

Petrography and geochronology of the Nxau Nxau kimberlites, north-west Botswana

Henrietta Farr¹, David Phillips¹ and Mike de Wit^{2, 3}

¹ KiDs (Kimberlites and Diamonds), School of Earth Sciences, The University of Melbourne, Parkville, 3010, Victoria, Australia

² Tsodilo Resources Ltd, Toronto, Ontario, Canada

³ Delrand Resources Pty Ltd., Toronto, Ontario, Canada

Introduction

The Nxau Nxau kimberlite cluster is part of the Xaudum province on the south-eastern margin of the Congo craton, which straddles the border between Namibia and Botswana. This kimberlite province is geographically isolated from other known kimberlites and occurs in an area previously thought to be part of the Damara mobile belt. The kimberlites were emplaced within the outer limits of the Okavango Mafic Dyke Swarm which was emplaced as part of the early Jurassic Karoo magmatism, although some dykes are Proterozoic in age (Jourdan et al. 2004). Nineteen kimberlites were discovered in 1997 with another 9 discovered in 2005-06 by Tsodilo Resources. Exploration interest in this area gathered momentum after ~20% of garnets analysed by Rio Tinto Namibia Pty Ltd. from 1994 to 1996 exhibited subcalcic G10 compositions (Hoal et al. 2000).

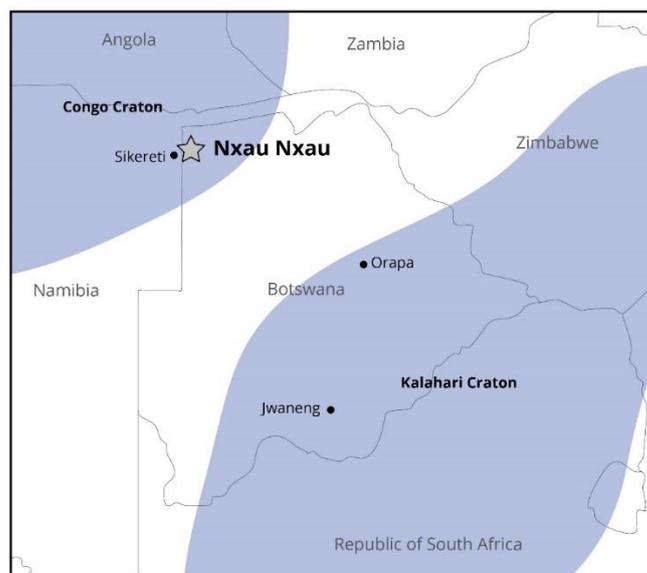


Figure 1: Map showing the location of the Nxau Nxau kimberlite field in relation to the Congo and Kalahari Cratons. The locations of the Sikereti, Orapa and Jwaneng kimberlites are also shown.

Petrography

A variety of volcanoclastic and hypabyssal units were observed in the Nxau Nxau samples. Samples from kimberlites in close proximity to the dykes are predominantly volcanoclastic and contain a higher proportion of crustal xenoliths. The hypabyssal samples can be broadly described as coherent macrocrystic olivine, calcite kimberlites, with serpentinised and calcitised olivine typically up to 1mm in size. Titanomagnetite and perovskite (<100µm) are the dominant groundmass phases with apatite and phlogopite being less common. Phlogopite is most abundant in sample B8/1 but generally uncommon. Later veins of kimberlite cross-cut some of the hypabyssal samples with an earlier generation of kimberlite present in one drillhole (2164A1).

As evident from cross-cutting relationships and xenoliths present within the kimberlites, the kimberlites intruded rocks of the Karoo Supergroup (late Carboniferous – early Jurassic) (Smith 1984), the Damara Supergroup (late Precambrian) and basement granites and gneisses that have been dated at 2.9-2.5Ga (Batumike et al. 2009). Karoo dolerite and Nosib quartzite are the dominant crustal xenoliths present with lesser amphibolite occurrences.

Geochemistry & Geochronology

Five samples from four bodies containing sufficient fresh perovskite were analysed for strontium isotopes using *in situ* LA-ICPMS methods. Four of the samples analysed define a narrow $^{87}\text{Sr}/^{86}\text{Sr}_i$ range around 0.7036. The most altered sample (C15/3) gave a significantly higher $^{87}\text{Sr}/^{86}\text{Sr}_i$ value of 0.7042. These results are consistent with values characteristic of archetypal (Group I) kimberlites (Woodhead et al. 2009). A sixth sample (2164A1) contained extensively altered perovskite which was unable to be analysed.

The same five samples were dated using *in-situ* U-Pb LA-ICPMS methods, giving a weighted average age of 84 ± 4 Ma. Phlogopite from one kimberlite was also analysed by $^{40}\text{Ar}/^{39}\text{Ar}$ and Rb-Sr dating yielding an $^{40}\text{Ar}/^{39}\text{Ar}$ inverse isochron age of 86.5 ± 8.6 Ma (Fig. 2) and a two-point Rb-Sr age of 87.1 ± 3.1 Ma. All ages are within error of one another.

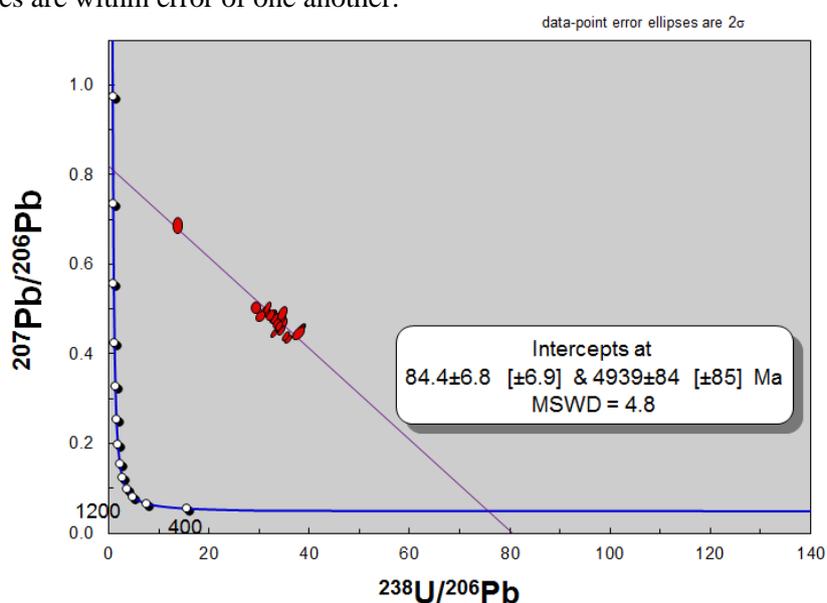


Figure 2: Tera-Wasserburg concordia diagram for sample 21181A4, ellipses show 2σ

Table 1: Summary of kimberlites ages. U-Pb perovskite ages have been corrected for common lead using the measured abundances of $^{207}\text{Pb}/^{206}\text{Pb}$ and $^{238}\text{U}/^{206}\text{Pb}$ (Tera and Wasserburg 1972). Several other methods of constraining common lead were tested with some giving higher precision; however, the TW intercept proved the most consistent and was deemed the most accurate.

Sample	Age (Ma)	Method	Analysis
21181A4	84.4 ± 7	U-Pb perovskite	LA-ICP-MS 23 spots
A36/3	84.0 ± 9	U-Pb perovskite	LA-ICP-MS 24 spots
B8/1	82.5 ± 1	$^{40}\text{Ar}/^{39}\text{Ar}$ phlogopite	Total gas (3 steps) from single grain
	86.5 ± 9	$^{40}\text{Ar}/^{39}\text{Ar}$ phlogopite	Inverse isochron (3 steps) from single grain
	87.1 ± 3	Rb-Sr phlogopite	Two leached fractions
C15/3	79.0 ± 6	U-Pb perovskite	LA-ICP-MS 20 spots
1821C16/3	82.2 ± 8	U-Pb perovskite	LA-ICP-MS 26 spots

Discussion

All three dating techniques applied are in agreement that the Nxau Nxau kimberlite field was emplaced at ~84 Ma. In this study it is considered that U-Pb perovskite dating gives the most robust and precise results due to extraneous argon and argon loss affecting phlogopite analyses. Therefore, the weighted average of the U-Pb ages (84 ± 4 Ma) is proposed as the best estimate for the time of emplacement of the Nxau Nxau kimberlites. These kimberlites represent the first known expression of Cretaceous alkaline magmatism in this area and join a large number of other kimberlites emplaced during the Cretaceous from ~70-90 Ma. The emplacement of kimberlites in the Cretaceous is considered to be related to the break-up of Gondwana and relevant tectonic stresses. In the case of these kimberlites, a significant reorganisation of global tectonic stresses with the cessation of intra-continental movements within Africa at 84 Ma (Chron 34) may have been a trigger for kimberlite magmatism (Nürnberg and Müller 1991).

The cross-cutting kimberlite (seen in sample 2164A1) was unable to be dated, however, the pervasive alteration suggests that it is significantly older than 84 Ma. Perovskite in this kimberlite is petrographically similar to that of kimberlites in the Kuruman Province, South Africa. From this it is suggested that the older Nxau Nxau kimberlite may fall within the 1000-1200Ma or 1600-1800Ma periods of alkaline magmatism.

References

- Batumike JM, Griffin WL, O'Reilly SY, Belousova EA, Pawlitschek M (2009) Crustal evolution in the central Congo-Kasai Craton, Luebo, D.R. Congo: Insights from zircon U-Pb ages, Hf-isotope and trace-element data *Precambrian Research* 170:107-115 doi:<http://dx.doi.org/10.1016/j.precamres.2008.12.001>
- Hoal K, Hoal B, Griffin W, Armstrong R (2000) Characterization of the age and nature of the lithosphere in the Tsumkwe region, Namibia *Communications of the geological survey of Namibia* 12:21-28
- Jourdan F et al. (2004) The Karoo triple junction questioned: evidence from Jurassic and Proterozoic $^{40}\text{Ar}/^{39}\text{Ar}$ ages and geochemistry of the giant Okavango dyke swarm (Botswana) *Earth and Planetary Science Letters* 222:989-1006 doi:<http://dx.doi.org/10.1016/j.epsl.2004.03.017>
- Nürnberg D, Müller RD (1991) The tectonic evolution of the South Atlantic from Late Jurassic to present *Tectonophysics* 191:27-53
- Smith RA (1984) The lithostratigraphy of the Karoo Supergroup in Botswana. Geological Survey Department with the authority of Ministry of Mineral Resources and Water Affairs, Republic of Botswana,
- Tera F, Wasserburg G (1972) U-Th-Pb systematics in three Apollo 14 basalts and the problem of initial Pb in lunar rocks *Earth and Planetary Science Letters* 14:281-304
- Woodhead J, Hergt J, Phillips D, Paton C (2009) African kimberlites revisited: In situ Sr-isotope analysis of groundmass perovskite *Lithos* 112S:311-317