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Petrogenesis of the earliest Early Cretaceous mafic rocks from the Cona area of the eastern Tethyan Himalaya in south Tibet: Interaction between the incubating Kerguelen plume and the eastern Greater India lithosphere?

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Abstract

The relationship between the breakup of eastern Gondwanaland and the Kerguelen plume activity is a subject of debate. The Cona mafic rocks are widely exposed in the Cona area of the eastern Himalaya of south Tibet, and are studied in order to evaluate this relationship. Cona mafic rocks consist predominantly of massive basaltic flows and diabase sills or dikes, and are divided into three groups. Group 1 is composed of basaltic flows and diabase sills or dikes and is characterized by higher TiO_2 and P_2O_5 content and OIB-like trace element patterns with a relatively large range of εNd(T) values (+1.84 to +4.67). A Group 1 diabase sill has been dated at 144.7±2.4 Ma. Group 2 consists of gabbroic sills or crosscutting gabbroic intrusions characterized by lower TiO_2 and P_2O_5 content and “depleted” N-MORB-like trace element patterns with relatively higher, homogeneous εNd(T) values (+5.68 to +6.37). A Group 2 gabbroic diabase dike has been dated at 131.1±6.1 Ma. Group 3 basaltic lavas are interbedded with the Late Jurassic–Early Cretaceous pelitic sediments; they have compositions transitional between Groups 1 and 2 and flat to slightly enriched trace element patterns. Sr–Nd isotopic data and REE modeling indicate that variable degrees of partial melting of distinct mantle source compositions (enriched garnet–clinopyroxene peridotite for Group 1 and spinel-lherzolite for Group 2, respectively) could account for the chemical diversity of the Cona mafic rocks. Geochemical similarities between the Cona mafic rocks and the basalts probably created by the Kerguelen plume based on spatial–temporal constraints seem to indicate that an incubating Kerguelen plume model is more plausible than a model of normal rifting (nonplume) for the generation of the Cona mafic rocks. Group 1 is interpreted as being related to the incubating Kerguelen plume–lithosphere interaction; Group 2 is likely related to an interaction between anhydrous lithosphere and rising depleted asthenosphere enriched by a “droplet” originating from the Kerguelen plume, while Group 3 may be attributed to thermal erosion resulting in the partial melting of lithosphere during the long-term incubation of a magma chamber/pond at a shallow crustal level. The Cona mafic rocks are probably related to a progressively lithospheric thinning beneath eastern Gondwanaland from 150–145 Ma to 130 Ma. Our new observations seem to indicate that the

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Kerguelen plume may have started its incubation as early as the latest Jurassic or earliest Cretaceous period and that the incubating Kerguelen plume may play an active role in the breakup of Greater India, eastern India, and northwestern Australia.
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1. Introduction

The Kerguelen Plateau in the South Indian Ocean is one of the best-known Large Igneous Provinces (LIPs) on earth (Larson, 1991; Coffin and Eldholm, 1994). This LIP has been linked to the presence of the long-lived Kerguelen mantle plume, situated at present beneath the northwestern margin of the Kerguelen Plateau (Storey et al., 1992; Kent et al., 1996; Coffin et al., 2002). Cretaceous and Cenozoic igneous rocks related to the Kerguelen plume in the eastern Indian Ocean region and neighboring continental margin (Fig. 1a) have been widely dispersed from their original sites of emplacement due to the changing motions of the Antarctic, Australian, and Indian plates from the Early Cretaceous period to the present (Mahoney et al., 1983; Storey et al., 1989; Davies et al., 1989; Storey et al., 1992; Müller et al., 1993; Frey et al., 1996; Kent et al., 1997; Kent et al., 2002; Ingle et al., 2002, 2003, 2004; Srivastava et al., 2005).

The first manifestation in an oceanic environment probably attributable to the Kerguelen plume is exposed on the Southern Kerguelen Plateau (120–110 Ma, Coffin et al., 2002). On the neighboring continental margins (Fig. 1a), the Rajmahal–Sylhet Traps (118 Ma; Sarkar et al., 1996; Kent et al., 1997, 2002), igneous complexes in the Shillong Plateau (115–107 Ma, Ray and Pande, 2001; Srivastava et al., 2005) from eastern India and alnoites from Antarctica (110 Ma, Ghose et al., 1996) have been widely accepted as the result of the Kerguelen plume for their geochemical affinity with the contemporaneous construction of the oldest portion of the Southern Kerguelen Plateau (Storey et al., 1992; Ghose et al., 1996; Ray and Pande, 2001; Coffin et al., 2002; Kent et al., 2002; Ingle et al., 2002, 2003, 2004; Kumar et al., 2003; Srivastava and Sinha, 2004; Srivastava et al., 2005). However, for the older uncontaminated Bunbury Casuarina basalts of southwestern Australia (132 Ma), Frey et al. (1996) proposed that their geochemical similarity with younger oceanic lavas from Ninetyeast Ridge and the Kerguelen Archipelago that have been related to the Kerguelen plume might be fortuitous, whereas other authors have argued that the Bunbury Casuarina basalts may be the first manifestation in a continental marginal environment potentially attributable to the Kerguelen plume (Davies et al., 1989; Duncan and Storey, 1992; Kent et al., 2002; Ingle et al., 2002, 2004).

The differing statements above on the Bunbury basalts resulted in a contentious issue regarding the relationship between the breakup of eastern Gondwanaland and the Kerguelen plume activity. Some investigators believe that the oldest (120–110 Ma) known lavas from the Southern Kerguelen Plateau and Rajmahal–Sylhet Traps associated with the Kerguelen plume (Mahoney et al., 1983; Class et al., 1993; Baksi, 1995) are considerably younger than the initial breakup (~132 Ma, Powell et al., 1988) of southwest Australia and Greater India, and have thus concluded that the plume was not a major factor in the breakup of eastern Gondwanaland (Frey et al., 1996). Others, however, believe that the first manifestation of the Kerguelen plume around 132 Ma, exposed in southwestern Australia (Bunbury Casuarina basalt), is significantly coeval with the initial seafloor magnetic anomaly of the eastern Indian Ocean at ~132 Ma (Powell et al., 1988). They have therefore suggested that the Kerguelen plume played a significant role in the breakup of eastern Gondwanaland (Ingle et al., 2002; Coffin et al., 2002).

The reason for this contentious issue is that it is a more complicated question, where three important concerns need to be considered. These are: (1) the large distance between the proposed Kerguelen plume location and southwest Australia during the eruption of the Bunbury basalts is often cited as a possible argument against a plume origin (Frey et al., 1996; Coffin et al., 2002); however, the distance of 700–1100 km between the Kerguelen plume and southwestern Australia at ~120 Ma is not believed to be a convincing argument against a common plume source for the Bunbury basalts and the Kerguelen Plateau basalts (Ingle et al., 2004); (2) the older Bunbury Casuarina basalts (~132 Ma) preceded the presumed initiation of volcanism on the Kerguelen Plateau (~120–110 Ma) by 12–22 Ma; and (3) the small volume of Bunbury Casuarina basalts (~10^3 km^3, Coffin et al., 2002) is incompatible with the traditional plume model (Frey et al., 1996; Coffin et al., 2002). Therefore, an appealing question is whether we can find the older magma manifestations potentially related to the early activity of the Kerguelen plume on

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