

The discovery of the lower mantle derived SWS 21 intrusion in the Mmadinare area of Botswana

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1 Introduction

The Mmadinare area in northeastern Botswana is located to the west of the Cu-Ni Selebi Phikwe Mine and is situated in the southern and central zones of the Limpopo Mobile Belt (LMB) which extends northwards between the Kaapvaal and Zimbabwe Cratons. The area has been prospected for diamonds by at least two major companies in the past three decades with no success. Historically the area was subjected to soil sampling. Two styles of soil samples were collected, stream sediment samples and loam samples. The size fraction of the soil samples were between 0.425 and 2mm. Although garnet, spinel and picroilmenite were found, no significant numbers of traditional kimberlite indicators were recovered during these historical exploration programmes.

2 Satellite Imagery

With more recent access to satellite imagery via GoogleEarth on the internet it is possible to review any given area in Botswana with great detail. One of the advantages of using GoogleEarth is that it is possible to change the scene viewed between different time shots, presenting the opportunity to view the same area during different seasons. In an area which suffers from droughts and has a very different vegetation pattern between winter and summer, this is a very useful exploration tool.

A study was conducted over known kimberlites within the central and northern zones of the LMB with the object of identifying any geobotanical anomalies associated with the known kimberlites. In particular, the Mwenezi (Williams and Robey, 1999) and Mambali-Ngulube kimberlites fields, discovered by De Beers and Trillion Resources from Canada respectively, were studied. Based on the observations made over these kimberlites a detailed GoogleEarth study was undertaken over the Mmadinare area and in excess of twenty targets were identified for ground follow-up.

3 Trace Elements

The paucity of traditional kimberlite indicator minerals (KIM's) recovered from the

Mmadinare area during previous exploration programmes which sampled the area extensively indicated that traditional soil sampling was not the route to follow in this area. Recent advances in analytical techniques which allow for the analysis of trace elements in small samples to the parts per billion level has provided the opportunity to geochemically discriminate between GoogleEarth features selected for investigation. Samples were collected over two known kimberlites in the Jwaneng Kimberlite field and analysed for 72 elements, including V, La, Nb, Nd, LREE's and HREE's, Th, U, Sr, Rb and Ba. A trace element profile was established over these two known kimberlites (Daniels et al., 2012).

The GoogleEarth targets selected within the Mmadinare area were sampled for KIM's and trace element samples taking one 40 litre soil sample in the central part of the feature. The -2mm + 0.425mm fraction was processed through a 1 tph DMS plant for traditional KIM's. No KIM's were recovered from any of the samples.

The -0.425mm fraction of each sample was screened to -180 micron and 50g of this size fraction was submitted to Activation Laboratories in Ancaster, Ontario, Canada for trace element analysis utilising an enhanced enzyme leach technique. Anomaly SWS 21 (Figure 1) was characterised by the most anomalous Ni and Sr. The sum of Y + La + Nd for SWS 21 returned the third highest value obtained from the trace element samples. V, which was considered to be a significant kimberlite trace element in the Jwaneng Orientation survey was found to be subdued over SWS 21 and marginally above background (Figure 2).

Based on the combination of the GoogleEarth imagery and the trace element results, a pit was excavated in the SWS 21 feature. A highly weathered rock, light green in colour, with a hand specimen appearance of weathered kimberlite, was intersected at less than 2 metre depth.



Figure 1. The SWS 21 geobotanical feature observed utilising Google Earth satellite imagery.

Petrographically, the rock has been described as an olivine-rich ultrabasic rock with clinopyroxene, phlogopite and apatite. Due to the absence of two generations of olivine the rock has not been classified as a kimberlite.

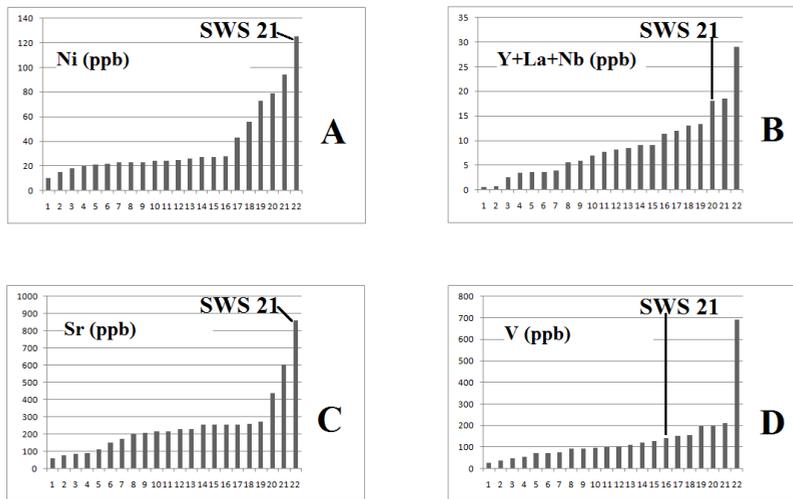


Figure 2. Trace element results from 22 targets identified in the Mmadinare area, Botswana, from GoogleEarth imagery. (A) Ni (ppb); (B) Y+La+Nd (ppb), (C) Sr (ppb) and (D) V (ppb).

4 Kimberlite Indicator Minerals

Garnet, spinel, micro-ilmenite, clinopyroxene and manganese ilmenites have been recovered as indicator minerals from the weathered intrusive rock. The minerals were analysed by microprobe at CF Laboratories, Kelowna, British Columbia, Canada.

Table 1. Representative concentrate mineral compositions from the SWS 21 intrusion

Mineral	OLV	SPN	SPN	CPX	CPX	GAR	GAR	GAR	PILM
SiO ₂	40.09	0.03	0.02	54.98	54.47	40.92	41.75	40.61	-
TiO ₂	0.02	0.31	0.36	0.21	0.06	0.04	0.02	0.19	50.12
Al ₂ O ₃	0.05	28.43	16.42	2.28	2.48	23.28	20.74	17.21	0.02
Cr ₂ O ₃	0.05	29.98	41.74	0.59	1.86	0.11	3.95	8.28	0.69
Fe ₂ O ₃	-	10.09	10.60	-	-	-	-	-	9.18
FeO	10.03	18.58	21.53	4.61	1.67	16.10	8.68	7.72	31.71
MnO	0.13	0.31	0.40	0.14	0.07	0.45	0.47	0.49	0.60
MgO	48.72	11.45	8.29	18.46	15.05	14.57	19.07	18.92	7.35
CaO	0.11	N.D.	0.01	15.74	21.30	5.14	5.47	6.13	-
NiO	0.40	0.31	0.18	0.08	0.04	-	-	-	-
Na ₂ O	0.01	-	-	1.72	2.05	0.03	0.02	0.02	-
Total	99.61	99.49	99.55	98.81	99.05	100.64	99.54	99.57	99.67

A total of 19 mantle derived garnets were recovered from a 20 kg sample. Both eclogitic as well as peridotitic garnets are present. No subcalcic garnets were recovered from this sample. The composition of one khorringite-rich garnet is similar to the composition of garnets from a diamondiferous xenolith from Premier Mine (Viljoen et al., 2004). The chromian spinels follow a mantle trend of garnet-spinel peridotites as observed in lamproites in Australia (McCandless and Dummert, 2003; Jacques et al., 2014). Six clinopyroxenes with 0.59 – 2.48 wt% Cr₂O₃ were recovered and their compositions are consistent with a derivation from

garnet lherzolites (Stephens and Dawson, 1977). A forsteritic olivine and one microilmenite (7.35 wt% MgO, 0.69wt% Cr2O3) were also recovered from the sample (Table 1).

Five manganian ilmenites recovered from the discovery pit at SWS 21 have compositions consistent with ilmenites recovered as inclusions in diamonds from alluvials and from a Pandrea kimberlite in the Juina area, Mato Grosso State, Brazil. These manganian ilmenites have a lower mantle paragenesis (Kaminsky et al., 2001, 2009). The ilmenites are characterised by low MgO (0.01 to 0.27 wt%) and MnO 0.63 – 2.10 wt% and negligible Cr2O3 (Table 2, Figure 3).

Table 2 – Manganian Ilmenites from the SWS 21 Intrusion, Mmadinare, Botswana

Mineral	ILM	ILM	ILM	ILM	ILM
TiO2	48.15	49.80	48.95	49.26	47.43
Al2O3	0.10	N.D.	0.04	0.04	N.D.
Cr2O3	N.D.	N.D.	N.D.	N.D.	0.03
Fe2O3	7.57	6.05	7.04	6.48	9.85
FeO	42.66	43.51	43.13	43.03	40.52
MnO	0.63	0.77	0.86	1.06	2.10
MgO	0.04	0.27	0.03	0.12	0.01
CaO	N.D.	0.01	N.D.	N.D.	N.D.
Nb2O5	0.06	0.02	N.D.	0.03	0.07
Total	99.21	100.43	100.05	100.02	100.01

N.D. = Not Detected

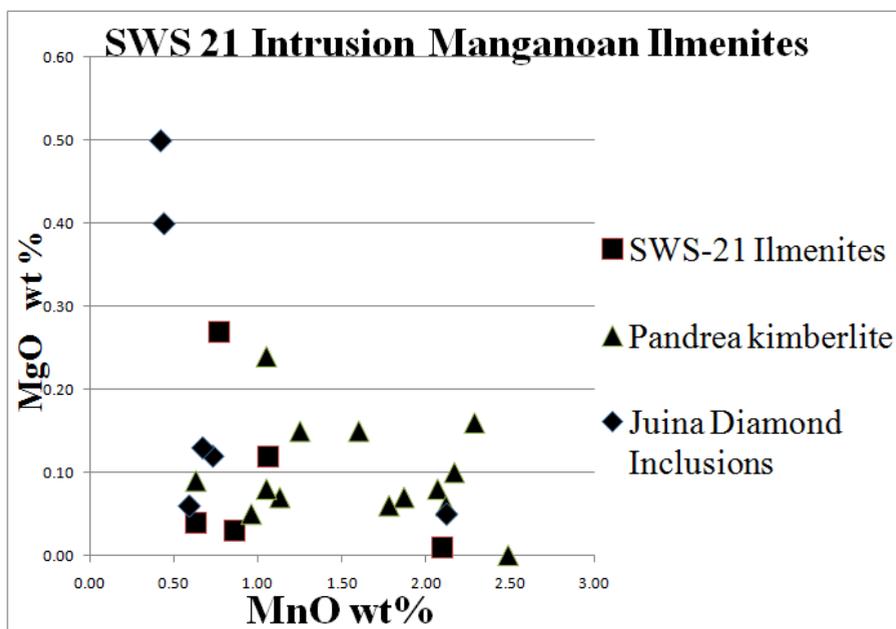


Figure 3. MnO wt% vs MgO wt% plot for manganian ilmenites from the SWS 21 intrusion, diamond inclusions from Juina alluvials and the Pandrea kimberlite in Mato Grosso State, Brazil (Kaminsky et al., 2001, 2009).

5 Discussion and conclusions

The absence of two generations of olivine from the SWS 21 intrusion precludes the rock from being classified as a kimberlite even though it is an olivine-rich ultrabasic intrusive rock with clinopyroxene, phlogopite and apatite containing traditional kimberlite indicator minerals derived from the upper mantle.

The manganoan ilmenites recovered from the SWS 21 intrusion are similar in composition to the Mn-ilmenites that occur as inclusions in diamonds from alluvials in the Juina area of Mato Grosso State, Brazil. The Juina Mn-ilmenites co-exist in diamonds with other minerals that are consistent with a derivation from the transition zone at depths of 660 km and the lower mantle (Kaminsky et al., 2001). One of the garnets recovered from the SWS 21 intrusion is a knorringite-rich pyrope similar in composition to a diamondiferous lherzolite reported from the Premier diamond mine, South Africa (Viljoen et al., 2004) indicating a derivation from within the diamond stability field. It is concluded that the SWS 21 volcanic intrusion transected the diamond stability field in the upper mantle.

Kaminsky et al. (2001) concluded that Mn-rich, MgO poor ilmenites should be included as potential diamond indicator minerals and that in such areas where these ilmenites are encountered the “traditional” KIM’s like pyrope garnet and Cr-spinel may be in the minority or absent. The paucity of traditional KIM’s in the Madinare area suggests that the manganoan ilmenites recovered from the SWS 21 intrusion should be considered as an alternative diamond indicator mineral in this area of Botswana.

The combination of GoogleEarth satellite imagery and trace elements can lead to discovery.

6 References

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