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# Report: Preliminary geochemical data for dolerite dykes and sills of the southern part of the Etendeka Igneous Province

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## Introduction

Over the last 15 years systematic geochemical and petrological investigation of the igneous rocks of the Early Cretaceous - Late Jurassic Etendeka Igneous Province of northwestern Namibia have focused on the tholeiitic basaltic lavas and interbedded silicic volcanic rocks (Erlank *et al.*, 1984; Milner, 1988; Milner & Ewart, 1989; Duncan *et al.*, 1988) and the large central subvolcanic complexes of Brandberg (Diehl, 1990), Erongo (Pirajno, 1990), Okenyenya (Le Roex & Watkins, in progress), Messum (Duncan, Erlank, Bailey, Hirschel, Harris & Marsh, in progress), Doros (Duncan & Marsh, in progress) and Cape Cross (Reid, in progress). Previously these rocks were grouped into the Karoo Volcanic Province of South Africa, but in view of the distinct age difference between the igneous rocks of the Etendeka region and Karoo rocks occurring elsewhere in southern Africa, we propose to regard them as constituting a separate Etendeka Igneous Province which exhibits a close lithological, geochemical and temporal correlation with the Paraná Flood Basalt Province of South America.

In previous studies in the Etendeka Igneous Province, only cursory attention has been directed to the extensive swarms of tholeiitic dykes and sheets which are widespread from the Kuiseb River northwards to the Kunene River (Fig. 1). Nevertheless, Erlank *et al*. (1984) identified a suite of dykes that are geochemically distinct from any of the basic lavas. These are the MORB-like *Horingbaai dolerites* (Duncan *et al.*, 1990) which intrude basement rocks and the overlying Etendeka lavas in the coastal region between Cape Cross and the Huab River. Other dykes studied by Erlank *et al.* (1984) were

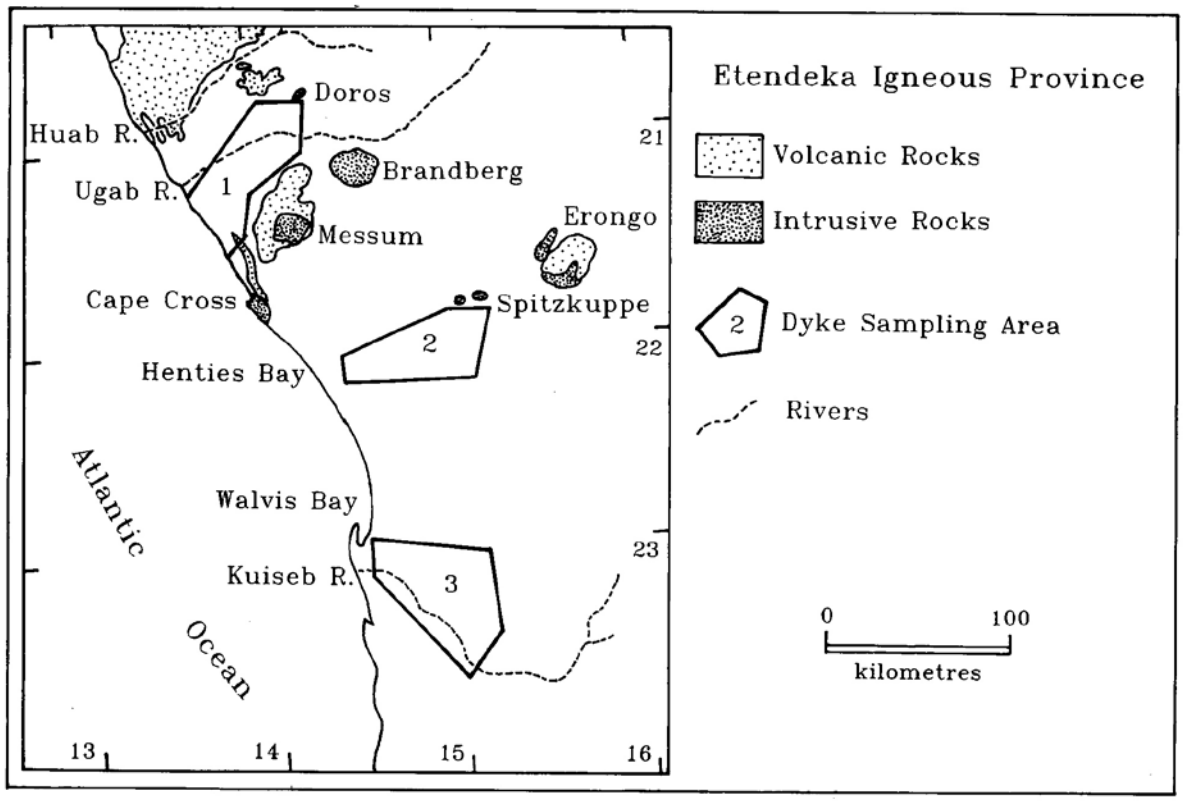


**Fig. 1:** Map of northwestern Namibia showing the location and limits of the three areas from which dolerite samples were obtained.

classified either as *Tafelberg-type dolerites* on the basis of having compositional and petrographic attributes identical to the Tafelberg-type basalts, or as *Regional dolerites*. The latter are more mafic than the Tafelberg basalts but exhibit geochemical affinities to this type. Furthermore, both the Tafelberg and Regional dolerites appear to be widespread compared to the Horingbaai dolerites.

In a detailed study of the large Huab sill complex underlying the southern part of the main Etendeka volcanic remnant, Duncan *et al.* (1989) identified the presence of 4 geochemically distinct types of dolerite, named Huab type-I to Huab type-4 dolerites. Three of these types can be distinguished from the Tafelberg-type basalts and dolerites and all of them can be distinguished from the Horingbaai dolerites on the basis of geochemistry.

Thus, these studies indicate that at least *five* basaltic magma types occur in the southern part of the Etendeka Igneous Province. These types *exclude* the high-$TiO_2$ basaltic lavas that are known from the northern Etendeka Igneous Province (Duncan *et al.*, 1988) and any basaltic magma type which occurs in the central complexes. Against this background, the current study was undertaken to determine:

(a) the distribution of the known magma types in the extensive dyke and sill swarms;

(b) whether any hitherto unidentified basic magma types occur in the dyke swarm; and

(c) the petrogenetic relationships between the different magma types.

Our studies in both the Karoo and Etendeka Igneous Provinces have shown that the elements Zr, Y, and Nb, alone or in ratios, are amongst the most useful elements for distinguishing different basalt magma types. These elements can be easily and precisely determined by wavelength-dispersive x-ray fluorescence spectrometry. In a preliminary attempt at meeting some of the aims of this study, we have analyzed all the dykes for these elements as well as Rb and Sr. This report discusses these results.

## Sampling strategy

Dolerite dykes and sheets are so abundant in the southern part of the Etendeka Igneous Province that it is impossible to sample them all. Sample collection was therefore focused in three areas (Fig. 1). Area 1, just south of the Ugab River, lies adjacent to the southern most rem-nants of the Etendeka lavas and includes the areas of known occurrence of the Horingbaai and Huab magma types. Area 2, extending S and WSW of the Spitzkuppe almost to Henties Bay on the coast, covers outcrops of a particularly prominent NNE-trending swarm of dykes. Area 3, to the E and SE of Walvis Bay, lies on the northern edge of the Namib sand sea and covers the southern most accessible occurrences of Etendeka intrusions. Detailed sampling was carried out in each of these areas to ensure that no dolerite types remained unsampled. Some 182 samples were collected for analysis. This sample suite was supplemented by a number of dolerites sampled in the Ugab River Valley by R. Swart of the Namibian Geological Survey.

## Petrography

The dykes are hypo- to holocrystalline with intergranular, ophitic, poikilophitic, or hyalophitic textures. Some samples are aphyric but most are sparsely phyric and the proportion of phenocrysts seldom exceeds 10%. Grain size and the proportion of glass in the sample depends on the size of the intrusion and the sampling position within it. In general, the dolerites resemble those described by Botha & Hodgson (1976) and Erlank *et al.* (1984). One outstanding feature emerging from the current study is the widespread presence of olivine, frequently in abundance, in more than 70% of the samples. This is in notable contrast to the basaltic lavas where Erlank *et al.* (1984) recorded the absence of olivine in the Tafelberg-type lavas. This emphasizes the more basic nature of the dolerites compared to the basalts. However, thin flows of olivine-phyric basalt have been found recently near the base of the volcanic succession in the volcanic remnants south of the Huab River (Milner & Ewart, 1989). These lavas would clearly extend the known compositional range of the basaltic lavas to more primitive compositions.

Some of the dykes sampled by us are lamprophyres and theralites. The majority of these dykes were found close to Henties Bay in Area 2 and are believed to be related to the poorly exposed alkaline igneous complex in this area. Although field relationships indicate that the alkaline dykes are contemporaneous with the tholeiitic magmatism, the alkaline dykes are not considered further in this report.

## Geochemistry

Zr, Nb, and Y concentration data are presented in Fig. 2. Preliminary observations on these data can be summarized as follows:

1. Dolerites in all three areas exhibit variable degrees of differentiation as indicated by the wide range of Zr concentrations. This is consistent with the results obtained previously by Erlank *et al.* (1984) for basic volcanic rocks of the Etendeka Province.

2. Most dolerites have Zr/Nb >10 and overlap with the compositions of the Tafelberg-type basaltic lavas. However, it is evident that the majority of the dolerites are less evolved than the lavas in terms of Zr concentration. This is particularly true for Areas 1 and 2. The less-evolved geochemical character of the dolerites is consistent with the petrographic differences between the dolerites and the lavas noted earlier. Although less evolved, it is evident that the dolerites with Zr/Nb >10 could have differentiated by fractional crystallization to yield compositions lying in the field for Tafelberg-type

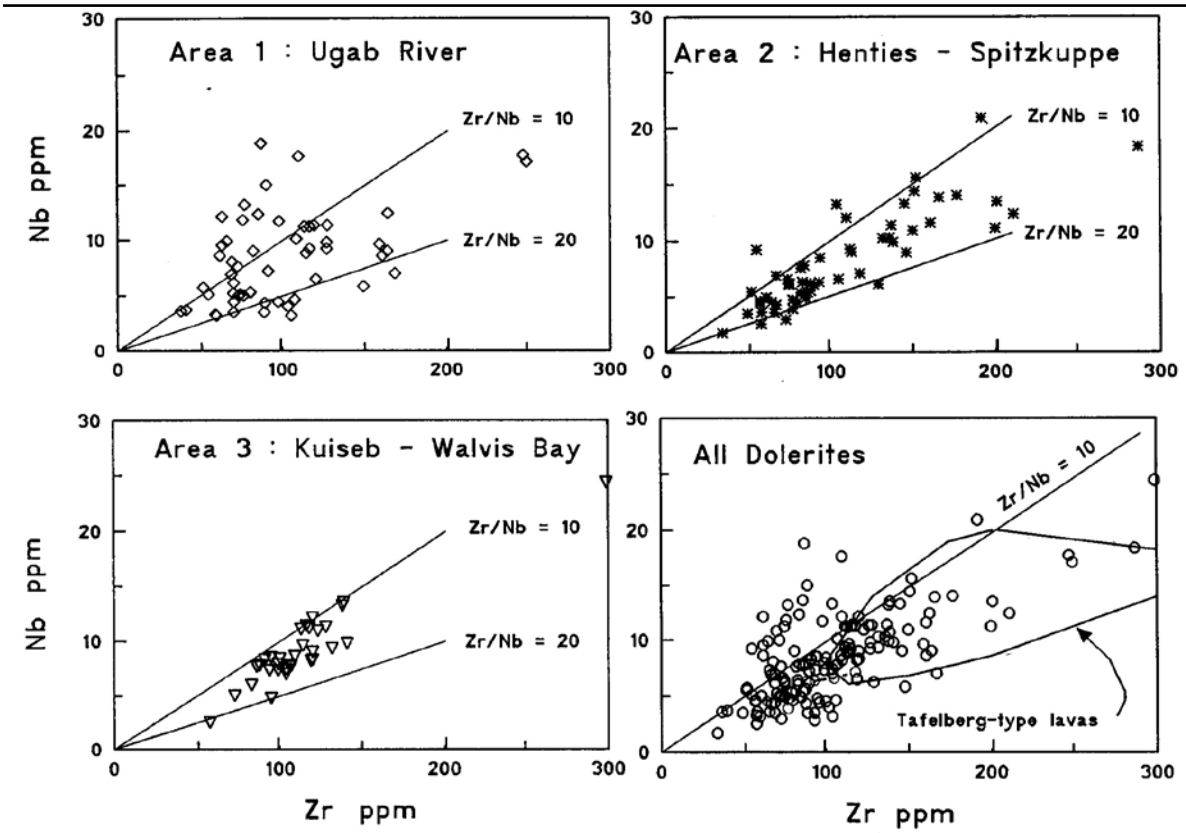


**Fig. 2:** Variation diagrams of Zr and Nb concentrations in the dolerites. The field for Tafelberg-type lavas is taken from Erlank *et al.*(1984).

lavas.

3. A significant number of dolerites from Area 1 have Zr/Nb <10 and have probably not crystallized from Tafelberg-type magmas. Erlank *et al.* (1984) and Duncan *et al.* (1989, 1990) have shown that the Horingbaai dolerites and the Huab type-l and type-4 dolerites have similar low Zr/Nb ratios and it is possible that the low Zr/Nb dolerites sampled in the current study are representative of these magma types. This correlation would be consistent with the known geographical extent of the Huab and Horingbaai dolerites. Zr/Y data, although not as definitive, support these correlations, the confirmation of which must await complete chemical analyses of the samples.

## Summary

Preliminary geochemical data for dykes lying between the Doros intrusive complex (Fig. 1) and the Kuiseb River appear to confirm results of previous studies of volcanic rocks and intrusive dykes and sills in the Etendeka Igneous Province. The Tafelberg-type basaltic magma is the most voluminous and widespread mafic magma type in the Etendeka Igneous Province. The basaltic lavas are on average more differentiated than the associated dolerite dykes and sills. The Huab and Horingbaai dolerite types are relatively restricted in distribution, being largely confined to the areas where they were first recognized.

## Acknowledgements

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