Induced sinkholes in the Rand mining field

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BOX 8.1. INDUCED SINKHOLES IN THE RAND MINING FIELD

The most catastrophic collapses of some of the world's largest sinkholes, and the greatest loss of life in any sinkhole disaster, occurred in one small area of dolomite karst in the Far West Rand district of Transvaal, South Africa, just south-west of Johannesburg. Events were due to an exceptional combination of a very mature karst, a thick soil cover and inducement by an unusually massive decline of the water table. Though the sinkholes have now been filled in (by vast quantities of readily available mine waste), the events of 30 years ago remain a classic within the field of engineering on karst (Brink, 1979; Swart *et al.*, 2003).

The Rand karst is formed in over 1,000 m of gently dipping, Proterozoic, impure, chert-rich dolomites. These are capped to the south by Karoo sandstones, and underlain by a thick lava sequence below which lie the sedimentary Witwatersrand Group with their gold-bearing conglomerates. The dolomite outcrop is over 10 km wide along the Wonderfontein valley (Figure 8.1.1), where the karst rockhead is buried beneath soils generally 10–100 m thick. Vertical syenite dykes each about 50 m thick break the dolomite aquifer into hydrologically discrete compartments, each originally drained by a valley-floor spring against its downstream dyke (Figure 8.1.1). The very old karst has matured into a complex terrain with a pinnacled rockhead, large buried sinkholes and many shallow

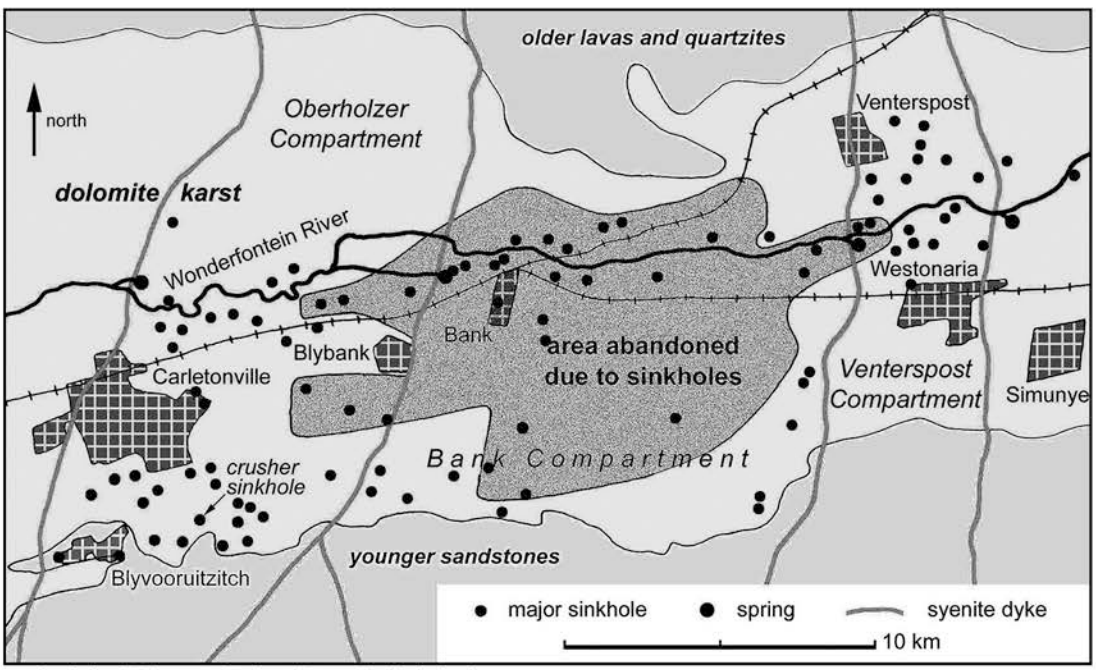

Figure 8.1.1. Map of the Rand sinkhole area.

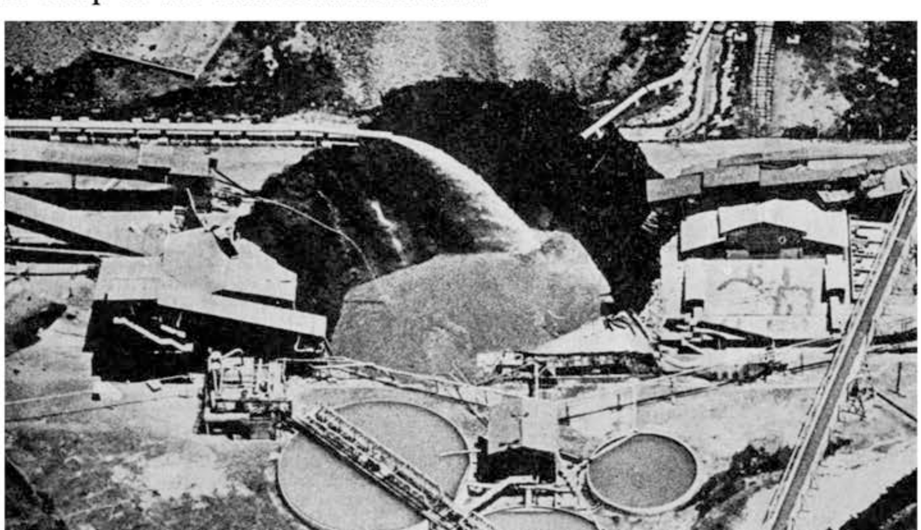

Figure 8.1.2. The subsidence sinkhole that engulfed the mine crusher plant in 1962.
Photo: Consolidated Goldfields.

phreatic caves; the original water table lay 2–26 m above the average rockhead level. Pumping records indicate that porosity in the 30 m below the original water table is up to 10%, largely in sub-vertical fissure caves, but this declines rapidly with depth to values of about 0.1% more than a few hundred metres down.

In 1934 the first successful deep mine worked the valuable gold deposits in the Venterspost Compartment, but encountered water problems as the workings extended beneath increasing areas of the karst aquifer. Massive de-watering was therefore instigated, and the calendar of events (Table 8.1.1) recorded major sinkhole development following major water table decline in each compartment as the mines extended through the goldfield. The worst single event was the sudden collapse of the sinkhole that destroyed the mine's crusher plant at West Dreifontein and killed 29 people (Figure 8.1.2). The plant had been built on a grouted soil mat where rockhead was 117 m deep in a buried sinkhole elongated along a fault in the dolomite. Over a period of three years, minor precursor movements were on a scale regarded as normal over the buried karst (De Bruyn and Bell, 2001), but suffosion must have developed significant soil voids within the fill of the buried sinkhole to allow the instantaneous collapse large enough to swallow the entire crusher building.

Six years later, the same mine was flooded to a depth of 800 m before an inrush of nearly 5 m^3/sec could be controlled by splendid emergency operations (Cousens and Garrett, 1970). A heading had reached through the Bank dyke, where stopes were opened with just 30 m of quartzite separating them from the dolomite karst aquifer, then undrained within the Bank Compartment. Fractures opened up in the de-stressed hanging wall to let the water into the mine. Stemming the flood saved the higher workings in the Oberholzer Compartment, but left those in the Bank Compartment totally flooded, and the only way to resume mining was by total de-watering of the Bank Compartment. It was appreciated that this would induce sinkholes within the compartment, but the foreseeable costs of the damage were outweighed by the value of the mineable gold. In the event, new subsidence and compaction sinkholes were very effectively induced, and a threat of major dropout sinkholes was recognised after drilling revealed large soil voids. Consequently, the Bank township was completely evacuated (Figure 8.1.1). Abandoned houses in the closed area were slowly destroyed (Figure 5.12) by differential compaction over buried sinkholes up to 70 m deep. The greatest compaction subsidence was recorded where the original water table was less than 30 m deep within the soil profile, and the prime site for new dropout sinkholes was over the steepest margins of the large buried sinkholes. The land remains undeveloped today, as the dolomite is still de-watered.

In subsequent years, new sinkholes have continued to develop throughout the de-watered buried karst. Five more people have died in dropout sinkholes around Westonaria; after each event, nearby houses have been demolished and the sinkholes have been filled – and have remained stable. By 1987, a recorded 271 sinkholes had an average volume of 9,000 m^3 – a spectacular testimony to the effects of unusually massive de-watering of a soil-covered karst.

Table 8.1.1. Calendar of events in the Rand karst followed de-watering in the three mined compartments.

Venterspost Compartment	
1957	*De-watering was largely completed*
1958	First sinkhole, 80 m across, collapsed in December
	Over the next 25 years, 165 more sinkholes occurred
Oberholzer Compartment	
1959	*De-watering was completed*
1962	29 people died when sinkhole 55 m across, 30 m deep, swallowed the crusher at West Dreifontein Mine
1963	Schutte's compaction sinkhole developed, reaching 180 m across after 3 years
1964	5 people died when a sinkhole 30 m deep collapsed beneath houses in Blyvooruitzicht
1966	*The water table had declined to 160 m below ground level*
	The largest of 8 sinkholes was 125 m across and 50 m deep in open countryside
	Over the past 4 years, 454 houses had been deomolished or evacuated
Bank Compartment	
1968	*The West Dreifontein mine was flooded where workings had breached the Bank dyke so that they were beneath the undrained karst aquifer in the Bank compartment*
1969	*De-watering was largely completed in the first 6 months*
1970	Bank township was evacuated in January, the road was closed and the railway made freight-only, after large compaction sinkholes developed and soil voids were found
1971	*The water table had declined to 300 m below ground level*
1975	The railway through Bank was reopened to passenger traffic; 8 days later a train was derailed into a sinkhole 20 m wide and 7 m deep