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U-PB GEOCHRONOLOGY OF PEROVSKITE AND ZIRCON FROM THE CHIGICHERLA KIMBERLITES, ANANTAPUR DISTRICT, INDIA

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INTRODUCTION AND CONTEXT

During 2001, BHP Billiton conducted exploration-level reconnaissance surveys of four known kimberlites near Chigicherla, Anantapur district, Andra Pradesh. The work program included conventional indicator mineral sampling of soils and local streams, mapping of kimberlite outcrop and subcrop, orientation-style geophysical surveys, core drilling, and sampling of kimberlites for characterization in terms of petrography, indicator mineral compositions and microdiamond content. Outcrop and subcrop for the four Chigicherla kimberlites (CC1, CC2, CC4 and CC5) ranges between 0.4 to 2.3 ha in surface area, and microdiamond sample results (Table 1) are consistent with low diamond grades reported earlier by the Geological Survey of India. Garnet compositions indicate entrainment of substantial Ca-poor depleted cratonic lithosphere

Table 1: Microdiamond counts from Chigicherla (by square- mesh sieve size, in µm)

Source	Weight(kg)	100+	150+	212+	300+	425+	600+
CC1	90.6	15	13	22	7	5	1
CC2	77.6	22	28	14	9	5	1
CC4	67.4	72	41	17	5	0	0
CC5	80.1	80	28	13	2	2	0
	Ave/10 kg	6.0	3.5	2.1	0.7	0.4	0.1
CC1 Lag	8.4	165	102	17	0	0	0
CC2 Lag	9.9	103	87	8	0	0	0
CC4 Lag	11.3	132	59	7	0	0	0
CC5 Lag	1.9	10	4	0	0	0	0
	Ave/10 kg	130	80.2	10.2	0	0	0

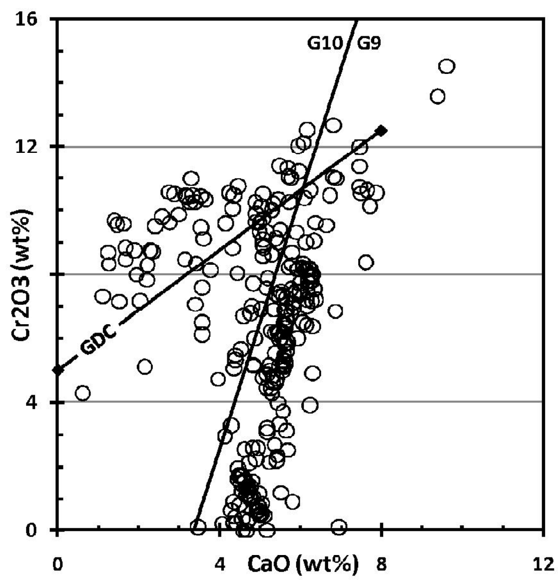

Fig. 1: Cr-Ca compositions of 129 garnet xenocrysts from Chigicherla CC4 and CC5. The data support entrainment of Ca-poor, probably Archean, cratonic lithosphere to depths of 53 kbar minimum (using the P41 barometry model of Grütter et al., 2006)

(Fig. 1), likely of Archean age. Nimis-Taylor (2000) thermobarometry using clinopyroxene xenocrysts from CC1, CC2 and CC4 outlines a ~ 41 mW/m2 model-conductive geotherm similar to that obtained for garnet lherzolite xenoliths from the nearby Wajrakurur kimberlites (63 km away), and also overlapping a reference 41 mW/m2 clinopyroxene geotherm for garnet lherzolite xenoliths from the Kirkland Lake kimberlites in Canada (see Grütter 2009).

A diamond exploration joint venture over some 55,000 km2 of Indian tenements was formed with Dwyka Diamonds during November 2002, and exploration activities naturally focused in areas outside of the Chigicherla kimberlite cluster. However, academic research continued on perovskite and zircon from samples collected at Chigicherla, and that work is reported and discussed below.

EXTENDED ABSTRACT

PEROVSKITE U-PB GEOCHRONOLOGY

Sample Selection and Analysis

The Chigicherla kimberlite outcrops are substantially calcretized in places, but partially altered to comparatively fresh hypabyssal kimberlite float with pseudomorphed olivine macrocrysts is readily available. Petrographic examination confirmed such samples as Group-1 type kimberlite with opaque- and perovskite-rich, phlogopite±monticellite- carbonate-serpentine groundmass mineralogy. Groundmass perovskite is common and fresh to slightly altered in these kimberlites (Fig. 2) and 100% pure hand-picked perovskite separates were prepared and analysed using standard U-Pb ID- TIMS procedures at the University of Alberta (Heaman and Kjarsgaard, 2000).

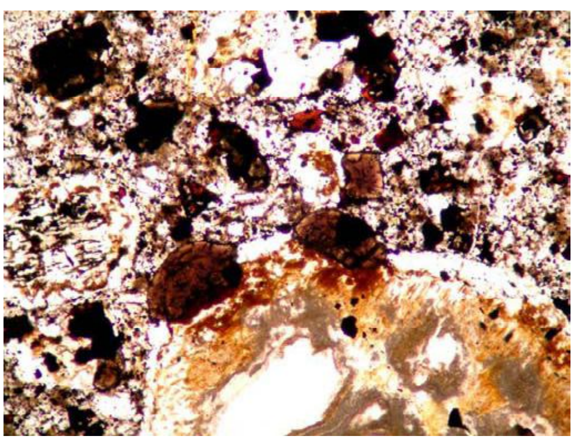

Fig. 2: Transmitted-light photomicrograph of CC4 illustrating preservation of coarse brown perovskite in an opaque-rich altered serpentine-carbonate groundmass. Note yellow-brown alteration superposed on olivine pseudomorph. Field of view is 0.7 mm.

Results and emplacement ages

Weighted average 206Pb/238U age results for perovskite from three Chigicherla kimberlites indicate there are at least two distinct Mesoproterozoic emplacement events: 1) 1131.2±2.0 Ma (CC2) and 2) 1101.2 ± 3.3 Ma (CC4) to 1102.5 ± 2.1 Ma (CC5). A grab sample from Wajrakurur Pipe-2 produced a 206Pb/ 238U perovskite date of 1128.5±2.6 Ma, overlapping within error the 1124+5-3 Ma perovskite date previously reported for this kimberlite (Kumar et al., 2007). All age uncertainties are reported at the 95% confidence level. The older emplacement age obtained for CC2 clearly overlaps age- dates for Wajrakurur Pipe-2, indicating that this period of kimberlite emplacement occurs in at least two distinct clusters separated by approximately 65 km.

ZIRCON U-PB GEOCHRONOLOGY AND HF ISOTOPY

Sample Selection and Analysis

Microdiamond samples collected from oxide-rich surficial lags overlying the Chigicherla kimberlites produced a very marked enrichment of < 212 µm diamonds when compared to samples taken from the kimberlites (Table 1). Since fine- fraction zircon grains could be similarly enriched, the caustic- fusion residues of kimberlite and surficial lag samples were examined for non-metamict zircon grains. A total of 336 zircon grains were submitted for U-Th-Pb isotopic analysis by laser-ablation-SF-ICP-MS at the Goethe University Frankfurt using a 23µm spot size. A representative set of 138 grains, which yielded concordant U-Pb analyses, were selected for LA-MC-ICP-MS Hf isotope analyses using spot sized of 33 and 40 µm, respectively.

Analytical protocols and standardization procedures are given in Gerdes & Zeh (2006, 2009).

Results and interpretation

Seventy-nine of 165 zircon grains from surficial lag samples yielded results that are > 90% concordant (i.e. ratio 206Pb/238U age / 207Pb/206Pb age > 0.9) and define a major age peak at 2.57 Ga (69 grains) with some minor peaks at 2.62, 2.7, 2.8, and 3.2 Ga. The remaining moderately to strongly discordant data for 86 grains indicate Pb-loss during Neoproterozoic (0.5-0.7 Ga) metamorphic events. Zircon recovered from caustic fusion residues of kimberlite samples yielded generally more concordant data (127 of 171 grains) with well defined age maxima at 2.57 Ga (52 grains), at 2.83 Ga (5 grains), between 2.71-2.62 Ga (22 grains), between 1.96-1.82 Ga (20 grains) and at 1.1 Ga (13 grains). In addition some apparently concordant ages fall at age ranges 3.3-3.1 Ga (3 grains), 2.45-2.0 Ga (9 grains) and 1.3-1.5 Ga (3 grains).

The 3.3-2.57 Ga U-Pb ages we obtained are broadly consistent with the known range of Archean crustal ages for the East Dharwar craton, and specifically reflect regionally significant 2.7-2.5 Ga ages related to the multi-phase Dharwar granitoid batholith and intervening schist belts (e.g. Balakrishnan et al.,1999; Chadwick et al., 2000). Zircon recovered directly from kimberlite samples additionally record numerous Proterozoic events that likely reflect deep crustal magmatic and/or thermal events not readily apparent in exposed crustal rock types. Our age-dating work shows that zircon grains derived from caustic fusion residues of kimberlite samples represent an untapped resource that may be used to constrain both the readily apparent upper crustal and the more cryptic lower crustal evolution of Archean cratons (see also Moser and Heaman, 1997).

EXTENDED ABSTRACT

ZIRCON HF ISOTOPIC ANALYSES

The ~2.57 Ga old zircons from surficial lag samples are characterized by εHf of 3.5±1.9 (±2SD; n=32), which is indistinguishable from the ~2.57 Ga zircon recovered from kimberlite samples (εHf of 3.0±1.7; n=28). The slightly older 2.6-2.7 Ga zircon grains from both surficial lag and kimberlite samples yield overlapping and somewhat more positive εHf of 5.2±1.1 (n=13) and 5.4±2.0 (n=15), respectively. The positive åHf of these Neoarchean zircons (2.5-2.7 Ga) imply that they crystallized from magmas that formed directly by melting of the depleted mantle or by melting of young, juvenile island arc crust. Together with 2.1, 1.96-1.85, 1.5, 1.3 and 1.1 Ga old zircons, the ~ 2.57 Ga zircons define a crustal evolution trend with depleted mantle model (TDM) ages of 2.7-2.5 Ga and 176Lu/177Hf of 0.011 (Fig. 3). In contrast, all 2.8 to 3.25 Ga and some younger 2.7, 2.3 and 1.1 Ga zircon grains define a second crustal evolution trend with more negative åHf values and older TDM ages

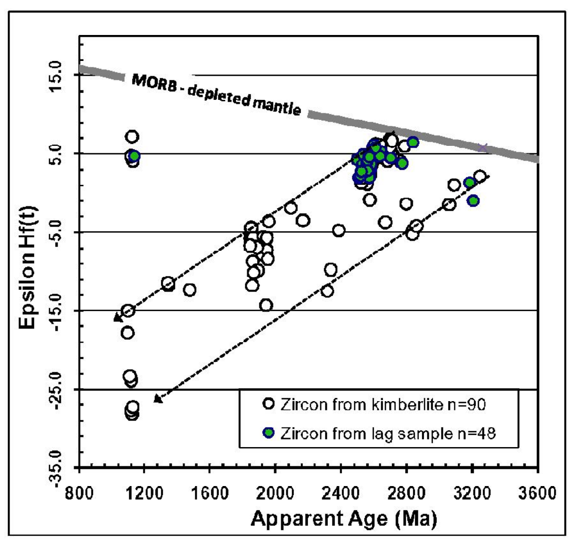

Fig. 3: εHf evolution diagram showing results of single-zircon LA-MC-ICP-MS analyses for pre-selected grains with concordant U-Pb ages. Stippled arrows denote loosely interpreted bounds for the evolution of Archean crust from the Anantapur district (see text).

of 3.3-3.1 Ga. The second trend has a 176Lu/177Hf slope of 0.011, identical to that of the first trend (Fig. 3). Various zircon grains yield åHf that fall between these two evolution trends, suggesting that they derived from reworking or mixing material from both sources. Our zircon Hf isotopic data is consistent with the idea that the crust of the Anantapur district was formed during two major events at 3.3-3.1 and 2.7-2.5 Ga, and was subsequently recycled during Palaeproterozoic to Mesoproterozoic events.

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