher-frequency relative sea-level changes were superimposed on this long-term trend. Lateral shifts in the position of highstand and lowstand shoreface facies indicate a shoreline excursion of ~70 km for a single high-frequency cycle. Given that bathymetry did not exceed ~40 m depth ~250 km from shore, the gradient of the shelf was ~1:6000. Therefore, the 70 km shoreline excursion observed indicates a relative sea-level fall of ~12 m. The Cardium Formation contains 9 sequences that preserve evidence of relative sea-level fall; available geochronology indicates that the total duration of the Cardium Formation was ~2.3 m.y. Relative sea-level changes therefore had a magnitude of ~12 m and a frequency of ~250 k.y.

Conclusions

The allostratigraphic framework for the Cardium Formation has now been extended into southern Alberta and northern Montana, and embraces both outcrop and subsurface strata. Recognition of regionally extensive allomembers in outcrop will provide an essential framework in which future studies of biostratigraphy, geochronology, and cheomostratigraphy can be discussed.

Facies distribution and stratal relationships indicate that the Cardium Formation contains 9 sequences that are related to relative sea-level fall. When combined with the results of previous studies, these sequences have now been correlated >900 kilometres along strike, and ~300 kilometres offshore, crossing tectonic domains and subsidence-controlled depocentres. The sequences are therefore best explained in terms of eustasy. Eustatic fluctuations with a magnitude of ~12 m and a frequency of ~250 k.y. are best explained in terms of glacioeustasy.

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