Chapter 7

Detailed West to East Cross Section of Cretaceous and Lower Tertiary Rocks Across the South Part of the Bighorn Basin, Wyoming

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Introduction

This cross section presents the results of a detailed study of the depositional settings of Cretaceous and lower Tertiary rocks across the southern part of the Bighorn Basin, Wyoming, with a focus on the Upper Cretaceous marine shale interval. The wells are closely spaced in order to portray the detailed stratigraphy of these marine strata. The principal method of correlation was to trace distinctive patterns of the resistivity curves on electric logs. In low-resistivity shales such as the Cody Shale, these patterns can generally be correlated throughout the study area, particularly where well spacing is less than 3–4 mi (Johnson, 2003). Asquith (1970) attributed these patterns to variations in bentonite content from volcanic ash and used such variations to establish time-stratigraphic correlations in the Cretaceous shales of Wyoming. A large number of correlation lines are shown on the cross section, some of which could be recognized in nearly all wells, whereas others could be recognized only locally.

The cross section generally parallels a section presented by Asquith (1970) across the Bighorn Basin. The lower 550–900 ft of the Cody Shale is distinctive in that the strata appear to prograde to the east. Asquith (1970) was the first to recognize the inclined character of these strata, and the numbers one through six labeled on the cross section presented here correspond to the stratigraphic markers labeled on Asquith's Bighorn Basin cross section (his fig. 8). The inclined strata slope eastward at about one-half degree, and Asquith (1970) believed that these strata were deposited on the slope that occurred between the shelf and the deep part of the Cretaceous seaway. Asquith (1970) estimated the water depth at the time of deposition of these inclined strata at from 240 to 475 ft.

Ten different depositional settings for the Cretaceous and lower Tertiary rocks are recognized: 1) dark-gray to black organic-rich shales deposited in an offshore marine setting; 2) dark-gray to black organic-rich, siliceous marine shales deposited in an offshore marine setting during a time of extensive regional volcanism; 3) gray shale and silty, sandy, and calcareous gray shale displaying large-scale clinoform features suggesting deposition on an offshore slope or ramp; 4) gray shale and silty, sandy, and calcareous gray shale displaying largely horizontal time lines suggesting deposition in a marine shelf setting; 5) complex, persistent, blanket-like intervals of mainly sandstone, conglomerate, and minor mudstone deposited in a sand-rich coastal plain and marginal marine setting; 6) sandstone deposited in shoreface and nearshore-marine settings; 7) medium- to dark-gray shale, coal, lenticular fluvial sandstones, and persistent crevasse-splay sandstones deposited in a poorly drained coastal plain setting; 8) medium- to dark-gray shale, lenticular fluvial sandstones, and persistent crevasse-splay sandstones with only thin coal beds deposited in a well-drained coastal plain setting; 9) gray shale and thick, amalgamated fluvial sandstones deposited in a sandy coastal plain to continental basin setting; and 10) variegated maroon, purple, green, and gray mudstone and fluvial channel sandstones deposited in a well-drained continental basin setting.

The Cloverly Formation, the basal Cretaceous unit in the Bighorn Basin, is Early Cretaceous in age and consists mainly of sandstone and variegated mudstone of both marine and nonmarine origin (Keefer and others, 1998). The Prior Conglomerate, where present, is a readily recognizable basal unit, but where absent, the contact with the underlying Jurassic Morrison Formation is difficult to define because of lithologic similarities. Hence, the contact can only be approximately located along the line of cross section. The Cloverly Formation varies in thickness from about 140 to 325 ft along the line of section.

The Thermopolis Shale, as originally defined by Lupton (1916) from exposures near Thermopolis in the south-central part of the Bighorn Basin, included upper and lower shale units separated by muddy sandstone, which is now known as the Muddy Sandstone. The upper shale was referred to as the Shell Creek Shale by Eicher (1962). Present usage (Keefer and others, 1998) generally restricts the Thermopolis Shale to only the lower shale, treats the Muddy Sandstone as a separate formation, and includes the upper shale with the Mowry Shale. The Thermopolis Shale is Early Cretaceous in age and is about 100 to 190 ft thick along the line of section.

The Mowry Shale is Early to Late Cretaceous in age (Obradovich and others, 1996) and can be divided into a lower unit of soft, fissile shale similar lithologically to the

Thermopolis Shale, and an upper unit of hard, brittle siliceous shale (Keefer and others, 1998). Thin beds of bentonite occur throughout, but are most numerous in the upper part. The contact with the overlying Frontier Formation is placed at the base of a prominent bentonite bed that generally marks a lithologic change from hard siliceous shale below to soft fissile shale above. The Mowry Shale is about 450–500 ft thick along the line of section.

The Upper Cretaceous Frontier Formation overlies the Mowry Shale and consists of two to four nearshore marine, marine shelf, and estuarine sandstones interbedded with marine shale. In outcrop in the southeastern part of the basin, Merewether and others (1998) recognized marine sandstones deposited in a variety of marine environments. The Frontier ranges in thickness from about 450 to 550 ft along the line of cross section.

The Upper Cretaceous Cody Shale overlies the Frontier Formation and ranges in thickness from about 2,700–3,700 ft. It interfingers with the underlying Frontier Formation and the overlying Mesaverde Formation. The Cody Shale consists of a main part that forms the bulk of the formation, and the Claggett Member that is a westward projecting shale tongue within the Mesaverde Formation. The inclined strata in the lower part of the Cody studied by Asquith (1970) appears to be "unique" in the Cody, as marker beds for the remainder of the Cody Shale are not inclined and largely horizontal. The Claggett Member is about 100–250 ft thick and generally thickens to the east before merging with the main part of the Cody Shale, which is the eastern limit of the lower member of the Mesaverde Formation.

The Upper Cretaceous Mesaverde Formation is a variable sequence of sandstone, mudstone, coal, and carbonaceous shale deposited in a variety of marginal marine and coastal plain settings (Johnson and others, 1998) along the west margin of the Cretaceous seaway. It overlies and interfingers with the Cody Shale and consists of: 1) the lower member, 2) the middle part, and 3) the Teapot Sandstone Member (Keefer and others, 1998; Johnson and others, 1998). The lower member contains sandy intervals deposited in shoreface, nearshore marine and marine shelf environments at its top and base. The rest of the unit consists of medium- to dark-gray shale and carbonaceous shale, coal, lenticular fluvial channel sandstones, and thin persistent crevasse-splay sandstones deposited in a poorly-drained, lower coastal plain setting. Most of the coal in the Mesaverde Formation is in the lower member. Maximum thickness of the lower member is about 650 ft at the western end of the cross section. It thins and pinches out into the Cody Shale near the middle of the cross section.

The middle part of the Mesaverde Formation is separated from the lower member by the Claggett Member of the Cody Shale, and ranges in thickness from about 450 to 750 ft. Along the western part of the cross section, the middle part consists of a basal marginal marine sandstone that is overlain by a nonmarine sequence deposited in a coastal plain setting. The unit grades to the east into mainly marginal marine sandstone, and then into mostly marine shale.

The Teapot Sandstone Member varies in thickness from about 100 to 200 ft and is a persistent blanket-like complex interval of mainly sandstones that are locally conglomeratic deposited in nonmarine and marginal marine environments. It is mainly nonmarine along the western part of the cross section, where it is overlain and underlain by rocks deposited in a coastal plain setting, and has characteristics of marginal marine deposits along the eastern part of the cross section, where it is overlain and underlain by marine shale (Johnson and others, 1998).

The Upper Cretaceous Meeteetse Formation is a distinctive unit consisting of banded dark-gray shale, sandstone, carbonaceous shale, and coal deposited in a marginal marine and coastal plain setting west of the Lewis Seaway. The formation generally contains less sandstone than the underlying Mesaverde Formation, although locally there is abundant sandstone (Johnson and others, 1998). The Meeteetse Formation, which is about 600–900 ft thick along the line of section, intertongues with the Lewis Shale in the eastern part of the cross section.

The Upper Cretaceous Lance Formation overlies the Meeteetse Formation with apparent conformity along the line of section. It varies in thickness from 400 to 1,200 ft with the thinnest section being in the extreme eastern part of the cross section. The lower part of the Lance consists of thick amalgamated fluvial sandstones and gray shales that are easily distinguished from the underlying, much less sandy, Meeteetse strata. This interval of amalgamated fluvial sandstones can be as much as 900 ft thick along the line of section. It grades up into a much less sandy sequence in the upper part of the formation.

The Paleocene Fort Union Formation overlies the Lance Formation. The upper part of the formation is eroded along most of the line of section. Only in the British Petroleum no. 1 Gillies Draw well (well no. 2 on cross section) is the Fort Union section complete. The Fort Union Formation is 5,750 ft thick in that well. A pronounced angular unconformity between the Lance and overlying Fort Union Formation can be recognized along both the east and west margins of the basin (Keefer and others, 1998). However, this angularity diminishes rapidly toward the center of the basin and throughout the central part of the basin, including along the line of cross section presented here, and the contact between the Lance and Fort Union Formation is difficult to locate. The contact is somewhat arbitrarily placed at the base of a thick fluvial sandstone, because a sandstone occurs at the base of the Fort Union Formation at many localities around the margins of the basin (Roberts, 1998: Keefer and others, 1998; Johnson and others, 1998).

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