JUST ADD WATER

Kimberlite is the host rock of natural diamonds, but it is a complex rock reflecting its violent past as a volcanic pipe. Here it would blast the diamonds up from deeper than 120 kilometres below the earth's surface. Not all kimberlites are the same and differ in the diamonds they contain. Some 94% of kimberlite pipes do not have significant diamond contents. After the kimberlite pipe blasted through the earth's crust, cooled and solidified, the minerals were further changed through slow weathering.

→ *Some types of kimberlite rock (left) disintegrate within three hours of immersion in water. The photograph on the right shows particles of another kimberlite that was immersed in water for six days with no disintegration. The particles are approximately 20 mm across.*

When kimberlites are mined and processed to extract diamonds, the differences in mineral content give different physical properties, as can be seen from the photographs of the kimberlite rocks. Some kimberlites literally fall apart within a few hours of immersion in water. This causes unwanted fine material to form that must be separated laboriously from the processing water to allow the water to be recycled.

Kimberlite that disintegrates in mines can lead to dangerous mudflows, yet some kimberlites appear to be immune to this disintegration.

Understanding the differences in the composition of kimberlites that cause their behaviour to differ this much was the task of doctoral student Jacqueline Morkel from the University of Pretoria's Department of Materials Science and Metallurgical Engineering.

Of all the many different kinds of minerals in kimberlite rocks, clays turned out to be the key – specifically swelling clays. As the name suggests, swelling clays expand when exposed to water.

All clays consist of submicroscopic parallel sheets that contain oxides and hydroxides of silicon and aluminium. In swelling clays, charge imbalances trap metal cations between the sheets. These cations attract water molecules into the interlayer. The entry of the water molecules then separates the sheets, giving large expansions (around 20% in the first step) in the direction perpendicular to the sheets.

These expansions are large and the pressure exerted by the swelling clay can be high, with values of up to a thousand times atmospheric pressure being quoted.

The internal stresses generated by the swelling clays are thought to be the cause of the disintegration of some kimberlites when they are immersed in water. If this is so, there should be a relationship between the swelling clay content of kimberlites and their tendency to disintegrate.

Morkel found exactly such a relationship with kimberlites that contain more swelling clay undergoing more severe disintegration (but with some scatter in the relationship), indicating that there is scope for further work to understand the detail of the fracture behaviour of clay-containing kimberlite.

Water is the answer
Understanding the behaviour is important. An engineer wishes to go beyond understanding, to influencing behaviour. Morkel showed that this could be done.

Given that the origin of swelling is the metal cations that sit between the clay layers, changing these cations will affect swelling. Swelling clays can exchange the interlayer cations with others from the surrounding solution. So, if the kimberlite is placed in water that contains dissolved salts, the expansive tendency of the swelling clays in the kimberlite should change – giving more or less disintegration. Both are possible. If the interlayer cations are replaced with potassium ions, the swelling tendency is significantly reduced. The resulting decrease in disintegration is potentially the basis of a practical treatment to slow down the collapse of mine tunnels that pass through kimberlite.

The opposite is also possible: with the right choice of salts, disintegration can be enhanced. While disintegration of the kimberlite is an unwanted effect in the normal processing route, a novel processing route may take advantage of this. Instead of crushing the kimberlite rock, the kimberlite can simply be soaked in water (with appropriate added salts), using the internal forces within the kimberlite to break it apart.

This would have two notable advantages. Firstly, mechanical crushing requires a substantial amount of energy (and hence electricity consumption) and it would be advantageous to reduce this.

Secondly, there is a definite danger of fracturing diamonds when the rock is crushed. Much effort is already expended to try to limit this in diamond processing by, for example, using high-pressure grinding rolls instead of conventional crushers. The danger of diamond breakage would be largely eliminated if the kimberlite disintegrated of its own accord, without applying external forces. These ideas are being explored in further projects.

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SLEEPING EASY IS A WEIGHTY MATTER FOR NEWBORNS

Displaying the functioning of the apnoea/weight monitor are (from left to right): Prof. Johan Hanekom (Head: Bioengineering Group, University of Pretoria), Adrian Eeldeers and Prof. Tania Hanekom (project supervisor).

Two of the most pressing concerns for parents of newborn babies are the detection of sleep apnoea, which could cause sudden infant death syndrome (SIDS), and monitoring the baby's weight to assess growth.

A project to combine the monitoring of both sleep apnoea and body weight was lead by Prof. Johan and Prof. Tania Hanekom of the Bioengineering Group of the University of Pretoria's Department of Electrical, Electronic and Computer Engineering. The system was designed and developed by final-year electronic engineering student, Adrian Eelders.

The main technical challenge was developing a completely non-invasive breathing sensing system that required no connections to the baby and which could also weigh the infant. The device is mounted in a cot system that uses sensors (coil pairs with driven electronic circuitry) embedded in a mattress to detect breathing signals. Weight is measured by monitoring the air pressure in cushions beneath the base of the mattress. All signals are digitally processed by a mixed signal processor. The system has a digital user interface that switches between apnoea detection and weight assessment.

The apnoea monitor is able to detect central apnoea conditions and normal breathing. Alarms are sounded if an apnoea condition occurs, if the infant moves off the mattress sensors or if a power failure occurs. The scale can produce measurements accurate to within 20g. The maximum weight that can be measured is 15kg.

The specifications of the scale make it possible to monitor both the baby's weight and the amount of food given during a feeding, which is always a concern for mothers who breastfeed their infants. The system is also suitable for use in surgical veterinary applications.

For more information on the work of the Bioengineering Group, contact Prof. Johan Hanekom at johan.hanekom@up.ac.za or Prof. Tania Hanekom at tania.hanekom@up.ac.za or go to www.ee.up.ac.za.