SHRIMP U-Pb dating of Perovskites from southern Indian kimberlites

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In the Eastern Dharwar Craton of southern India, kimberlites occur in two main areas, the Wajrakarur kimberlite field (WKF) in the Anantapur district and the Naryanpet kimberlite field (NKF) in the Mahbubnagar district of Andhra Pradesh (Fig. 1). Lamproites occur within and near the northern and north eastern margins of the Cuddapah Basin.

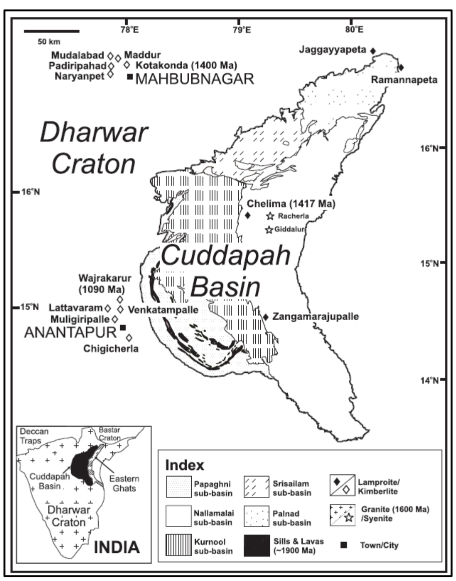

Fig. 1: Locations of kimberlites and lamproites in southern India (from Chalapathi Rao et al., 2004)

All the so far dated kimberlites and lamproites from this region are Proterozoic in age. However, there is a current debate about whether all southern Indian kimberlites are contemporaneous or non-contemporaneous the resolution of which is imperative for any geodynamic inferences for this region.

The Rb-Sr isotopic analysis of groundmass phlogopites from several NKF and WKF kimberlites have yielded ages around 1090 Ma (Kumar et al., 1993, 2001, 2007). This dataset has been used to argue for a contemporaneous emplacement for all the kimberlites in the Eastern Dharwar Craton around 1.1 Ga (e.g., Kumar et al., 2007). Further speculation has been made regarding a period of ultrapotassic, alkaline and mafic magmatism on a greater scale across India when two other lamproite bodies (Majhgawan (1067 ± 31 Ma) and Hinota (1170 ± 46 Ma)), located 1000 km to the north of the WKF are considered. Kumar et al. (2007) also suggested that the 1.1 Ga potassic-ultrapotassic and alkaline mafic-magmatism in India was a part of a global geodynamic event as kimberlites and lamproites of similar ages are recognized worldwide in countries such as Australia, Greenland, Liberia, North America, Scandinavia and South Africa.

Chalapathi Rao et al. (2004) dispute these proposals; they dated some kimberlites from the NKF and WKF and lamproites from the Cuddapah basin and at its NE margin (Krishna lamproites) using K-Ar (Chalapathi Rao et al., 1996) and Ar-Ar techniques on phlogopites (Chalapathi Rao et al., 1999). They obtained ages of variable precision (± 10-50 Ma) for Pipe-5 (Muligiripalle) kimberlite (1150 Ma) from WKF, 1400 Ma for kimberlite (Kotakonda) from NKF and 1380 Ma for lamproites from Chelima and Krishna lamproites (Ramannapeta). Chalapathi Rao et al. (1996, 1999) therefore argued for at least two episodes of kimberlite and lamproite emplacement in southern India at ~1400 Ma and ~1090 Ma. These authors further suggest that the WKF along with the Majhgawan and Hinota lamproites appear to constitute a younger kimberlite/lamproite episode around ~1090 Ma to ~1150 Ma. The Chelima and Ramannapeta lamproites along with the Kotakonda kimberlite and possibly the rest of the NKF appear to be from a distinctly older episode at ~1380-1400 Ma. Kumar et al. (2001) also obtained ages of 1350 Ma for Chelima lamproite, 1225 Ma for Ramannapeta lamproite and 1090 Ma for Zangamarajupalle lamproite. This would seem to clearly establish that the kimberlite and lamproite emplacement in Indian sub-continent is non-contemporaneous supporting the view of Chalapathi Rao et al., (1996). However, Kumar et al. (2001) argued that the apparently older Ar-Ar and K-Ar ages for NKF samples may be due to excess argon within the phlogopite structure that can result in anomalously old but similar step ages. Kumar et al. (2001) add that their Rb-Sr ages determined for Chelima and Zangamarajupalle are only tentative as they may be an artifact resulting from extensive secondary carbonation, and although the Ramannapeta lamproite age is reliable, they believe that it is part of an extensive alkaline magmatism to the east of the Cuddapah Basin. Thus, the debate on whether the southern Indian kimberlites are contemporaneous (Kumar et al., 1993) or non contemporaneous (Chalapathi Rao et al., 1996) remains unresolved.

To address the apparent discordance between different isotopic systems that have been applied to infer emplacement ages for southern Indian kimberlites, we have initiated a project to perform *in-situ* U-Pb dating of perovskites from a number of southern Indian kimberlites using the SHRIMP (sensitive high resolution ion microprobe) technique.

Perovskite ($CaTiO_3$) is an abundant mineral in many kimberlites and as it contains high uranium concentrations, is suitable for U-Pb dating (Smith, 1989). The groundmass perovskite crystallizes directly from the kimberlitic magma and therefore perovskite U-Pb ages are believed to represent the time at which the mineral crystallised within the kimberlitic magma (Heaman, 1989), and in turn dates the kimberlite emplacement age.

In earlier U-Pb analysis of perovskite, difficulties arose in the separation and purification of very fine-grained perovskite for isotope dilution measurements from the other kimberlite matrix minerals (Smith et al., 1989). This was carried out using a combination of chemical and magnetic separation methods (Smith et al., 1989). However, technological advances now allow single inclusion dating of either sulphides or phases suitable for U-Pb geochronology (Kinny et al., 1994).
An analytical protocol was developed using the SHRIMP technique to date meteoritic perovskite directly in polished thin sections (Ireland et al., 1990). This technique has been subsequently adapted and used to date kimberlites and related rocks (Kinny et al., 1997), where all but the smallest perovskite grains can be targeted by SHRIMP, which has a typical analysis area of 20 μm.

The SHRIMP technique has the added advantage of allowing *in situ* analysis of very small areas or amounts of samples without the need for chemical preparation, thus minimizing the possibility of contamination (Kinny et al., 1997). The SHRIMP is also minimally destructive of samples compared with other techniques and therefore analysed grains are available for further trace element and isotopic studies (Hamilton et al., 2003).

Analytical protocols for *in situ* perovskite U-Pb age determinations have recently been developed for the SHRIMP II ion microprobe at the Hiroshima University, Japan. Instrumental Pb/U fractionations are corrected by empirical reference to a well-characterized, precisely-dated perovskite standard (Tazheran perovskite, 463 Ma by TIMS) analyzed in parallel with the perovskites in Indian samples.

The NK-3 (Mudalbid) kimberlite and Kotakonda kimberlite in the Narayanpet kimberlite field are dated by Rb-Sr technique at ~1090 Ma (Kumar et al., 2001) The Maddur kimberlite located in NKF was the first sample analysed using SHRIMP for its U-Pb age. The Maddur kimberlite consists of several pipes and the pipe being dated is known as MK1. Using the two-stage model of Stacey and Kramer (1975), the common Pb corrected data for Maddur perovskites suggest a $^{206}Pb/^{238}U$ age of 1156 ± 32 Ma (2 σ). This age is in agreement with the previously reported Rb-Sr age for this kimberlite (Kumar et al., 2001). This therefore supports the case for a contemporaneous emplacement for at least some Southern Indian kimberlites but is far from conclusive until ages of more of the kimberlites in the area have been determined by employing similar techniques.

We are now in the process of obtaining U-Pb ages on perovskites from Kotakonda kimberlite, KK1 (Fig. 2). This kimberlite has already been dated by three different isotopic techniques. Chalapathi Rao et al. (1996) dated it at 1363 ± 48 Ma using K-Ar, Chalapathi Rao et al. (1999) dated it at 1401 ± 4.6 Ma using Ar-Ar and Kumar et al. (2001) dated it at 1085 ± 14 Ma using Rb-Sr.

Fig. 2: Kotakonda kimberlite (KK1).

It is anticipated that the U-Pb age for Kotakonda kimberlite would help resolve some of the issues related to the emplacement ages of southern Indian kimberlites.

In addition to the U-Pb dating of perovskites, we are also undertaking high precision Ar-Ar dating of phlogopites using state-of-the-art laser-probe technique pioneered at the Open University, UK (e.g., Kelley 2002). These studies will provide further age constraints on previously known as well as recently discovered kimberlite and lamproite fields from southern India.

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