^{40}Ar-^{39}Ar age of carbonatite-alkaline magmatism in Sung Valley, Meghalaya, India

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^{40}Ar-^{39}Ar analyses of one alkali pyroxenite whole rock and two phlogopite separates of calcite carbonatites from the Sung Valley carbonatite-alkaline complex, which is believed to be a part of the Rajmahal-Bengal-Sylhet (RBS) flood basalt province, yielded indistinguishable plateau ages of 108.8 ± 2.0 Ma, 106.4 ± 1.3 Ma and 107.5 ± 1.4 Ma, respectively. The weighted mean of these ages, 107.2 ± 0.8 Ma, is the time of emplacement of this complex. This implies that Sung Valley complex and probably other such complexes in the Assam-Meghalaya Plateau postdate the main flood basalt event (i.e., the eruption of tholeiites) in the RBS province by $\sim$10 Ma.

1. Introduction

The formation of large igneous provinces during the Early Cretaceous at the continental margins of eastern Antartica (Rodak lake alnoites), western Australia (Bundbury basalts) and eastern India (Rajmahal Traps) is generally ascribed to the melting of a major plume head (i.e., starting plume), the remnant of which (i.e., the plume tail) is now present as a hot spot beneath the Kerguelen islands in the Indian Ocean (e.g., Storey *et al* 1992). The eruption of the Rajmahal Traps, and probably of the Bengal and the Sylhet Traps on the Indian subcontinent $\sim$ 117 Ma ago (Baksi 1995) is believed to mark the beginning of the Kerguelen plume activity beneath the Indian plate (Mahoney *et al* 1983; Class *et al* 1993; Baksi 1995). The alkaline rocks of the Bengal Basin and the carbonatite-alkaline complexes of the Assam-Meghalaya Plateau (AMP) are also considered to be constituents of the Rajmahal-Bengal-Sylhet (RBS) large igneous province (e.g., Ghose *et al* 1996). Although volumetrically small, alkaline activities of a continental flood basalt province (CFB) are known to provide valuable information about plume incubation and duration (e.g., Basu *et al* 1993; Sen 1995). It has been observed that in a CFB province, alkaline magmatism marks the beginning and the end of the main flood basalt event (e.g., Basu *et al* 1993), and therefore knowledge of the timing of these activities is important to the understanding of a plume evolution. In this regard, the precise age determination of the four known carbonatite-alkaline complexes of the Rajmahal-Sylhet-Bengal CFB province (figure 1) becomes vital to the documentation of the Kerguelen plume history. The available geochronological data on these complexes, based on K-Ar, fission track, Pb-Pb and Rb-Sr methods, vary from 90 Ma to 156 Ma (e.g., Chhattopadhyay and Hashimi 1984; Veena *et al* 1998; Ray *et al* 2000), precluding any clear assessment of their temporal relation to the main phase of the RBS volcanism. In an attempt to provide a precise chronology of these complexes, we dated the Sung Valley carbonatite-alkaline complex, the largest of all, by the ^{40}Ar-^{39}Ar method.

Keywords. ^{40}Ar-^{39}Ar dating; carbonatite; Sung Valley; Rajmahal Traps; Kerguelen plume.

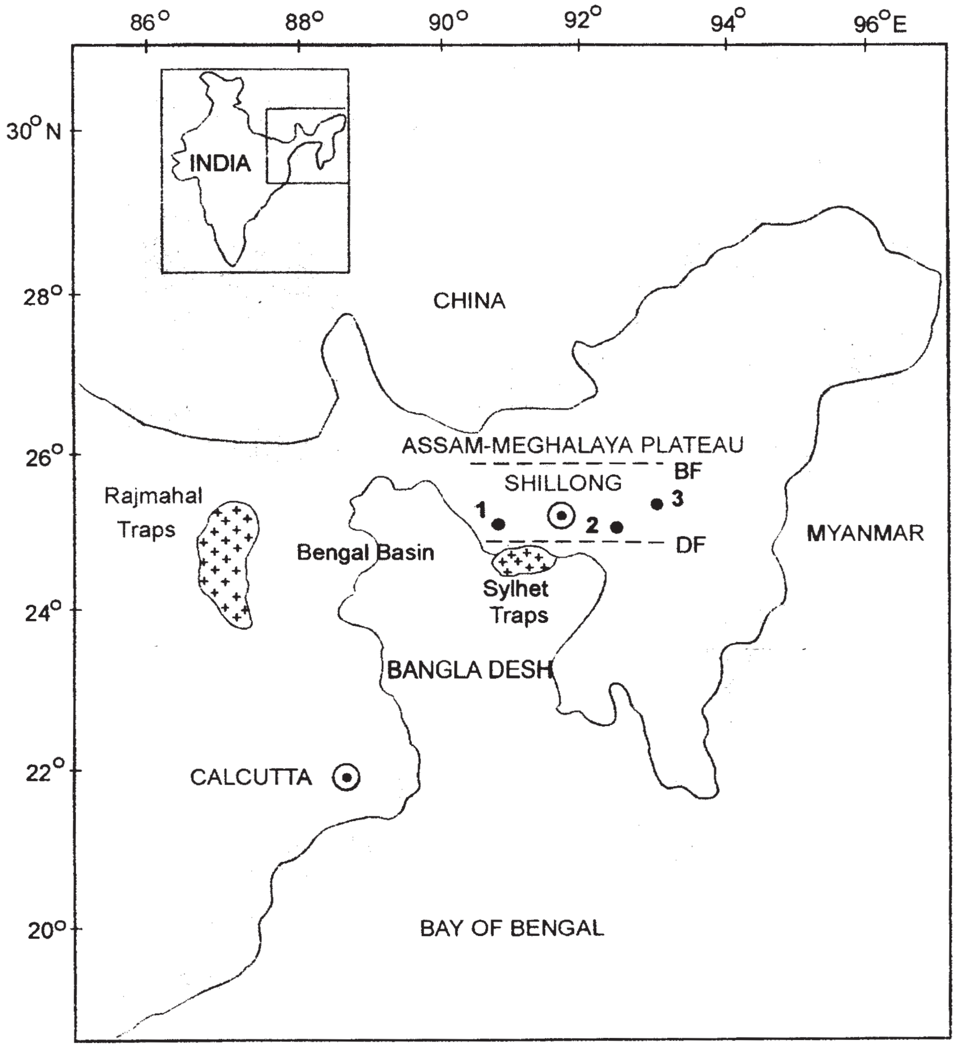

Figure 1. Sketch map of eastern India showing the locations of the Rajmahal and the Sylhet Traps (++) and the four carbonatite-alkaline complexes (**1** = Swangkre; **2** = Sung Valley; **3** = Samchampi; **4** = Jasra) in the Assam-Meghalaya Plateau. **DF** and **BF** are Dauki and Bramhaputra faults.

2. Geology and earlier work

The Sung Valley hosts one of the four carbonatite-alkaline complexes in the RBS flood basalt province in northeastern India (figure 1). This occurs in a horst like feature called the Assam-Meghalaya Plateau (AMP) bounded by two East-West trending faults (figure 1; Krishnamurthy 1985). The rocks of this complex intrude the Archean gneiss and schist and the Proterozoic Shillong group rocks (quartzite, phyllite, and amphibolite). This is an oval shaped pluton with the core being occupied by serpentinized peridotite and rimmed by pyroxenite. Apart from peridotite and pyroxenite, the complex comprises of melilitite, ijolite, and nepheline syenite (Sen 1999). Carbonatites occur as small stocks, lenses, dykes and veins within the pyroxenite in the southern part of the complex (figure 2). Field relations suggest that the peridotite and pyroxenite are the earliest phases of the magmatic activity. Two textural types (coarse and medium-fine grained) of pyroxenites have been reported from this complex (Krishnamurthy 1985). These pyroxenites are made up of mainly diopsidic augite with trace amounts of aegerine-augite, phlogopite, and magnetite (Krishnamurthy 1985; Viladkar *et al* 1994; Ray 1997; Sen 1999). Ijolite appears to form a ring dyke and a central plug, whereas syenite occurs as minor dykes (figure 2). Calcite carbonatite is the major carbonatite type in the Sung Valley. It contains calcite, magnetite, and apatite with minor/trace amounts of dolomite, phlogopite, olivine, pyrocholore, perovskite, and fluorite.

The time of emplacement of the Sung Valley complex has remained a contentious issue since

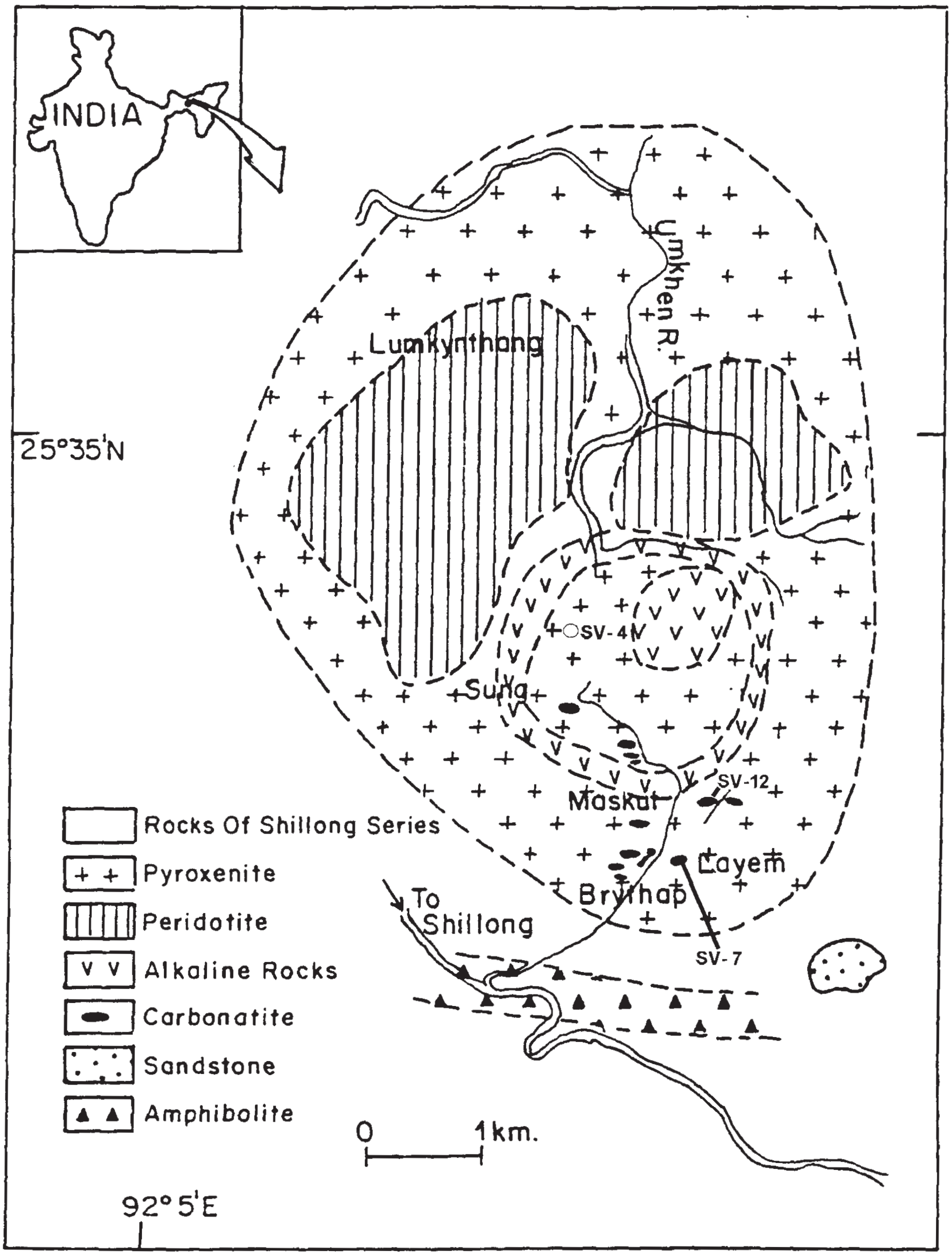

Figure 2. Geological map of the Sung Valley carbonatite-alkaline complex (after Krishnamurthy 1985).

the earliest measurements of fission track ages of 80 ± 13 Ma and 90 ± 10 Ma on apatite by Chattopadhyay and Hashimi (1984). More recent results of dating efforts are: 149 ± 5 Ma (K-Ar age of phlogopite from carbonatite; Sarkar *et al* 1996), 134 ± 20 Ma (Pb-Pb wr-carbonate isochron age of carbonatite; Veena *et al* 1998), and 106 ± 11 Ma (Rb-Sr phlogopite-wr isochron age of carbonatite and pyroxenite; Ray *et al* 2000). Most of these numbers have very high uncertainties that restrict their usefulness. In addition, the large spread in these ages (80–149 Ma) makes it difficult to establish the exact time of emplacement of this complex. Two other complexes of the RBS province, Samchampi and Swangkre (figure 1), have been dated at ∼105 Ma (K-Ar; Acharyya *et al* 1986) and 107 ± 4 Ma (K-Ar; Sarkar *et al* 1996), respectively.

3. Samples and experimental procedures

In this work, we selected a coarse-grained, unaltered pyroxenite (SV-4) and phlogopite separates from two calcite carbonatite samples (SV-7 and SV-12). These three samples along with a neutron-flux monitor (the 520.4 ± 1.7 Ma old Minnesota Hornblende; Samson and Alexander 1987) were irradiated in the central core of the light water mo-

Table 1. *Summary of results of ^{40}Ar-^{39}Ar dating of Sung Valley samples.*

Sample	Steps	Plateau % ^{39}Ar	Plateau Age (Ma)	Isochron Age (Ma)	Isochron Trap	Inverse isochron Age (Ma)	Inverse isochron Trap	Integrated Age (Ma)
SV-4	4	91.8	108.8 ± 2.0	108.0 ± 3.9	342 ± 60	107.7 ± 27.0	352 ± 62	118.8 ± 4.2
SV-7	9	97.3	106.4 ± 1.3	106.6 ± 3.9	284 ± 71	105.9 ± 34.5	319 ± 73	107.0 ± 3.7
SV-12	9	98.4	107.5 ± 1.4	107.5 ± 3.8	299 ± 30	107.3 ± 16.0	304 ± 31	108.6 ± 3.7

Note: Trap: Initial $^{40}Ar/^{36}Ar$ (trapped argon); Errors are 2σ.

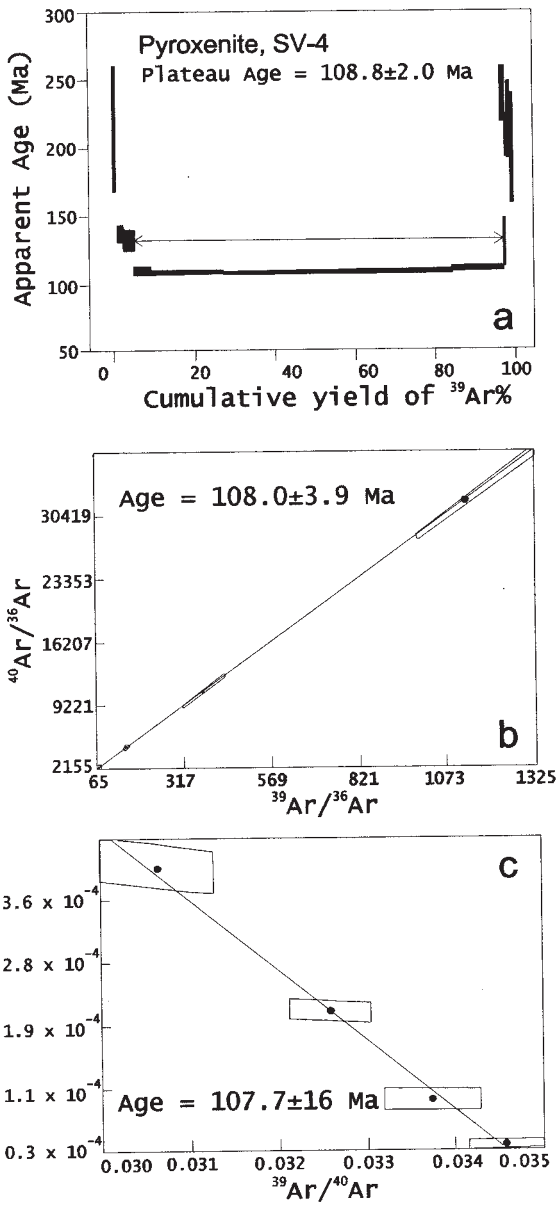

Figure 3. (**a**) Step heating ^{40}Ar-^{39}Ar apparent age spectrum from SV-4 (pyroxenite). the age shown is the plateau age, which includes 2σ error on **J** but the vertical width of individual plateau boxes indicate 2σ errors calculated without error on **J**. (**b**) and (**c**) are isotope correlation diagrams ($^{40}Ar/^{36}Ar$ vs. $^{39}Ar/^{36}Ar$, and $^{36}Ar/^{40}Ar$ vs. $^{39}Ar/^{40}Ar$, respectively) for SV-4 showing 2σ error envelopes and isochrons.

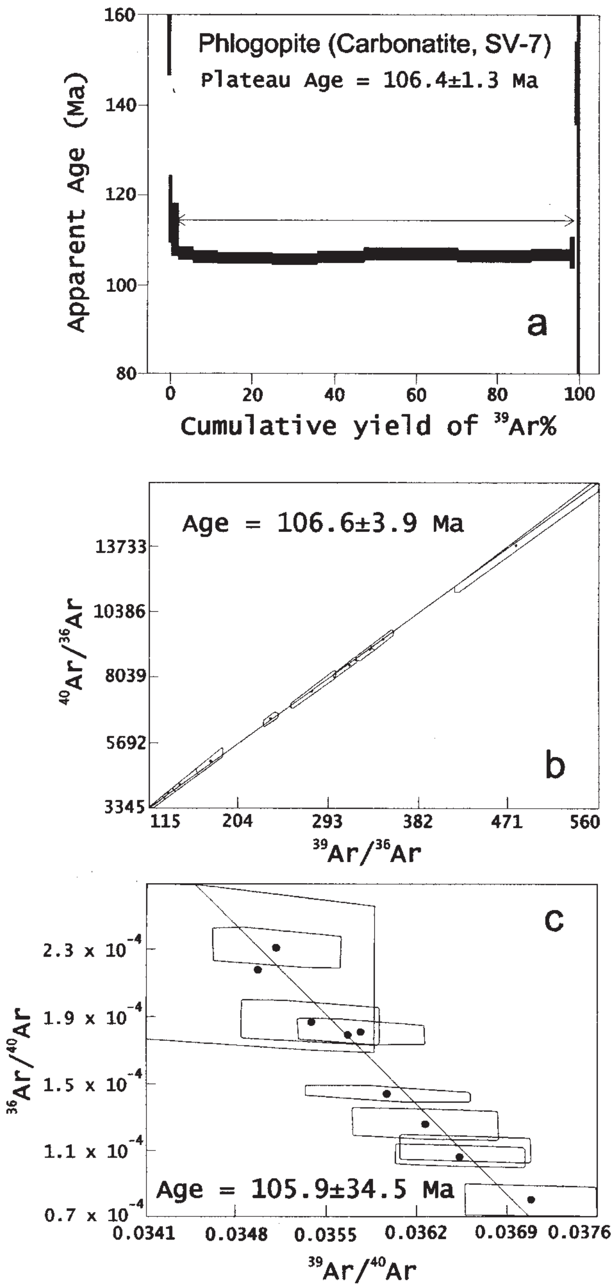

Figure 4. Step heating ^{40}Ar-^{39}Ar apparent age spectrum from SV-7 (phlogopite separate from a carbonatite) (**a**), and isotope correlation diagrams (**b & c**) similar to that in figure 3.

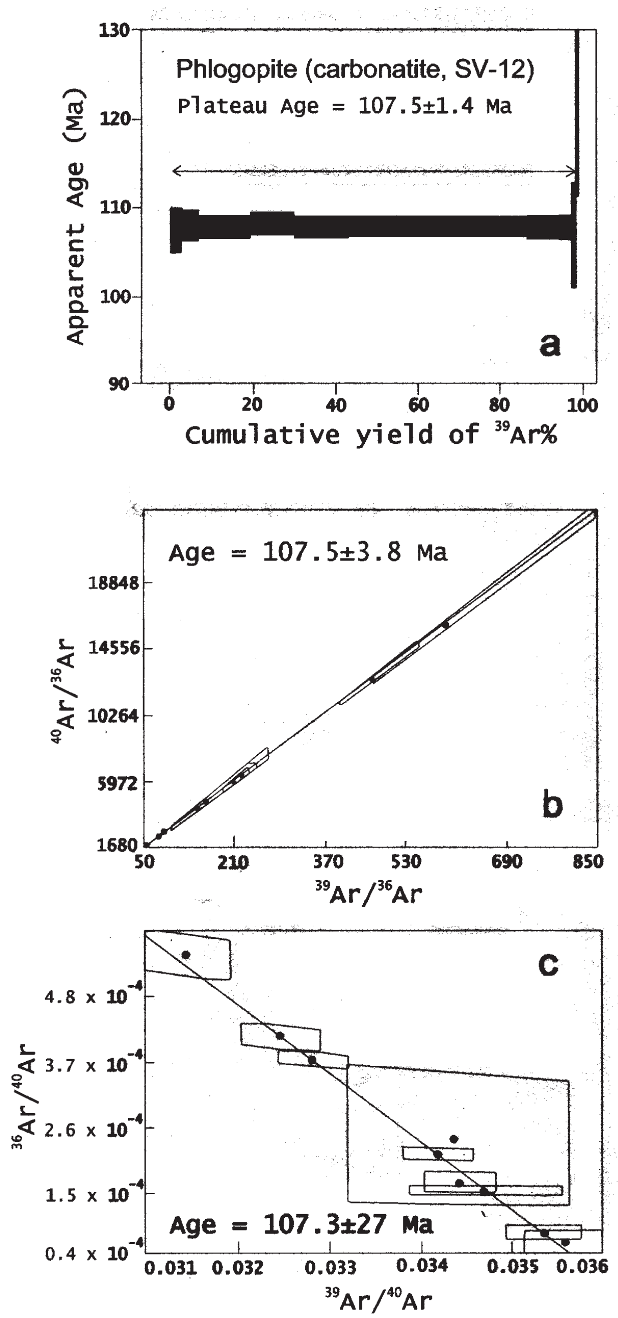

Figure 5. Step heating ^{40}Ar-^{39}Ar apparent age spectrum from SV-12 (phlogopite separate from a carbonatite) **(a)**, and isotope correlation diagrams **(b & c)** similar to that in figures 3 and 4.

derated APSARA reactor at the Bhabha Atomic Research Center, Mumbai, for ~ 100 hours. Interference corrections were based on analysis of pure CaF_2 and K_2SO_4 salts irradiated with the samples. The values for $^{36}Ar/^{37}Ar$, $^{39}Ar/^{37}Ar$, and $^{40}Ar/^{39}Ar$ ratios in these salts are: 0.0003112, 0.0006827, and 0.079, respectively. The details of the analytical procedure are given in Pande *et al* (1988) and Venkatesan *et al* (1993). From each sample, argon gas was extracted in a series of 15 or more steps of increasing temperature up to 1400°C in an electrically heated ultra-high vacuum furnace. Isotopic ratios of the argon gas released in each step, and purified in two stages were measured in an AEI MS10 mass spectrometer operated in static mode. We define a plateau as comprising four or more contiguous steps with apparent ages that agree within their error (2σ). $^{40}Ar/^{36}Ar$ – $^{39}Ar/^{36}Ar$ and $^{36}Ar/^{40}Ar$ – $^{39}Ar/^{40}Ar$ isochron plots were based on the two-error regression procedure of York (1969).

4. Results and discussion

The results of ^{40}Ar-^{39}Ar analysis of Sung Valley samples are presented in table 1, and their apparent age spectra along with isotope correlation diagrams are shown in figure 3 – 5. Table 1 contains a summary of all three plateaus, isochron and inverse isochron ages of plateau steps, trapped argon isotopic ratios, and integrated (total) ages. All the plateau ages are indistinguishable from each other and in excellent agreement with corresponding isochron ages (table 1). The initial $^{40}Ar/^{36}Ar$ ratios agree with the atmospheric argon ratio of 295.5 within error. Therefore, the plateau ages represent the near surface crystallization (or emplacement) ages of these rocks. The plateau age of 108.8 ± 2.0 Ma for the pyroxenite (figure 3a) and 106.4 ± 1.3 Ma (figure 4a) and 107.5 ± 1.4 Ma (figure 5a) for the phlogopites are the same within the experimental error. This supports the earlier suggestion that pyroxenites and carbonatites of Sung Valley are co-genetic (Viladkar *et al* 1994; Sen 1999; Ray *et al* 2000). The weighted mean of all plateau ages, 107.2 ± 0.8 Ma therefore, corresponds to the time of emplacement of the Sung Valley complex.

The 107.2 ± 0.8 Ma age of the Sung Valley complex is much younger than the K-Ar and Pb-Pb dates reported earlier but is identical to, and more precise than the Rb-Sr isochron age of 106 ± 11 Ma (Ray *et al* 2000) . Also, this age is indistinguishable from the K-Ar age of the Swangkre complex and overlaps with that of the Samchampi within error, which support the hypothesis that all these alkaline complexes of the AMP are coeval. Moreover, it is distinctly younger than the ~ 117 Ma ^{40}Ar-^{39}Ar age for the Rajmahal traps (Baksi 1995). This clearly suggests that the emplacement of the carbonatite-alkaline complexes of the RBS province postdates the main flood basalt event by ~ 10 Ma and probably marks the end of the Kerguelen-Rajmahal plume activity in the Indian subcontinent.

5. Conclusions

We have determined a precise ^{40}Ar-^{39}Ar age of 107.2 ± 0.8 Ma for the Sung Valley carbonatite-alkaline complex of the Assam-Meghalaya Plateau. This age is indistinguishable from the Rb-Sr isochron age of 106 ± 11 Ma for this complex. The contemporaneity of the Sung Valley complex with two other complexes (Samchampi and Swangkre) of the Rajmahal-Bengal-Sylhet province suggests that a major alkaline activity took place ~ 107 Ma ago, 10 Ma after the main flood basalt event that probably marked the end of the Kerguelen plume activity in the Indian subcontinent.

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