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Technical Note

The influence of potassium on the weathering properties of kimberlite and the information provided by different testing methods

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1. Introduction

Kimberlites are described as ultrabasic igneous rocks that occur as volcanic pipes, dykes and sills [1]. The minerals and mineral groups present in kimberlites vary widely and can include from trace to predominance any of the following minerals or mineral groups: apatite, calcite, chlorite, diopside (pyroxene), feldspar, magnetite, monticellite, olivine, phlogopite (mica), perovskite, quartz, serpentine, smectite and talc. It has been shown that kimberlite is prone to weathering when smectite minerals are present [2] and that weathering correlates with the abundance of smectite. Cation exchange takes place in smectites and changes the mechanical properties of the kimberlite [3–6]. K^+ is one of the few cations that collapse the swelling clay interlayer of smectites [7–9]. The collapsing capability of K^+ in smectite minerals is investigated in this paper to evaluate the effect on the mechanical properties of kimberlite This paper furthermore investigates different tests for evaluating the degradation properties of kimberlite.

2. Experimental work, results and discussion

2.1. Material

For this study, kimberlite samples were obtained from the Venetia, Dutoitspan and Cullinan Diamond Mines of De Beers Consolidated Mines in South Africa. A sample of Red Kimberlite was obtained from Venetia Diamond Mine, while Dutoitspan provided a Tuffisitic Kimberlite Breccia (TKB). Two TKB kimberlites were collected from Cullinan Diamond Mine from Level 717, Tunnel (T)24 and T66N (north). The kimberlites are named Venetia Red, Dutoitspan, Cullinan T24 and Cullinan T66N. The samples were received as large blocks 20–30 cm in length and width, and 15 cm high. Samples were prepared according to the requirements for each testing method. Mineralogical characterisation of these kimberlites was conducted utilising XRD to confirm the presence and abundance of smectite.

2.2. Particle size distribution

A particle size distribution (PSD) before and after a weathering test could give an indication of the extent of weathering/degradation that took place. For this test a 1.5 kg Dutoitspan kimberlite sample (lumps) was sized in the $-16+13.2$ mm size fraction after crushing. This sample was exposed to distilled water and a 0.05 M potassium chloride (KCl) solution for six days. Tests were performed at room temperature in 10 L flat-bottomed plastic containers using 5 L solution. The particles were spread as a single layer, not touching and no dispersion took place. The weathered samples were removed from the water/medium after the weathering period and left to air dry for one day. The dried sample was sieved and a PSD curve obtained.

The PSD for the distilled water and 0.05 M KCl solutions are shown in Fig. 1. For comparative purposes the PSD curve can be cut at a constant sieve size to report a single data point as output. The cumulative % passing at 10.3 mm is 20.8% in the distilled water compared to 7.5% in the potassium (K^+) solution. K^+ shows an inhibiting effect on kimberlite weathering, which can be demonstrated by a PSD. The output of a PSD is complicated, as it

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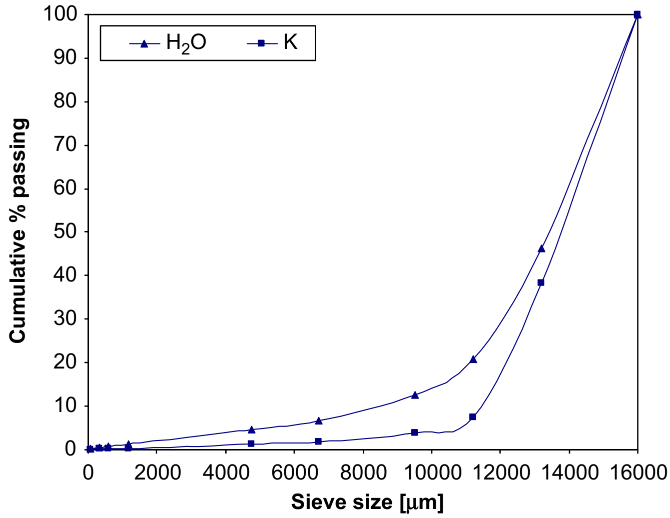

Fig. 1. The particle size distribution for a 1.5 kg Dutoitspan kimberlite sample (−16 + 13.2 mm) weathered in distilled water and a 0.05 M KCl solution for 6 days.

is a data series instead of a single value. The other disadvantage of this method is that different kimberlite types will not be comparable if different particle sizes are used. This is an easy and inexpensive test, which can be done in-house rather than utilising commercial laboratories. This specific test was performed in six days, but the time can be reduced in some instances. The other advantage of this test is that it can be adapted to fit the specific requirements.

2.3. Slake durability index test

The slake durability index (SDI) test combines the effect of cyclic swelling and abrasion to accelerate the rate of weathering, which enables measuring the resistance of the rock to physical, mechanical and (to some extent) chemical weathering. A study by Gökçeoglu et al. [10] found a correlation between the SDI of the clay bearing rocks and the expandable clay minerals. This indicates possible correlation between kimberlite weathering and SDI since smectite (expandable clay) determines kimberlite weathering [2].

This test was standardised by the American Society for Testing and Materials (ASTM D4644-04). The sample is rotated in a steel mesh drum partially immersed in water for 10 min (~200 rotations); with oven drying for 8–12 h at ~80 °C between slake cycles. These steel drums are made of sieve mesh of 2 mm, allowing all particles smaller than this to pass into the water bath. The SDI is defined as the percentage of the final weight (>2 mm) compared to the initial dry weight [10]. SDI values are normally categorised (see Table 1) to provide a simple weatherability classification for ores.

The SDI test unit utilised for test work is located at the De Beers Ground Support Laboratory in Johannesburg, South Africa. The kimberlite samples were crushed

Table 1
Defining the slake durability index values

Amount of slaking	Slake durability index (%)
Very low	0–25
Low	25–50
Medium	50–75
High	75–95
Very high	95–100

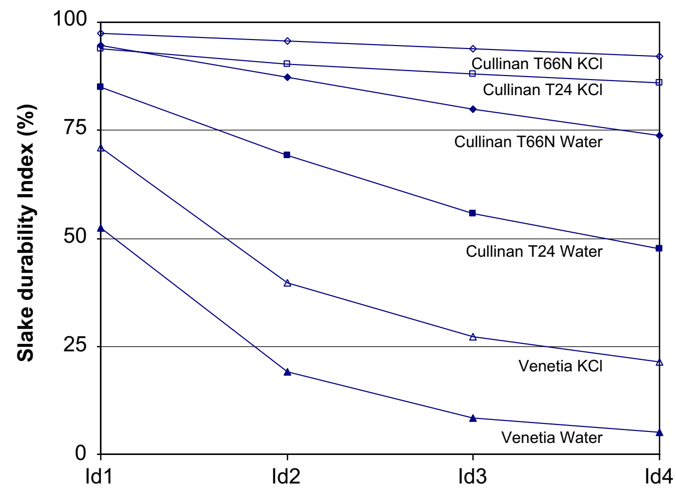

Fig. 2. Slake durability index test results for Venetia Red, Cullinan T24 and Cullinan T66N in distilled water and a KCl solution.

to pieces in the order of 3 cm and 400–600 g utilised per test. Venetia Red kimberlite was exposed to the SDI test in distilled water and a 1.0 M KCl solution whilst Cullinan T24 and T66N samples were exposed to distilled water and a 1.5 M KCl solution. These tests utilised four cycles, drying for 1 day at 80 °C between each cycle and reporting the weight loss during each cycle.

The SDI results are shown in Fig. 2. The SDI of Venetia Red kimberlite was improved from ~5% to 20% with the addition of K^+ to the test solution (after the fourth cycle). SDI results for Cullinan T24 kimberlite was improved from ~48% to 86%, and Cullinan T66N was improved from ~74% to 92% in the presence of K^+ cations.

The SDI test was also utilised to investigate the influence of K^+ concentration, results are shown in Fig. 3. The SDI of Venetia Red kimberlite was improved from 5% to 19% in a 0.5 M K^+ solution, and to 22% in a 1 M K^+ solution. Increasing the K^+ concentration improved slaking behaviour in this case. The Cullinan T24 SDI result is the same for both concentrations with an increase of ~40% compared to distilled water.

The SDI test can evaluate kimberlite weathering and is an easy and cost effective test. It does, however, take a few days to perform due to wetting and drying cycles.