Mine Dewatering Studies at Jwaneng Open Pit Diamond Mine - Botswana

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Abstract
The geological environment at Jwaneng Mine in Botswana is characterized by a complex faulting system that preceded the emplacement of kimberlite into the Transvaal sedimentary sequence. Mine dewatering studies at Jwaneng have previously focused on identifying water bearing structures on the faulting systems that transgress the current mine pit excavations and also on the hypothesis that dolomites occurring at depths in excess of 350 m are karstified. New information from the ongoing drilling program however suggests that the Jwaneng fractures associated with the faulting system may be dry. All boreholes that intersected dolomite at depth showed no evidence of karstification. The only evidence of seepage during the dry season is confined to the south sector of the open pit where the seepage face is as high as 150 m. Coincident with this phenomenon is the water bearing zone of over-break investigation borehole that yields approximately 2 m^3/h drained off by gravity. This borehole also happens to be the only yielding borehole out of the seven that were drilled to investigate the spatial extent of the stress relief relaxed zone resulting from open pit excavation. The only dewatering borehole for the mine, GH03, is also located more or less in the south sector of the mine pit. The Jwaneng (Mine) Resources Evaluation Project (JREP) boreholes have intersected high total dissolved solids (TDS) water on the kimberlite – country rock contact, particularly in the same area where evidence of seepage is prevalent. Treatment plants slimes dams are located some 300 – 400 m south of the mine pit. Preliminary chemical analysis of water from mine seepage, GH03, JREP 113 kimberlite – country rock contact borehole and process water indicate a somewhat similar chemistry with evidence of mixing with pristine regional groundwater. None of the preliminary analysis showed evidence of dolomitic water. Of striking interest is the main faulting system or structures that seem to directly underlie the slimes dam when extrapolated southward. An alternative conceptual model is suggested which proposes that leakage water from the slimes dam is conveyed via the localized faulting system to a highly permeable kimberlite/country rock contact zone where it meets with high TDS meteoric water in storage for centuries.

Key words: kimberlite, mine dewatering, karstification, seepage, relaxed zone, slimes dams, alternative conceptual model.

Introduction
Jwaneng mine is located in a region that forms part of the semi arid eastern Kalahari Desert in south – central Botswana with most of the area being covered by thick (50 to 80m) superficial deposits. The mine pit has a NE-SW orientation with long and short axes of 2.4 and 1.6 km, respectively. The bottom of the pit is currently at a depth of approximately 350 metres below ground level (mbgl) with a pit slope of 60^o on the northwest footwall and 40^o on the southeast hanging wall. The regional geology comprises a depositional sequence of dolomites, shales and quartzites laid down in Proterozoic times. Dolomites are well known karstified aquifer systems in Botswana and South Africa and it is for this reason that the initial conceptual hydrogeological model assumed them to be potentially water bearing and hence required investigations for active dewatering as mining progressed deeper. In the vicinity of the mine, the strata dip $20\text{-}40^o$ towards the northwest and the sequence is broken up by extensional shears, thrusts and steep block faults. The Jwaneng orebody itself comprises three kimberlite pipes (and a fourth minor kimberlite intrusion) that have intruded the host rocks along the predominant NE-SW trending steep fault orientation (De Beers, 2006). The extremely complex block geology of the country rocks, including the numerous fault zones described, require special attention with respect to slope stability in the highwalls during surface mining.

Objective
The primary objective of hydrogeological investigations was to build a conceptual hydrogeological model that would be the basis of a numerical flow model to be used primarily for assessment of open pit mine inflows and slope instabilities.

Key Observations

Borehole yields in the vicinity of the mine pit ranged from 0 – 12 m3/h with the exception of the only dewatering borehole at the mine, GH03 that had a cumulative yield of up to 45 m^3/h with most yielding boreholes located in the southern sector of the area. Boreholes that intercepted dolomite had low fracturing and did not show any evidence of karstification. A key observation was that only one borehole out of the six angled holes drilled to investigate the extent of the permeable relaxed zone behind the highwalls intercepted fresh water at the contact between the country rock and the kimberlite and it happened to be located on the south sector of the pit. Artesian conditions of brackish water have been encountered in a few pit bottom boreholes that intersected the contact zone at depth. A hydrocensus undertaken in a 15 km radius centered on the mine has confirmed that groundwater flow is from SE to NW (water table at an elevation of approximately 1050mamsl) with a cone of depression having developed around the mine. Water levels in the southern and eastern sectors of the mine pit however show elevated levels of up to 1100 mamsl. Permanent seepage occurring in the southern kimberlite pipe contact zones is visible all year round.

Most of the mapped structures underlie the Plant and slimes dams when extrapolated outward and it is therefore perhaps no coincidence that this sector of the pit is notably wetter than the other areas of the pit. Point piezometers installed coreholes located within the pit high walls show that potentiometric levels are decreasing with time due to the excavation of the pit, at a rate of between 50-70 m during one year. Shut-in pressure testing undertaken on two artesian coreholes located in the pit bottom indicate that the pressure head in that area was 6.27 m and 17 m, above the elevation of the top of the casing showing that depressurisation due to a combination of passive drainage and pumping GH03 had occurred to almost pit bottom elevations, in agreement with the a deep piezometer installed in the northern sector of the mine pit.

Shallow groundwater levels boreholes located close to the Naledi Valley could be associated with perched alluvial aquifers in the Kalahari beds. An assessment of the water balance figures for the mine 6.5 Mm^3 of process water was lost to evaporation and 2 Mm^3 to seepage (Debswana, 2007b). Most of this could flow into the pit as all the infrastructure is within the zone of drawdown induced by the mining. With re-circulation as high as envisaged, it may be anticipated that the seepage and GH03 water is a mixture of Jwaneng Northern Wellfield groundwater delivered to the plant for mineral processing needs, slimes dams seepage and process water as well as the minor groundwater associated with the Timeball Hill shales and quartzites. If the water inflows into the pit were due to the high head of the dolomites intruding along faults and joints through the shales, the seepage should have a similar chemistry to the dolomites. A review of the water quality data assisted in delineating the possible origins of the water inflows into the pit. Figure 1 shows a Piper plot of selected water samples with each representative of the possible sources of groundwater that could inflow to the mine pit. There are two distinct mixing lines apparent namely between the recently recharged wellfield water, the slimes, kimberlite water and the groundwater contaminated by the Plant process water (EH4).

Alternative Conceptual Model

The previous conceptual model figure 3(a) assumes that there were major inflows from the very large regional catchment via geological structures, with leakage along the kimberlite contacts, the relaxed zone and overshot zone within the pit. The dolomite, which occurs at 450mbgl, was thought to be karstified and hence expected to contribute to inflow as the pit deepens. The recharge to these dolomites was thought to be in areas where it outcropped to the south of the mine (Debswana, 2006).

An alternative conceptual model (figure 3(b) is being proposed which takes into account the likelihood that prior to the discovery of the Jwaneng DK2 pit, the topographical surface was a slight depression due to the preferential weathering of the kimberlite covered by a flat sequence of conglomerate, calcrete, silcrete and Aeolian sands. This would have resulted in enhanced infiltration of meteoric water over the centuries buiding high TDS prior to discovery of the pipe. Water levels and the mine water balance seem to suggest that there is active recharge to this contact and via leakage along faults connecting slimes dam with water being re-circulated into the pit as seepage flow from the high angle structures. The permeable faults themselves have passively been dewatered over time as mining excavations progressed. The shales and dolomites have been shown to be of very low primary permeabilities except in lithological contact zones near surface and also in zones where fractures have developed. The Naledi paleo valley is thought to be contributing to pit inflows via the semi perched alluvial sediments.

Figure 1 *Piper plots of water samples in the Jwaneng mine area, Debswana, 2007b*

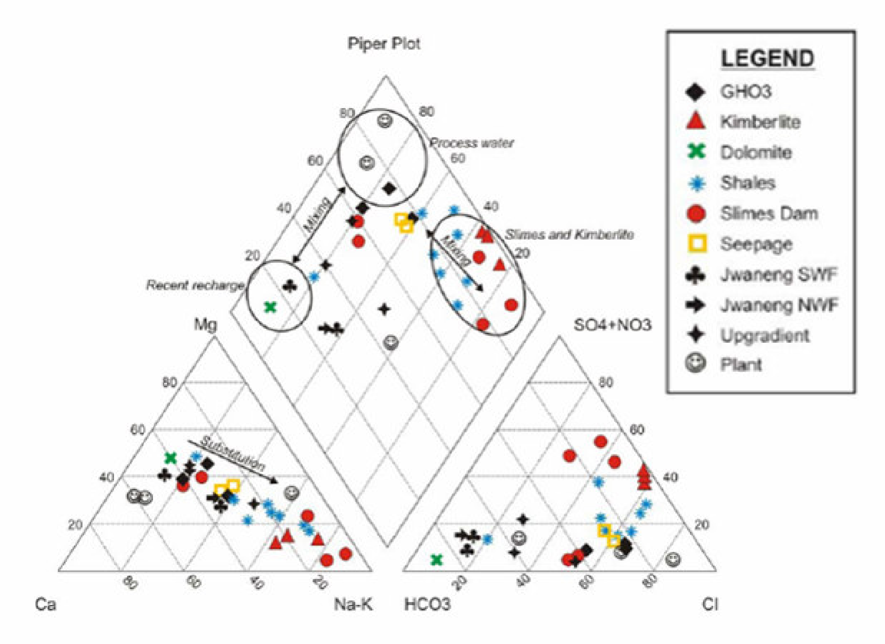
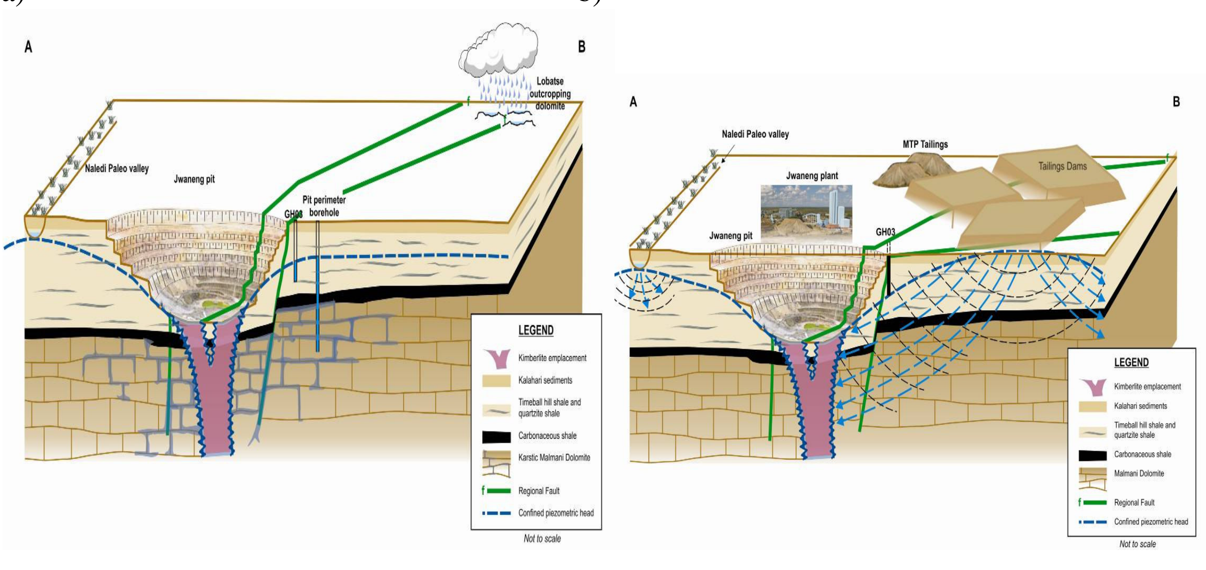


Figure 2 *(a) Initial conceptual model showing recharge areas in dolomite outcropping further south of the mine pit and the karstified dolomite beneath the mine and (b) Alternative conceptual model showing the slimes dams as a source of recharge with seepage being conveyed via permeable structures to the open pit. Source: Debswana, 2007b*

a) b)



Conclusion

The possible influence of surface sources of water have been taken into account in developing an alternative conceptual model for open pit inflows into Jwaneng mine. The new approach suggests that leakage from slime dams is conveyed via structures to a highly permeable kimberlite/country rock zone where it appears as highwall seepage. This leakage also contributes to recharge of the high TDS contact zone water in storage for centuries. Dolomites occurring at depth are unlikely contributing to seepages seen in the mine pit.

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