Kimberlitic rocks of New York State: The Dewitt “kimberlite”

David G. Bailey,
Hamilton College, Clinton, NY 13323
dbailey@hamilton.edu

Marian V. Lupulescu
New York State Museum, Albany, NY 12230
mlupules@mail.nysed.gov

INTRODUCTION

One of the very first scientific descriptions of a kimberlite was published in 1839 by Lardner Vanuxem in his third annual report on the geology of central New York State (Vanuxem 1839). The locality and samples he described were from the city of Syracuse, and were provided by the Principal of the Syracuse Academy, Oren Root (Williams 1887a, b). These early samples all came from a cluster of complexly related small intrusions in the northern portion of the city (Figure 1). Vanuxem (1842) described these rocks as part of “a great mass” of “well characterized serpentine” containing “particles of a yellow or golden color” (phlogopite) and “others of the red color of blood-stone” (pyrope). These intrusions received moderate scientific interest over the next thirty years as geologists struggled to understand the presence of these unusual rocks in the middle of the flat-lying Paleozoic sedimentary sequence of upstate New York (Dana 1878; Geddes 1860; Hunt 1858). Following the breakthrough work of Lewis (1887), who was the first to recognize that serpentinized, mica-bearing peridotites were the source rocks of gem diamonds in South Africa, the interest in the kimberlitic rocks of central NY increased dramatically. Over the next twenty years, numerous scientific reports (Clark 1908; Clarke 1899; Darton and Kemp 1895; Kraus 1904; Schneider 1902, 1903; Williams 1887b) and stories in local newspapers ("Gems here at home" 1906; "Syracuse has diamond hunt" 1905; "Would advance cash to probe stratums" 1902) were published on the Syracuse kimberlites.

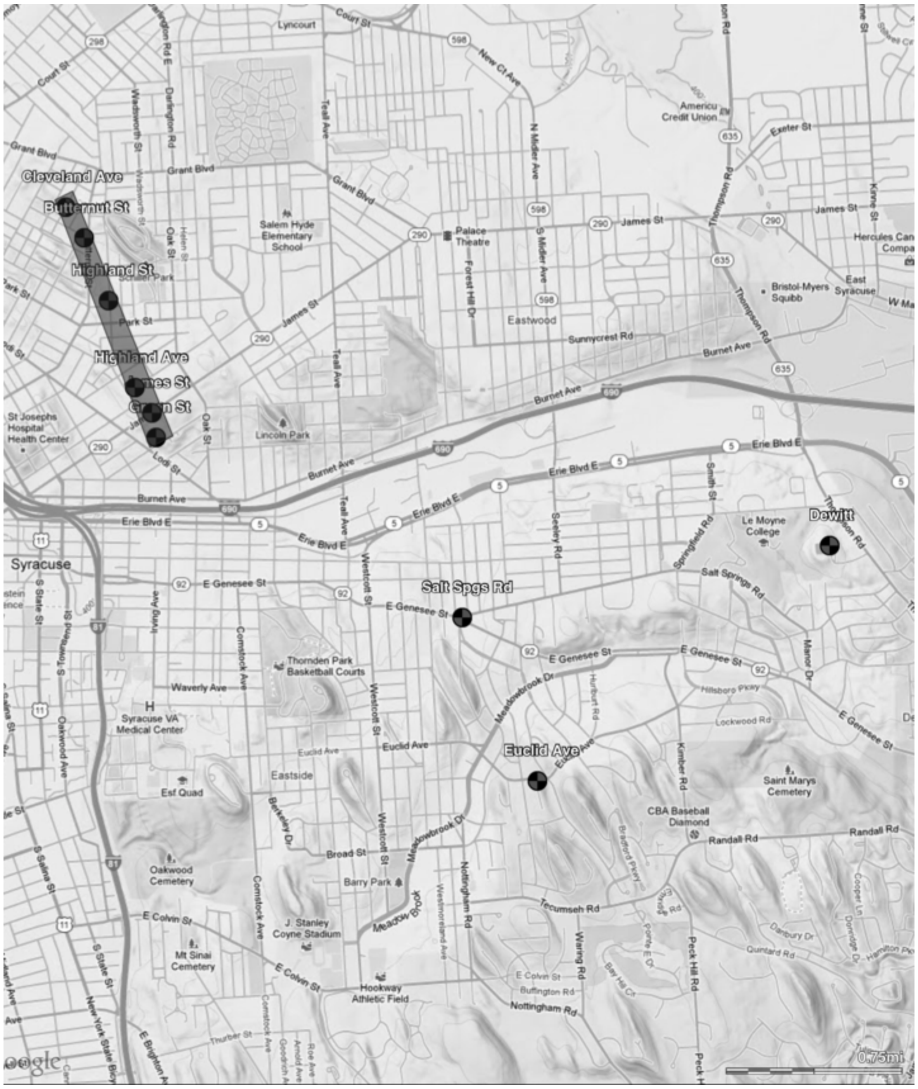

Figure 1. Map showing the reported locations of the Dewitt and other kimberlitic rocks in the vicinity of Syracuse, NY.

BACKGROUND & HISTORY

The Dewitt kimberlite was discovered in 1894 during the construction of a new water reservoir on the top of a small hill in east Syracuse (Figure 1) (Darton and Kemp 1895; Hopkins 1914). The dike was discovered by Philip Schneider, a teacher at Syracuse High School, who sent samples to J. F. Kemp at Columbia University for analysis (Darton and Kemp 1895). According to Darton, the reservoir was already filled with water by the time Schneider discovered the kimberlite, so few details about the size, shape, or number of intrusions are known. The following information was passed on from the contractor to Schneider, and recorded by Darton:

"The dike was exposed by excavations for the reservoir and does not appear to reach the natural surface. It was buried under a mantle of glacial drift, and in part, at least, was covered by shales and limestones of the Salina formation. .... According to the statements of the contractor, the rock occurred in masses imbedded in a greenish-yellow earth which underlaid the entire area of the excavation, which was about 200 by 250 feet." (Darton and Kemp 1895), p.456.

Samples were sent to the United States Geological Survey for whole-rock analyses (Clarke and Hillebrand 1897), but following that, no significant scientific studies were done on the Dewitt kimberlite for more than 80 years.

AGE OF INTRUSION

Obtaining precise and accurate intrusion ages on kimberlites is difficult because they are complex and often highly altered rocks. In addition, many of the mineral phases are either xenocrystic, or of secondary (non-magmatic) origin. Researchers have tried to obtain ages on the NY kimberlites using the following methods: Rb-Sr and/or K-Ar on phlogopite macrocrysts (Watson 1979; Zartman 1967), fission track on apatite (Miller and Duddy 1989), K-Ar total fusion on whole rock samples (Basu et al. 1984), and most recently, U-Pb on perovskite separates (Heaman and Kjarsgaard 2000). Most of the analyses yielded Mesozoic ages of 180 to 110 Ma, with most between 120 and 150 Ma. The one date on the Dewitt kimberlite (K-Ar whole-rock) yielded an age of 130 +/-13 Ma (Basu et al. 1984). How closely this approximates the actual intrusion age is not clear because of the presence of xenocrystic material and the extensive alteration of many of the primary igneous phases. We attempted to extract groundmass perovskites for U/Pb dating because this technique yields the most precise estimates of the timing of intrusion and crystallization, but we have not yet been successful because the perovskites are very small (< 30 μm) and are commonly altered.

PETROGRAPHY & MINERALOGY

Like all kimberlitic rocks, the Dewitt intrusion is petrographically complex and highly variable. Every hand sample is texturally and mineralogically different. Phases identified to date in samples from the Dewitt reservoir include the following:

Macrocrysts

Most samples of the Dewitt kimberlite contain abundant, large (up to 1 cm), olivine macrocrysts. Most are anhedral, rounded, highly fractured, and partly to completely replaced by serpentine, magnetite, and/or calcite (Figure 2). Some samples contain a surprising amount of fresh olivine (Fo_{89-91}); no other New York kimberlite contains as much unaltered olivine. Some of the smaller olivine grains are sub- to euhedral, and are apparently microphenocrysts (Figure 3).

Much less common are macrocrysts of clinopyroxene ($\sim Di_{50.5}\ En_{45.5}\ Fs_{4.0}$) and pyrope garnet ($\sim Py_{73}\ Alm_{14}\ Gr_{13}$). The clinopyroxene grains are all anhedral and rounded like the olivine macrocrysts, but they are unaltered and often are very faint green under plane-polarized light. Garnet macrocrysts up to 5 mm in diameter are uncommon; they are all rounded, fractured, and have large opaque reaction rims (Figure 4). The garnets are homogeneous, Cr-bearing pyropes that classify as “G9” garnets, typical of garnets derived from lherzolitic mantle (Grutter et al. 2004).

Phlogopite macrocrysts, which are common in many New York kimberlites, are surprisingly uncommon in the Dewitt kimberlite. Those that exist are relatively small (< 1mm), and often highly altered and replaced by clouds of fine-grained opaques. Phlogopite macrocrysts, when found, are often deformed, indicating a xenocrystic origin (Figure 5).

Spinel and ilmenite macrocrysts are uncommon, always anhedral, and relatively small (< 0.5 mm). The spinels vary widely in color (from deep green to red-brown to opaque) and

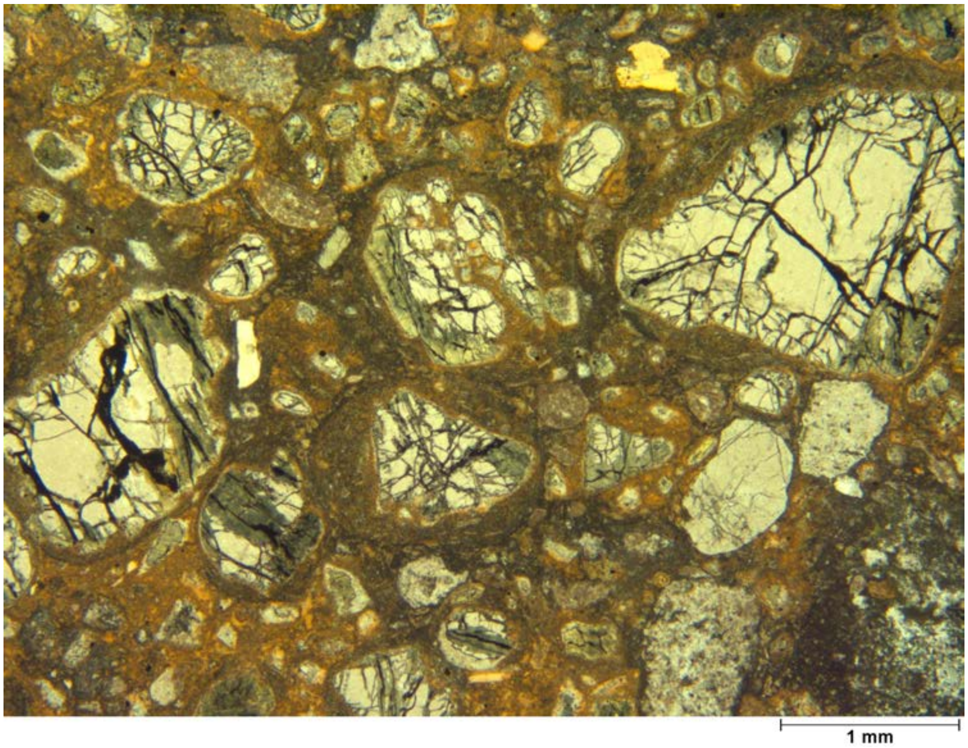

Figure 2. Sample of relatively unaltered kimberlite from Dewitt with abundant, anhedral, partly serpentinized olivine macrocrysts (Sample DT-2; PPL).

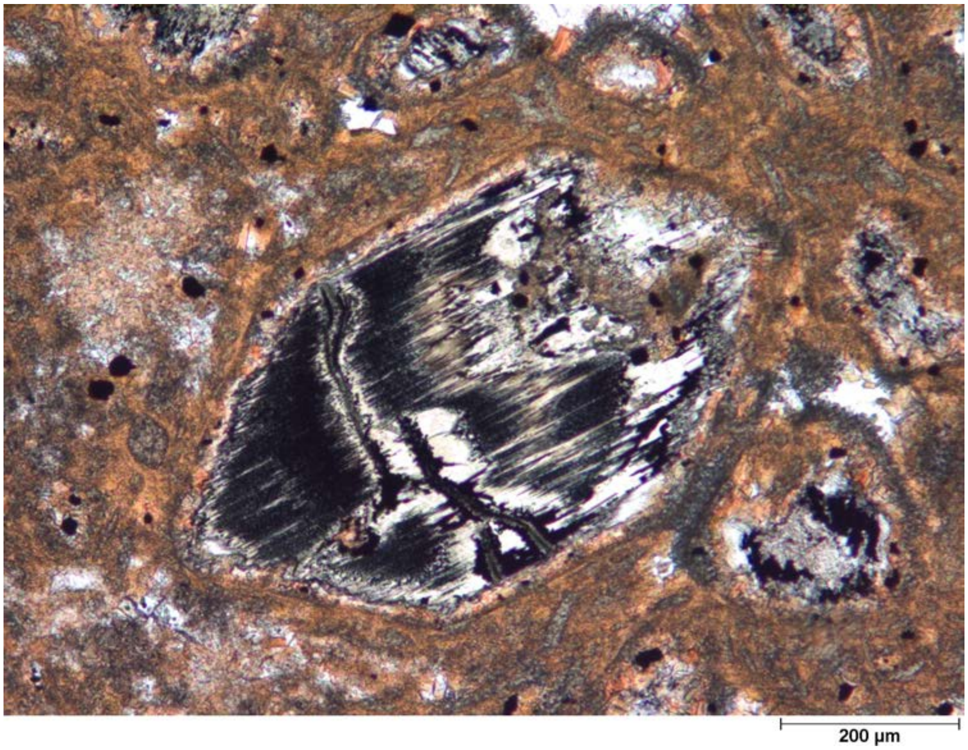

Figure 3. Small microphenocryst of olivine; replaced by serpentine and magnetite (Sample-DT-2a; PPL).

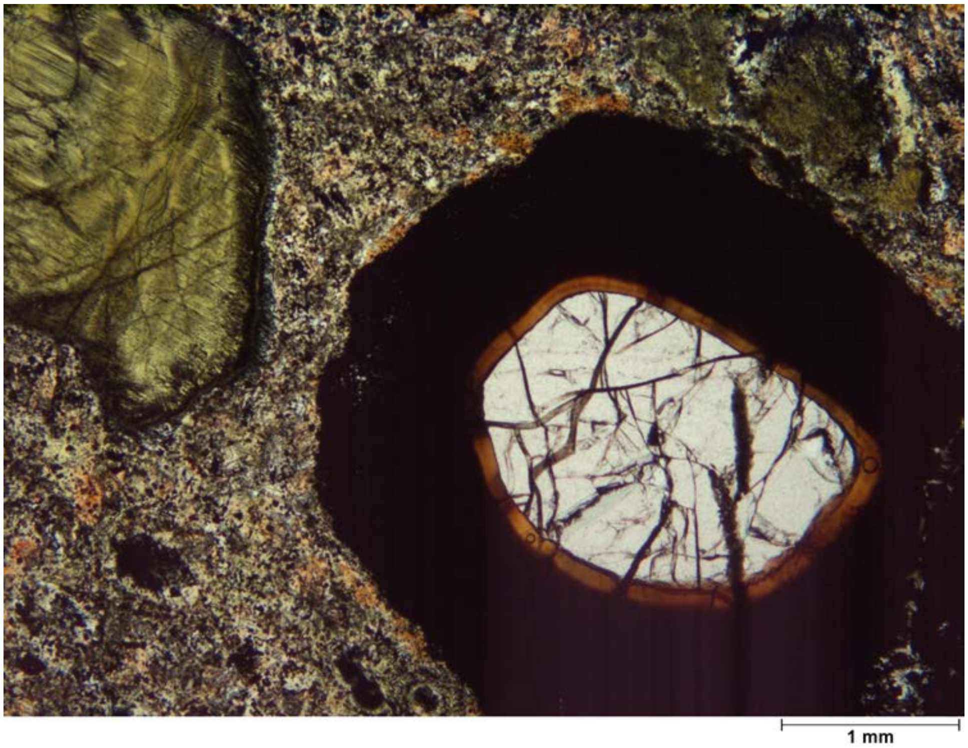

Figure 4. Garnet xenocryst with thick reaction rim (Sample DT-1a; PPL).

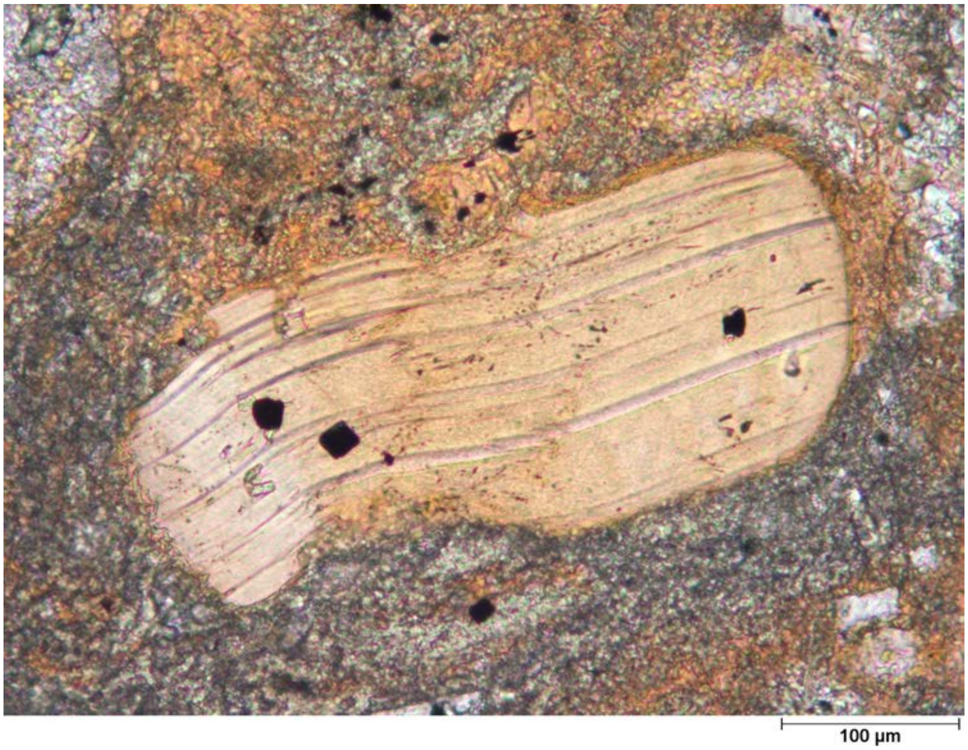

Figure 5. Small, deformed, xenocrystic phlogopite with chromite inclusions (Sample DT-2a; PPL).

composition (from true spinel to chromite to magnetite). They also vary in mode of origin, although a comprehensive and systematic study of the spinels in these rocks has not yet been done. The ilmenite macrocrysts are always rounded and surrounded by a zone enriched in dark orange phlogopite. The only other NY kimberlites with ilmenite macrocrysts are from the Green Street dike cluster in Syracuse, and the dikes in East Canada Creek in Montgomery County.

Groundmass phases

The groundmass of the Dewitt kimberlite is highly variable in texture and mineralogy. Serpentine, calcite, phlogopite, diopside, apatite, perovskite, and opaques are visible in most thin sections. Many additional phases have been identified by energy-dispersive X-ray spectrometry on a scanning electron microscope (e.g. magnetite, ilmenite, chromite, baddelyite, melilite, sodalite, Ni-pyrite, pyrrhotite, galena, sphalerite, and barite). With the exception of the opaque oxides, all of these phases are generally very small (<100 um). The sulfides tend to occur as small anhedral grains distributed throughout the groundmass; the sulfates tend to occur as small fracture fillings, and the melilite and sodalite are most common in the reaction zones surrounding crustal xenoliths. A number of complex, and as yet unidentified, Ti-silicates also have been found replacing perovskite and /or rutile. Undoubtedly, many more phases are present in the fine-grained groundmass of this intrusion.

WHOLE-ROCK CHEMISTRY

Kimberlites are, by nature, hybrid rocks containing complex mixtures of mantle and crustal derived materials, and almost all have experienced extensive post-emplacement hydrothermal alteration and/or surficial weathering. Because of these complications, whole-rock compositions almost certainly do not represent, or even approximate, magmatic liquid compositions. This limits our ability to understand the mineralogical and chemical nature of the mantle source of kimberlitic magmas, and their subsequent evolution. Nevertheless, whole-rock chemistry does provide important information that allows us to categorize and classify these unusual rocks, and to constrain the geological processes involved in their formation. Forty-three whole-rock samples were analyzed by WD-XRF and ICP-MS at the Geoanalytical Laboratory at Washington State University; representative analyses are provided in Bailey & Lupulescu (2007).

Despite the extensive alteration and contamination, the whole-rock data allow us to identify individual dikes and/or clusters of dikes that have distinct geochemical signatures, particularly in terms of the ratios of relatively immobile, high field strength (HFS) minor and trace elements. All of the intrusions in the Syracuse area are chemically similar, and can be identified by their low Ti and Nb concentrations relative to the other kimberlitic rocks in New York (Figure 6).

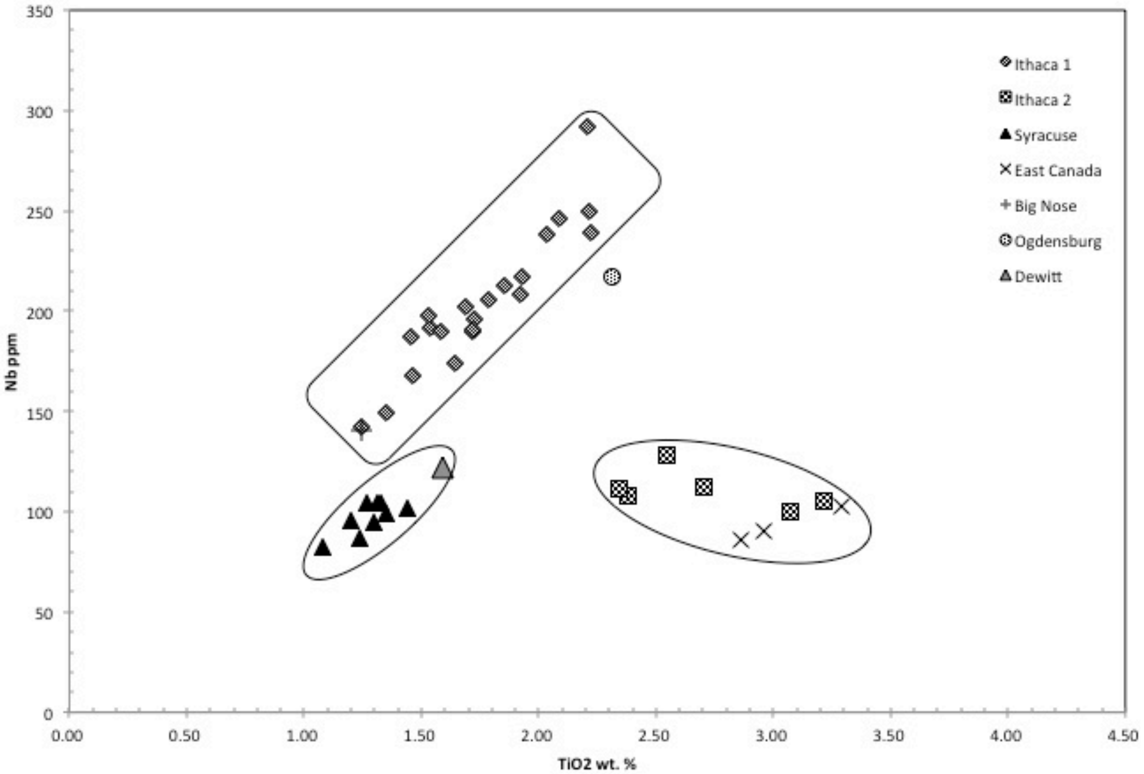

Figure 6. Scatter plot of Nb and TiO_2 concentrations in New York State kimberlites.

The average trace element contents of the Syracuse kimberlites are illustrated in Figure 7, along with the average compositions of the Lac de Gras and Kirkland Lake kimberlites in Canada. The Syracuse and Canadian kimberlites have broadly similar trace element signatures, although the Syracuse kimberlites exhibit significantly higher K/Ba and K/Nb ratios.

Figure 7. Primitive-mantle normalized spider diagram of trace element concentrations in the Syracuse kimberlites compared to the Lac de Gras (LDG) and Kirkland Lake (KL) kimberlites in Canada (average of six analyses of each). Data sources: Syracuse (Bailey, unpublished), Lac de Gras and Kirkland Lake (MacBride 2005) Normalizing factors from (McDonough and Sun 1995)

CLASSIFICATION

Are these unusal rocks really kimberlites? Over the years they have been referred to as “serpentine bodies” (Vanuxem 1842), peridotites (Williams 1887b), alnoites (Smyth 1893), and kimberlites (Matson 1905). For most igneous rocks, classification is now straightforward, based primarily on modal mineralogy, rock texture, and/or rock chemistry (Le Maitre et al.

2002). Unfortunately, due to the mineralogical complexity of kimberlites, a simple definition does not exist; they are, in fact, a clan of complexly related rocks. The situation is nicely summarized by Winter (2001) who states: "The confusion (in classification) is most evident in the highly potassic lamprophyre-lamproite-kimberlite group, a diverse array of mafic to ultramafic rocks with high volatile contents. The numerous intertwined petrographic and genetic similarities and differences in this broad group present a classification nightmare." (p.362)

Kimberlites are currently divided into two groups (Le Maitre et al. 2002; Skinner 1989; Smith et al. 1985). Group I kimberlites are the analogue of the rocks originally found and described at Kimberley, South Africa (the "basaltic kimberlites" of Wagner, 1914). Group II kimberlites are the equivalent of the micaceous kimberlites of the Orange Free State, South Africa, and are also called orangeites (or "lamprophyric kimberlites" after Wagner (1914)). The two groups of kimberlites display subtle differences in their mineralogical composition (Mitchell 1995; Skinner 1989; Smith et al. 1985; Tainton and Browning 1991). According to Mitchell (1995), kimberlites are "characterized by the presence of macrocrysts and subhedral microphenocrysts of olivine set in a groundmass consisting of spinel, perovskite, monticellite, phlogopite, apatite, serpentine, and calcite" (p.74), whereas orangeites are composed principally of macrocrystal and "microphenocrystal phlogopite set in a fine-grained groundmass consisting essentially of phlogopite-tetriferriphlogopite and minor apatite, chromite, Mn-ilmenite, and perovskite with a mesostasis of calcite and/or dolomite together with serpentine" (p.61). Unfortunately, there is no one single defining mineralogical, or chemical characteristic of either group: for example, kimberlites can contain phologopite macrocrysts, and orangeites can contain olivine macrocrysts. Compositional trends of the groundmass spinels are one of the best criteria for distinguishing Group 1 kimberlites from orangeites (Mitchell 1995; Tappe et al. 2005).

Petrographically, the Dewitt intrusion exhibits features of both groups: the abundant olivine macrocrysts and quench texture apatite in the groundmass are features common in Group 1 kimberlites, whereas the abundant phlogopite and diopside in the groundmass are features more commonly seen in Group 2 kimberlites (orangeites) (Mitchell 1995). Presently, we do not have enough compositional data on the groundmass spinels to identify clear evolutionary trends.

Chemically, the two groups can usually be discriminated on the basis of whole-rock TiO_2 and K_2O concentrations (Figure 8). The Syracuse intrusions do not clearly lie within one field or the other; they appear to straddle the boundary between the two categories of kimberlitic rocks. Thus, both the chemical and petrographic features of these rocks indicate that, while the Syracuse intrusions clearly belong to the broad family of kimberlitic rocks, they are not archetypical Group 1 or Group 2 kimberlites. Overall, they tend to have stronger affinities with Group 2 kimberlites (orangeites).

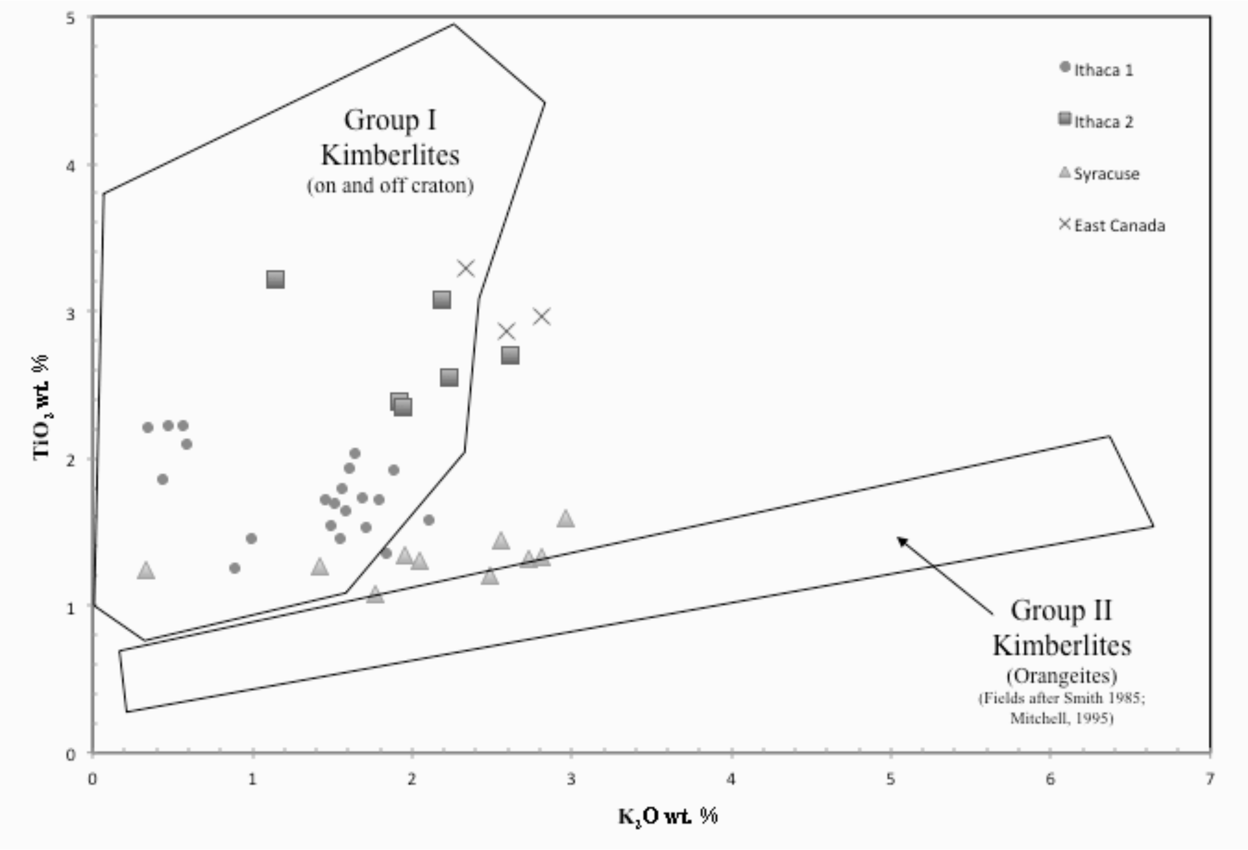

Figure 8. TiO_2 vs. K_2O concentrations for New York State kimberlites. Broad compositional fields for Group 1 and Group 2 kimberlites drawn based upon data in Smith et al. (1985) and Mitchell (1995).

ORIGIN

Currently, there are two theories that have been put forth to explain the origin of the Mesozoic kimberlitic rocks in New York state (Figure 9): 1) They are part of a chain of small, alkaline intrusions in eastern North America related to passage of the North American plate over the Great Meteor hot spot (Heaman and Kjarsgaard 2000); or 2) they are part of a belt of kimberlitic intrusions along the western flanks of the Appalachian Mountains that were intruded along old structures that were reactivated by crustal extension related to rifting and opening of the Atlantic Basin (Parrish and Lavin 1982). We believe the spatial and temporal distribution of the kimberlitic rocks in eastern North America is most consistent with the second hypothesis, although the lack of unequivocal and precise intrusion ages on most of the eastern North American kimberlites makes this, at present, a relatively speculative interpretation.

SUMMARY

The Dewitt intrusion is one of the largest kimberlitic intrusions in New York State; it is also one of the least altered, with some samples containing up to 30% fresh olivine. The material available today is mineralogically and texturally variable, but the abundance of phlogopite and clinopyroxene in the groundmass of many samples suggest that the intrusion has stronger affinities with orangeites than with Group 1 kimberlites.

The Dewitt intrusion is early Cretaceous in age, and is probably the result of small degrees of partial melting in the underlying asthenospheric mantle in response to lithospheric extension along the newly developed eastern margin of the North American plate. The kimberlitic magmas moved toward the surface along major crustal structures on the western flanks of the Appalachian Mountains that were reactivated during Mesozoic rifting.

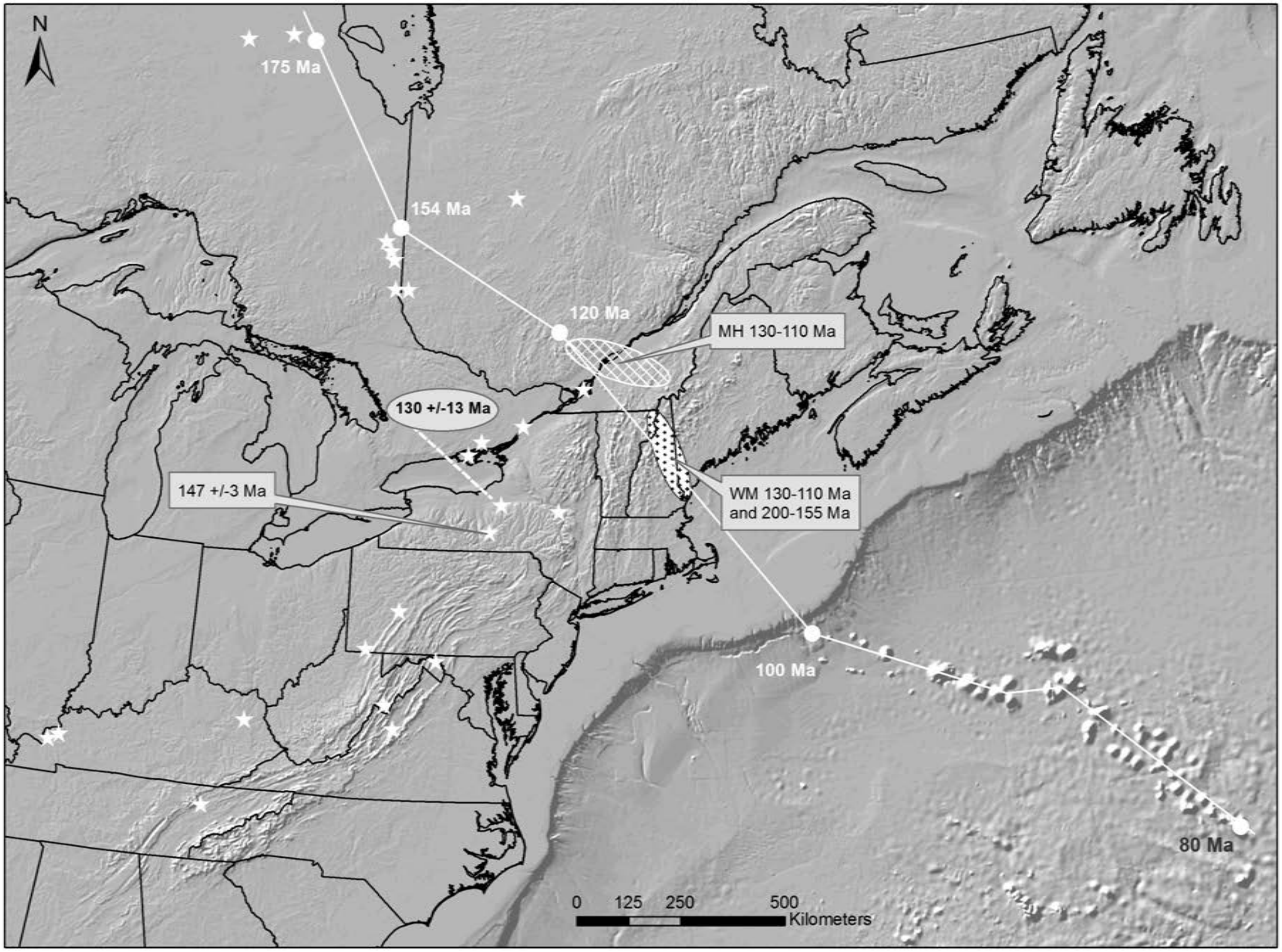

Figure 9. Locations of select Mesozoic age igneous rocks in eastern North America shown in relation to the Appalachian Mountains and the Great Meteor Hot Spot track (shown by line and solid white circles). White stars = kimberlitic rocks; MH = Monteregian Hills Alkaline Province; WM = White Mountains Magmatic Complex. Compiled from (Basu et al. 1984; Creasy 1989; Heaman and Kjarsgaard 2000; Meyer 1976; Parrish and Lavin 1982).

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ROAD LOG

****Note:** The Dewitt kimberlite locality is on property currently owned by LeMoyne College. This is private property, and permission must be obtained from the college administration prior to parking, hiking to the locality, and collection of any samples. Because specimens are limited, please only collect specimens for scientific research or for educational uses.**

Stop #1. The Dewitt "Kimberlite" (Lat: 43.049223, Long: -76.080701)

Park near the LeMoyne College Physical Plant, and follow the well-maintained trails to the slopes of the reservoir. Centimeter to meter-scale blocks can be found in the woods along the slopes of the reservoir. Please do not dig or excavate large blocks from the slopes!

We will examine a number of specimens and discuss the mineralogy and petrology of the intrusion.