Allostratigraphy and Biostratigraphy of the Upper Cretaceous (Coniacian-Santonian) Western Canada Foreland Basin

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ALLOSTRATIGRAPHY AND BIOSTRATIGRAPHY OF THE UPPER CRETACEOUS (CONIACIAN-SANTONIAN) WESTERN CANADA FORELAND BASIN

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Preface

NEIL H. LANDMAN, A. GUY PLINT, AND IRENEUSZ WALASZCZYK

This bulletin contains three closely integrated papers that treat Upper Cretaceous (Coniacian-Santonian) strata of the Western Canada Foreland Basin (WCFB). Our research is the culmination of the collective efforts of seven scientists from eight institutions in the United States, Canada, Poland, and the United Kingdom. It presents the results of 12 seasons of geological fieldwork in the Rocky Mountain Foothills of Alberta. As in many other high-latitude studies, some sites were difficult to access and required transport by helicopter, and fieldwork could be carried out only in July and August. The outcrops were measured in detail, with particular attention to depositional cycles and bounding surfaces that indicate relative changes in sea level. Fossils of molluscs were collected at each locality and placed precisely within each section. The results of these outcrop investigations were integrated with a public database comprising thousands of wireline logs, supplemented by cores, which provided the regional control to reconstruct the stratal geometry, facies relationships, and paleogeography of the basin in three dimensions.

The principal purpose of our research is to present a detailed allostratigraphic and biostratigraphic framework for the Coniacian and basal Santonian succession in the WCFB. The studied strata, approximately 100 m thick, comprise the lower part of the Wapiabi Formation (Coniacian to lower Campanian) that extends east from the Rocky Mountain Foothills and covers much of Alberta, and parts of Saskatchewan and Manitoba. Because of rapid flexural subsidence in the western foredeep, the Wapiabi Formation preserves an expanded record of terrestrial and shallow marine sedimentation. The rocks are dominated by mudstone and subordinate sandstone and were deposited on a very low-gradient, storm-dominated marine ramp. The rocks are organized into a series of upward-coarsening, upward-shoaling successions, bounded by marine flooding surfaces. These surfaces constitute proxy time planes that provide a framework within which to assess the temporal and spatial distribution of the molluscan fossils that furnish the basis for biostratigraphic correlation. The WCFB thus represents a natural laboratory in which to elucidate the interplay between the principal physical controls on sedimentation, namely tectonism, sediment supply, and eustasy, as well as the evolutionary patterns of the organisms that lived in the area during this time.

In the first paper of the bulletin, Plint et al. synthesize information from well-exposed sections in the fold-and-thrust belt of the Rocky Mountain Foothills and combine this information with data from a large correlation grid of wireline logs, supplemented by a few cores. In the Coniacian part of the section, they identify 24 flooding surfaces that can be traced for >750 km along strike in the subsurface. These flooding surfaces form the boundaries of 24 informal allomembers. Some of these surfaces are mantled with intra- or extrabasinal pebbles that imply a phase of shallowing and, potentially, subaerial emergence of the inner part of the ramp. Flooding surfaces represent small intervals of time relative to the rock units that they bound and, therefore, allow the subsidence history of the basin to be reconstructed in a series of relatively short time-steps. This new allostratigraphic framework emphasizes the importance of marine erosional surfaces, and their genetic relationship to relative changes in sea level. Development of such a regional subsurface allostratigraphic framework helps resolve stratal geometry and facies distributions, from which paleogeography, paleobathymetry, subsidence patterns, relative sea-level changes, and overall depositional history can be reconstructed.

The allostratigraphic framework constitutes the physical and temporal matrix within which the vertical and lateral distribution of molluscan fossils, principally inoceramid bivalves and scaphitid ammonites, can be assessed. Regional mapping reveals that allomembers, which exhibit a near-tabular geometry, can be grouped into "tectono-stratigraphic units" that span hundreds of thousands of years and fill saucer-shaped, flexural depocenters. Successive depocenters are offset laterally by several hundred km, which probably reflects episodic lateral shifts in the locus of active thickening in the Cordilleran orogenic wedge, and a corresponding lateral shift in the locus of maximum isostatic subsidence.

As a complement to the allostratigraphic study, Plint et al. present preliminary carbon-isotope data from one section of Coniacian strata in Alberta, and compare the results to the reference curve from the UK Chalk succession, and to results from coeval rocks in Colorado. On the basis of shape-matching and biostratigraphic tie-points, the Light Point, East Cliff, and White Fall carbon-isotope events (CIE) of the UK Chalk succession appear to be present in Alberta. The astronomically calibrated succession of CIE in the English Chalk suggests that each of the 24 mapped allomembers in Alberta has an average duration of approximately 125,000 kyr. Because allomembers can be traced for hundreds of km, an allogenic control, probably eustasy, appears to be the most likely genetic mechanism responsible for sea-level cycles.

The WCFB yields a rich and well-preserved molluscan fauna dominated by inoceramid bivalves. This is treated by Walaszczyk et al. in the second paper in this volume. In the upper lower Coniacian to basal Santonian, six successive inoceramid zones are recognized. In ascending stratigraphic order, they are the *Cremnoceramus crassus crassus–deformis deformis* Zone, the *Inoceramus gibbosus* Zone, the *Volviceramus koeneni* Zone, the *V. involutus* Zone, the *Sphenoceramus subcardissoides* Zone, and the *Sphenoceramus* ex gr. *pachti* Zone. The base of the middle Coniacian is marked by the lowest occurrence of the taxonomically variable *Volviceramus* fauna including *V. koeneni* (Müller, 1888), *V. exogyroides* (Meek and Hayden, 1862), and *V. cardinalensis,* sp. nov., in association with *I. undabundus* Meek and Hayden, 1862. The base of the upper Coniacian is marked by the lowest occurrence of the characteristically northern inoceramid species *S. subcardissoides* (Schlüter, 1877). The lowest occurrence of *V. stotti* sp. nov., described for the first time from the Canadian sections, is also close to this boundary. The base of the Santonian is marked by the lowest occurrence of *S.* ex gr. *pachti* (Arkhangelsky, 1912). Several of the zonal assemblages are known widely from the Euramerican biogeographic region, although they are mostly representative of the northern boreal area. This new inoceramid-based zonation allows correlation with other parts of the Euramerican biogeographic region.

The lowest occurrence of each inoceramid species can be interpreted in the context of the relative sea-level framework developed by Plint et al. The lowest occurrences of *Cremnoceramus crassus crassus* (Petrascheck, 1903), various species of *Volviceramus, Sphenoceramus subcardissoides*, and *S.* ex gr. *pachti* are immediately above major flooding surfaces, suggesting that the first appearances of these taxa are closely linked to episodes of relative sea-level rise. Thus, the boundaries of biozones appear to coincide with physical stratigraphic (flooding) surfaces. The generally rare species *Inoceramus gibbosus* Schlüter, 1877, is abundant in the upper part of the lower Coniacian. This species is usually absent in both Europe and North America due to a stratigraphic gap resulting from a eustatic lowstand. The preservation of this species in Canada is attributed to rapid subsidence of the foredeep, which outpaced the eustatic sea-level fall.

The WCFB also contains a rich record of scaphitid ammonites (scaphites), which are described by Landman et al. in the third paper in this issue. These species are widespread and restricted to higher latitudes and allow correlation with other parts of the Western Interior of North America, as well as with western Greenland. In ascending order, Landman et al. recognized four ammonite zones, the *Scaphites* (*S.*) *preventricosus* Zone, the base of which coincides with the base of the lower Coniacian, the *S.* (*S.*) *ventricosus* Zone, the base of which coincides with the base of the *Inoceramus gibbosus* Zone and marks the upper part of the lower Coniacian, the *S.* (*S.*) *depressus* Zone, the base of which coincides with the base of the upper Coniacian, and the *Clioscaphites saxitonianus* Zone, the base of which coincides with the base of the Santonian. The lowest occurrence of each scaphite species can be interpreted in the context of the relative sea-level framework developed by Plint et al. The lowest occurrence of *S.* (*S.*) *preventricosus* Cobban, 1952, is just above an erosional surface that indicates the beginning of a major transgression that commenced in the very latest Turonian. The lowest occurrence of *S.* (*S.*) *ventricosus* Meek and Hayden, 1862, is just below an interpreted highstand and prior to a regression in the latest early Coniacian. The lowest occurrence of *S.* (*S.*) *depressus* Reeside, 1927, is in an overall regressive succession, which marks the base of the upper Coniacian, and the lowest occurrence of *Clioscaphites saxitonianus* (McLearn, 1929) coincides with a major transgression at the base of the Santonian. All of these species exhibit some degree of stratigraphic overlap, which implies evolutionary episodes of cladogenesis rather than anagenesis, which was the mechanism previously postulated to explain the evolution of these scaphites.

The most distinctive feature in the ontogenetic development of these scaphites is the change in coiling during ontogeny. At the approach of maturity, the shell uncoils slightly, forming a shaft, which then recurves backward approaching the earlier secreted phragmocone. As a result, the aperture faces upward during the lifetime of the animal, so that the buccal apparatus can extend outward to collect small organisms in the water column. The sequence of species leading from *Scaphites* (*S.*) *preventricosus* to *Clioscaphites saxitonianus* appears to form an evolutionary lineage, suggesting a long-term trend toward recoiling of the adult shell, while still maintaining the same position of the aperture during life. This trend is accompanied by an increase in adult size (possibly caused by a delay in the timing of maturation) and degree of shell depression. This tendency toward more recoiled shell shapes and larger adult sizes occurred against a background of changing environmental conditions in the Western Interior Seaway during the Coniacian that reflected an overall relative rise in sea level and the expansion of the seaway to cover nearly all of Alberta. This transgression resulted in an expansion of offshore habitats that may have promoted the evolutionary appearance of larger scaphite species with more closely coiled shapes and more depressed whorl sections, which were better adapted to these environments.

REFERENCES

Arkhangelsky, A.D. 1912. Upper Cretaceous deposits of the eastern part of the European Russia. Reprinted in Akademik A.D. Arkhangelsky, Izobrannye Trudy, vol. 1: 133–466. Moskva: Izdatelstvo Akademii Nauk SSSR. [in Russian]

Cobban, W.A. 1952. Scaphitoid cephalopods of the Colorado Group. U.S. Geological Survey Professional Paper 239, 42 pp.

Meek. F.B., and Hayden, F.V. 1862. Description of new Cretaceous fossils from Nebraska Territory, collected by the expedition sent out by the government under the command of Lieut. John Mullan, U.S. Topographical Engineers, for the location and construction of a Wagon Road from the sources of the Missouri to the Pacific Ocean. Proceedings of the Academy of Natural Sciences of Philadelphia 14: 21–28.

Müller, G. 1888. Beitrag zur Kenntnis der oberen Kreide am nördlichen Harzrande. Jahrbuch des Preußischen Geologischen Landesanstalt 8: 372–456.

McLearn, F.L. 1929. Cretaceous invertebrates: Mesozoic paleontology of Blairmore region, Alberta. Canada National Museum Bulletin 58: 73–79.

Petrascheck, W. 1903. Ueber Inoceramen aus der Kreide Böhmens und Sachsens. Jahrbuch der Kaiserlich-Königlischen Reichsanstalt 53: 153–168.

Reeside, J.B., 1927. Cephalopods from the lower part of the Cody Shale of Oregon Basin, Wyoming. U.S. Geological Survey Professional Paper 150-A: 1–19.

Schlüter, C. 1877. Kreide-Bivalven. Zur Gattung *Inoceramus*. Palaeontographica 24: 250–288.

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