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BENFONTEIN-02 KIMBERLITE, FREE STATE PROVINCE, SOUTH AFRICA

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INTRODUCTION

Benfontein-02 is a Group I kimberlite sill located approximately 11 km to the southeast of Kimberley, in the Boshof District, Free State Province. It occurs about 1.5 kilometers to the east of the Benfontein-01 kimberlite, which has been known for its magmatic flow banding and density stratification (Dawson & Hawthorne, 1973). Following the discovery of the kimberlite in 2004, surface geological mapping was done. Sample analysis for major and trace elements; and mineral identification were done by X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) methods using the University of Witwatersrand laboratory facilities.

GEOLOGICAL SETTING

The three main geological units in the Kimberley area are the Archean Basement Complex, Ventersdorp Supergroup, and the Karoo Supergroup (Clement et al., 1986; Hawthorne, 1968). The Archaean basement is exposed in underground mine workings and comprises banded biotite gneisses that have been dated at 3.2 Ga (Schmitz et al., 2004), as well as amphibolites, chlorite schists and talc schists. Subsequent migmatization and metamorphism have been constrained at 2932 – 2926 Ma (Schmitz et al., 2004). The Ventersdorp Supergroup is represented in the area by the Platberg Group dated at 2.71 Ga (Armstrong et al., 1991). It rests uncomformably on the Archaean basement and consists mainly of intercalated quartzite, as well as amygdaloidal and massive lavas that are andesitic to basaltic in character (Clement et al., 1986).

The Karoo Supergroup is represented in the area by the Dwyka and Ecca Groups (Hawthorne, 1968). The Dwyka dolerite sills and dykes (Dawson and Hawthorne, 1973). At Benfontein, the kimberlite sills were preferentially emplaced along the contact of dolerite sills with shales. The Benfontein sills are Cretaceous in age, having

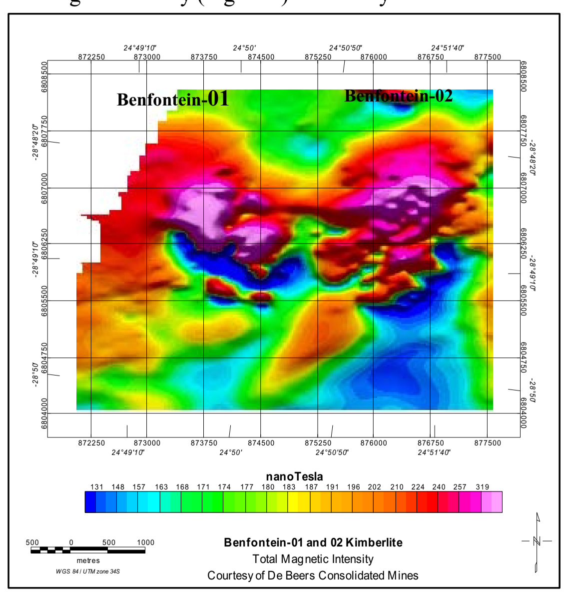

Figure 1: Airborne magnetic map (minimum: 131 nano Tesla and maximum: 319 nano Tesla) depicting the Benfontein-01 and -02 kimberlite sills.

been dated at 88 ± 3 Ma using U–Pb perovskite dating (Wu et al., 2010) and intrude the upper shales of the Dwyka Group (Hawthorne, 1968).

MAPPING RESULTS AND GEOPHYSICS OF THE STUDY AREA

Benfontein-01 and Benfontein-02 sills were detected by an aeromagnetic survey (Figure 1). The study area is characterized by sparse outcrops (<10%) of kimberlite, dolerite and shale (Figure 2). Kimberlites occur as isolated bodies. The largest kimberlite sill outcrop has a length of 80 m with varying width. Combined, the sills cover an area of 2.25 ha. Host rock dolerites are hard, greyish-black, medium-grained rocks that are well exposed. Shales are greyish, thinly bedded and mainly weathered.

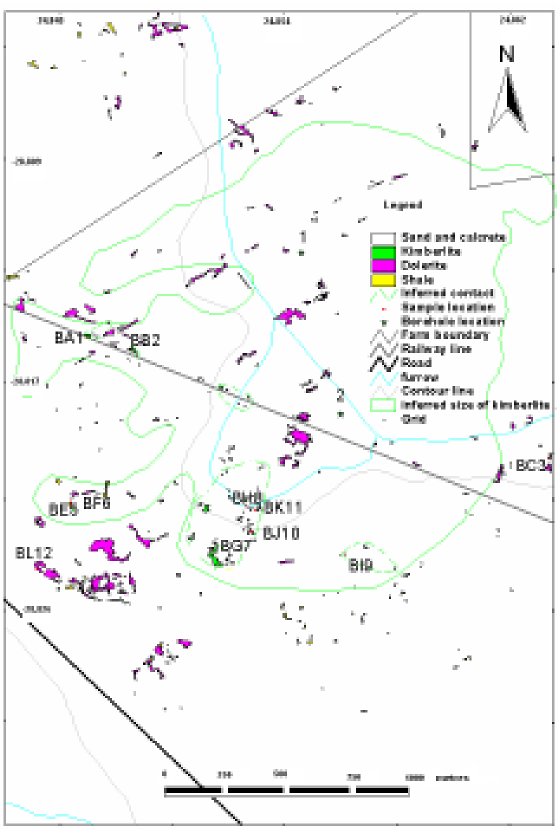

Figure 2: Geological map of the project area (BA1 – BK11 are sample locations; 1 and 2 are borehole locations)

The surrounding host shales have a quiet magnetic background whilst the kimberlite is associated with areas having high magnetic intensities. Two holes drilled into magnetic high features led to the discovery of the kimberlite sills emplaced between dolerite and shale. Dolerite of about 10 m in thickness forms a cap over the kimberlite. The kimberlite sills have thicknesses varying from 1 to 9 m. As 3a suggested by Mitchell (1986), impermeable layers act as barriers to magma rising during sill emplacement. This mode of occurrence is similar to that of the Benfontein-01 kimberlite.

PETROGRAPHY AND MINERALOGY

Macroscopically, Benfontein-02 is a dark grey, macrocrystic kimberlite with carbonate veins and patches and minor dolerite xenoliths. Microscopic studies show two generations of olivine (rounded macrocrysts [xenocrysts] and euhedral phenocrysts), spinel, perovskite, apatite, phlogopite and carbonate (Fig. 3a & b). Serpentinisation is the dominant type of alteration in these rocks, with lizardite being the most prominent alteration product. XRD results indicate the presence of all three serpentine minerals, namely lizardite, chrysotile and antigorite. The

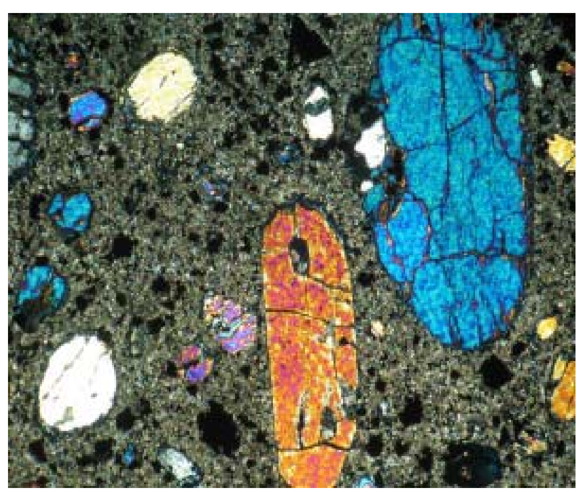

Figure 3a: Photomicrograph displaying ellipsoidal olivine xenocrysts and spinels (sp).

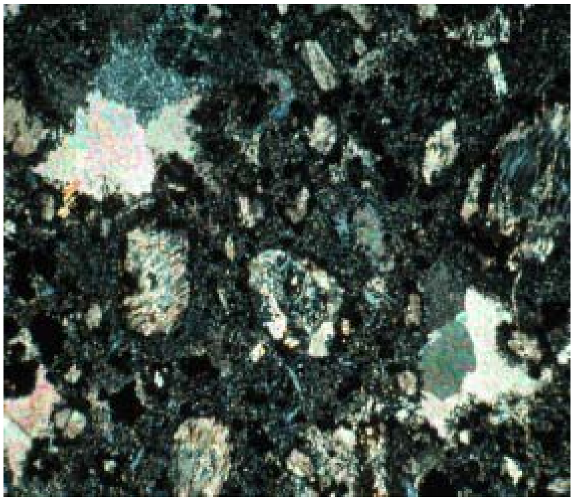

Figure 3b. Photomoicrograph showing carbonate (ca) patches and altered olivines (ol).

kimberlite mineralogy is comparable to that of Benfontein-01 as described by Dawson and Hawthorne (1973).

GEOCHEMISTRY

Geochemical data of kimberlite samples from Benfontein- 01 and Benfontein-02 are provided in Tables 1 & 2.

Major element analyses

The major element analyses for Benfontein-02 are relatively similar to the composite sample of Benfontein-01 kimberlite with slightly higher LOI and lower MgO and K_2O, and higher TiO_2, contents, which is probably due to a lower abundance of phlogopite and a higher abundance of spinel, respectively. Mitchell (1995) described this relationship as one of the typical characteristics of kimberlites. Like many kimberlites, Benfontein-02 has low SiO_2 contents. It has elevated CaO contents, which is probably due to high carbonate abundance. The Benfontein-02 kimberlite has similar TiO_2, P_2O_5 and Al_2O_3, slightly lower MgO, SiO_2, K_2O, Na_2O and higher CaO, LOI and FeOT compared to other Group I kimberlites (Dawson and Hawthorne, 1973).

Table 1: Major element analyses of Benfontein-02 and a composite Benfontein-01. Sample 1: composite kimberlite; 2: olivine-magnetite- perovskite kimberlite (Dawson and Hawthorne, 1973). Data in wt%.

Kimberlite	Benfontein-02				Benfontein-01	
Sample	BC3	BF6	BI9	BK11	1	2
SiO_2	26.68	25.17	26.14	22.18	25.19	28.63
TiO_2	1.99	2.10	2.23	2.06	1.89	1.07
Al_2O_3	1.98	2.08	2.07	2.33	2.87	2.01
FeO_T	10.40	10.60	11.30	10.30	10.40	9.40
MnO	0.21	0.21	0.22	0.22	0.22	0.14
MgO	28.38	25.11	28.46	24.09	29.69	34.02
CaO	13.59	16.62	12.55	18.17	13.59	11.92
Na_2O	0.00	0.00	0.35	0.00	0.01	0.20
K_2O	0.03	0.06	0.10	0.10	0.15	0.05
P_2O_5	1.80	2.47	1.11	2.53	2.20	0.27
LOI	14.63	16.09	15.76	18.10	13.98	11.74
H_2O-						0.23
Total	99.64	100.49	100.31	100.09	100.23	99.68

Table 2: Trace element analysis of Benfontein-01 and Benfontein-02 [Benfontein-01 sample: NK, normal kimberlite (Dawson and Hawthorne, 1973)]. Data in ppm.

Kimberlite	Benfontein-02				Benfontein-01
Sample	BC3	BF6	BI9	BK11	NK
Rb	10	20	17	9	9
Sr	1574	2084	1091	1705	995
Y	25	25	25	23	4
Zr	311	309	340	307	260
Nb	223	240	208	234	
Co	67	59	70	60	
Ni	861	715	929	770	1500
Cu	65	92	21	83	
V	162	167	103	169	
Cr	975	938	1081	909	
Ba	1721	1863	1146	2234	1295
Zn	91	94	89	84	

Trace element analyses

The Benfontein-02 kimberlite is classified as belonging to Kimberlite Group I based on the Nb vs Zr plot (Figure 4) by Taylor et al., (1994). In comparison to the Benfontein-01 kimberlite, the Benfontein-02 kimberlite has higher Rb, Y, Zr, Ba and lower Ni contents. It also exhibits slightly lower Cr, Ni, Rb, Co and slightly higher Ba, Nb, Zr, Y, Zn, V, Sr and Cu contents in comparison to other Group I kimberlites (Dawson and Hawthorne, 1973). Variations in trace element concentrations can be explained by compatibility of Ni, Cu, Co and Zn in spinel and of Co and Ni in olivine as suggested by Smith et al. (1985).

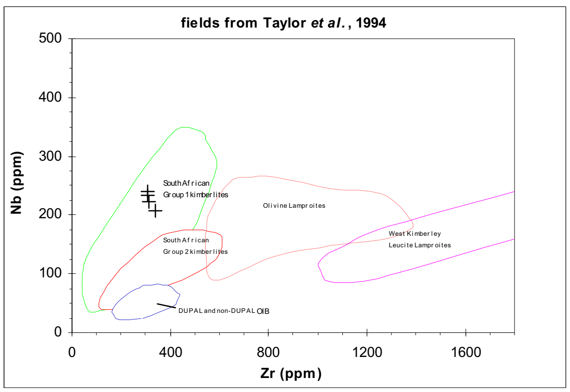

Figure 4: Nb (ppm) vs Zr (ppm) diagram showing the Benfontein-02 kimberlite sill samples plotting on the South African Group 1 kimberlites field.

DISCUSSION AND CONCLUSION

Benfontein-02 kimberlite was detected through aeromagnetic surveying and subsequent drilling. Dolerite forms a cap that acted as a barrier and caused lateral flow and sill development. The Benfontein-02 kimberlite is enriched in carbonate which occurs both as primary and secondary minerals. The former occur as minute patches and their occurrence was described by Hess (1989) as a characteristic feature of co-existence of two liquids. Hess (1989) also indicated that this kind of occurrence is a result of immiscible carbonate and silicate, which separated from the common magma. Similar globular masses were described by Dawson and Hawthorne (1973), who also attributed this to the process of liquid immiscibility. MacMahon and Haggerty (1984) proposed that these features are a result of amygdale infilling, liquid immiscibility, and crystallisation of low temperature residual liquids.

The major similarities between Benfontein-01 and Benfontein-02 are that they both contain carbonate patches and few crustal xenoliths (dolerite and shale xenoliths) and are therefore classified as being of the massive hypabyssal type, based on the kimberlite classification by Dawson (1980). What was found different from the Benfontein-01 kimberlite however, is the absence of dendritic calcite, garnets and ilmenite macrocrysts in samples from the study area. In addition to this, phlogopite is rare in the Benfontein-01 kimberlite (Boctor and Boyd, 1981) and occurs as macrocryst (Dawson and Hawthorne, 1973), whereas phlogopite in Benfontein-02 is rare but small in size**.** Based on these studies, Benfontein-02 is classified as a macrocrystic, carbonate-rich Group I kimberlite.

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