The anatomy and circulation of mine water in carbonatite mines with specific reference to kimberlite pipes.

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Abstract

Ground water occurrence and movement around and in Carbonatite mines, specifically diamond pipes, are dominated by three types of structures; first is the weak zone which allowed the carbonatite to be emplaced; second are the structures that opened when the emplacement occurred and third are the relaxation structures created by mining the ore body and country rock. The latter is described as a Zone of Relaxation (ZOR). They are all significant because they control the mechanism allowing the country rock water to enter the mine workings and are important components of the conceptual hydrogeological model. Knowledge and measurement of the three structural domains enable more accurate interception and control of the dewatering over life of mine. Generic domains are discussed, and examples are given from Finsch diamond mine, South Africa.

Keywords: Dewatering, inflows, kimberlite, Zone of Relaxation, ZOR, conceptual modelling, fracture flow

Introduction

Thirty-six years' experience and research has been consolidated into understanding the anatomy of the flow paths of water into deep and shallow mines over their life and closure. Often the ore body is a carbonatite that has been extruded into very old and hard rocks. The hydrogeology of fractured rocks (predominantly metasediments) is different to the hydrogeology described in most European and North American text books, which emphasize primary permeability in sedimentary aquifers.

Some of the main findings are the hydrogeological parameters of the country rock changes as the mine void allows relaxation of the country rock. This creates zones of relaxation and preferred pathways for ground water flow. This necessitates bespoke monitoring designs to ensure accurate and relevant measurement of hydraulic head.

In general, the mine hydrogeology changes over time and depth, and there are specific zones of relaxation with ground water flow along tensional structures, which require targeted dewatering techniques and detailed monitoring for effective and accurate mine water control.

The main applications of this research are in cost effective mine dewatering design for block cave mines and other deep mines; as well as in more intelligent monitoring of high walls and open pit development. Case studies are used to Illustrate the testing and measurement of ground water movement in highwalls, pit bottom and at the contact between the ore body and country rock.

Big Data techniques are used to design, install and implement automated multi probe monitoring systems, often linked to geotechnical monitoring systems. These assist the distinct levels of mine management including production, engineering as well as board level control and allow financial accountability.

Explanation

Understanding of the conduits for ground water flow into a mine has been developed through years of observation as mines developed from open pit to underground. Hypotheses were developed and tested using infiltration tests and packer testing. Results of specific tests are reported in Morton 2008.

The structure of the country rock initially determines the position of the emplacement of the carbonatite or ore body with the ore injection exploiting zones of weakness. For example, during kimberlite emplacement, the country rock is affected by the implosion of the pipe. During mining, the blasting of the excavation and the relaxation of the rocks into the mining void also alter the original country rock competence and therefore affect the hydrogeology. For hydrothermal emplaced ore bodies, the structural detail can be very fine with openings associated with each branch of stock work.

There are therefore three main structural sets of relevance when interpreting the hydrogeological regime of a mine:

The three types of structures are

1. The pre- emplacement crustal structure and concomitant regional lineaments
2. Structures created during emplacement. This includes the carbonatite-country rock unbonded contact, radial structures and intra-ore body structures between each intrusion
3. Structures created or opened during mining.

Figure 1 illustrates the three types of structures that control ingress of water

The pre-emplacement crustal structure can de determined from regional geological maps of the area and from aerial photo interpretation. Figure 2 shows the pre-cursors as-

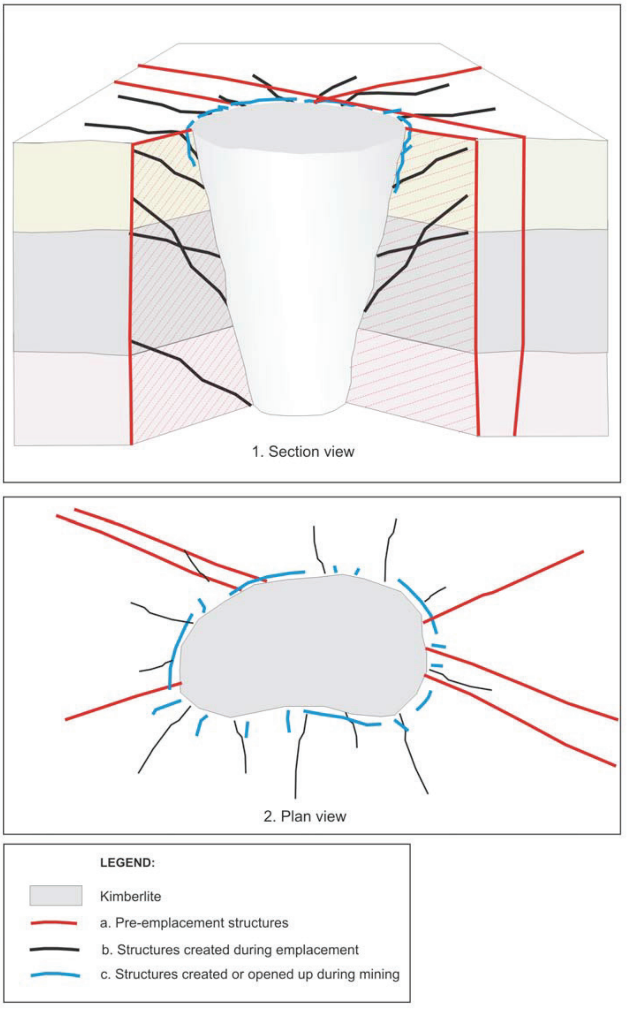

Figure 1 Three types of geological structures associated with carbonatite ore body mines.

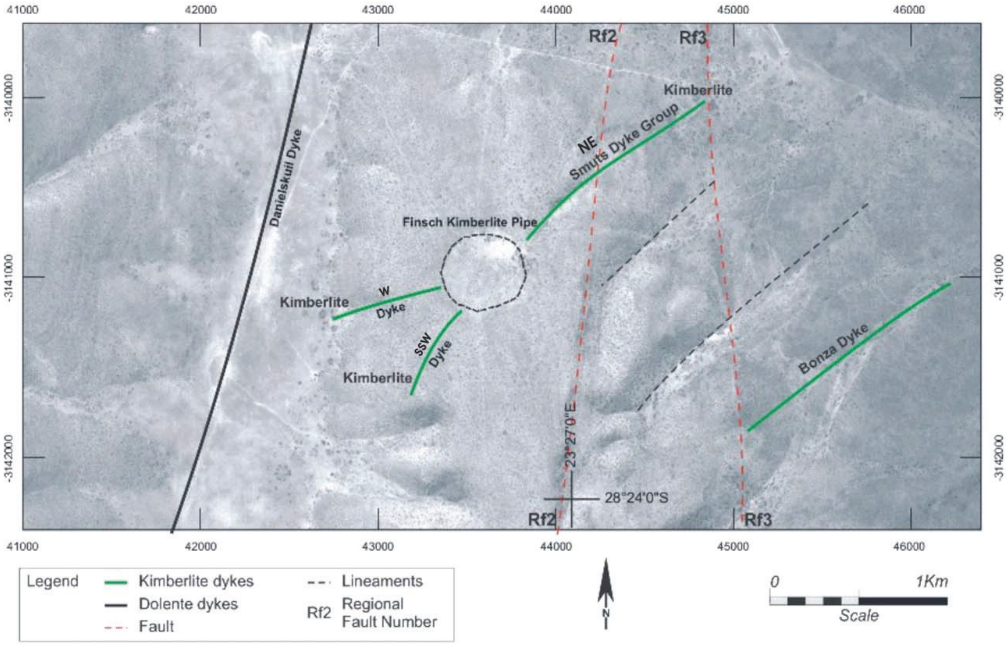

Figure 2 *Aerial photograph of Finsch kimberlite pipe and kimberlite dykes (pre-cursors) pre- mining 1959*

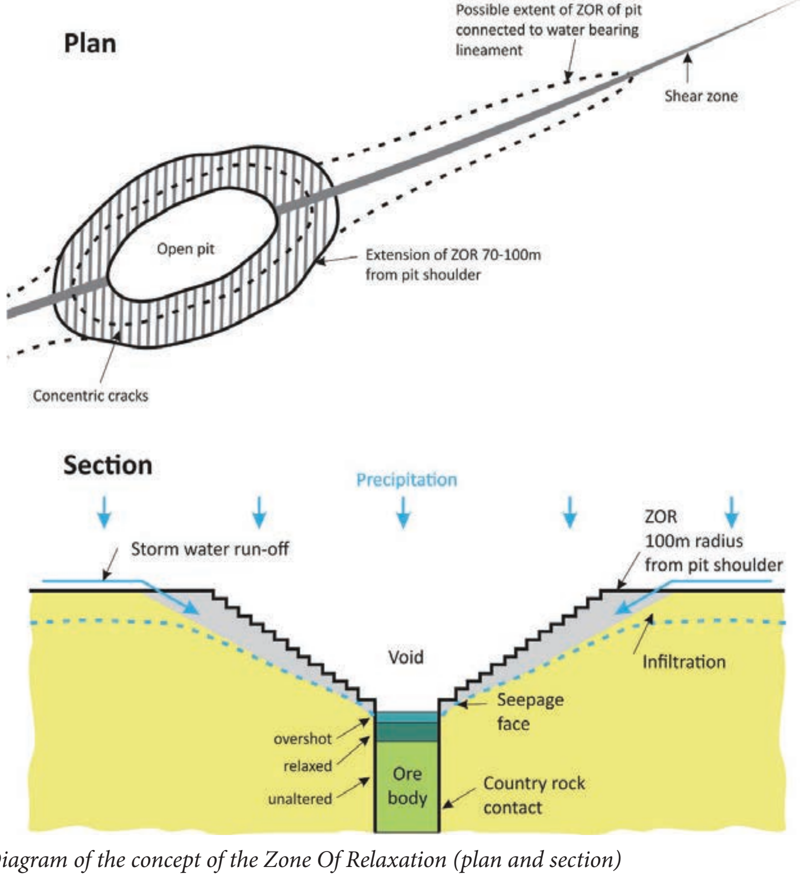

Figure 3 *Diagram of the concept of the Zone Of Relaxation (plan and section)*

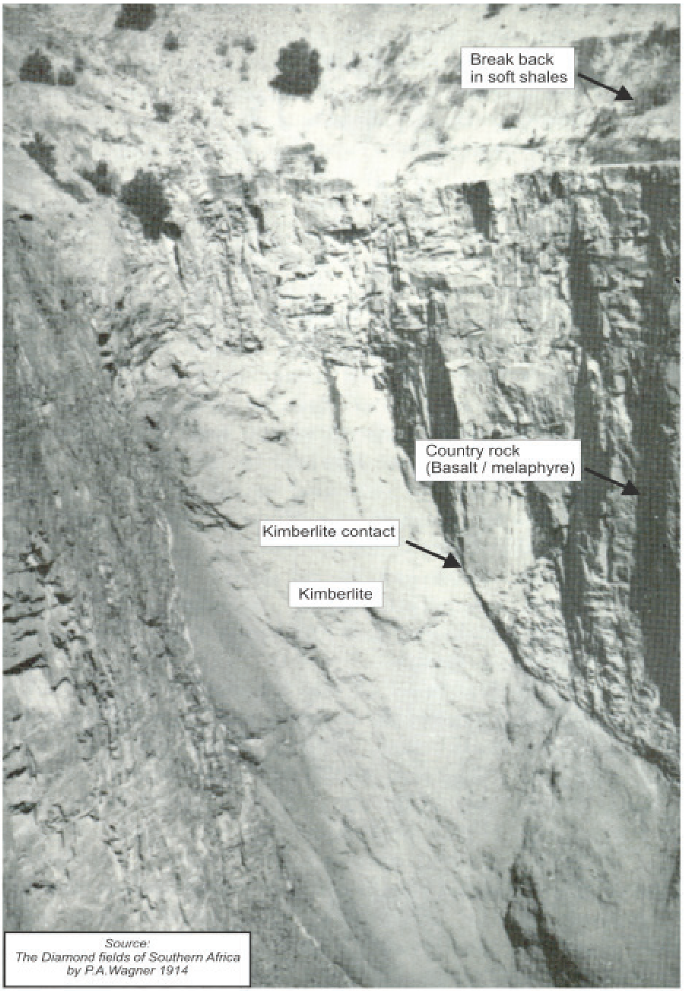

Figure 4 *Kimberlite pipe showing clear contact between pipe and country rock (Kimberley Mine) Wagner 1914*

sociated with the emplacement of the Finsch kimberlite pipe. Each precursor, when intercepted underground created a conduit for water inflow to the underground workings to 650m depth and below.

Once mining starts the rocks around the pit relax into the void, creating a circular wedge of transmissive rock. Figure 3 illustrates the Zone of Relaxation (ZOR) in plan and section.

Kimberlites have an unbonded contact with the country rock that when relaxed allows rapid movement of ground water.

The floor of an open pit is also connected to the ZOR and shows three layers of differing hydraulic conductivity;

1. The higher K overshot zone created by blasting, typically 3m – 5m thick
2. The relaxed rock beneath the pit floor, created by pressure release following the removal of the overlying weight of rock, typically 10m – 20m thick but dependent on internal structure and age of pit
3. The unaltered rock below

They are also illustrated in Figure 3. Packer and airlift tests done at Venetia Mine (Morton and Muller 2003) gave K values of the overshot zone that were 20 times higher than the unaltered ore body.

Figure 4 shows the unbonded kimberlite /country rock contact at Kimberley mine. South Africa.

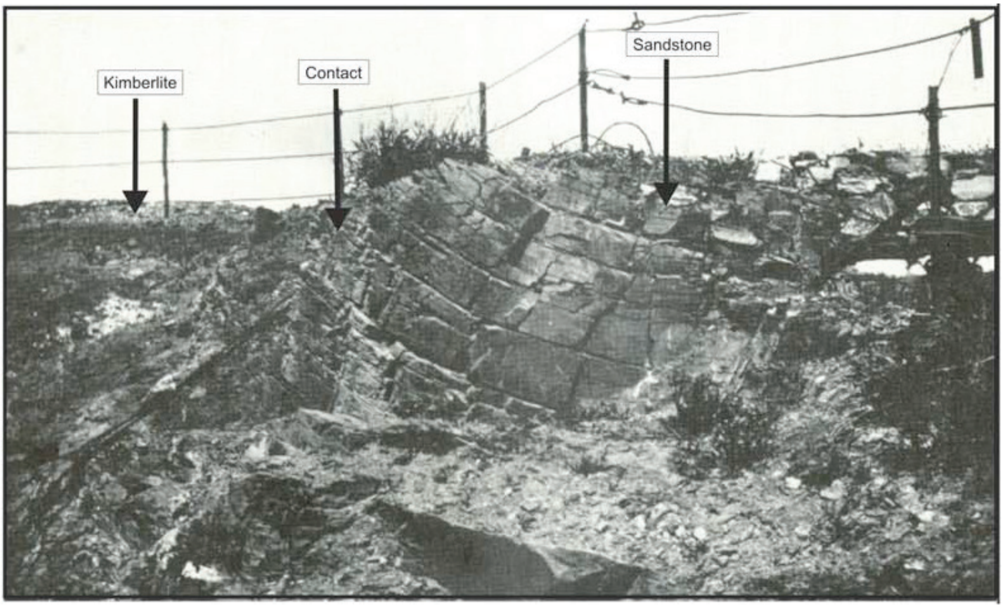

Figure 5 *Upturned sandstone at Jagersfontein (Source P.A. Wagner (1914)*

Figure 5 shows the upturned sandstone at Jagersfontein mine, South Africa created during emplacement. Figure 6 shows the wet contact at Jwaneng Mine, Botswana created by ground water movement along the open contact.

Figure 7 is the zone of relaxation observed in Finsch Mine open pit.

Packer testing done from underground at Finsch mine in horizontal core holes both inbound and outbound of the ring tunnels on 43 Level (430 mbgl), 59 Level (590 mbgl) and 65 Level (650 mbgl) showed decreasing hydraulic conductivity with depth (Morton 2008). This supported the hypothesis that the ZOR pinches with depth. Figure 8 shows the

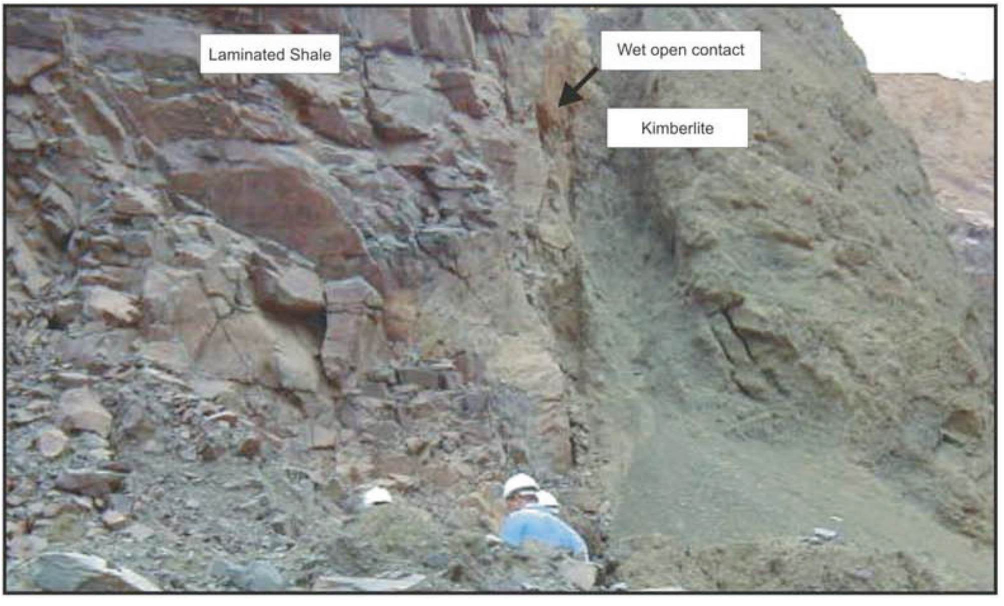

Figure 6 *Jwaneng Mine Zone of Relaxation and wet kimberlite contact (crater)*

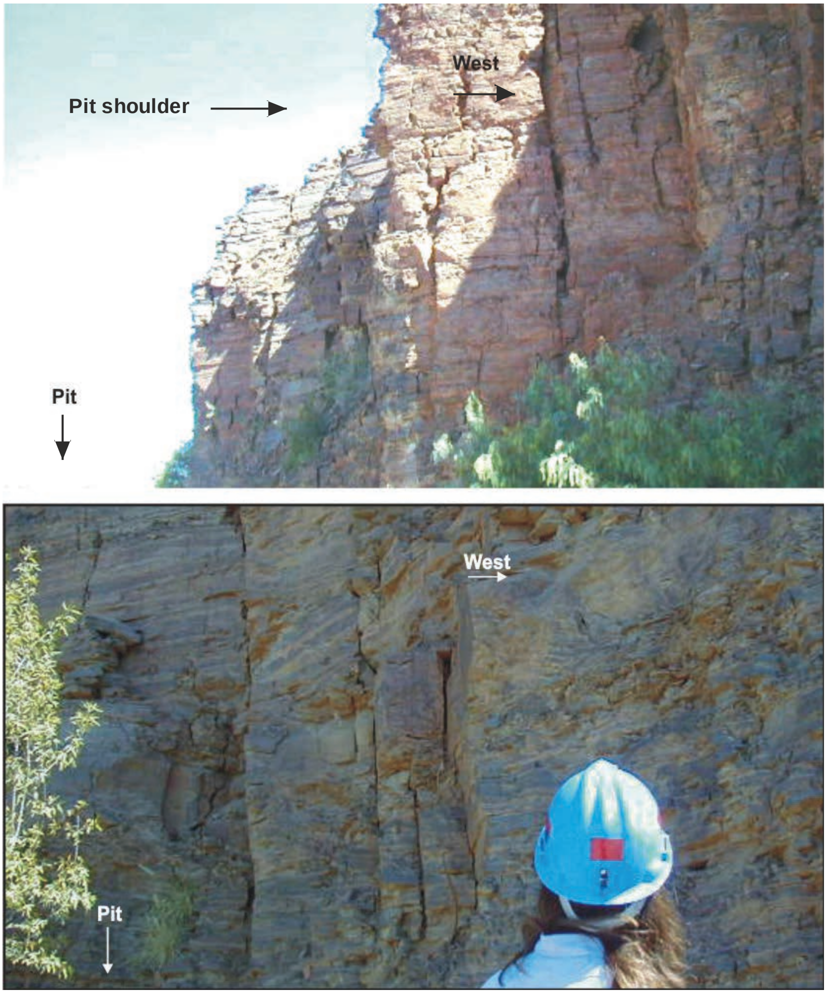

Figure 7 *Observation of the Zone of Relaxation (ZOR) in Finsch pit 2002*

location of the tested core holes underground in plan view.

Figure 9 gives the hydraulic conductivities and geology in section plotted from the tests conducted on 59 Level.

Knowledge of the three types of structures are useful for understanding then predicting inflows to a mine in a fractured aquifer, as it enables interception of the inflows, management of the water and accurate placement of monitoring devices. The monitoring devices can then be linked to dashboards to illustrate and quantify the effectiveness of dewatering, as well as link expenditure to success.

Conclusions

Experience in watching and monitoring the movement in mines over 35 years of their lives has shown the importance of understanding the flow paths that ground water (and surface water) follows into the workings. Three sets of structures have been observed at carbonatite mines; the weak crustal structures that facilitate the emplacement of the ore body, the structures created during emplacement and the relaxation structures created during mining. All three are important to plot, monitor and manage.

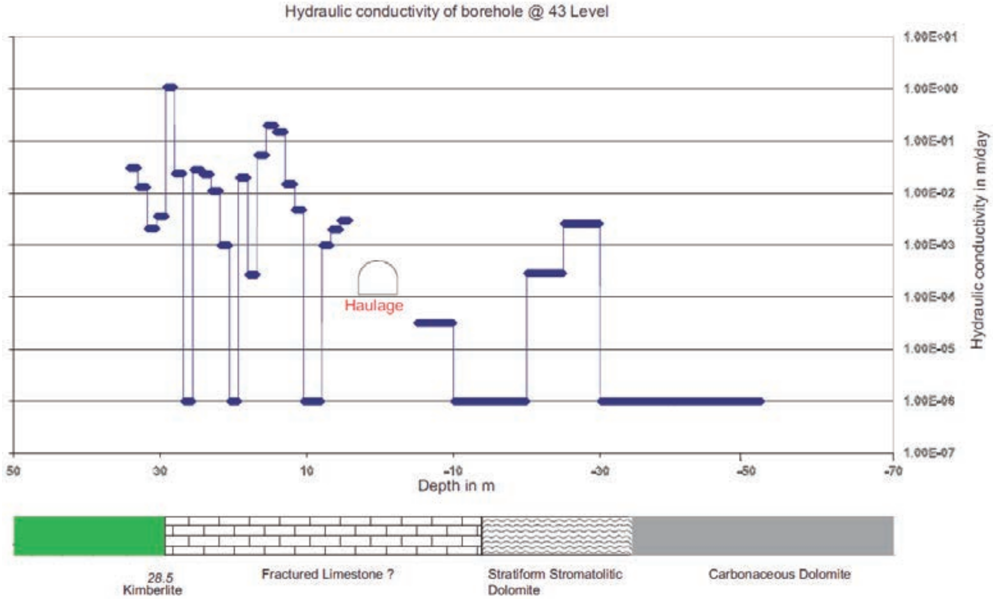

Figure 9 *ZOR core hole testing results for 43 level in section*

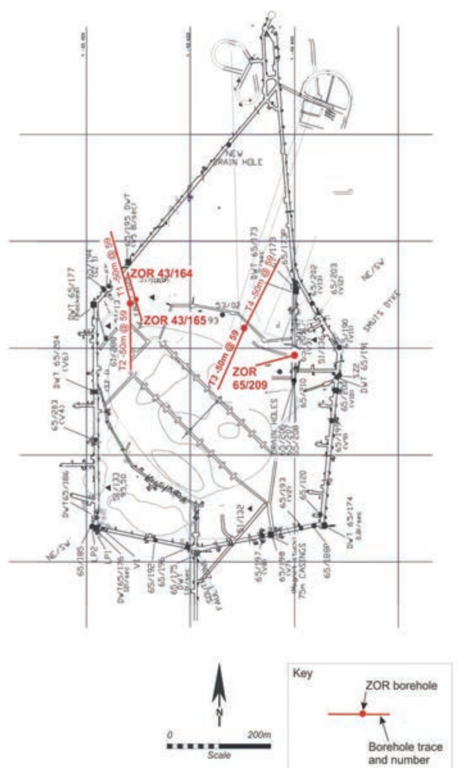

Figure 8 *Overlay of the horizontal packer tested core holes on 43,59 and 65 Levels.*

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References

Morton KL (2008) The Hydrogeology of Kimberlite Mines in Southern Africa with specific reference to Finsch Mine. PhD thesis, Imperial College, London University 439pp

Wagner PA 1914 (3rd Edition reprint) The diamond Fields of Southern Africa Struik Cape Town 355pp

Morton KL and Muller S (2003) The hydrogeology of Venetia Diamond Mine, South Africa, in South African Journal of Geology 106 Number 2/3 September 2003 pp193 – 204