Comparison of ground TEM and VTEM responses over kimberlites in the Kalahari of Botswana

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INTRODUCTION

One hundred meter square in-loop ground TEM soundings were an effective way to screen aeromagnetic, ground gravity, and Falcon® gravity gradiometer signatures caused by kimberlite intrusions overlain by 40-120 meters of transported Kalahari sedimentary cover in the Kokong kimberlite field of Botswana (Figure 1). Ground TEM's effectiveness in identifying kimberlite pipes led to the flying of the VTEM aeroTEM system over selected areas at Kokong. Ten kimberlites previously covered by ground TEM surveys were over flown by the VTEM survey (Figure 2). A comparison of the ground TEM and VTEM responses show that the VTEM effectively drill-screened nine out of the ten kimberlite magnetic or gravity signatures, whereas the ground TEM systems effectively screened all 10 kimberlite signatures (Table 1). KS40, the largest kimberlite at Kokong and the one kimberlite less well mapped by the VTEM was, at 10-30 milliseconds (msec), a later-time conductor that best responded after the VTEM's last channel 27 at 7.5 msec. KS40's kimberlite crater was mapped as a good late-time conductor (later than 7.5 msec) by both ground TEM systems. The ground TEM systems employed were a Geonics TEM57 transmitter and PROTEM receiver, and two Zonge ZT-30 transmitters and GDP32 receivers; their specifications are compared with the VTEM in Table 2 below.

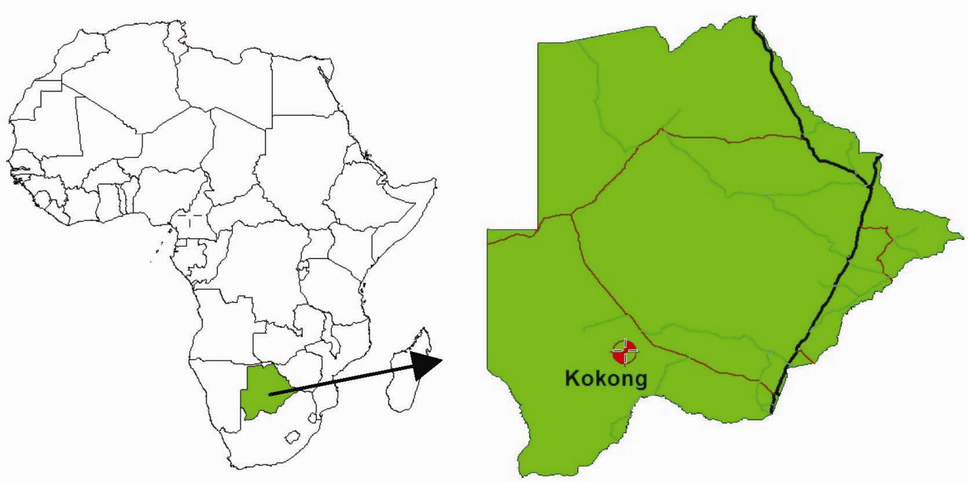

Figure 1. Location of the Kokong kimberlite field in the southern Kalahari of Botswana.

FIELD COMPARISON OF THE KIMBERLITE TEM RESPONSES

Ten kimberlites were traversed by both ground and airborne TEM surveys. Kimberlite KN70 (Figures 3 and 4 below) illustrates an excellent conductive TEM response for an epiclastic crater kimberlite overlain by 107 meters of Kalahari cover sequence. Conductive responses were noted for eight of the 10 kimberlites. Conductivity depth image (CDI) modelled responses in all cases except KS40's smoothed out more obvious raw channel responses. The raw profiles (Figure 4) were usually more effective for sighting boreholes than the smooth models (Figure 5).

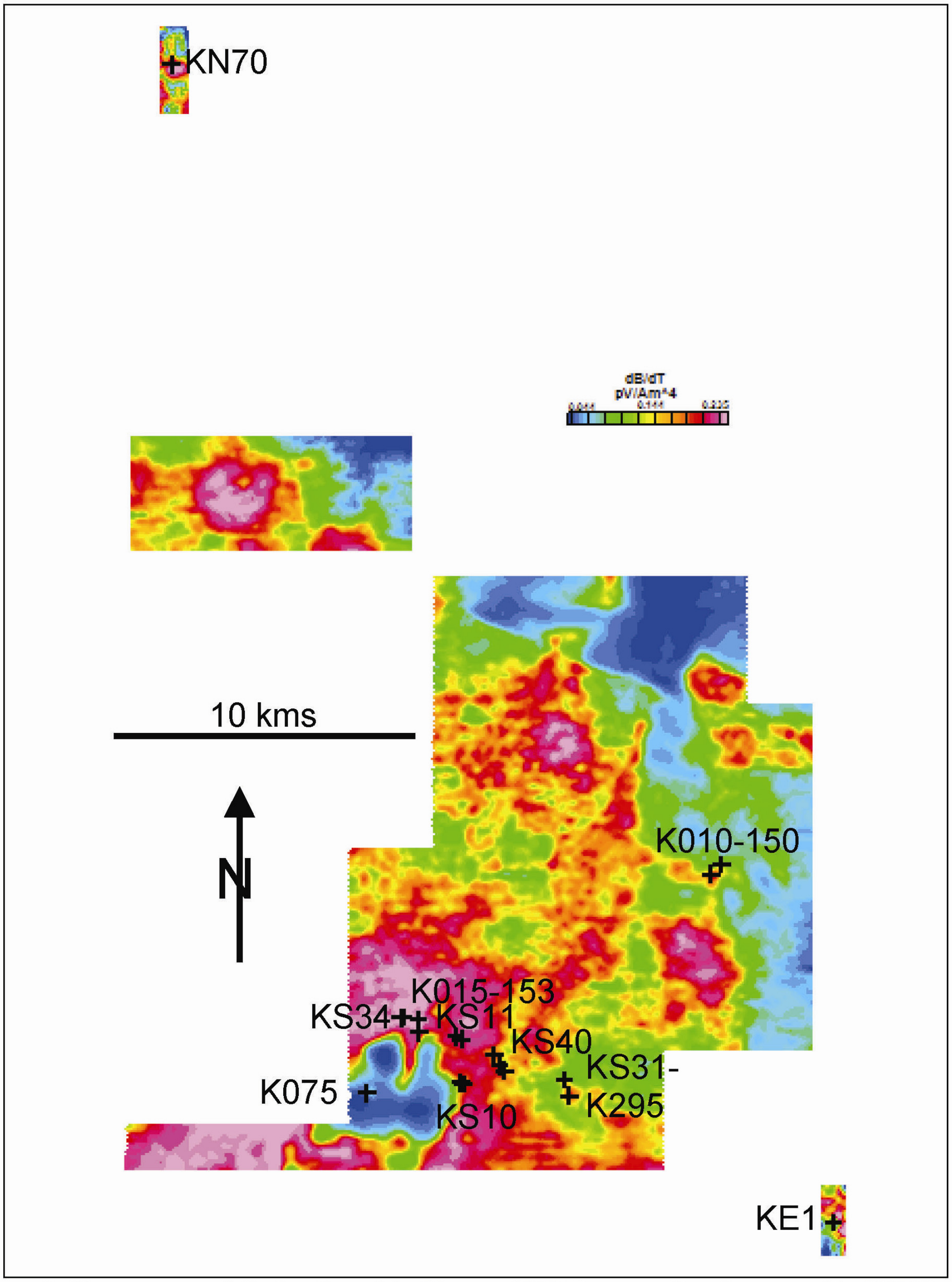

Figure 2. The crosses mark the location of the 10 ground TEM traverse sites also covered by VTEM surveying that were kimberlite, the crosses marking the site of boreholes that intersected kimberlite. Background image is the VTEM Channel 27 plan of 7.54 msec with dB/dT in pV/Am^4. The plan generally maps background Kalahari conductivities that can be considered regional geologic noise, though a few discrete conductive signatures are identified outright over epiclastic crater kimberlites, such as at K075, KS31-295, K010-150, and KN70. A discrete resistive response is noted over hypabyssal kimberlite KE1. There is not an obvious conductive channel 27 (Ch27) response over the center of the large kimberlite KS40's crater, that's best mapped by an 83 hectare ground gravity negative signature.

Table 1. List of the 10 kimberlites traversed by a ground TEM system and the VTEM. A "n/a" means that ground system was not applied. Whether a kimberlite was mapped by a particular TEM system or not was based on borehole collar locations in relation to TEM peak anomalies and on kimberlite being returned from the borehole, that for kimberlites with conductive TEM signatures were usually thick epiclastic clay sequences.

Kimberlite name	Kimberlite area from gravity	Kalahari thickness	Type of signature screened	Did the PROTEM map kimberlite?	Did the ZeroTEM map kimberlite?	Did the VTEM map kimberlite?
KN70	26 Hectares	107 meters	gravity & magnetic	A conductor	A conductor	A conductor
KS40	83 Hectares	120 meters	gravity	A conductor	A conductor	Uncertain
KE1	19 Hectares	80 meters	gravity & magnetic	A resistor	n/a	A resistor
K075	13 Hectares	95 meters	magnetic & Falcon Gzz	A conductor	n/a	A conductor
KS10	11 Hectares	99 meters	gravity & magnetic	n/a	A conductor	A conductor
KS11	17 Hectares	90 meters	gravity & magnetic	A conductor	n/a	A conductor
KS34	45 Hectares	70 meters	magnetic	n/a	A conductor	A conductor
KS31-K295	11 Hectares	80 meters	gravity & magnetic	A conductor	n/a	A conductor
K015-K153	21 Hectares	91 meters	magnetic & Falcon Gzz	A conductor	n/a	A conductor
K010-K150	37 Hectares	51 meters	gravity & magnetic	A conductor	n/a	A conductor

Table 2. Technical specifications of the three TEM systems as set up during years 2001-2004 at Kokong. The current year 2008 VTEM system reportedly uses lower base frequencies providing the measurement of decays later than 7.54 msec, and readings in integrated B-field mode. All systems measured the Z component

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System------------>	PROTEM	Zonge ZT-30	VTEM 2004
Loop Type	Ground In-Loop	Ground In-Loop	Aero In-Loop
Loop Size	100m square	100m square	26m diameter
Loop Area	10000 sq. meters	10000 sq. meters	531 sq. meters
No. of Turns	1	1	4
Peak Amperage	25	30	140
Peak Moment NIA	250,000	300,000	297,000
Sounding separation	100m	100m	3m (average)
Tx Waveform	Square	Square	Trapezoid
Duty Cycle	50%	50%	40%
Base Frequency	6.25 Hz	4 Hz	30 Hz
# Rx Channels	20	31	27
Rx decay time range	0.346 to 28.1 msec	0.126 to 48.1 msec	0.130 to 7.54 msec

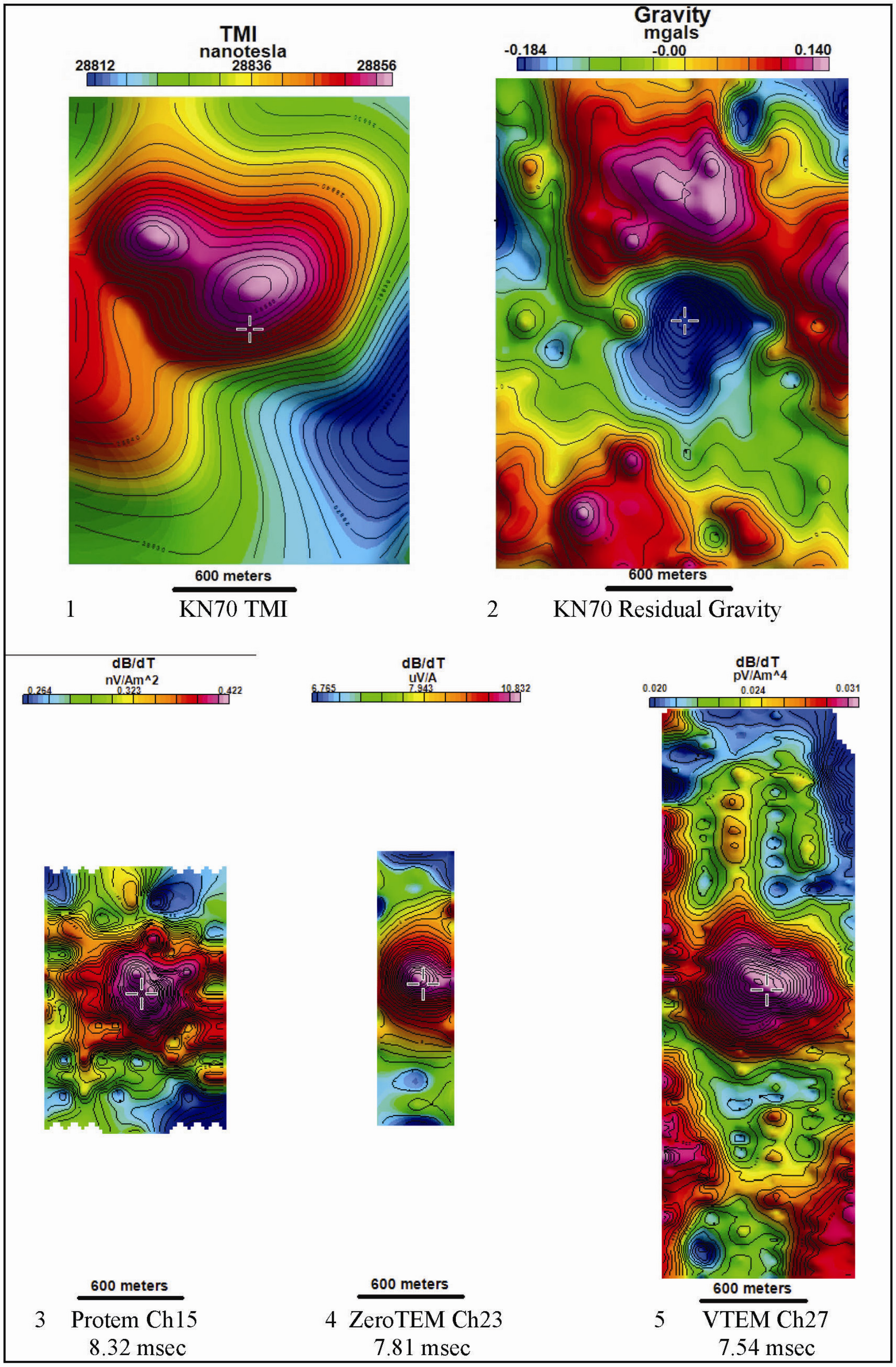


Figure 3. KN70 TMI grid panel 1, gravity panel 2, Protem panel 3, Zerotem panel 4, and VTEM panel 5, crosshair in same spot on all panels. The gravity signature is sub coincident with the TMI signature, being offset 200 meters southward. All TEM plan responses are similar and well map the kimberlite's epiclastic crater as being coincident with KN70's gravity negative signature.

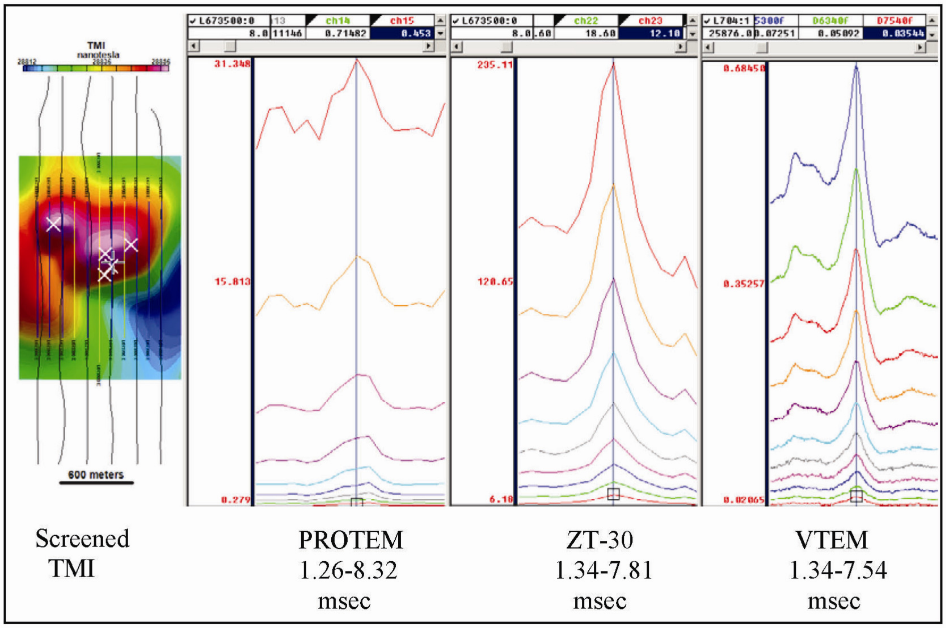
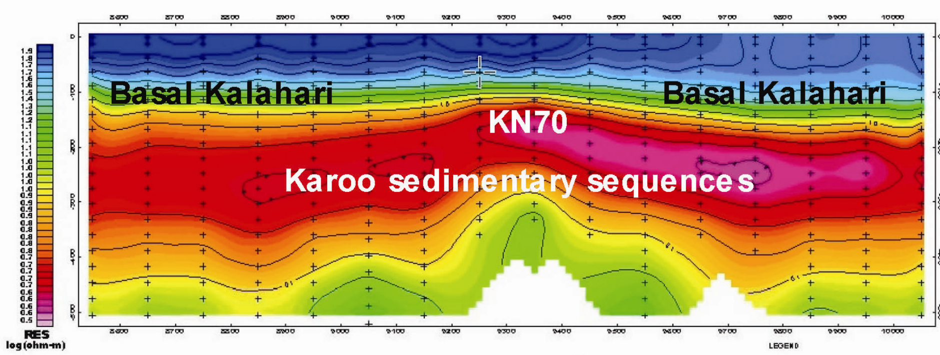
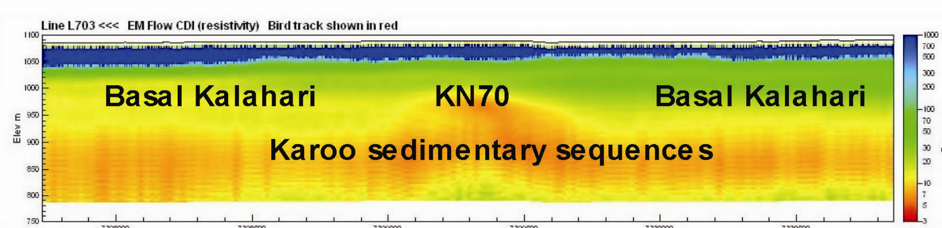


Figure 4. TEM-screened KN70 TMI grid leftmost panel with the PROTEM Ch7-15, ZeroTEM Ch14-23, and VTEM Ch17-27 dB/dT profile responses l-r respectively. The white crosses mark boreholes that intersected kimberlite. In all cases the three peak TEM response locations closely correspond, with the ZeroTEM and VTEM responses being the most similar.



KN70 Zonge ZT-30 CDI



KN70 VTEM EMFlow CDI

Figure 5. KN70 CDIs, the kimberlite models as an upward bulge at the basal Kalahari–Karoo sedimentary contact interface on both the Zonge and EMFlow models.

Large contiguous VTEM databases such as that used to create the grid in Figure 2 can be subset to the background area just surrounding the magnetic or gravity signature being screened, to enhance an often-subtle kimberlite VTEM response. Subset channel response grids can then be created from the small databases. KS34's subset VTEM response in Figure 6 illustrates why this is effective. When the larger VTEM dataset was subset for all 10 kimberlites in this case study, the VTEM screened the magnetic signatures as well as the ground TEM profiles in 9 out of 10 cases, and often screened the magnetic signatures as well as the ground gravity did. An alternative to data sub setting would be for the VTEM to fly small rectangular survey grids over pre-existing magnetic signatures as was done effectively over KN70, KE1, and K075.

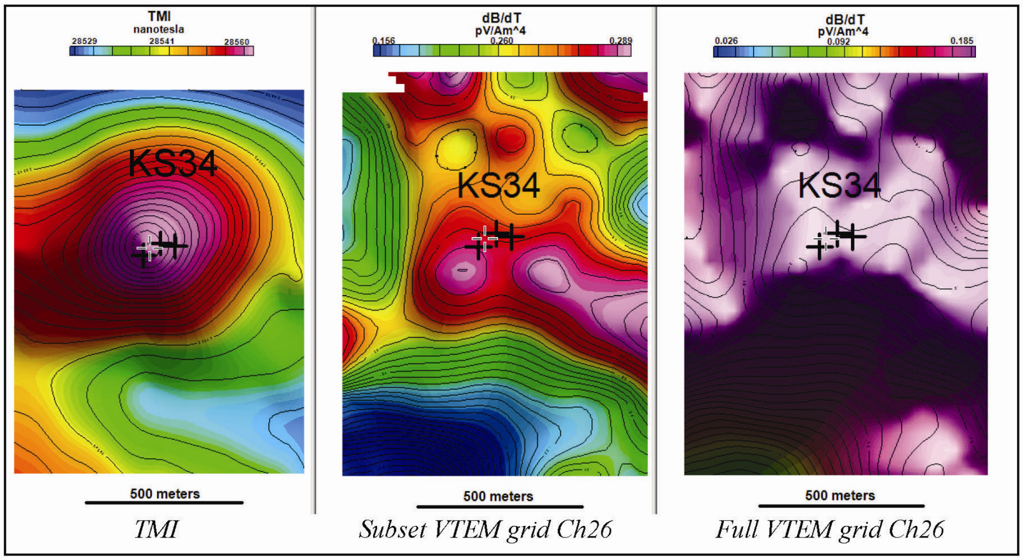


Figure 6. KS34 higher resolution VTEM grid (center panel) created from a subset VTEM database that just surrounds the magnetic signature being screened (left panel). Right panel is the coarser full VTEM dataset grid zoomed in on the magnetic signature. Crosshair in same spot on all images, with the three black crosses being boreholes that intersected kimberlite.

CONCLUSIONS

Ground TEM was as effective a method as ground gravity for the screening of magnetic signatures from kimberlite pipes overlain by 40-120 meters of Kalahari cover in the Kokong kimberlite field. The VTEM was as effective as the ground TEM method in 9 out of the 10 examples presented, and was often as effective a screening method as ground gravity surveying. The one kimberlite not as well mapped by the VTEM was the large KS40, a later-time conductor. For better magnetic signature screening, subset VTEM databases enhance the subtle late-time VTEM signatures of kimberlites covered by thick Kalahari sequence. An alternative to data subsets would be to fly small rectangles over existing magnetic signatures at survey time.

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