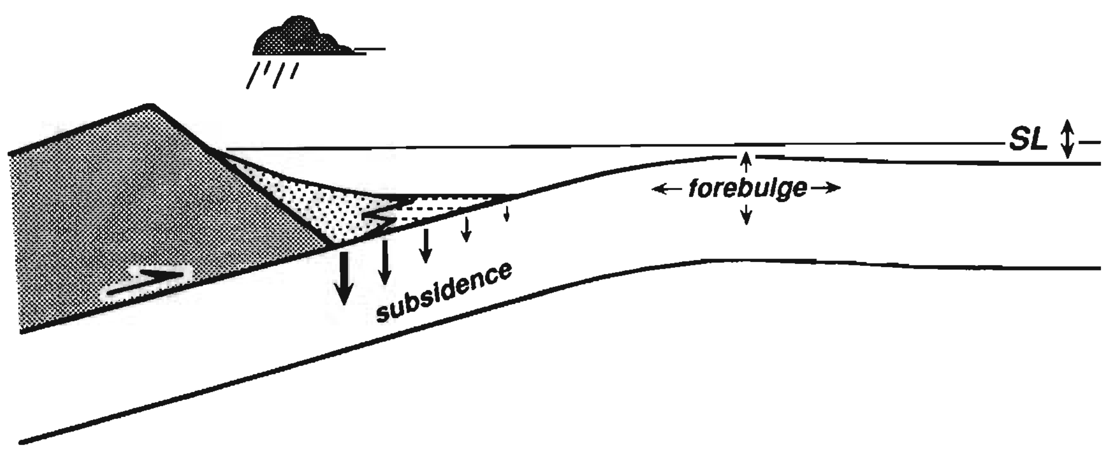
STRATIGRAPHIC EVOLUTION OF FORELAND BASINS



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STRATIGRAPHIC EVOLUTION OF FORELAND BASINS
INTRODUCTION

A strong case can be made that foreland basins are where the causal links between sedimentation and tectonic events were first recognized, as evidenced by the interpretations of geologists working in classic foreland areas such as the Alpine foreland and the Appalachian Basin (Dana, 1873; Stille, 1913; Kay, 1947, 1951; Trümpy, 1960). The development and acceptance of plate tectonic theory provided a mechanism that coupled hinterland deformation, foreland basin subsidence, and sedimentation (Dickinson, 1973; Price, 1973; Bally and Snelson, 1980). Since then, foreland basins have been the focus of many studies, as indicated by classic papers on their geodynamic evolution and sedimentary fill (Beaumont, 1981; Jordan, 1981; Quinlan and Beaumont, 1984; Stockmal and others, 1986; Flemings and Jordan, 1989; Sinclair and others, 1991), paleohydrology (Bethke, 1985; Garven, 1989), thermal history (Hitchon, 1984; Kominz and Bond, 1986), and several recent compendia on foreland basins and their sedimentary fill (Allen and Homewood, 1986; Macqueen and Leckie, 1992).

This Special Publication was derived from a Research Symposium entitled "Stratigraphic Sequences in Foreland Basins," held at the annual joint meeting of the American Association of Petroleum Geologists and SEPM on June, 1992 in Calgary, Alberta, Canada. Approximately half of the papers in this volume were given as presentations at the Calgary meeting, while the other half were contributed after the meeting. This volume does not provide a comprehensive synthesis of foreland basin stratigraphy because every foreland basin has a unique kinematic history and tectonic setting which, in turn, results in unique stratigraphic sequences. We hope instead that this volume provides a well-balanced perspective of current research on foreland basin stratigraphy and also serves as another element in the evolving framework that comprises our understanding of foreland basins. Given that so many of earth's resources (potable ground water, hydrocarbons, and base metal deposits) are found in foreland basins and that foreland basin strata often provide the only preserved record of the tectonic events that led to basin development, the impetus for continued studies of foreland basin strata should remain for many generations of geologists to come.

QUANTITATIVE MODELS OF FORELAND BASIN EVOLUTION

Early quantitative models for the geodynamic evolution and subsidence history of foreland basins examined the flexural effects of vertical loading on a lithospheric plate. These models attempted to find the best-fit between observed or reconstructed basin profiles and model profiles that were constructed by varying the rheological properties of the plate and the dimensions and density of the orogenic wedge that served as the vertical load. Erosion of the orogenic wedge and redistribution of the vertical load was added to subsequent models. Recent modeling efforts and stratigraphic studies have examined how rheological and mechanical heterogeneities in the loaded plate can influence subsidence patterns and basin geometries. Intraplate stresses also are gaining wider scrutiny as an important component of foreland basin subsidence and its consequent effects on sedimentation patterns.

Several papers in this volume have incorporated additional factors that affect the stratigraphic fill in foreland basins, even though they may have only subtle stratigraphic expressions. Johnson and Beaumont present an elegant model that relates climate, orographically-controlled precipitation, drainage patterns and river power, balance between tectonic and erosional mass fluxes, basin type, and basin subsidence to stratigraphic fill in several hypothetical foreland basins. Peper and others present models which suggest that variations in intraplate stress can be as significant as eustasy in its relative effect on the stratigraphic evolution of foreland basins, although rate of orogenic wedge growth is also important. The Permian Basin of West Texas and southeastern New Mexico is used by Yang and Dorobek as an example of how intraforeland, structural discontinuities act to partition strain during basin development and to demonstrate how these structural elements might influence regional subsidence and sedimentation patterns.

PROVENANCE STUDIES

The provenance of siliciclastic sediment in foreland basins has been used for over a century to provide important constraints on the sources of siliciclastic sediment in foreland basins and on the relative timing of deformation and depositional events.

Provenance studies, however, have evolved significantly beyond classical petrographic approaches which focus on the composition and relative proportions of framework components. Two papers in this volume use U-Pb isotopic analysis of detrital zircons to place additional constraints on sediment provenance in foreland basins. Mustard and others demonstrate that the Cretaceous–Paleogene Nanaimo Group along the Cordilleran margin of southern Canada received detritus from source areas that were hundreds of kilometers inboard of the basin and imply long-distance transport across tectonic strike. The Devonian clastic wedge of the Canadian Arctic is an order of magnitude larger than the classic Catskill delta of the Appalachian Basin, yet fundamental questions regarding sediment provenance persist, in part reflecting the very quartzose framework composition of the Arctic sediments. McNicoll and others use ages of detrital zircons to document a Caledonide-Greenland source area for the clastic wedge in the Canadian Arctic, effectively constraining the foreland fill as being transported longitudinally along the basin axis, parallel to the Ellesmerian orogenic front.

Mudrocks often comprise a large part of the total volume of foreland basin sediment, yet their provenance has rarely been examined. Andersen uses whole-rock chemical composition and clay mineralogy in Ordovician mudstones of the Appalachian Basin in order to determine if the mudstones record first-order trends in provenance that are related to tectonic events.

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REGIONAL STUDIES OF FORELAND BASINS

The remainder of this volume consists of regional studies that illustrate how interactions between tectonics, climate, sea-level change, and sedimentation affect foreland basin stratigraphy.

In their study of conglomeratic units in Lower Cretaceous, nonmarine strata from central Wyoming, May and others document partitioning of the Wind River Basin by a series of horsts and grabens, which controlled the distribution and geometry of fluvial networks. Upper Paleozoic strata in the Black Warrior Basin, described in a paper by Thomas, illustrate how the location of the basin next to two, nearly orthogonal orogenic fronts (i.e., the Ouachita and Appalachian thrust belts) influenced subsidence and sedimentation patterns in the basin. Carbonate strata are not generally considered to be signature lithologies of foreland basins, with much greater emphasis placed on siliciclastic facies. Dorobek presents an overview of modern and ancient marine carbonate platforms in foreland basin settings and suggests that these strata may provide a more sensitive record of basin evolution than siliciclastic facies. In this context, Yang and Dorobek examine the stratigraphic and structural evolution of the classic Permian Basin of West Texas and New Mexico as they relate to compressional tectonics of the Marathon-Ouachita fold belt and associated intraforeland deformation.

A number of papers in this volume focus on the Late Devonian-Mississippian Antler orogeny and its effects on foreland basin development along the western margin of North America. Mississippian carbonate platform sedimentation in southern Nevada and eastern California, a structurally complex and poorly understood part of the Antler puzzle, are described in a paper by Stevens and others. Giles and Dickinson discuss stratigraphic relationships in the classical Antler foreland basin of Nevada and Utah, but emphasize interactions between eustasy and flexure on both the basinward and cratonward side of the inferred peripheral bulge and the consequent stratigraphic signature. Savoy and Mountjoy analyze the Devono-Mississippian succession of the southern Canadian Rocky Mountains in the context of Antler-age plate convergence, a view that was somewhat heretical previously but which is gaining wider acceptance amongst Canadian geologists.

Li and others provide a departure from the Antler theme in their study of the stratigraphic evolution of the thick, nonmarine fill of the Triassic-Jurassic Ordos Basin of China. They suggest that the Ordos Basin formed as a response to oblique collision and closure of a complex and irregular Tethyan margin.

The volume is completed by two papers by Gardner on mid-Cretaceous strata from the Western Interior of North America. The first paper provides an overview of controls on regional base-level changes which, in turn, affected the hierarchy of time-stratigraphic units across the Western Interior Foreland Basin. In his second paper, Gardner focuses on central Utah, where detailed stratigraphic and facies analyses provide evidence for eustasy, not tectonism, as the dominant control on sedimentation.

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