Note: A Sr isotope study of the Eureka Carbonatite, Damaraland, Namibia

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Introduction

The investigated carbonatite occurrence is situated in the southern part of the farm Eureka No. 99 which is located on the south-eastern border of Damaraland (Fig. 1). Von Knorring and Clifford (1960) have previously interpreted the monazite-rich carbonate veins as skarn deposits. While the U-Pb isotope study of Burger *et al* (1965) on monazites from these "marbles of the Hakos Series" yielded a concordant age of 500 ± 20 Ma, an igneous origin of the Eureka carbonatite dykes was considered by Verwoerd (1967). A detailed re-investigation of the occurrence by Dunai (1989) led to the present Sr-isotope study to assess a possible magmatic origin of the Eureka carbonatite dykes.

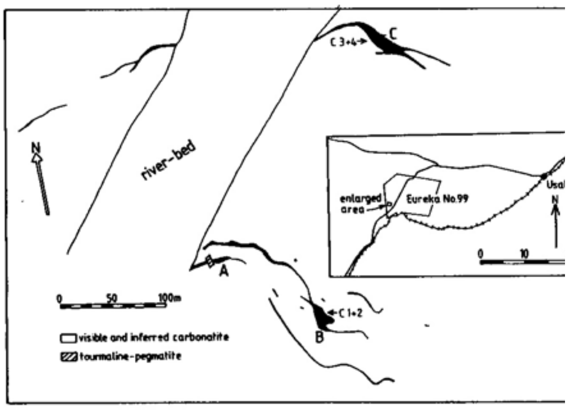

Fig. 1: Sketch map of the Eureka carbonatite showing sar localities with an inset showing the general location of

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The Eureka carbonatite dykes are located close to the intersection of the Omaruru Lineament with the Welwitschia Lineament Zone (Corner, 1983). The carbonatite dykes have intruded feldspathic quartzites of the Etusis Formation, which interfinger with calc-silicate layers of the Khan Formation in the study area. The country rock appears to be intensely folded. At one locality the southern carbonatite dyke is crosscut by a strongly weathered, tourmaline-bearing pegmatite of late Pan-African age (Fig. 1). This relationship provides a minimum age for the carbonatites since Miller (1983) has observed that the pegmatites of the area are not younger than 450 Ma. A combination of this minimum age with the concordant U- Pb age of 500 ± 20 Ma for monazites from the carbonatite dykes (Burger *et al*, 1965) yields a relative age range of 450-500 Ma for the emplacement of the Eureka carbonatites. Such a late Pan-African age clearly separates the Eureka carbonatites from the Mesozoic carbonatite complexes of the Damaraland Province.

The carbonatite dykes with an average thickness of 1-2 m (max. 7 m) consist mainly of medium- to coarse-grained beforsite with highly variable monazite contents. The large central outcrop B (Fig. 1) is free of monazite whereas carbonatites from the northern and southernmost outcrops show REE_2O_3 contents of up to 15 wt%.

Fenitisation of the country rock is indicated by the presence of 20 cm thick (max.) orthoclasites along the contact with the carbonatites and by metasomatic alteration of quartzites up to 20 m from the contact (Dunai, 1989). Metasomatism of the quartzites resulted in a decrease in K content, as mineralogically shown by the alteration of biotite to hydrobiotite, and an increase in Na towards the orthoclasites (Dunai, 1989). In the calc-silicate layers plagioclase is commonly partly replaced by scapolite. Skarn-like material consisting of actinolite/tremolite and diopside/hedenbergite with minor amounts of orthite occurs locally.

Sample collection and preparation

A total of four whole-rock samples of 1-2 kg was collected from the two largest carbonatite outcrops B and C on the farm Eureka (Fig. 1). Samples C1 and C2 were taken from the monazite-free central dyke B whereas C3 and C4 were collected from the monazite-rich northern dyke C. About 20 g of unweathered translucent rock fragments were handpicked from the crushed material of each sample in order to avoid contamination of the carbonatitic material with calcrete. Due to the strong weathering of the carbonatite material, it was only possible to gather a limited amount of fresh material.

Analytical techniques

An aliquot of each of the four analysed rock samples was dissolved in a mixture of hydrofluoric and perchloric acid. After evaporation the samples were dissolved in hydrochloric acid. The concentrations of Rb and Sr in the samples and the isotopic composition of Sr were determined using the isotope dilution method according to Jäger (1979). The Rb analyses were carried out

TABLE 1: Tabulation of Rb and Sr results obtained for the Eureka carbonatites.

Sample No.	Rb ppm	Sr ppm	$^{87}Sr/^{86}Sr$	anal. error (2 σ)
C1	0.369	25 650	0.70286	± 0.00003
C2	0.056	24 550	0.70289	± 0.00007
C3	0.176	30 580	0.70269	± 0.00005
C4	0.137	25 260	0.70378	± 0.00006

on a "Ion Instruments" solid source mass spectrometer while the Sr analyses were done on a "VG Sector" mass spectrometer. Isotopic constants given by Steiger and Jäger (1977) were used to correct age and fractionation of the samples.

Results

A tabular listing of the results is given in Table 1. All the samples have Rb concentrations <0.369 ppm while their Sr concentrations range between 24 550 ppm and 30 580 ppm. A correction of the $^{87}Sr/^{86}Sr$ ratios allowing for the radiogenic ^{87}Sr does not result in a significant change of the measured values. For an assumed age of 500 Ma a correction of the $^{87}Sr/^{86}Sr$ ratio of the sample with the highest Rb content (C1) would only result in an increase of the $^{87}Sr/^{86}Sr$ ratio of $2.95 * 10^{-7}$ which is far below the analytical error. Therefore the measured fractionation- and spike-corrected $^{87}Sr/^{86}Sr$ ratios which range between 0.70286 and 0.70318 may represent the initial $^{87}Sr/^{86}Sr$ ratios of the samples. Such low initial ratios preclude a sedimentary origin for the analysed carbonates since Fig. 2 shows that the $^{87}Sr/^{86}Sr$ ratio of seawater never dropped below 0.7065 since the Precambrian. When compared to the mantle evolution curves in Fig. 2, the initial $^{87}Sr/^{86}Sr$ ratios of the samples plot slightly above the straight line which represents strontium evolution in a Rb-depleted mantle region and which connects the Basaltic Achondritic Best Initial value (BABI) to a present value of 0.702. Nevertheless, the data also lie within the range of hypothetical evolutionary paths for Sr in the sub-continental mantle which are defined by curved lines indicating a time-dependent decrease in the Rb/Sr ratio of the upper mantle.

Conclusions

The results of this study dearly confirm a magmatic origin for the Eureka carbonatite dykes which intruded along zones of crustal weakness provided by the Omaruru Lineament and the Welwitschia Lineament Zone. Their slightly increased $^{87}Sr/^{86}Sr$ initial ratios compared to the evolution path of a Rb-depleted mantle region may be explained in two ways:

- The source region in the upper mantle originally had a slightly increased Rb/Sr ratio, similar to curve A2 in Fig. 2, before the separation of the carbonatite magma.
- The carbonatite magma was slightly contaminated with wall rock carbonates during its emplacement.

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