PART I

TECTONICS AND STRUCTURE OF SUPERCONTINENT BREAKUP

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Introduction

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The chapters in part I provide new and valuable information about the tectonic and structural evolution of eastern North America during the breakup of the Pangean supercontinent. Specifically, these chapters reveal a remarkably consistent story about the synrift and postrift stages of development of this passive continental margin. This consistency is especially noteworthy because the authors employ different approaches applied at different scales along virtually the entire length of the Mesozoic rift system.

In chapter 3, Dennis V. Kent and Giovanni Muttoni use paleomagnetic data to discuss the likely plate-tectonic configurations of Pangea from Permian to Middle Jurassic time. In eastern North America, this time interval corresponds to the prerift, synrift, and early postrift stages. Robert J. Altamura in chapter 5; Dave Goldberg, Tony Lupo, Michael Caputi, Colleen Barton, and Leonardo Seeber in chapter 7; and Rolf V. Ackermann, Roy W. Schlische, Lina C. Patiño, and Lois A. Johnson in chapter 8 use the orientation of small-scale structures to define the NW–SE extension direction in eastern North America during the synrift stage. Altamura's work defines the extension direction specifically for Middle Triassic time (238 Ma). This information, together with previously published studies of Early Jurassic age diabase dikes (e.g., McHone 1988) and sediment-filled fissures (Schlische and Ackermann 1995), indicates that a NW–SE extension direction was temporally consistent, at least in the northeastern United States and maritime Canada. In chapter 4, Roy W. Schlische complements these studies of small-scale structures by integrating structural and stratigraphic data at the basin scale. He describes a broad outline of diachronous rifting and drifting in eastern North America, synthesizing this study with work he did previously with Martha O. Withjack and Paul E. Olsen (Withjack, Olsen, and Schlische 1995; Withjack, Schlische, and Olsen 1998). Specifically, rifting ended earlier and drifting began earlier in the south. Given the diachronous nature of the large-scale breakup of Pangea, it is not surprising that the central North Atlantic margin also had a diachronous history. As discussed in chapter 6, MaryAnn Love Malinconico's work with vitrinite reflectance data from the Taylorsville basin, Virginia, supports the concept that the cessation of rifting was diachronous in eastern North America. Her work suggests that rifting ceased in the south during the latest Triassic and earliest Jurassic.

Schlische (chapter 4) reviews the field and seismic evidence for postrift shortening and inversion in eastern North America. (Basin inversion is a two-stage tectonic process in which a contractional phase follows the extensional phase [Buchanan and Buchanan 1995].) Malinconico (chapter 6) provides independent support for inversion with her vitrinite reflectance study in the Taylorsville basin. Particularly noteworthy is her observation that the amount of postrift erosion is highest over inversion-related anticlines. Although we have known that most rift basins of eastern North America have experienced considerable postrift erosion, Malinconico was the first to demonstrate that at least part of this erosion is controlled directly by structures produced during basin inversion. Fracture studies by Goldberg and colleagues (chapter 7) and by Ackermann and co-workers (chapter 8) corroborate the theory that postrift shortening occurred in eastern North America. These authors (along with Withjack, Olsen, and Schlische 1995; Withjack, Schlische, and Olsen 1998; and Schlische [chapter 4]) conclude that the postrift shortening direction was NW–SE. Previous studies, however, support different shortening directions. For example, structural analyses in the Newark basin indicate a N–S (Lomando and Engelder 1980) or NE–SW (Lucas, Hull, and Manspeizer 1988) shortening direction. The postrift shortening direction is generally difficult to constrain because the geometries of the preexisting extensional structures strongly influence the geometries of the inversion structures. Moreover, the timing of postrift shortening is difficult to constrain because of an absence of growth strata. We believe that additional work is needed to define conclusively the timing and direction of postrift shortening in eastern North America. The modern state of stress and strain, defined by borehole breakouts and quarry buckles, is NE–SW compression and shortening (e.g., Goldberg et al. [chapter 7]; Ackermann et al. [chapter 8]).

The chapters in part I also provide insights into some general aspects of extensional tectonics and passive margin development. The Mesozoic rift basins of eastern North America can (and should) serve, therefore, as models for interpreting other less well studied or less well understood rift basins and passive margins.

PREEXISTING FABRIC AND OBLIQUE RIFTING

In chapter 5, Altamura reports that the Lantern Hill fault, a reactivated Paleozoic contractional structure, was oblique to the Triassic extension direction, resulting in oblique-slip faulting. Oblique extension as applied to the Hartford basin is described in Clifton and colleagues (2000). Schlische (chapter 4) describes its application to the Fundy basin and to the Narrow Neck.

FAULT-POPULATION SYSTEMATICS

The Solite Quarry, described in chapter 8, has been useful in understanding the scaling relationship between fault length and displacement (Schlische et al. 1996), the deflection geometry associated with normal faults (Gupta and Scholz 1998), and the mechanics of fault interaction (Gupta and Scholz 2000b). The Solite faults have shown that fault populations do not always follow a simple power-law distribution of fault sizes (Ackermann and Schlische 1997), as is conventionally assumed (e.g., Marrett and Allmendinger 1991; most papers in Cowie, Knipe, and Main 1996). Experimental models (e.g., Ackermann, Withjack, and Schlische 2000) and field data from Afar (Gupta and Scholz 2000a) show that fault populations change from power-law to exponential-size distributions with increasing strain. Modeling work by Ackermann, Withjack, and Schlische (2000) has further demonstrated that this transition is governed by mechanical-layer thickness. In chapter 8, Ackermann and co-workers further describe the importance of mechanical stratigraphy in controlling fracture populations. The lack of self-similar (power-law) fault growth under certain conditions poses problems for the very simple basin-filling models described by Schlische (1991, chapter 4) and by Contreras, Scholz, and King (1997).

FAULT SPATIAL RELATIONSHIPS

In chapter 5, Altamura highlights the fact that more faults were active during rifting than those that now preserve synrift units in their hanging-wall blocks. This is especially the case during the early stages of rifting. Data from the Taylorsville basin (LeTourneau 1999) and from other rift systems indicate that faulting is distributed originally on many small faults but that it localizes on a few large faults. Localization occurs because of stress-enhancement and stress-reduction zones (e.g., Cowie 1998; Gupta and Scholz 1998). Stress-enhancement zones encourage the along-strike linkage of colinear fault segments, whereas stress-reduction zones deactivate noncolinear but parallel segments. Ackermann and colleagues (chapter 8) describe small-scale examples of stress-reduction zones in the Solite Quarry (see also Ackermann and Schlische 1997).

BASIN INVERSION ON PASSIVE MARGINS

Like many other passive margins (as described in Hill et al. 1995; Doré and Lundin 1996; Vågnes, Gabrielsen, and Haremo 1998; Withjack and Eisenstadt 1999), the rift basins of eastern North America have undergone basin inversion. However, unlike most other inverted basins, many of those in eastern North America are exposed. Thus field and seismic data allow us to determine more accurately the three-dimensional geometry of inversion structures and related smaller-scale fractures, which is essential for constraining the shortening direction (or directions) involved with the inversion and the cause (or causes) of this shortening in a passive margin setting. Possible mechanisms for producing basin inversion in this tectonic setting are reviewed by Withjack, Olsen, and Schlische (1995); Withjack, Schlische, and Olsen (1998); Vågnes, Gabrielsen, and Haremo (1998); and Schlische (chapter 4). Finally, basin inversion may be even more widespread than currently assumed. Experimental models (Eisenstadt and Withjack 1995) indicate that some inversion structures may be difficult to recognize. Unless the magnitude of shortening exceeds the magnitude of extension, inversion structures may have a subtle, anticlinal expression and may be overlooked easily. These low-amplitude anticlines would be the first to be removed during the erosion associated with uplift.

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