

PART II

THE CENTRAL ATLANTIC LARGE IGNEOUS PROVINCE

9

Introduction

Paul E. Olsen and J. Gregory McHone

Large igneous provinces (LIPs) comprise enormous edifices of basaltic lava and associated igneous rocks emplaced over a relatively brief time interval (Coffin and Eldholm 1994). Two of the largest terrestrial LIPs, the Siberian Traps ($\sim 2.5 \times 10^6 \text{ km}^3$) and Deccan Traps ($\sim 2.6 \times 10^6 \text{ km}^3$), are continental flood basalts associated in time with a mass extinction—the Siberian Traps with the end-Permian extinction at 250 Ma and the Deccan Traps with the end-Cretaceous extinction at 65 Ma (McLean 1985; O’Keefe and Ahrens 1989; Caldeira and Rampino 1990; Courtillot et al. 1994) (figure 9.1). The early Mesozoic basaltic rocks of eastern North America recently have been recognized as part of a third giant continental LIP closely associated in time with a mass extinction, this time the Triassic–Jurassic ($\sim 201 \text{ Ma}$) boundary (Marzoli et al. 1999; Olsen 1999) (figure 9.2). These lavas and associated igneous intrusions are now called the Central Atlantic Magmatic Province (CAMP) (Marzoli et al. 1999). The CAMP, the topic of part II of this volume, covers major parts of at least four tectonic (continental) plates and is integral to the rifting of the supercontinent of Pangea and formation of the Atlantic Ocean.

Although CAMP has very familiar geologic features with a venerable literature (e.g., Percival 1842; Davis 1883; Darton 1890; Walker 1940; May 1971), the fact that it may well be the largest continental LIP on Earth has been recognized within only the past few years (Marzoli et al. 1999). According to J. Gregory McHone and John H. Puffer (chapter 10), CAMP originally may

have produced lavas extending over more than $7 \times 10^6 \text{ km}^2$ prior to the formation of the Atlantic. In their chapter, McHone and Puffer review the distribution, chemistry, age, and stratigraphic setting of the CAMP, and they suggest that the eruption of the lavas could have triggered ecologically catastrophic climate change through massive input of volatiles into the atmosphere, as has been suggested for several other LIPs (McLean 1985; Rampino and Stothers 1988; Courtillot et al. 1994; Renne et al. 1995; McHone 1996, 2000). Recent direct fossil evidence does suggest a link to the CAMP (McElwain, Beerling, and Woodward 1999; Palfy et al. 2000).

To one extent or another, the other chapters in part II consider the somewhat controversial origin of the CAMP and the geodynamic conditions necessary for the production of LIPs. The controversy centers on the “deep-mantle plume” model versus the “shallow-mantle convection” model for generating large amounts of basalt (essentially Campbell and Griffiths’s [1990] model versus King and Anderson’s [1995]). Wilson (1997) and McHone (2000), among others, have suggested applications of these contrasting models to the CAMP. Although both models are essentially variations on the geometry of mantle upwelling (figure 9.3), there are fundamental differences in how each can cause continents to rift and massive basalts to erupt, so both deserve serious attention. Geophysical data that can conclusively demonstrate the requisite mantle geodynamics unfortunately are exceedingly difficult to collect and afterward to interpret. Needed are testable

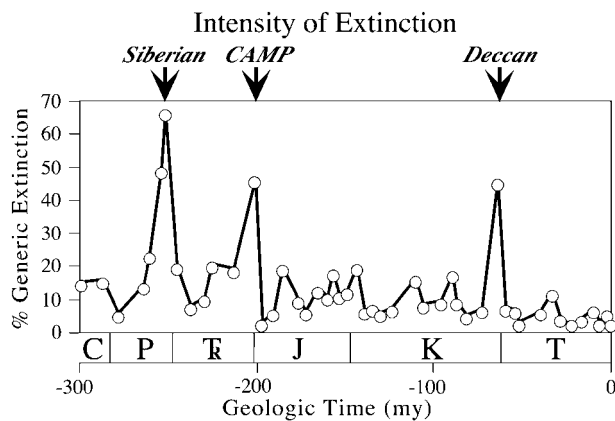


FIGURE 9.1 Extinction rate of “shelly” marine invertebrates through the Phanerozoic, showing the major continental LIPs. (Based on Sepkoski 1997, with timescale modified according to Kent and Olsen 1999)

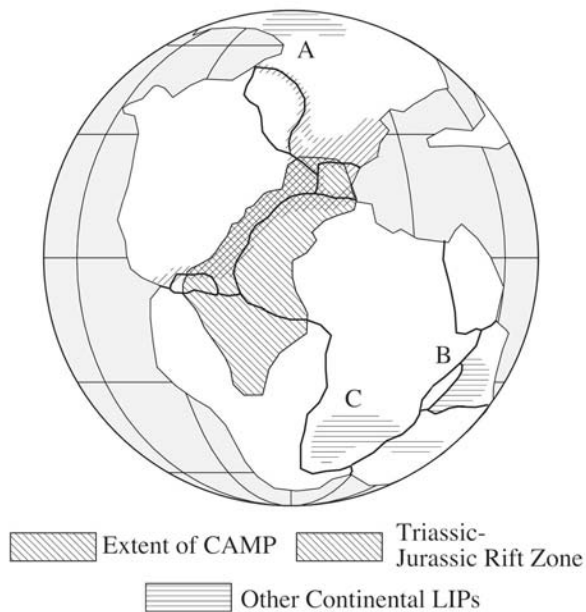


FIGURE 9.2 Distribution of the CAMP, Siberian Traps, and Deccan Traps with a Late Triassic plate configuration. (Based on Olsen 1999)

hypotheses that predict associated chemical, physical, dimensional, and temporal characteristics unique to each model (or, quite possibly, unique to some variant model yet to be realized).

In chapter 11, John H. Puffer places the CAMP flood basalts in a larger petrological context with various other continental flood basalt LIPs, including those of the Rodinian and pre-Rodinian superconti-

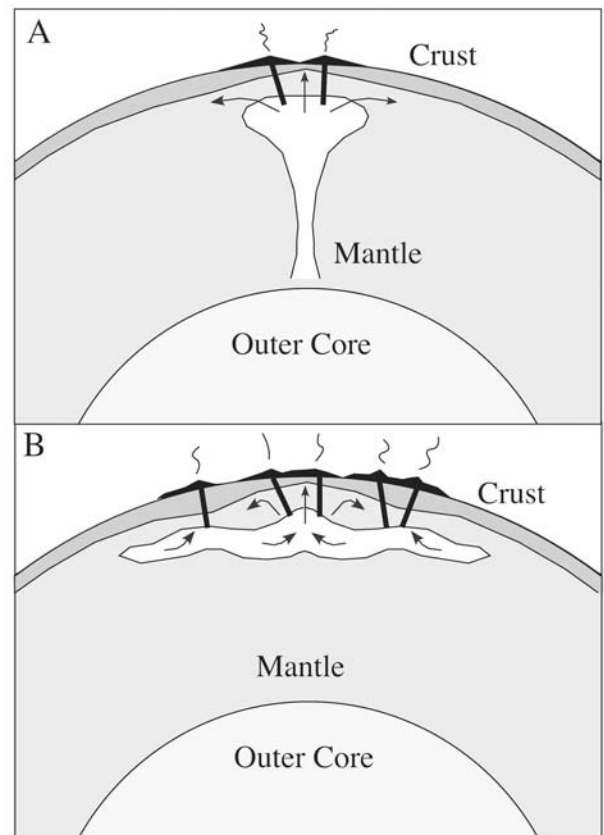


FIGURE 9.3 General geodynamic patterns envisioned for (A) the deep-mantle plume model and (B) the upper-mantle convection model. Note the more narrowly focused volcanism attributed to the plume model versus the wider-ranging volcanism from upper-mantle convection.

nent, the Siberian Traps, the Karoo Province, the Deccan Traps, and the Columbia River Basalts. Surprisingly, CAMP basalts appear similar to arc volcanics, and Puffer concludes that global plate reorganization was the motive force behind the emplacement of the gigantic igneous province, unlike some other continental LIPs that may have been produced by hot spots. Paul C. Ragland, Vincent J. M. Salters, and William C. Parker (chapter 12) examine a massive database of major-oxide analyses from the southeastern U.S. portion of the CAMP and hypothesize that the observed chemical trends indicate melting at deeper levels toward the southwestern portion of the southeastern United States in an area of thicker crustal derivation of the magma from more “fertile” mantle influenced by a hot spot. The different models for origin of LIPs, especially the CAMP, make different prediction of the

mechanism of emplacement though dikes. In chapter 13, Jelle Zeilinga de Boer, Richard E. Ernst, and Andrew G. Lindsey describe anisotropy of magnetic susceptibility (AMS) data from the northeastern United States that they conclude indicates northeasterly directed lateral flow in dikes. This flow would be more compatible with a southeastern United States mantle plume source than with any other mechanism.

McHone and Puffer (chapter 10) and Ragland and colleagues (chapter 12) also briefly discuss one of the largest and most critical unanswered questions about the CAMP: What is the relationship between the CAMP and the seaward-dipping reflectors off the eastern United States (Holbrook and Kelemen 1993; Talwani et al. 1995; Withjack, Schlische, and Olsen 1998)? This question, unlikely to be dealt with seriously without extensive scientific drilling (Olsen, Kent, and Raeside 1999), bears directly on the mechanism of supercontinent breakup, the origin of initial oceanic crust, and the magnitude of the CAMP and its environmental effects.

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