JOHN RAKOVAN
Department of Geology
Miami University
Oxford, Ohio 45056
rakovajf@muohio.edu

Kimberlite

One of the best preserved dikes—and possibly the first found—is currently located in a parking lot on Green Street in downtown Syracuse, New York.

My guess is that the number of mineral collectors who recognize the term *kimberlite* is far out of proportion to the abundance of this unusual rock type. This, of course, would be the result of the enchanting treasure found in many kimberlites: diamonds!

Kimberlite is an igneous rock that is chemically rich in potassium (ultrapotassic), iron, and magnesium and poor in silica (ultramafic). The magmas from which kimberlites crystallize are also rich in dissolved CO_2 and H_2O. Mineralogically, kimberlite's primary constituents are olivine, phlogopite, pyroxene, and garnet. It commonly contains a variety of unusual minor and trace minerals including ilmenite, chromite, perovskite, apatite, and sometimes diamond. Scientists distinguish several different types of kimberlites, based on their exact mineralogy and chemistry.

Kimberlitic magmas form within Earth's mantle, usually at depths between 150 and 450 kilometers. Their formation is the result of partial melting of a mantle rock known as *peridotite*, which is mineralogically composed of olivine, pyroxene, and minor garnet. When kimberlitic magmas ascend from their places of origin to Earth's surface, eventually erupting as a kimberlite volcano, they often entrain pieces of unmelted mantle; thus, they are one of our primary windows into Earth's interior (Dawson 1980). These fragments of unmelted mantle are classified as *xenoliths* (rock fragments) and *xenocrysts* (single crystals or fragments thereof). Diamonds found in kimberlites are xenocrysts. This term, meaning "foreign crystal," indicates that diamond did not crystallize from the kimberlitic magma. Rather, the magma formed below the depth of diamond formation and only acted as a transport agent as it rose through the mantle and crust. Some kimberlite magmas may have originated above that region of the mantle where diamonds form (at a depth of less than 150 kilometers). Thus, as they rose to Earth's surface, they did not encounter any diamonds to carry with them.

Once at Earth's surface, kimberlitic magmas will explosively erupt; however, some will crystallize in the conduits through which the magma ascended. In the region just below a kimberlitic volcano, a conical-shaped pipe called a *diatreme* is formed (Rakovan 2006a). In the diatreme zone, kimberlite is found highly brecciated and mixed with fragments of country rock as well as the xenoliths and xenocrysts of mantle and deep crustal origin (fig. 1). Below this, kimberlitic dikes and sills are encountered (Mitchell 1986) (fig. 2). No one has ever seen the eruption of a kimberlitic volcano. Two of the more intriguing aspects of these rare geologic features are the predicted rates of magma ascension and their eruptive force. The presence of diatremes, even in very strong country rocks such as granite, indicates an extremely energetic eruptive nature. One of the key observations related to the rate of kimberlitic magma ascension is that diamonds are brought to Earth's surface without transforming to graphite. At low pressures found near Earth's surface, diamond is not stable; rather, graphite is the stable polymorph of carbon. Given enough time, a diamond at these conditions will undergo a phase transformation to graphite

Figure 1. **Core sample of a diatreme breccia from the Riley County kimberlite, Kansas. John Charlton photo, courtesy of the Kansas Geological Survey.**

Dr. John Rakovan, an executive editor of Rocks & Minerals, *is a professor of mineralogy and geochemistry at Miami University in Oxford, Ohio.*

Figure 2. **Kimberlite dike with xenoliths of the surrounding country rock, Ithica, New York.**

(Rakovan 2006b). At the high temperatures found in kimberlitic magma, such transformations will happen much more rapidly. Thus, because diamonds are found at Earth's surface, we know that they had to have been transported at rates that exceeded the rate of the diamond-to-graphite transformation at high temperature. There have been numerous predictions of the speed involved—for example, 70 kilometers per hour (Meyer 1985)—but one thing is certain: they must have been extremely fast compared to the ascension rates of other, more common magma types (fractions of a kilometer per year to kilometers per ten thousand years).

The name *kimberlite* is intimately interwoven with the history of diamonds and their discovery in South Africa. The first diamond-bearing kimberlite was found in 1869 on the Bultfontein and Dorstfontein farms, also known as Dutoitspan, close to the original alluvial discoveries where the Vaal, Orange, and Riet rivers meet (Mitchell 1986). Although it was soon afterward realized that the rock now known as kimberlite was probably the original source of diamonds, and thus was of great economic importance, very little attention was paid to its mineralogy and chemistry. In 1886, Henry Lewis presented the first mineralogical description of the rock as a porphyritic, mica-bearing peridotite of volcanic origin (Lewis 1887). Based on nomenclature conventions of the time, the rock was named after Kimberly, South Africa. That area, composed of Colesberg, New Rush, and Vooruitzigt, derives its name from Lord Kimberly, the British secretary of state for the colonies at the time.

Contrary to popular belief, the first discovery of kimberlite was not from the Kimberly region. It was not even from the African Continent. As early as 1837, "mica-peridotites" had been found in the Manheim, Ithaca, and Syracuse areas of New York State (Vanuxem 1837; Williams 1887). Soon afterward, similar rocks were found in Kentucky at Ison Creek. It is only with more recent studies that both of these occurrences have been found to be true kimberlites. To date, roughly eighty-two kimberlitic dikes and two small diatremes have been found along a northeast-southwest lineament between Syracuse and Ithaca (Martens 1924; Kay and Foster 1986). These are collectively known as the Finger Lakes kimberlites. One of the best preserved dikes—and possibly the first found—is currently located in a parking lot on Green Street in downtown Syracuse. U-Pb dating of perovskite from two kimberlite dikes in the Ithaca area gave ages of 147.5 +3 and 146 +1.9 Ma (Heaman and Kjarsgaard 2000). Kay et al. (1983) propose that the magmas associated with the Finger Lakes kimberlites may have formed at depths less than 100 kilometers, based on xenolith and xenocryst assemblages. This is one possible reason for the absence of diamonds in these kimberlites. Interestingly, if the New York kimberlites were recognized at their discovery as the unique rock type that they are, then this column may have been titled Word to the Wise: "Ithacaite."

ACKNOWLEDGMENTS

I thank Elizabeth Widom and Marian Lupulescu for their reviews of this column and Marian for his suggestion to write it.

REFERENCES

Dawson, J. B. 1980. *Kimberlites and their xenoliths.* New York: Springer-Verlag.

Heaman, L. M., and B. A. Kjarsgaard. 2000. Timing of eastern North American kimberlite magmatism: Continental extension of the Great Meteor hotspot track? *Earth and Planetary Science Letters* 178:253–68.

Kay, S. M., and B. P. Foster. 1986. Kimberlites of the Finger Lakes region. In *New York State Geological Association, 58th annual meeting, field trip guidebook,* vol. 68, 219-38.

Kay, S. M., W. T. Snedden, B. P. Foster, P. Brayton, and R. W. Kay. 1983. Upper mantle and crustal fragments in the Ithaca [U.S.] kimberlites. *Journal of Geology* 91:277–90.

Lewis, H. C. 1887. On diamantiferous peridotite and the genesis of diamond. *Geological Magazine* 4:22–24.

Martens J. H. C. 1924. Igneous rocks of Ithica, New York and vicinity. *Geological Society of America Bulletin* 35:305–20.

Mitchell, R. H. 1986. *Kimberlites: Mineralogy, geochemistry, and petrology.* New York: Springer.

Meyer, H. O. A. 1985. Genesis of diamond: A mantle saga. *American Mineralogist* 70:344–55.

Rakovan, J. 2006a. Word to the wise: Diatreme. *Rocks & Minerals* 81:153–54.

———. 2006b. Word to the wise: Phase transition. *Rocks & Minerals* 81:467–69.

Vanuxem, L. 1837. Mafic dikes at East Canada Creek. In *Annual report of the New York Geological Survey,* 3rd district 2, 265.

Williams, G. H. 1887. On the serpentine and peridotite occurring in the Onondaga Salt Group at Syracuse, New York. *American Journal of Science* 34 (series 3): 137–45. ❑