Whole-rock elemental and zircon Hf isotopic geochemistry of mafic and ultramafic rocks from the Early Cretaceous Comei large igneous province in SE Tibet: constraints on mantle source characteristics and petrogenesis

Di-Cheng Zhu[1,*], Xuan-Xue Mo[1], Zhi-Dan Zhao[1], Yaoling Niu[2] and Sun-Lin Chung[3]

[1] *State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, CHINA*
[2] *Department of Earth Sciences, Durham University, Durham DH1 3LE, UK*
[3] *Department of Geosciences, National Taiwan University, Taipei 106, TAIWAN*
[*] *For correspondence, email: dchengzhu@163.com*

The Early Cretaceous Comei large igneous province (CLIP) aged from ca. 145 to 128 Ma with peak activity at ca. 132 Ma was recently identified in southeastern Tibet (Figure 1a, Zhu et al. 2008a). The CLIP is dominated by dismembered mafic lava flows, sills and dikes, with subordinate ultramafic and silicic rocks. Seventy mafic and ultramafic intrusion samples collected via three N-S transects from 28° N to 29° N and 90°30´E to 92° E in the CLIP (Figure 1b) were subjected to detailed geochemical analyses involving whole-rock major and trace elements and Sr-Nd isotopes as well as zircon Lu-Hf isotopic measurements for constraint on mantle source characteristics and petrogenesis.

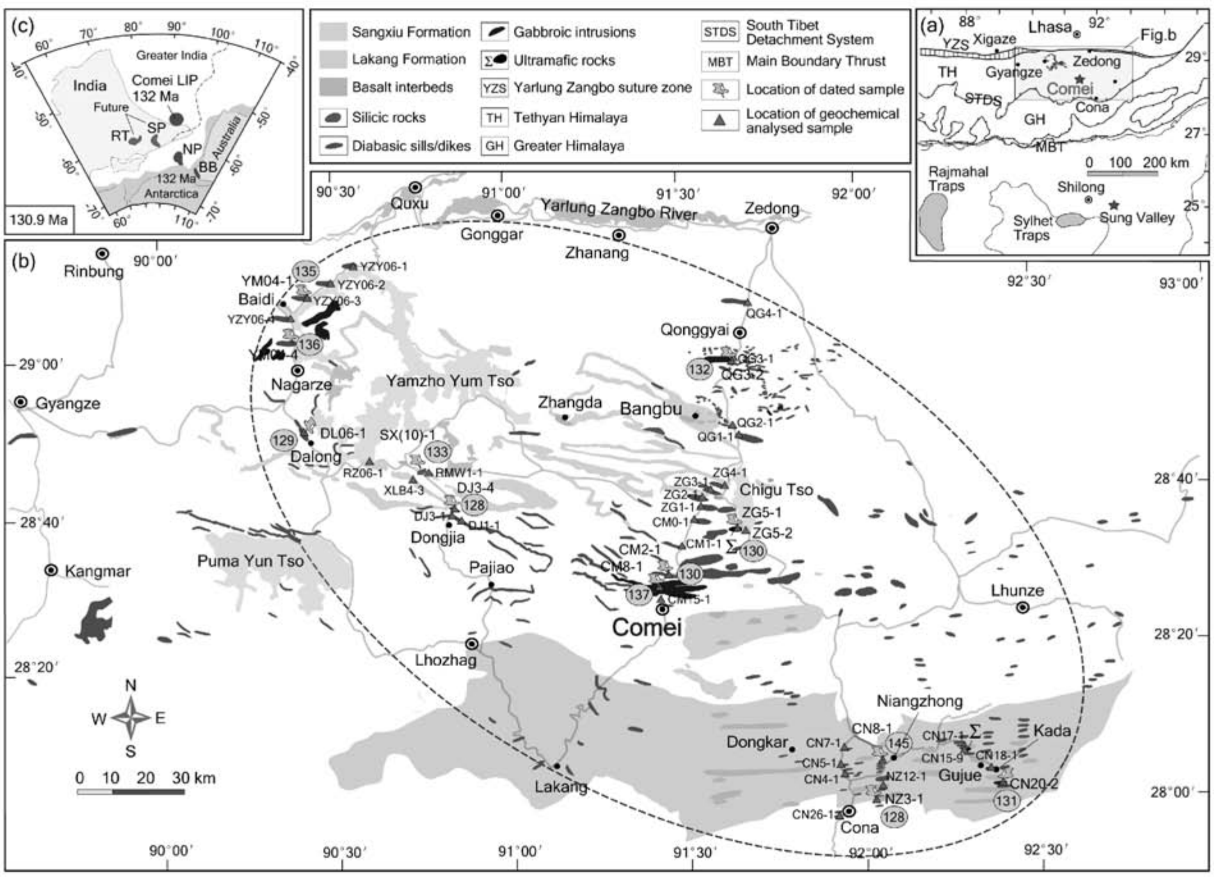

FIGURE 1. The spatial extent (dashed ellipse) of the Comei LIP in SE Tibet (Zhu et al. 2008a). (a). Sketch of the tectonic map in SE Tibet, showing the location of the Comei large igneous province (LIP) compared to the Rajmahal, the Sylhet Traps and the igneous complexes in Sung Valley of NE India (Coffin et al. 2002, Zhu et al. 2008b). (b). Simplified geology map showing the spatial extent (dashed ellipse) and distributions of ~ 132 Ma igneous rocks of the Comei LIP (Zhu et al. 2008a). (c). Plate reconstruction of the southern Indian Ocean region at ~ 130.9 Ma (Coffin et al. 2002). The major Proterozoic terranes for each continental block and the known locations of the Shillong Plateau (SP), Rajmahal Traps (RT), Naturaliste Plateau (NP), and Bunbury Basalt (BB) are labelled. The location of the Comei LIP is shown in view of present-day spatial extent and Cenozoic shortening relative to the Rajmahal Traps province.

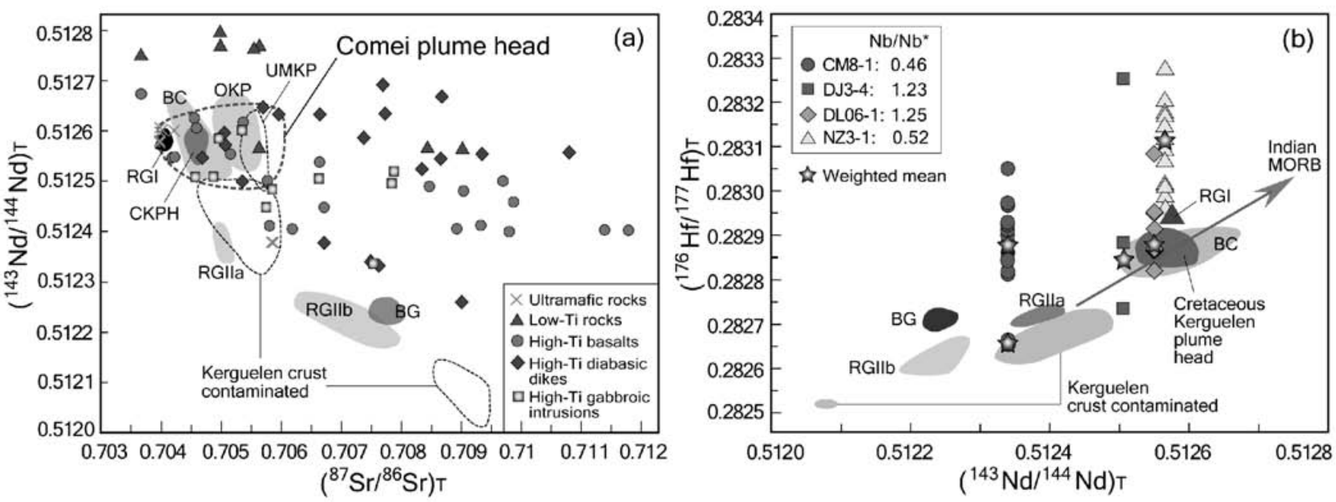

FIGURE 2. Whole-rock Sr-Nd and zircon Hf isotopic compositions of the Comei LIP in SE Tibet. Data sources: Bunbury Casuarina (BC) and Bunbury Gosselin (BG, Frey et al. 1996, Ingle et al. 2004); Rajmahal Group I (RGI) and Rajmahal Group II (RGII, Baksi 1995, Kent et al. 1997, Ingle et al. 2004); Oligocene Kerguelen Plume (OKP, Yang et al. 1998); Upper Miocene Kerguelen Plume (UMKP, Weis et al. 1993); Cretaceous Kerguelen Plume Head (CKPH, Ingle et al. 2004). Nb/Nb* = $Nb_{PM}/(La_{PM}$ × ThPM)1/2, PM is primitive mantle-normalized (Sun and McDonough 1989). The Sr-Nd isotopic compositions of the Comei plume head are designated by the 17 uncontaminated high-Ti group samples and 6 ultramafic samples (Figure 2a), which are filtered from 51 samples from different sites in the CLIP. The altered and contaminated samples have been excluded by geochemical diagnostic signatures (such as LOI content, and $(Th/Nb)_{PM}$ value) and petrographic observations.

The mafic rocks in the CLIP can be subdivided into two major groups in terms of TiO_2 and P2O5 contents, including the dominant high-Ti group (TiO_2 > 2.4%, P_2O_5 > 0.3%) that consists of basaltic lavas, diabasic sills/dikes, and gabbroic intrusions, and the low-Ti group (TiO_2 < 2.2%, P_2O_5 < 0.2%) that consists of basaltic lavas and gabbroic intrusions. Twelve SHRIMP zircon U-Pb age dates indicate that the high-Ti group is persisted from ca. 145 Ma to 128 Ma, and the tholeiitic magmatism is occurred at 132 Ma, and continued to 128 Ma (Zhu et al. 2008a).

Leaving out the altered and contaminated samples from 51 analyses by geochemical diagnostic signatures (e.g., LOI content, and [Th/Nb]PM value, PM is primitive mantle-normalized) and petrographic observations, the Sr and Nd isotopic compositions of (87Sr/86Sr)T = 0.70418 ~ 0.70596, $(^{143}Nd/^{144}Nd)_T$ = 0.512502 ~ 0.512647,εNd(T) = 0.67 ~ 3.81 for seventeen high-Ti group samples with Nb/Y ratios ranging from 0.53-1.07 (majority > 0.68), and 0.70397 ~ 0.70421, 0.512578 ~ 0.512606, 2.13 ~ 2.69 for six layered picrite porphyrite samples with Nb/Y ratios from 0.5 to 0.7, were obtained. It has been recognized that a long period of alkalic magmatism followed by enormous tholeiitic volcanism is typical of many flood-basalt provinces of the world (Sheth and Chandrasekharam 1997). We therefore interpret the isotopic compositions of the uncontaminated high-Ti group with alkalic to transitional nature and ultramafic samples as reflecting the source characteristics of the Comei plume head, which is: $(^{87}Sr/^{86}Sr)_T$ = 0.70398 ~ 0.70596, $(^{143}Nd/^{144}Nd)_T$ = 0.512502 ~ 0.512647, εNd(T) = 0.67 ~ 3.81 (Figure 2a). This isotopic composition overlaps those of basalts produced by the Kerguelen plume, e.g., the Cretaceous Rajmahal Group I basalts (Baksi 1995, Kent et al. 1997), the Bunbury Casuarina basalts (Frey et al. 1996), Oligocene (Yang et al. 1998) and upper Miocene Kerguelen plume materials (Weis et al. 1993), as well as the proposed Cretaceous Kerguelen "plume head" (Ingle et al. 2004) (Figure 2a). The geochemical similarity between the Comei plume head and the Kerguelen plume materials is also supported by the in situ zircon Hf isotopic composition of the uncontaminated high-Ti group samples. Zircons from sample DL06-1 (129.1 ± 1.2 Ma) and DJ3-4 (128.3 ± 1.9 Ma) (Zhu et al. 2008a) have εHf(t) values from + 4.6 to + 13.9, and from + 1.5 ~ +19.9, respectively with weighted mean values close to those of the Bunbury Casuarina and the proposed Cretaceous Kerguelen "plume head" (Ingle et al. 2004) (Figure 2b). Although these similarities in elemental and isotopic characteristics could be fortuitous (Frey et al. 1996), they are permissive evidence that the CLIP magmas are derived from the same as, or similar to, mantle sources for lavas from the Kerguelen plume recorded in the eastern Indian Ocean and neighbouring continental margins (Figure 1c).

The prolonged alkaline magmatism of the CLIP favors plume head incubation beneath an originally thick lithosphere, as many flood-basalt provinces of the world would have (Sheth and Chandrasekharam 1997). We propose that the relative wide range of Sr and Nd isotopic compositions of the Comei plume head would ascribe to the relative long incubation of the Comei plume head beneath thick Eastern Gondwana lithosphere at the transition from the Late Jurassic to the Early Cretaceous time.

Acknowledgements

The NSFC projects (40503005 and 40473020), and the Programme of Excellent Young Scientists of the Ministry of Land and Resources supported this study.

References

Baksi AK. 1995. Petrogenesis and timing of volcanism in the Rajmahal flood basalt province, northeastern India. *Chemical Geology* 21: 73-90

Coffin MF, MS Pringle, RA Duncan, TP Gladczenko, M Storey, RD Müller and LA Gahagan. 2002, Kerguelen hotspot magma output since 130 Ma. *Journal of Petrology* 43: 1121-1139

Frey FA, NJ McNaughton, DR Nelson, JR Delaeter and RA Duncan. 1996.

Petrogenesis of the Bunbury Basalt, Western Australia: interaction between the Kerguelen plume and Gondwana lithosphere? *Earth and Planetary Science Letters* 144: 163-183

Ingle S, JS Scoates, D Weis, G Brügmann and RW Kent. 2004. Origin of Cretaceous continental tholeiites in southwestern Australia and eastern India: Insights from Hf and Os isotopes. *Chemical Geology* 209: 83-106

Kent RW, AD Saunders, PD Kempton and NC Ghose. 1997. Rajmahal basalts, eastern India: mantle sources and melt distribution at a volcanic rifted margin. In: Mahoney, JJ and MF Coffin (eds.). Large Igneous Provinces: Continental, Oceanic and Planetary Flood Volcanism. *Geophysical Monograph, American Geophysical Union* 100: 145-182

Sheth HC and D Chandrasekharam. 1997. Early alkaline magmatism in the Deccan Traps: implications for plume incubation and lithospheric rifting. *Physics of the Earth and Planetary Interiors* 104: 371-376

Sun, SS and WF McDonough. 1989. Chemical and isotope systematics of oceanic basalts: implications for mantle composition and processes. In: Saunders, AD (eds.). Magmatism in ocean Basins. *Geological Society Publication* 42: 313-345

Weis D, FA Frey, H Leyrit and I Gautier. 1993. Kerguelen Archipelago revisited: geochemical and isotopic study of the Southeast Province lavas. *Earth and Planetary Science Letters* 118: 101-119

Yang HJ, FA Frey, D Weis, A Giret, D Pyle and G Michon. 1998. Petrogenesis of the flood basalts forming the northern Kerguelen Archipelago: Implications for the Kerguelen plume. *Journal of Petrology* 39: 711-748

Zhu DC, SL Chung, XX Mo, ZD Zhao, Y Niu and B Song. 2008a. Kerguelen plume activity identified in southeastern Tibet: The Comei large igneous province. *Geology,* in review

Zhu DC, XX Mo, GT Pan, ZD Zhao, GC Dong, YR Shi, ZL Liao and CY Zhou 2008b. Petrogenesis of the earliest Early Cretaceous basalts and associated diabases from Cona area, eastern Tethyan Himalaya in south Tibet: interaction between the incubating Kerguelen plume and eastern Greater India lithosphere? *Lithos* 100: 147-173