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Re-evaluation of the Albian–Cenomanian boundary in the U.S. Western Interior based on dinoflagellate cysts

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Abstract

The position of the Albian–Cenomanian boundary in the U.S. Western Interior Basin has been the subject of debate because the ammonites and foraminifers that define the boundary are endemic. Traditionally, the boundary, as defined in Europe by planktonic foraminifers and ammonites, is correlated with the last occurrence of the ammonite genus, *Neogastroplites* [Reeside, J.B., Cobban, W.A., 1960. Studies of the Mowry Shale (Cretaceous) and contemporary formations in the United States and Canada. U.S. Geological Survey Professional Paper 355, 126 pp]. More recently, the boundary was correlated with the first occurrence of *Metengonoceras teigenensis* [Cobban, W.A., 1951. Colorado shale of central and northwestern Montana and equivalent rocks of Black Hills. American Association of Petroleum Geologists Bulletin 35, 2170–2198]. These ammonites are associated with bentonites, the ages of which have been extrapolated to the type region of France to date the base of the Cenomanian from the Western Interior Basin. However, since cosmopolitan dinoflagellates are common to this region and the European reference sections where the boundary is defined, they can be used to reevaluate the position of the Albian–Cenomanian boundary in the Western Interior Basin. In our study, 224 samples from 29 outcrop sections in Montana, Wyoming, Colorado, Oklahoma and New Mexico were analyzed for dinoflagellate cysts, as well as other palynomorphs, foraminifers, bivalves and ammonites; these fossils were used for graphic correlation. The recovery and preservation of the dinoflagellate cysts varied from poor to good, and diversity varied from low to moderate. Typical Late Albian to Early Cenomanian taxa, including *Ovoidinium verrucosum*, *Ovoidinium scabrosum* and *Palaeohystrichophora infusorioides*, dominate the assemblages; however, dinoflagellate ranges in the five sections in which the neogastroplitid zones are defined (Arrow Creek, Ayers Ranch, Belt Butte, Geyser, Teigen) suggest correlation with the uppermost Albian. Dinoflagellate ranges were confirmed in additional Montana, Wyoming and northern Colorado sections by a few diagnostic taxa (*Aptea polymorpha*, *Apteodinium grande*, *Batioladinium jaegeri*, *Luxadinium propatulum*, *Chichaouadinium vestitum*), and they were graphically correlated with published

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European ranges. The result is that the Albian–Cenomanian boundary correlates with the 97 million year old Clay Spur Bentonite.

Keywords: Late Albian; Early Cenomanian; dinoflagellate cysts; U.S. Western Interior; graphic correlation

1. Introduction

The Albian–Cenomanian boundary separates the Lower and Upper Cretaceous series and has been defined traditionally by ammonites in its type section in France. The base of the planktonic foraminifer *Rotalipora globotruncanoides* 6 m below the first occurrence (FO) of *Mantelliceras mantelli* at the Mont Risou section in southern France now defines the base of the Cenomanian (Gale et al., 1996). Correlation of this boundary into the Western Interior Basin has been based on the evolutionary stage of endemic ammonites. Interbedded, well-dated bentonites have been used to calibrate the age of this boundary globally (Obradovich and Cobban, 1975). The geochronological position of this boundary has been frequently updated and was changed from 97.0 Ma to 98.9 Ma in 1995 and to 99. 6 Ma in 2004 (see Gradstein et al., 1995, 2004; Obradovich et al., 2002). Although foraminifers and sporomorphs have been used for biostratigraphic control, benthic taxa of the former are also endemic and very few taxa of the latter have proved useful due to their long ranges. Dinoflagellates provide the greatest potential for direct correlation of the U.S. Western Interior Basin into European stratotype reference sections as well as North African reference sections.

The primary objective of this study was to integrate dinoflagellate and ammonite biostratigraphies by resampling five key sections in central Montana (Arrow Creek, Ayers Ranch, Belt Butte, Geyser, Teigen) used for setting up the ammonite zones in the Western Interior (Reeside and Cobban, 1960; Eicher, 1960, 1965). Additional sections were sampled in Montana and Wyoming (Fig. 1) to integrate the dinoflagellate species with ammonites, foraminifers and radiolarians. This paper shows that dinoflagellate cyst ranges constrain correlation of the Albian–Cenomanian boundary in Europe with the section in the study area.

2. Stratigraphic setting

During the Late Albian and Early Cenomanian, the warmer Tethys Sea was transgressed into the U.S. Western Interior several times, connecting it with the cooler Boreal Sea. Traditional sequence models (Williams and Stelck, 1975; Kauffman, 1984; Scott et al., 1998) show that the first north–south connection between the Boreal and Tethyan provinces was made during the early Late Albian Kiowa-Skull Creek cycle (Fig. 2). Then both seaways were separated during the Late Albian to Early Cenomanian in SE Colorado, Oklahoma panhandle and NE New Mexico because of regression. Full connection was reestablished during the Middle Cenomanian when the Thatcher Limestone Member of the Graneros Formation was deposited during the Greenhorn Cycle. However, new evidence (Scott et al., 2001, 2004) suggests that two additional third-order transgressive/regressive episodes occurred between these two major flooding events and spanned the Early–Late Cretaceous boundary in the Western Interior Basin (Fig. 2).

In central Montana, Lower Cretaceous strata disconformably overlie Upper Jurassic strata. Aptian–Albian Kootenai Formation is the basal, wedge-shaped lithosome of nonmarine clastics that thins southeastward. It is disconformably overlain by the Fall River Formation, which is a transitional nonmarine to marine, cross-bedded sandstone up to 21 m thick (Maughan, 1993; Porter and Wilde, 1999a,b). The top of the Fall River Formation is a transgressive contact overlain by the Thermopolis Formation, which is a marine interval of mainly shale and thin beds of sandstone and bentonite that in central Montana is comprised from base up of the Skull Creek Shale, the sandy member (equivalent with the Muddy Sandstone) and the Shell Creek Shale (Fig. 2; Porter et al., 1993, 1997). The basal Skull Creek is dark gray shale with thin sandstone beds and is up to 53 m thick. It is disconformably overlain by the informal sandy member, which consists of thin sandstone beds interbedded with shale and is up to 95 m thick. The upper marine Shell Creek Shale is dark gray, soft fissile shale about 31 m thick.

The Mowry Shale conformably overlies the Thermopolis Formation and is bounded by the Arrow Creek Bentonite bed at the base and the Clay Spur Bentonite bed at the top (Fig. 3). The Mowry Shale is mainly hard brittle shale and siltstone up to about 60 m thick in this area. In central Montana, the Mowry Shale grades up into the Big Elk Sandstone, which is a lithosome similar to sandstones in the Belle Fourche Member of the