CHAPTER 15

Seismic Stratigraphy of Lower Cretaceous Foreland Basin Submarine Fans in the North Slope, Alaska

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Abstract

A sequence stratigraphic interpretation of the Aptian/Albian sedimentary fill of the Colville Trough, North Slope, Alaska recognizes a variety of clastic rocks deposited in the foreland basin in the ancestral Brooks Range. Submarine fans are a major part of this sedimentary fill and consist of alternating units of sandstone and shale that are up to tens to hundreds of meters thick.

Seismic character of the Colville Trough includes basinal, submarine-fan, slope, and shelf or delta facies. Basinal sediments have a sheet-like external form and consist of moderate-amplitude, parallel reflections in sandy units and low-amplitude, parallel reflections in shaley intervals. Submarine fans have mounded external and internal reflection geometry. Slope facies consist of low-amplitude, discontinuous reflections and isolated continuous reflections in sigmoid and tangential clinoforms. Shelf and deltaic facies are characterized by parallel, moderate-amplitude reflections.

Lowstand systems tracts are recognized that consist of basin floor fan and slope fan. Separate transgressive systems tracts exist that can be subdivided into (1) an aggradational/progradational unit, and (2) two or more progradational units by continuous, basinward-dipping slope reflections that correlate to low-velocity slope shales. Sand-prone basin-floor submarine fans exist within lowstand systems tracts whereas shale-prone fans correspond to highstand systems tracts. The basin-floor and highstand submarine fans, progradational units, and shale markers demonstrate a cyclicity in sedimentation that may be caused by climate-induced changes in base level and in the rate of sediment input to the basin.

Introduction

Foreland basins are characterized by an asymmetric cross-sectional basin geometry caused by crustal loading associated with thrust emplacement in the adjacent mountain belt. This loading creates rapid subsidence near the thrust load. A regional uplift farther away from the zone of subsidence, termed a peripheral bulge, may form in response to elastic crustal flexure (Beaumont, 1981; Jordan, 1981). After thrusting ceases, erosion of the thrust belt may result in isostatic rebound and elevation of the mountains and adjacent foreland basin (Heller et al., 1988).

Foreland basins offer an opportunity to examine the tectonic versus eustatic controls on shelf-margin sequences and their associated turbidite deposits. Eustatic changes will raise and lower depositional base level uniformly throughout the basin, whereas tectonic changes may alter basin shape and create different changes in base level in different parts of the basin. Variations in the rates of sediment input to the basin may also result from the rapid elevation of highlands adjacent to the basin as thrusts are emplaced or as crust rebounds due to erosion.

This chapter presents an interpretation of the seismic sequence stratigraphy and seismic facies of foreland basin submarine fan deposits from the Colville Trough of the Alaskan North Slope. The study of the North Slope foreland basin sedimentary fill was initiated to examine the sequence geometry of Lower Cretaceous rocks, to compare and contrast the North Slope sequences to the systems-tract model of Vail (1987), and to identify and separate tectonic and eustatic effects. This study also addresses the seismic facies cyclicity of the Albian turbidites and slope sediments.

An area in the National Petroleum Reserve, Alaska (NPRA) was selected for the following reasons. (1) The Lower Cretaceous sedimentary fill of the foreland basin is relatively undeformed by later tectonics and exhibits prominent progradational geometries with deltaic, slope, and deep-water basinal facies. (2) A large
amount of well and seismic data, which was collected as part of the petroleum evaluation of NPRA, is available. (3) The stratigraphic framework of the Lower Cretaceous foreland basin sedimentary fill is well documented (Molenaar, 1985).

Regional Setting

Structure

The Cretaceous foreland basin of the Alaskan North Slope is termed the Colville Trough, a basin that formed as a result of crustal loading as thrusts of the ancestral Brooks Range were emplaced during the Late Jurassic to Early Cretaceous (Mull, 1985) (Figs. 15.1, 15.2). The Colville Trough lies north of the Brooks Range and south of a large structural high, called the Barrow Arch, located beneath the present-day Coastal Plain (Fig. 15.1). As a result of Brooks Range crustal loading, basement under the Colville Trough dips to the south. Stratigraphic units within the foreland basin become thicker to the south toward the mountain front. North of the Barrow Arch, the basement beneath the sedimentary cover dips seaward and a series of deep-seated normal faults (Craig, et al., 1985) mark the Jurassic rifted margin of the Beaufort Sea (Grantz and May, 1982).

After the Late Jurassic/Early Cretaceous Brooks Range orogeny large-scale normal faults were active on the south side of the Brooks Range and may have resulted from a period of regional extension (Miller, 1987). Late Cretaceous to Paleogene compression created linear east-west, thrust-cored anticlines. Cretaceous and Tertiary deformation affected only the southern part of the Colville Trough (Noonan, 1987) and the lack of Paleogene deformation resulted in undeformed basin fill in northern NPRA.

In the Colville Trough, the continental block loaded by the Brooks Range thrusts is smaller than in most foreland basins. The Colville Trough crustal block is narrow (roughly 150 km...