Kimberlite Weathering: Mineralogy and Mechanism

By

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ABSTRACT

The aim of this study was to arrive at a fundamental understanding of kimberlite weathering and of factors which affect the rate and extent of weathering. Weathering was evaluated by measuring the change in size distribution after immersing crushed kimberlite in solutions of various compositions. Reproducibility of the measurements was found to be good, with the cumulative mass passing a given size differing by 7% or less, as tested for various weathering conditions.

Kimberlite mineralogy, specifically the swelling clay content, was found to play a central role: kimberlite ores containing no swelling clay were not prone to weathering under any of the conditions tested.

The cation exchange capacity (CEC) correlates well with the swelling clay content and with the weathering behaviour. The cation exchange capacity may be used in conjunction with the swelling clay content, as a predictor of possible kimberlite behaviour; however, given the relative complexity and cost of measuring swelling clay content (by X-ray diffraction), the CEC is the preferred parameter for practical use.

Cations in the weathering solution have a strong effect on kimberlite weathering; the strength of the effect followed the series Cu^{2+} > Li^{+} > Fe^{2+} > Ca^{2+} > Fe^{3+} > Mg^{2+}, whereas K^{+} and NH_4^{+} stabilised the kimberlite somewhat against weathering. This sequence was in reasonable correlation with the ionic potential (ratio of valency to ionic radius), but with exceptionally strong weathering effects of Cu^{2+}, and (to a lesser extent) of Li^{+} and Fe^{2+}. The strong effect of the latter group of cations may be related to their tendency to adsorb onto other crystal sites in addition to the interlayer – the associated change in surface energy can change the fracture behaviour of the kimberlite.

Measurement of the layer spacing of the swelling clay (by X-ray diffraction) showed no correlation between the weathering effect of a cation and the associated thickness of the interlayer. For solutions of cupric ions, the identity of the anion (chloride or sulphate) has little effect on weathering. The size of the crushed kimberlite ore similarly has little effect on the relative extent of size degradation by weathering.

The concentration of cupric ions affects weathering, as does the weathering time – although 85% of the weathering caused by 30 days' exposure was found to occur within the first 24 hours. Increasing the temperature to 40°C (in a magnesium chloride solution) also increased weathering strongly. The kinetics of exchange of cuprous and potassium ions was measured (for two different kimberlites); the apparent reaction order (with respect to the concentration of exchanging cations in solution) varied between 1 and 3.5, and exchange of potassium was more rapid.

This work has practical implications for in-plant processing of kimberlite, possible alternative kimberlite processing routes which eliminate one or more crushing steps, and for the stability of mine tunnels which pass through kimberlite.

KEYWORDS: Kimberlite, weathering, swelling, mineralogy, clay minerals, accelerated weathering, cation exchange

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My wish is that this study will really improve the understanding of weathering and the impact thereof on kimberlite material. I hope wholeheartedly that this goal was achieved.

Heb 13:21 May God make you perfect in every good work to do his will, working in you that which is wellpleasing in his sight, through Jesus Christ; to whom *be* glory forever and ever.

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ABBREVIATIONS

XRD: X-Ray Diffraction
XRF: X-Ray Fluorescence
Cpht: Carats per hundred tons of ore
ESP: Exchangable Sodium Percentage
CEC: Cation Exchange Capacity
REE: Rare Earth Elements
TKB: Tuffisitic Kimberlite Breccia
HYP: Hypabyssal Kimberlite
ppm: Parts per million
s: Seconds
μm: micrometer

LIST OF APPENDIXES