

# O- and H-isotope study of the Cretaceous Koegel Fontein Complex

Catherine Curtis<sup>1</sup>, Chris Harris<sup>1</sup>, Coenraad de Beer<sup>2</sup>, David Reid<sup>1</sup>, Robert B. Trumbull<sup>3</sup>,  
Rolf L. Romer<sup>3</sup>

1. Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

2. Council for Geoscience, Bellville, South Africa

3. GFZ German Research Centre for Geosciences, Telegrafenberg, Potsdam, Germany

## ABSTRACT

Koegel Fontein is a 30 km diameter anorogenic igneous complex that intruded Namaqualand gneisses during the initial phase of break-up of Africa and South America. It is notable for the presence of quartz porphyry dykes that formed from low- $\delta^{18}\text{O}$  magmas. Many of the igneous rocks show petrographic evidence for alteration and have had their  $\delta^{18}\text{O}$  values lowered by fluid-rock interaction at high temperatures. Partial melting and/or assimilation of this material produced the low- $\delta^{18}\text{O}$  magmas. Whole-rock  $\delta\text{D}$  and  $\delta^{18}\text{O}$  values indicate equilibrium with meteoritic water with a  $\delta^{18}\text{O}$  value around -10 ‰, which is abnormally negative given the relatively low latitude at the time of intrusion. A combination of an elevated volcanic edifice and the 'continental effect' is the most likely explanation.

**Key words:** Koegel Fontein; low- $\delta^{18}\text{O}$  magma; fluid-rock interaction

## INTRODUCTION

Koegel Fontein is the only known early Cretaceous intrusive igneous complex on the west coast of South Africa, although dolerite dykes of this age are described (Reid et al., 1991). The complex is situated 240 km south of the Orange River. It intrudes Namaqua metasedimentary rocks and gneisses. Published ages for the complex are between 135 and 145 Ma (Verwoerd and de Beer et al., 2006) suggest that the complex formed during the initial rifting phase of the breakup of Africa and South America.

The complex is 30 km in diameter. It is comprised of multiple intrusions consisting mainly of granite with subordinate syenite, quartz-feldspar porphyry, and a variety of felsic and mafic dykes. The rocks generally show extensive petrographic evidence for alteration, such as turbid alteration in feldspar.

## METHOD AND RESULTS

We have determined the  $\delta^{18}\text{O}$  values of minerals from a variety of Koegel Fontein samples. These comprise feldspar with varying degrees of alteration, quartz and amphibole. Quartz is a mineral which is resistant to interaction with external fluids and retains its original magmatic  $\delta^{18}\text{O}$  value. Where quartz phenocrysts were

separated, these had the typical 'high quartz' form, and all quartz was cleaned with warm 10% HF to remove adhered feldspar and secondary minerals. The most notable feature is the extremely low  $\delta^{18}\text{O}$  values for many of the quartz and feldspar separates, with quartz phenocrysts having  $\delta^{18}\text{O}$  values as low as 1.63‰, and non-phenocryst quartz from plutonic rocks having  $\delta^{18}\text{O}$  values as low as 0.50‰. The expected  $\delta^{18}\text{O}$  of quartz which crystallized from a mantle-derived magma that differentiated in a closed system would be about 7.5‰. Samples can be divided into two types groups on the basis of mineral  $\delta^{18}\text{O}$  values. The first group has  $\Delta\text{quartz-feldspar} \sim 1\%$ , indicating magmatic equilibrium for O-isotopes. The second group has  $\Delta\text{quartz-feldspar} > 2\%$ , indicating high-temperature interaction with fluids that lowered the  $\delta^{18}\text{O}$  value of feldspar.

The range of whole-rock  $\delta^{18}\text{O}$  and  $\delta\text{D}$  values, and the water content of the rocks are shown on Figure 1. All rocks analysed have a similar range of  $\delta\text{D}$  values, whereas the dykes have significantly lower  $\delta^{18}\text{O}$  values compared to the granite and syenite plutons (Fig. 1a). The country rock shows a range of  $\delta^{18}\text{O}$  values. There is no correlation between  $\delta\text{D}$  and water content (Fig. 1b).

**DISCUSSION**

At Koegel Fontein there are, therefore, both rocks that achieved low- $\delta^{18}\text{O}$  values due to interaction with fluids, and rocks that crystallized from low- $\delta^{18}\text{O}$  magmas. Low- $\delta^{18}\text{O}$  magmas are rare and usually form in extensional tectonic environments, where deep circulation of fluid was permitted via extension related faults. The most likely mechanism for formation of the low- $\delta^{18}\text{O}$  magmas at Koegel Fontein is by partial melting of hydrothermally altered igneous material that interacted with water at high temperatures. Whole-rocks and magmatic minerals have consistently low  $\delta\text{D}$  values (mean  $-99\text{‰}$ ,  $n = 66$ ,  $\pm 13\text{‰}$   $1\sigma$ ), which indicate equilibration with meteoric rather than sea water (Fig. 1a). This is confirmed by the presence of quartz veins associated with complex having  $\delta^{18}\text{O}$  values as low as  $-1.73\text{‰}$ . Taking the average whole-rock  $\delta\text{D}$  value of  $-99\text{‰}$ , and assuming  $\Delta\text{rock-water} = -30\text{‰}$ , the average  $\delta\text{D}$  of the hydrothermal fluid was  $-69\text{‰}$ . If the fluid is of meteoric origin, the average  $\delta^{18}\text{O}$  value of the unmodified fluid was around  $-10\text{‰}$  (Fig. 1a). Such negative values for meteoric water are unexpected at relatively low latitude and can only be explained by high altitude of recharge and/or a significant ‘continental effect’ (Dansgaard, 1961). Koegel Fontein is a large intrusion and it likely represents the eroded remnants of a much higher volcanic edifice.

No low- $\delta^{18}\text{O}$  rocks are known from the similar age Damara complexes in Namibia (Trumbull et al., 2004), which makes the Koegel Fontein Complex unique among the Mesozoic igneous rocks that formed prior to the rifting of southern Africa from South America. The explanation for this uniqueness may lie in the relative timing of rifting and magma generation.

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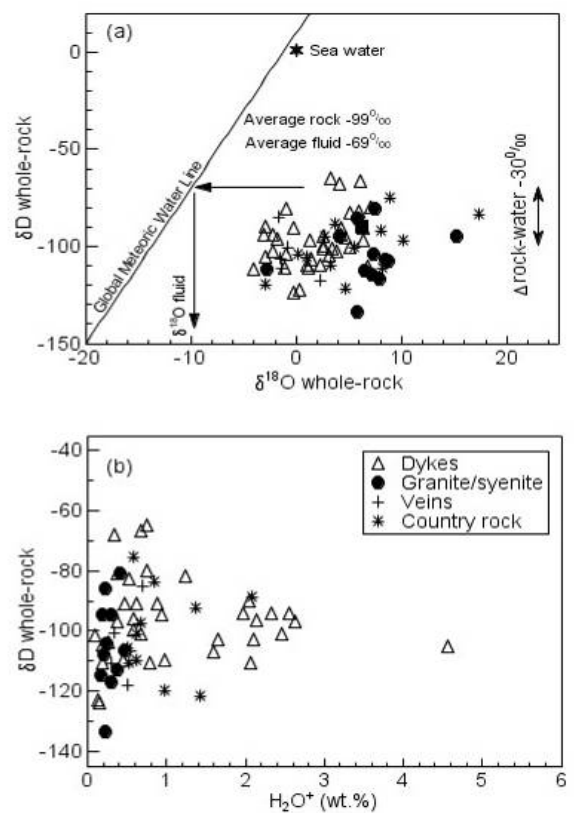
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**Figure 1. (a) Plot of  $\delta\text{D}$  vs.  $\delta^{18}\text{O}$  for whole-rock samples from the Koegel Fontein area. The average  $\delta\text{D}$  value is used to calculate the  $\delta^{18}\text{O}$  value of the fluid. (b) Plot of  $\delta\text{D}$  vs. water content of whole rocks.**