Trip A-3

KIMBERLITIC ROCKS OF CENTRAL NEW YORK

DAVID G. BAILEY

Department of Geosciences, Hamilton College, Clinton, NY 13323
e-mail: dbailey@hamilton.edu

MARIAN LUPULESCU

New York State Geological Survey, Albany, NY
e-mail: mlupules@mail.nysed.gov

INTRODUCTION

The term "kimberlite" was first formally used to refer to the diamond-bearing mica peridotites of South Africa by Henry Lewis in 1887 at a meeting of the British Association for the Advancement of Science (Lewis,1888; Mitchell, 1986). Interestingly, similar mica peridotites were first discovered in upstate New York fifty years earlier. In his first annual report on the geology of the third district of New York, Lardner Vanuxem reported the presence of "serpentine" veins cutting through the Paleozoic sediments on the banks of East Canada Creek (approximately 10km east of the city of Little Falls) (Vanuxem, 1837). In his final geological report for the Third District, Vanuxem (1842) described four dikes of uncommon igneous rocks in a ravine east of Ludlowville (Tompkins County), the dikes on East Canada Creek (Herkimer/Montgomery County), as well as a "serpentine body" in the city of Syracuse (Onondaga County). According to Williams (1887a,b), the Syracuse serpentinite was discovered in 1837 by Oren Root who brought the rock to the attention of Vanuxem. Thus, 1837 appears to be the year when kimberlitic rocks were first observed and described anywhere in the world.

The New York dikes are part of a larger north-south belt of kimberlitic intrusions on the western flank of the Appalachian mountain belt that extends from Tennessee to Quebec. These dikes are of particular interest to North American geologists because they provide the only direct information on the nature of the mantle and lower crust in the Appalachian interior, and they are the only expressions of Mesozoic magmatism in the region. Their age, origin, and relationship to plate tectonic processes are still poorly known or understood.

DISTRIBUTION OF DIKES

To date more than 80 distinct kimberlitic dikes and irregular intrusive bodies have been found in New York (Table 1). Most exist in clusters within an elongate NNE – SSW area between Syracuse and Ithaca, with the vast majority in ravines that feed into Cayuga Lake from the east, south, and west (Figure 1). Two somewhat isolated dikes in the Ithaca area are one at Filmore Glen State Park, and the other in a small quarry northwest of Ithaca (McDougal Rd dike) (Figure 2). The Ogdensburg (Eel Weir) dike in St. Lawrence County is the northernmost and most isolated dike in the state (Newland, 1931). Unfortunately, this dike is no longer exposed

TABLE 1—List of known kimberlitic intrusions in New York State (modified after Martens (1924), Foster (1970), and Kay & Foster (1986)). Numbers in first column correspond to location numbers displayed on the following maps

Map #	Locality Name	Location	Width (cm)	Strike	References	2007 Status
1	Macdougal Rd Quarry	Small quarry 400m west of intersection of NY96 and NY336. Dike in quarry floor.	40	N35W	Wells (1961); Foster (1970)	Unknown
2	Lively Run	Lively Run; 2.1km northeast of Interlaken; 425m east of N-S road. Two dikes, 6m apart.	2.5 4.5	N10W	Martens (1924)	Unknown
3	Frontenac Creek	Frontenac Creek; 460m west of NY89. Cluster of three dikes. One additional dike 150m upstream.	5 - 60	N10W	Foster (1970)	Unknown
4	Taughannock Creek	Five dikes at foot of Taughannock Falls.	2 - 10	~N-S	Matson (1905); Martens (1924)	Unknown
5	Taughannock Creek	Taughannock Creek; 1km east of NY96 bridge; ten dikes over distance of 500m.	250	N10W	Martens (1924); Foster (1970)	Cluster of three dikes (Foster's dikes 6-8) exposed on north side of creek. 18T 0366828 UTM 4709908
6	Glenwood Creek	Glenwood Creek; ~400m west of RR; 365m east of Duboise Rd; one dike on south side of creek.	270	N6E	Matson (1905); Martens (1924); Foster (1970)	Unknown
7	Glenwood Heights Rd	Unnamed creek north of Glenwood Creek, where creek meets bend in Glenwood Heights Rd.	45		Filmer (1939)	Unknown
8	Poyer Orchard 1	1.2km south of Glenwood Ck dike; diatreme(?).	6000		Barnett (1905); Martens (1924); Filmer (1939); Foster (1970)	Unknown
	Poyer Orchard 2 & 3	1.2km south of Glenwood Ck dike; two dikes, one 150m north of diatreme, one 180m north.	90 45			
9	Indian Creek	Indian Creek; north of old hospital along road to old heating plant; three dikes over 20m	4 - 60	N8W	Martens (1924); Foster (1970)	Unknown
10	Williams Brook	60m west of NY96; dike on north side of creek.	370	N3W	Filmer (1939); Foster (1970)	Well exposed on north bank. 18T 0374573 UTM 4701668
11	Six Mile Creek 1	Six Mile Creek; 1.2 km south of dam at Green Tree Falls.	5	N5E	Martens (1924); Foster (1970)	Unknown
12	Six Mile Creek 2	Six Mile Creek; 90m north of dam at Green Tree Falls.	5	N2W	Martens (1924); Foster (1970)	Unknown
13	Six Mile Creek 3	Six Mile Creek; 80m south of pumping station; two dikes 10m apart.	25 8	~N-S	Martens (1924); Foster (1970)	Unknown
14	Six Mile Creek 4	Six Mile Creek; 180m north of old pumping station; two dikes 10m apart.	25 10	N3E	Martens (1924); Foster (1970)	Unknown
15	Ithaca Reservoir	Near Six Mile Creek; 60m up ravine near small lake (now covered by Ithaca reservoir). Weathered diatreme?	300 by 240		Filmer (1939)	Unknown
16	Brandon Place Quarry	Small quarry in southeast portion of Ithaca (no longer accessible). Four dikes.	2 - 20	N2E	Martens (1924)	Unknown
17	Cascadilla Creek	Gorge below Central Ave; Cornell campus (next to Snee hall); Six dikes over 100m east and west of bridge.	5 - 100	N10W to N2E	Martens (1924); Foster (1970)	Unknown

TABLE 1 (continued)

| Map #	Locality Name	Location	Width (cm)	Strike	References	2007 Status
18	Willard Ravine	Ravine, Cornell campus; south of Willard Straight Union.	35		Sheldon (1927); Filmer (1939); Foster (1970)	Unknown
19	Fall Creek	Fall Creek Gorge; south side of gorge in first deep notch east of Stewart Ave.	10	~N-S	Martens (1924); Foster (1970)	Unknown
20	Portland Point	Portland Point; two dikes in east wall of Cayuga crushed stone quarry; one in underground Cargill salt mine.	25 - 70	N1W to N14W	Sheldon (1921); Martens (1924); Broughton (1950); Foster (1970)	Unknown
21	Townley Creek	Townley Creek east of Ludlowville; Seven dikes between 70 and 340m east of falls.	10 - 20	N2W to N10E	Vanuxem (1839); Matson (1905); Martens (1924); Foster (1970)	Unknown
22	Ludlowville	First ravine south of Townley's Creek; Eleven dikes between 300m and 700m east of falls.	2 - 18	N6W to N10E	Schneider (1903a); Martens (1924); Foster (1970)	Unknown
23	Fillmore Glen	South of Moravia; Fillmore Glen State Park, 120m above Pinnacle lookout.	40	N12E	Wells (1961); Foster (1970)	Could not be located.
24	Clintonville	Clintonville, north of Otisco Lake; first stream north of US20 that flows east to Nine Mile Creek; 366m upstream in south wall, 2 clusters of 3 dikes each.	4 - 33	N6E to N12E	Smith (1909), (1931); Hopkins (1914)	Only three dikes found on south bank of creek. 18T 0390385 UTM 4754434
25	Salt Springs Rd	Near intersection of Salt Springs Road and Genesee Street.	130	~N-S, 82E	Maynard & Ploger (1946)	Covered.
26	Butternut St./ Highland St./ Griffiths St.	Exposed during 1902 excavation for trunk sewer and subsequent excavations.	1000	N5E	Smyth (1902); Schneider (1902,1903b); Kraus (1904)	Covered.
27	Foot St./ Green Street/ James St.	Excavations exposed many poorly defined bodies of peridotite.	150 - 1200		Williams (1887a,b), (1890a,b); Schneider (1903b); Smyth (1902); Hogeboom (1958)	Loose blocks in vacant lot on Green St. 18T 0407359 UTM 4767653
28	DeWitt	0.5mi S of Dewitt Center; 3 mi east of Syracuse; under reservoir excavated in (1895)	~600	N80E	Darton & Kemp (1895a,b); Schneider (1903b)	Abundant blocks on banks /slopes of LeMoyne reservoir. 18T 0411980 UTM 4766854
29	Euclid Ave	Dike exposed in excavated hill south of Euclid Ave.	60	N35W 80E	Van Tyne (1958)	Covered.
30	East Canada Creek	East bank of ECC, 25m upstream of hydroelectric plant, two dikes 30 - 50m south of falls	20-30	N35E	Vanuxem (1842); Smyth (1892), (1893), (1896), (1898)	Well exposed on east and west banks. 18T 0521072 UTM 4763037
31	Big Nose	Dike exposed in road outcrop at "Big Nose" along the Mohawk River, north of NY Rt. 5.	4		Allers (pers. comm..)	Covered.
32	Ogdensburg	Dike exposed during construction of Eel Weir dam.	700(?)	NE, vertical	Newland (1931)	Covered.
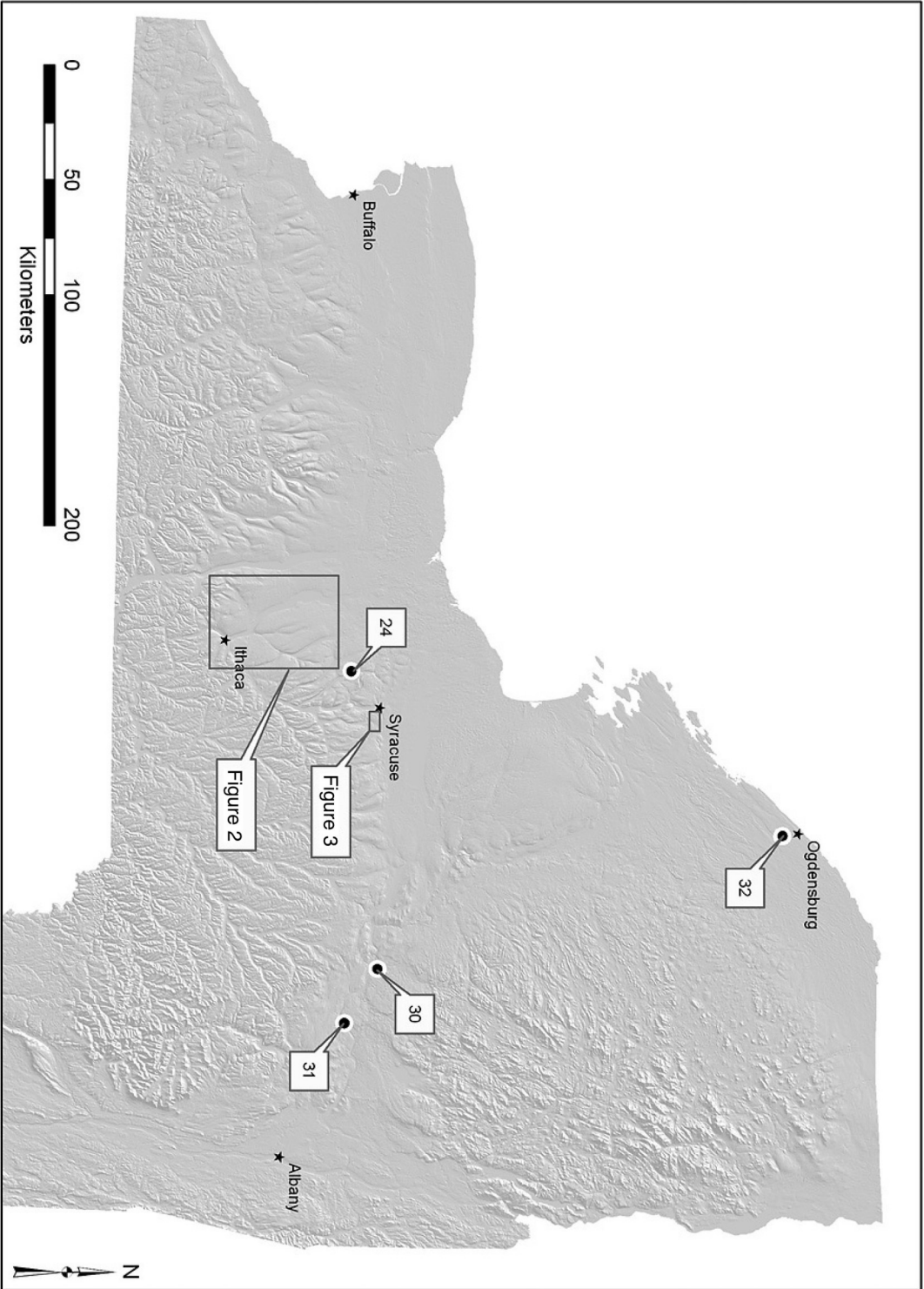
FIGURE 1—Locations of kimberlitic intrusions in New York State. Numbers correspond to localities listed in Table 1. Boxes outline areas covered by detailed maps (Figs. 2 and 3).

AGE OF THE INTRUSIONS

In general, kimberlitic rocks are very difficult to date because the xenoliths, xenocrysts, macrocrysts, and groundmass phases they contain can each have a different age. In addition, even if ages are determined on individual minerals, it is not always possible to determine if the minerals crystallized from the kimberlitic fluid or are xenocrystic. Finally, extensive post-emplacement metasomatism, alteration, and weathering make it difficult to find and extract suitable material for dating.

With the above caveats in mind, the published isotopic data on the kimberlitic rocks in New York suggest a Late Jurassic / Early Cretaceous emplacement age. The initial dates by Zartman et al. (1967) on coarse grained, phlogopite macrocrysts from two dikes, (one at Portland Point and the other one at Manheim), yielded K-Ar ages of 439 ± 22 Ma and 371 ± 19 Ma, respectively. While the age of the Manheim dike is geologically possible (the dike cuts the Upper Cambrian Little Falls dolostone), the age for the Portland Point dike is not (the dike intrudes a mid-Devonian limestone). Zartman et al. concluded that the K-Ar ages were affected by excess radiogenic argon. Rb-Sr isotopes on the same phlogopite samples yielded ages of 136 ± 8 Ma (Manheim dike) and 118 ± 15 Ma (Portland Point), suggesting crystallization (and emplacement?) during the Cretaceous.

Basu et al. (1984) reported whole-rock K-Ar ages of 139 ± 7 Ma (Williams Brook), 140 ± 8 Ma (Frontenac dike), 146 ± 8 Ma (Cascadilla Gorge), 121 ± 23 Ma (Taughannock Creek) and 113 ± 11 Ma (Portland Point). Kay and Foster (1986) suggested that these data indicated at least two distinct intrusion events. The large uncertainties associated with these dates, and the unresolved question of what exactly a bulk rock age on serpentinized peridotites represents, make the interpretation of distinct intrusive events highly speculative.

Miller and Duddy (1989) reported an apatite fission-track age data from one of the Ithaca dikes of 104 ± 22 Ma. They interpreted this age as the time of cooling when the region was exhumed and eroded.

Heaman and Kjarsgaard (2000) reported high precision U-Pb perovskite ages of 144 ± 8 and 146 ± 7 Ma for the Williams Brook dike, and 147 ± 5 Ma for the Glenwood Creek dike. These are probably the dates that most accurately reflect the emplacement age of the dikes because the perovskite crystals are ubiquitous in the groundmass of many of the dikes and are clearly of magmatic origin.

MINERALOGY AND PETROGRAPHY

Relatively large (2-15 mm) macrocrysts "floating" in a very fine-grained matrix form the usual texture of these rocks. The most common macrocrysts are olivine, phlogopite, garnet, clinopyroxene, and spinel; the groundmass contains phlogopite, calcite, serpentine, perovskite, and magnetite along with minor (and localized) clinopyroxene, clinoamphibole, epidote, chlorite, barite, celestite, spinels, ilmenite, pyrrhotite, pentlandite, and pyrite. Despite many extensive searches for diamonds, none have ever been found. The shallow emplacement level of the dikes, and the chemical compositions of the garnet and pyroxene macrocrysts indicate that diamonds are unlikely to exist in these intrusions. A brief overview of the features of the major mineral phases follows:

TABLE 2—Ranges of major element oxide contents (wt. %) in the silicate macrocrysts. Data by electron microprobe. (nd = not detected)

| Oxide	Olivine	Garnet	Diopside	Phlogopite
SiO_2	41.07-41.63	38.96-46.49	55.02-56.59	37.58-41.25
TiO_2	nd	0.08-2.11	0.00-0.17	0.84-3.41
Al_2O_3	0.00-0.03	11.25-22.44	0.45-2.65	6.62-16.93
FeO	8.42-12.49	6.06-24.25	1.75-6.66	4.00-13.34
MnO	0.09-0.20	0.05-0.45	0.09-0.36	0.01-0.14
MgO	47.56-50.63	8.60-20.55	13.46-17.77	19.70-24.51
CaO	0.03-0.10	4.61-22.89	19.35-25.78	0.01-0.42
Cr_2O_3	nd	0.00-5.77	0.00-1.60	0.00-2.00
V_2O_3	nd	0.02-0.10	nd	nd
NiO	0.29-0.57	0.00-0.08	nd	0.01-0.07
BaO	nd	nd	nd	0.06-3.24
Na_2O	nd	nd	0.00-1.91	0.00-0.45
K_2O	nd	nd	nd	7.88-10.04
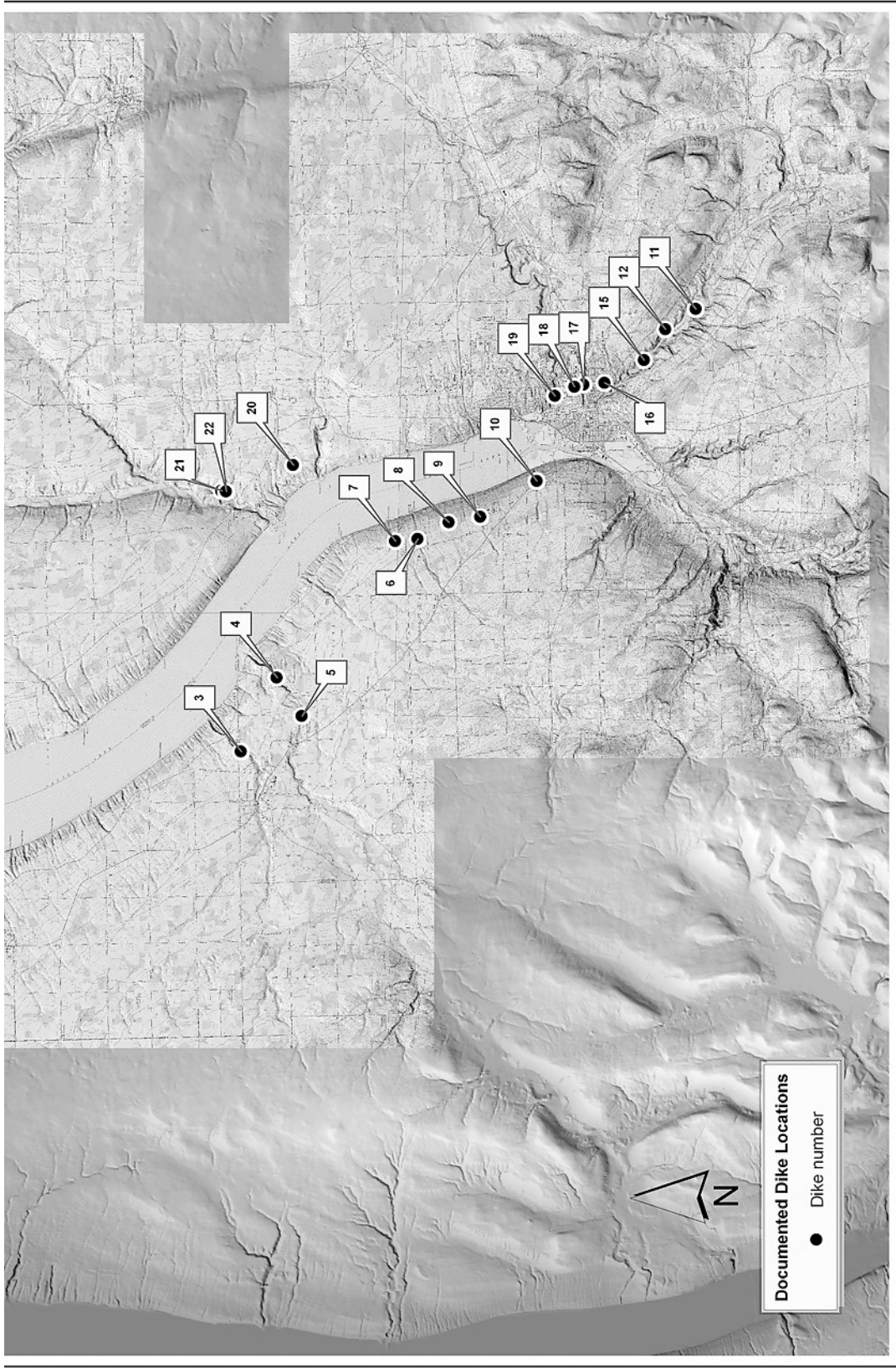
FIGURE 2—Locations of kimberlitic rocks in the Ithaca area. See Table 1 for descriptions
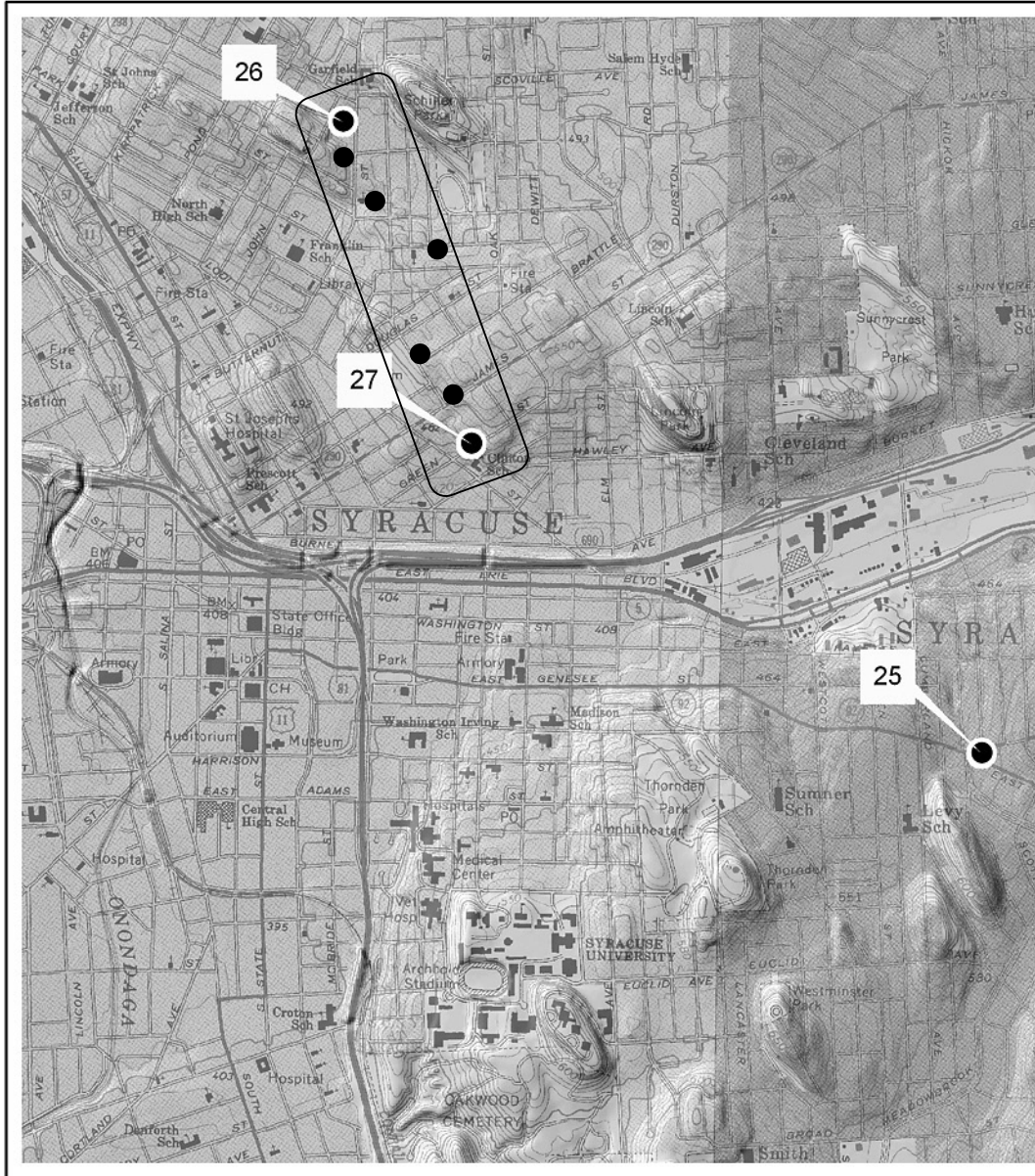
FIGURE 3—Locations of kimberlitic rocks in the Syracuse area. Box encloses zone of Green St. - Griffith St. intrusions. All of these intrusions were discovered during excavations. In 2007, none of the dikes are exposed; large blocks from previous excavations can still be found at Green St (#27) and at Dewitt Reservoir (#28). See Table 1 for descriptions.
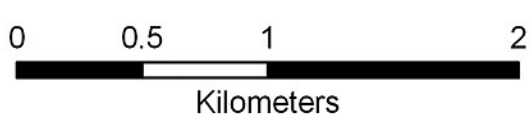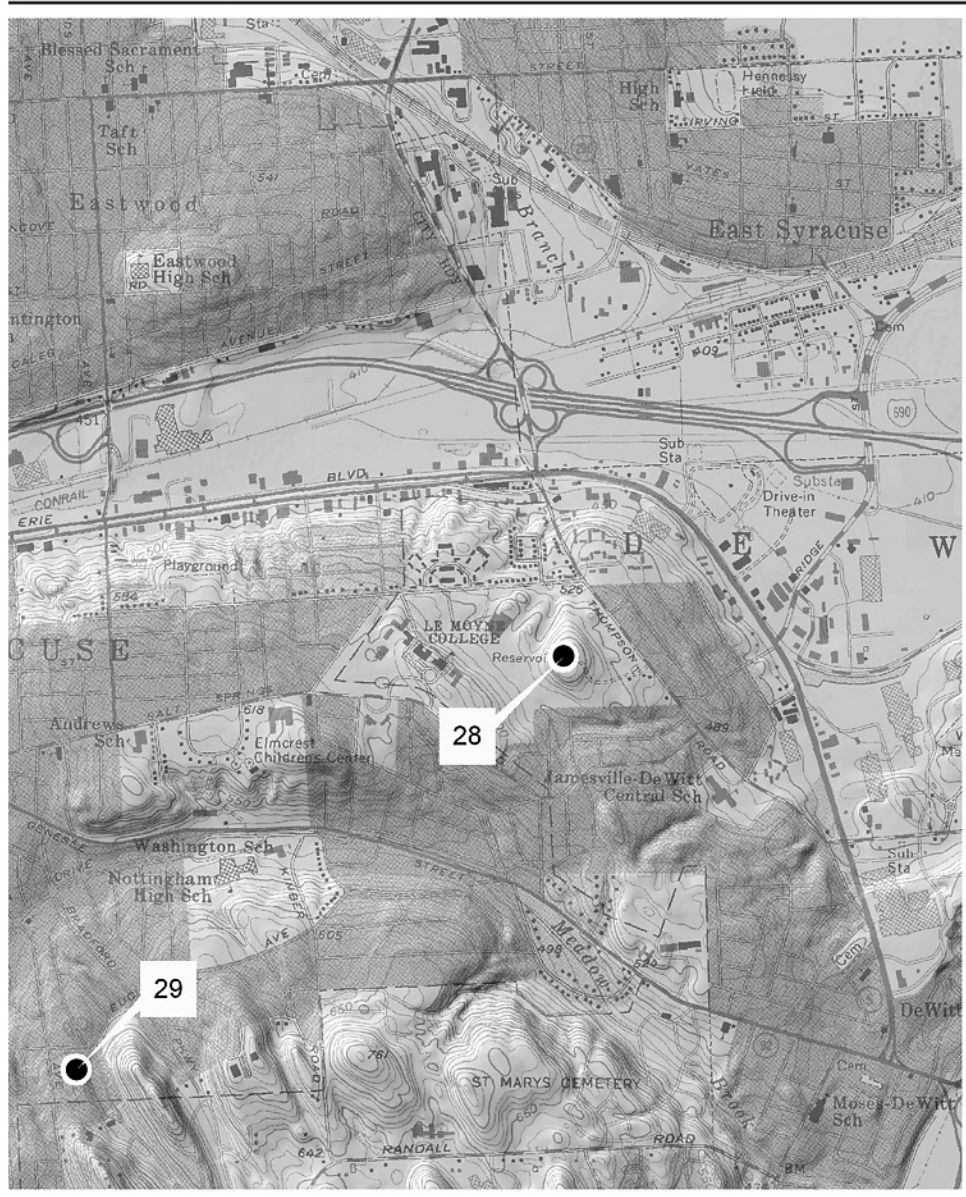
Olivine—Olivine is, for the most part, completely serpentinized, although some dikes from the Syracuse, Ithaca and Manheim groups contain macrocrysts with fresh cores of olivine. Most of the olivine macrocrysts range in size from a few millimeters to about one centimeter, although one macrocryst in the Euclid Ave. dike is 3.6 cm in length. Generally, large and small olivine crystals coexist in the same rock.

In some dikes two generations of olivine crystals can be recognized: one has an elongate lamellar habit and the other has a rounded habit and is often partially deformed. Remnant fresh cores are more common in the somewhat larger, rounded macrocrysts. The serpentine replacing the olivine macrocrysts is fibrous to scaly, or an aggregate of extremely fine-grained and nearly isotropic scales (chlorophaite). Color varies from a pale yellow to a very dark olive brown. Other products of the alteration of olivine are calcite, millerite, chlorite and spinels (predominantly magnetite).

Chemically, the olivine macrocrysts are relatively homogeneous (Fo_{87-91}), and contain moderate NiO contents (0.29 to 0.57 wt. %), and relatively low concentrations of CaO (0.03 to 0.10 wt. %) (Table 2). The Fo_{87-91} compositions are in the range of olivines from mantle peridotites (Dawson, 1980), so it is possible that they are coming from disaggregated xenoliths. They also are similar to the compositions of phenocrysts in ultrabasic magmas, and therefore, could also be of primary magmatic origin. Macrocrysts with distinct deformation lamellae are clearly of xenocrystic origin, but these are rare.

Garnet—Garnet was found only in the Taughannock Creek, Portland Point, and Dewitt Reservoir dikes, although the initial reports of the Green Street / Foot Rd dike in Syracuse describe the local children collecting large "rubies" from the excavated material (Williams, 1887a). In all occurrences, the garnet macrocrysts are rounded and have well-developed kelyphitic coronae (Figure 4). In contrast to the uniform nature of the olivine macrocrysts, the garnet macrocrysts are variable in color (pink to orange to yellow), and composition (Table 2).

Electron microprobe data reveal four groups of garnets: i) chrome-rich pyrope, ii) pyrope, iii) magnesian almandine, and iv) high-titanium ferro-magnesian grossular (Dawson & Stephens, 1975). The Cr-pyropes (which contain 3.67 to 5.77 wt. % Cr_2O_3), are compositionally similar to garnets in garnet lherzolites, one of the most common mantle xenoliths in kimberlites (Dawson & Stephens, 1975). Unfortunately, there is considerable compositional overlap with garnets in garnet peridotites and garnet pyroxenites, so these sources cannot be excluded on the basis of bulk composition. Trace element compositions obtained through laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) reveal high concentrations of the HREE ($Lu_{cn} =$ 9.65 to 11.14) and extremely low concentrations of the LREE ($La/Nb_{cn} = 0.03$) (Figure 5). The Sc/Yb and Ti/Sc ratios of the garnet macrocrysts are close to those of C1-chondrites. These features strongly suggest that the pyrope macrocrysts are derived from a garnet-lherzolite source.

The pyrope (1.96 to 2.14 wt. % Cr_2O_3), magnesian almandine (8.6 wr. % MgO) and grossular (2.11 wt. % TiO, 6.53 wt. % FeO) macrocrysts are most likely derived from disaggregated xenoliths that come from shallower mantle or crustal sources (eclogites?, grosspydites?).
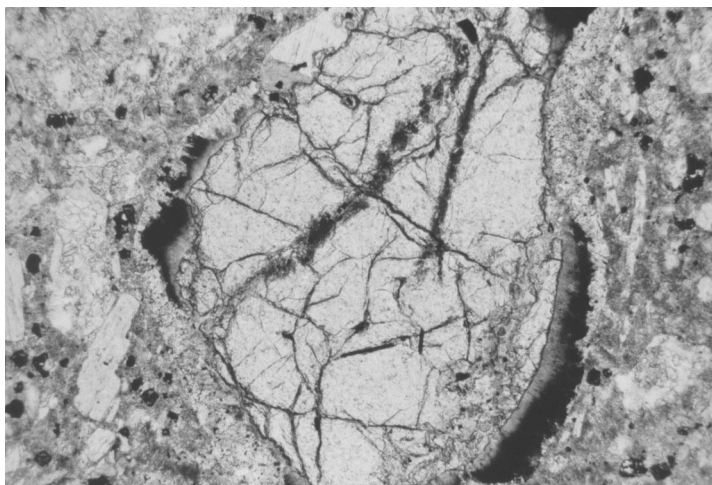

FIGURE 4—Fractured garnet macrocryst with kelyphitic corona, Taughannock Creek, Tompkins County. Width of photo = 3mm.
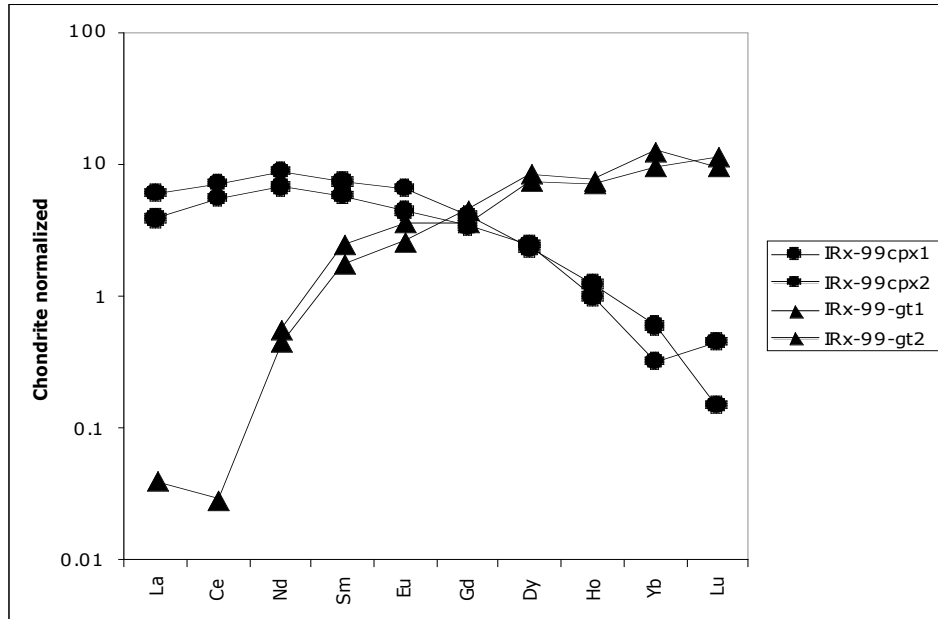
FIGURE 5—Chondrite normalized REE pattern for pyrope (IRx-99-gt) and low-Cr diopside (IRx-99-cpx) macrocrysts.

Diopside—Diopside is a fairly common macrocryst in many of the dikes in the Ithaca area but is quite scarce in dikes from other regions. It ranges in color from light to dark emerald green, to a pale yellow-green color. Similar to the garnet macrocrysts, the clinopyroxenes also exhibit kelyphitic coronae in some occurrences (Figure 6). The diopside crystals are no larger than a few millimeters in diameter. All are anhedral and extensively fractured.

Microprobe data show two groups of clinopyroxenes: low Cr-diopsides (with 0 to 0.05 wt. % Cr_2O_3) and high Cr-diopsides (with 1.52 to 1.60 wt. % Cr_2O_3). The high Cr-diopsides have 1.81 to 1.91 wt. % Na_2O, 2.54 to 2.65 wt. % Al_2O_3 and 2.83 to 2.89 wt. % FeO, showing affinities with clinopyroxenes in garnet lherzolites. The low Cr-diopsides have low Na_2O (0 to 0.37 wt. %) and low Al_2O_3 (0.45 to 1.04 wt. %). Kay et al. (1983) reported clinopyroxene compositions matching those of pyroxenes in garnet lherzolites and in garnet (or spinel) peridotites.
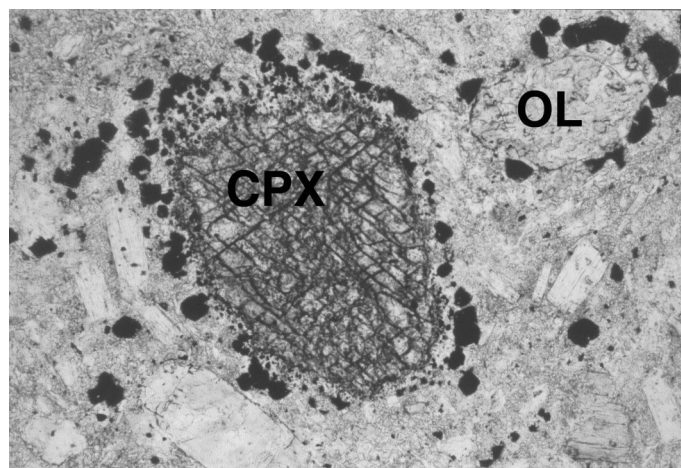

FIGURE 6—Diopside with a reaction rim of very small and coarse spinels. Olivine with a spinel rim in the upper right corner and phlogopite in the groundmass. Width of photo = 3.3mm.

The low-Cr clinopyroxene macrocrysts are relatively enriched in the LREE (La/Yb_N = 10.19 to – 12.16) and depleted in the HREE (Lu_N = 0.15 to 0.45) leading to subchondritic ratios of Sm/Nd_N (0.83 to 0.86) and Lu/Hf_N (0.02 to 0.14) (Figure 6). The Sc/Yb and Ti/Sc ratios of the clinopyroxene macrocrysts are suprachondritic. The trace element data are insufficient to characterize the source of the low-Cr diopside macrocrysts.

Phlogopite—The modal proportion of phlogopite to the other macrocrysts varies from dike to dike. Phlogopite is most abundant in the two East Canada Creek dikes, where flakes can reach 1.5 cm in diameter (Figure 5b). It is also abundant in the groundmass of many dikes. Rounding and strong deformation characterize all of the phlogopite macrocrysts. Chlorite, calcite, and Fe-Ti oxides replace some crystals along the (001) cleavage planes.
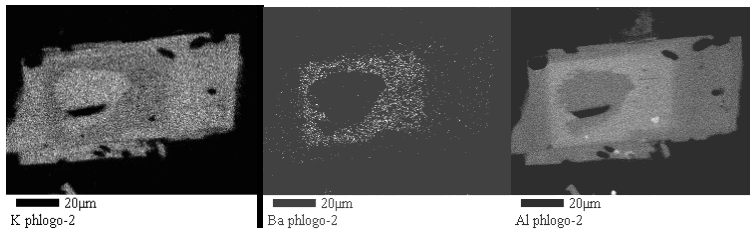

FIGURE 7a—X-ray elemental distribution maps on a zoned groundmass phlogopite (dike from the Syracuse group).
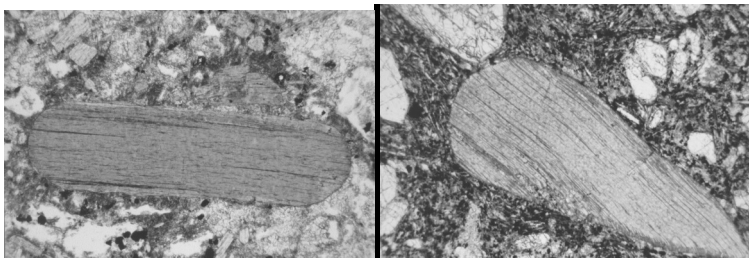

FIGURE 7b—Rounded and deformed phlogopite macrocrysts, East Canada Creek. Width of photo = 4mm.

Microprobe studies to date have not revealed any significant compositional differences between macrocryst and groundmass grains. Some of the phlogopite grains display zoning (Figure 7a) having a Ba-rich core (3.24 wt. % BaO) and a Ba-depleted rim (0.20 wt. % BaO). There also are compositional differences between dikes; for example, the phlogopites in the Williams Brook dike contain 1.45 wt. % Cr_2O_3 whereas the grains in the Portland Point dike have Cr_2O_3 contents around 2 %. TiO_2 contents also vary (between 0.84 and 3.41 wt. %), and NiO contents are very low (0.01 to 0.06 wt. %). These compositions are all within the range of mica compositions observed in other kimberlitic rocks (Mitchell, 1986).

Perovskite—Perovskite is found in all the dikes, but it is abundant in only a few of them (e.g. Williams Brook and Manheim dikes). It has a characteristic square cross section, is yellow-brown in color, and occurs as small (<0.25mm), isolated octahedral crystals in the serpentine and calcite dominated matrix. Clusters of small crystals also can be found as rims on magnetite grains (Figure 8). These two occurrences represent two different generations of perovskite: primary perovskite that crystallized from the kimberlitic fluid and secondary perovskite that formed as a post-magmatic reaction rim on magnetite. The chemical composition of both is in the range of perovskites from other kimberlitic rocks (Mitchell, 1986).
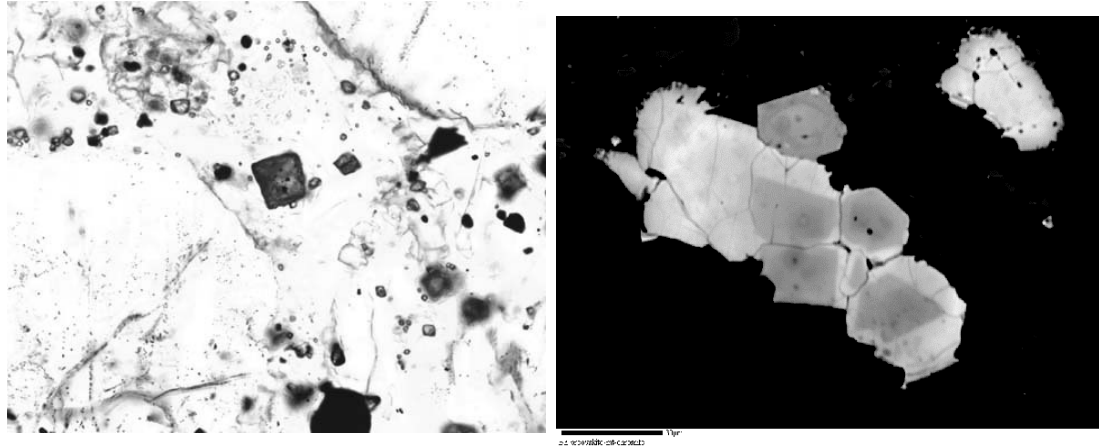
FIGURE 8—Photomicrograph (left) of primary <50μm perovskite crystals with characteristic square cross section, and back-scattered electron image (right) of 5-10μm perovskite rims (light gray) on magnetite (gray).

Spinel—Spinels are found with different sizes, textures and compositions (Figure 9). Grains range in size from micron scale grains in the groundmass (usually magnetite), to large (up to 5mm) macrocrysts (usually with Cr and Al-rich cores). They occur as isolated grains or as clusters of crystals, and most grains display compositional zoning. Three groups of spinels can be recognized according to their Cr, Al and Fe content. The first group contains the Cr- (> 23.49 wt. % Cr_2O_3) and Al-rich (> 11.99 wt. % Al_2O_3) spinels. These spinels are zoned with a Cr- and Al-rich cores and Fe-rich rims.
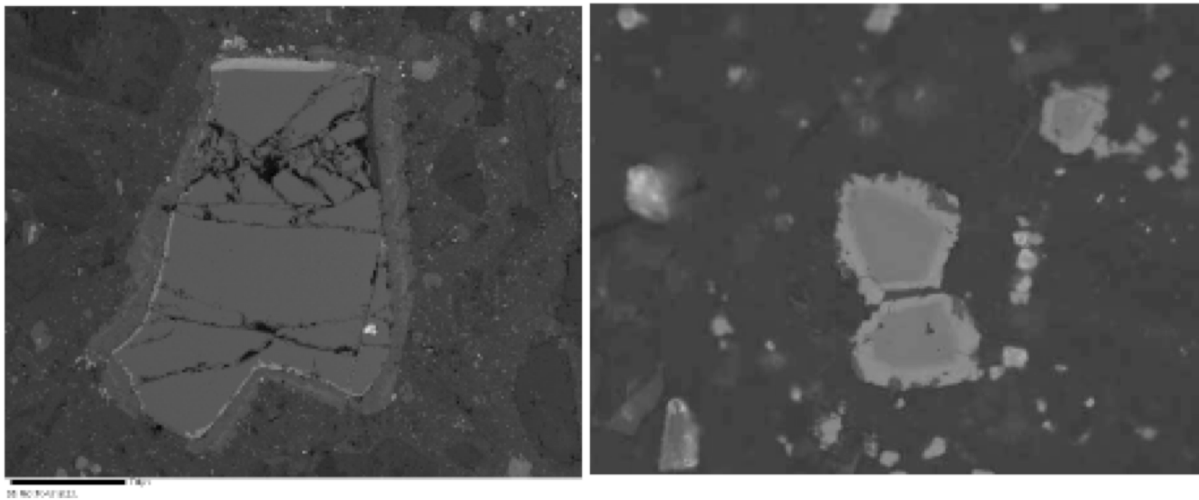
FIGURE 9—Left: Back-scattered electron (BSE) image of a spinel macrocryst (Taughannock Creek dike). The core is chromite and the fine whiter rim is magnetite. Both are enveloped by an unknown, non-stoichiometric Fe-rich compound. Below: Reflected light image of chromite (darker) with magnetite rim (lighter) in the Green Street dike.

The second group contains the low Al (< 5.15wt. % Al_2O_3) Fe-rich (> 70 wt. % FeO as total iron) spinels that plot into the magnetite compositional range. The TiO_2 (7.94 to 9.98 wt. %) and MgO (6.07 to 8.08 wt. %) contents confer a titanian and magnesian character. The third group makes the compositional transition from chromite to magnetite (magnesioferrite, magnesiochromite).

The wide range of spinel compositions observed is typical of kimberlitic rocks (Mitchell, 1986) and reflects their complex nature and history.

Ilmenite—Ilmenite is fairly common in the groundmass as irregular and tabular grains. Unlike the large MgO-rich macrocrysts commonly found in Group I kimberlites (Mitchell, 1986) these ilmenites are small and have relatively low MgO contents (0.90 to 6.85 wt. %).

Calcite—Calcite is a major component of the groundmass; in places, it also replaces the cores of olivine macrocrysts. Calcite could come from two sources: primary calcite derived from the CO_2-rich kimberlitic fluid, and secondary calcite derived largely from the surrounding calcareous shales and limestones.

WHOLE-ROCK CHEMISTRY

While there have been nearly one hundred scientific reports on the kimberlitic rocks of New York since they were discovered 170 years ago, only twenty bulk chemical analyses have been published. The first was a partial analysis by T. S. Hunt in 1858, and the most recent were three analyses by Foster in 1970. The paucity of chemical data is a consequence of the fact that the rocks are difficult to analyze, and the resulting data are difficult to interpret.

Kimberlites are, by nature, hybrid rocks containing complex mixtures of mantle and crustal derived materials, and almost all have experienced extensive post-emplacement hydrothermal and/or groundwater alteration. 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.

Thirty-two samples were analyzed by XRF and ICP-MS spectrometry for major and trace element compositions. Representative analyses are presented in Table 3. Major element oxide proportions reflect the fact that these rocks are composed primarily of variable proportions of serpentine, calcite, and magnetite (Figure 10).
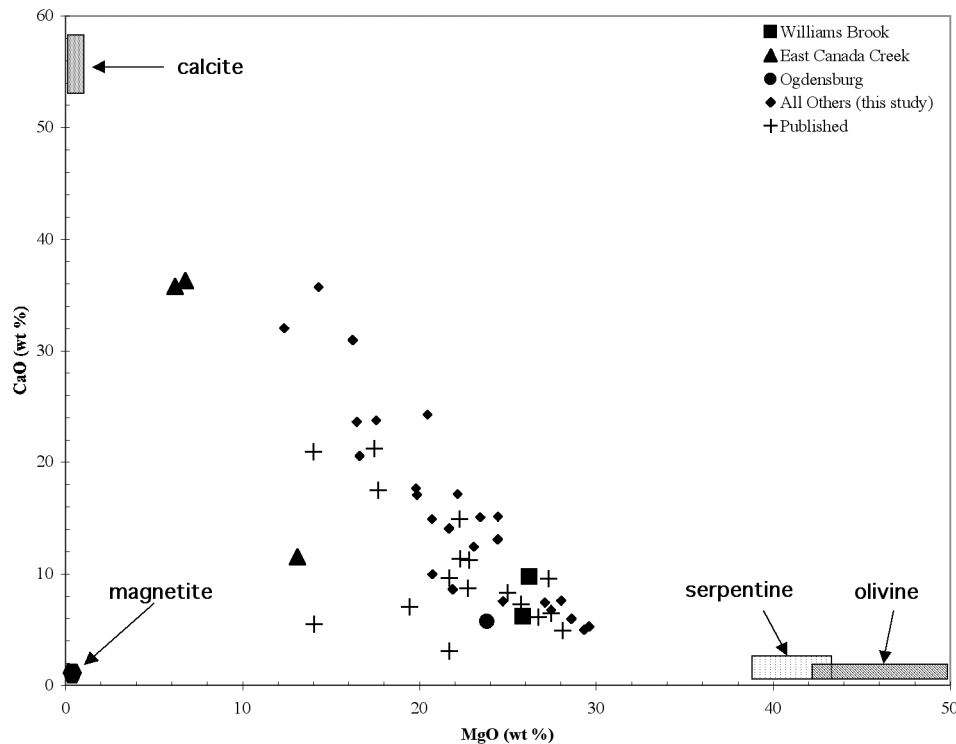

FIGURE 10—CaO vs. MgO in kimberlitic rocks of New York State. Major element oxide compositions reflect the variable modal mineral composition within and between dikes.

TABLE 2—Representative whole-rock analyses of kimberlitic rocks from New York State.

Map #:	5	10	17	20	24	25
Location Name:	Taughannock	Williams Br.	Cascadilla	Portland Pt.	Clintonville	Salt Spgs Rd
Sample#:	T1	W2	10069	IRx-99	IRx-100	10065
Major Element Oxides (XRF wt.%)						
SiO_2	27.34	32.05	34.40	27.55	34.55	37.70
TiO_2	1.53	2.42	1.55	1.37	1.58	1.39
Al_2O_3	2.89	3.09	3.26	2.59	6.37	4.33
FeO*	8.42	9.14	8.75	8.33	7.86	8.28
MnO	0.21	0.17	0.21	0.18	0.22	0.14
MgO	17.81	26.38	28.52	22.62	21.47	26.86
CaO	15.29	9.81	5.95	13.97	8.46	6.79
Na_2O	0.16	0.11	0.08	0.14	0.07	0.11
K_2O	1.37	1.94	1.50	0.93	2.09	2.88
P_2O_5	1.13	0.41	0.57	0.97	0.77	0.40
SO_3 >/=	0.34	0.22	0.30	0.09	0.10	0.30
Major oxides	76.50	85.74	85.09	78.73	83.53	89.19
Trace oxides	0.87	0.75	1.07	0.98	1.03	0.83
LOI	21.28	12.73	13.68	19.38	15.59	9.68
TOTAL	98.65	99.22	99.84	99.09	100.15	99.70
Trace Elements (XRF ppm)						
Ni	988	1013	1195	986	693	1083
Cr	1388	1875	1737	1340	1686	1755
Sc	24	17	19	19	26	16
V	262	227	262	216	323	147
Ba	1436	840	2861	1674	2795	1583
Rb	50	80	68	38	102	101
Sr	1473	511	926	1981	1152	806
Zr	287	142	189	246	225	147
Y	22	11	17	20	19	13
Nb	183	110	193	157	189	111
Ga	9	8	8	6	12	8
Cu	68	63	64	83	69	48
Zn	74	66	96	127	93	90
Pb	10	8	12	13	12	6
La	160	81	206	132	152	77
Ce	292	152	300	240	272	140
Th	21	13	27	20	25	14
Nd	112	59	98	93	95	50

TABLE 2 (Cont.)—Representative whole-rock analyses of kimberlitic rocks from New York State.

Map #:	27	28	29	30	31	32
Location Name:	Green St.	Dewitt	Euclid Ave	East Canada	Big Nose	Ogdensburg
Sample #:	GS1	15333	EA1	EC4f	BN1	11430
Major Element Oxides (XRF wt.%)						
SiO_2	34.25	37.41	36.99	22.24	30.63	31.62
TiO_2	1.27	1.72	1.13	2.55	1.19	2.33
Al_2O_3	3.46	4.96	3.71	4.66	3.50	7.67
FeO*	8.87	8.45	8.13	3.22	7.61	11.44
MnO	0.17	0.15	0.16	0.09	0.12	0.30
MgO	29.48	26.46	28.16	5.72	22.90	23.70
CaO	5.25	8.03	7.68	30.77	12.27	5.73
Na_2O	0.07	0.17	0.12	0.08	0.08	0.07
K_2O	1.43	3.20	1.86	2.43	0.79	1.37
P_2O_5	0.39	0.44	0.34	0.33	0.62	0.40
SO_3 >/=	0.08	0.22	0.23	0.34	0.34	0.03
Major oxides	84.73	91.21	88.51	72.43	80.04	84.66
Trace oxides	0.76	0.83	0.81	1.10	1.82	0.90
LOI	13.75	8.04	10.87	25.29	16.82	15.13
TOTAL	99.24	100.08	100.19	98.82	98.69	100.69
Trace Elements (XRF ppm)						
Ni	1160	1021	1226	943	993	535
Cr	1943	1523	2000	1382	2338	902
Sc	16	16	17	17	21	28
V	170	130	157	361	168	107
Ba	959	1432	1089	4351	9304	3360
Rb	66	99	74	112	34	85
Sr	402	1175	658	1016	1104	575
Zr	100	199	101	118	213	147
Y	12	12	9	11	13	25
Nb	105	132	86	77	135	218
Ga	7	11	7	9	7	16
Cu	48	42	40	99	57	23
Zn	75	125	70	161	18	64
Pb	6	17	5	6	7	7
La	81	89	68	58	93	207
Ce	145	148	124	102	172	328
Th	13	11	14	16	15	26
Nd	53	54	48	42	60	121

Because of the complex, hybrid nature of kimberlitic rocks, a number of chemical filters have been proposed to screen whole-rock analyses for the chemical effects of crustal contamination and/or weathering. Two that have been found to be useful are the contamination index [C.I. = $(SiO_2+Al_2O_3+Na_2O)$ / $(MgO+2*K_2O)$] (Ilupin and Lutz, 1971), and the molar Si/Mg ratio (Clement, 1982). Both of these indices are based upon the assumption that contamination by crustal rocks usually results in the addition of SiO_2, Al_2O_3, and Na_2O to the ultrabasic kimberlitic magma, and upon the fact that weathering usually leads to the removal of Mg and K cations and the relative enrichment in Si and Al. According to Mitchell (1986), contaminated rocks are considered to have Si/Mg > 0.88 and C.I. >1.5. Unfortunately, these indices are not universally applicable because of the diverse nature of potential crustal contaminants within and between kimberlite fields. In New York, for example, the kimberlite xenolith assemblage includes syenitic gneisses and amphibolites from the Grenvillian basement, as well as shale, dolostone, and limestone xenoliths from the Paleozoic cover. In one extreme example, the dike from the Cargill salt mine (sample BG 30) shows clear chemical evidence of contamination by the surrounding rock salt (Cl >1.3 wt. % and Na_2O > 2.2 wt. %). Considering the general nature and origin of kimberlitic rocks, probably all are chemically modified to some degree by the crustal rocks that they intrude.

Figure 11 is a plot of contamination index (CI) versus molar Si/Mg ratio; the boundaries between the fields for uncontaminated, moderately contaminated, and highly contaminated rock compositions are set at 1.25 and 1.75 for the CI, and at 0.9 and 1.2 for the Si/Mg ratio. While these values are somewhat arbitrary, they are consistent with the values adopted by Mitchell (1986) and are generally consistent with the macroscopic evidence for different degrees of contamination (i.e. abundance of crustal xenoliths). The diagram suggests that virtually all of the NY State kimberlites have been moderately to extensively chemically modified by weathering and/or crustal contamination. Somewhat surprisingly, the East Canada Creek dikes in the town of Manheim plot as the most contaminated samples, even though they contain the largest, most abundant and freshest phlogopite macrocrysts.
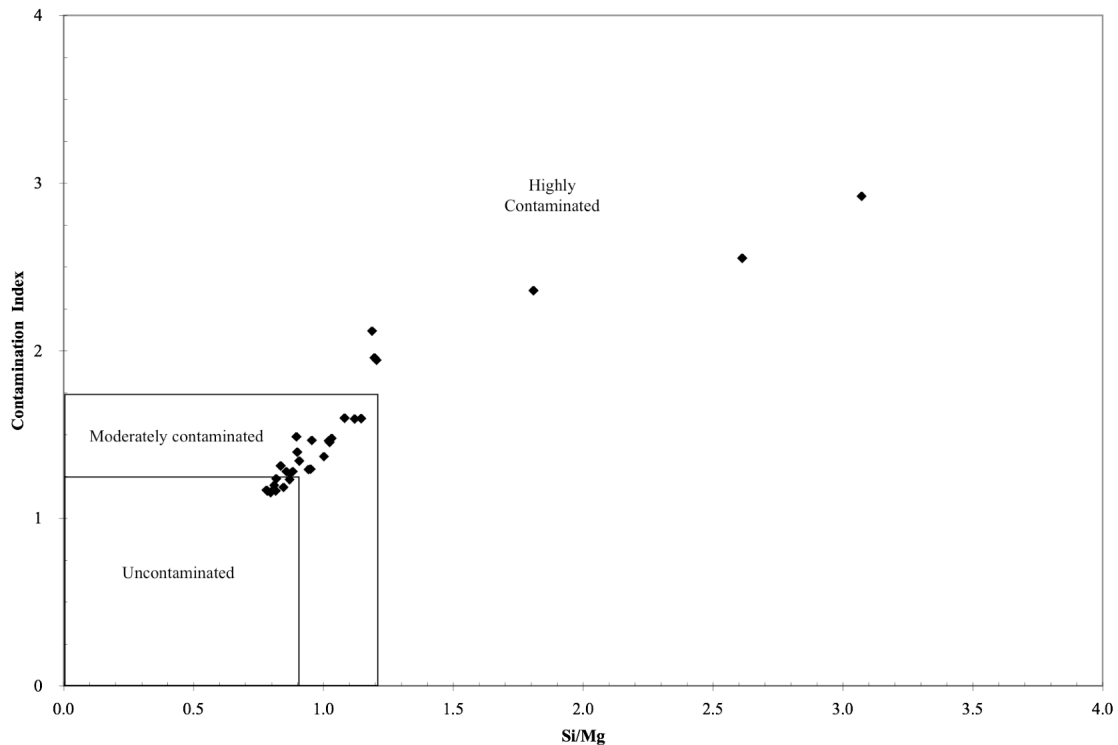

FIGURE 11—Plot of contamination index vs. molar Si/Mg ratio for New York State kimberlite-like rocks. [C.I.= $(SiO_2+Al_2O_3+Na_2O)$ / $(MgO+2*K_2O)$].

Despite the extensive alteration and contamination, the new 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 (e.g. Nb /TiO$_2$ - Figure 10). It is clear from these diagrams that the Williams Brook dike northwest of Ithaca, and the two dikes on East Canada Creek are chemically distinct intrusions and quite unlike all of the other dikes in central NY. While the significance of this is not yet fully understood, this is the first time that such systematic compositional differences have been observed in the kimberlitic rocks of New York. Additional radiometric dating and mineral trace element studies are planned to investigate these differences in more detail.
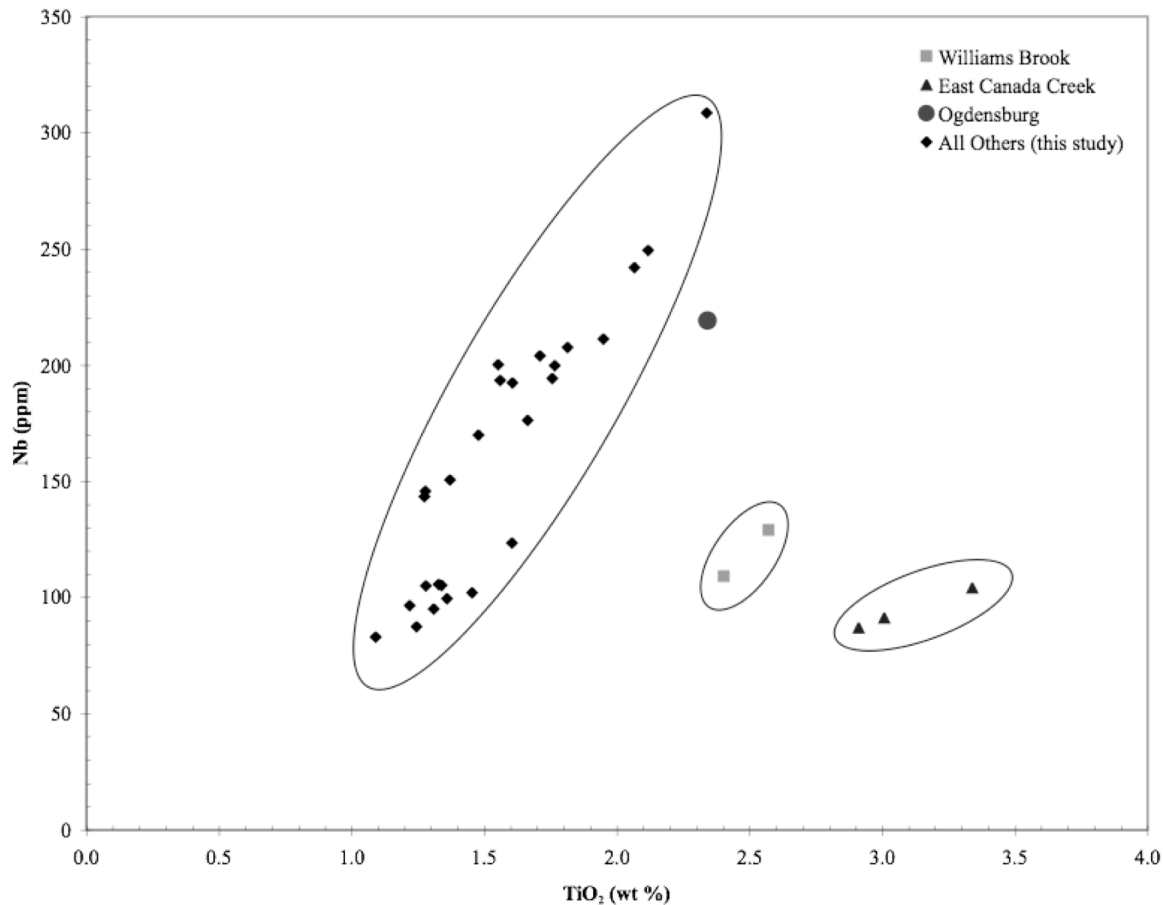

FIGURE 12—Nb (ppm) vs TiO$_2$ (wt. %) concentrations in kimberlitic rocks from New York State. Dikes from East Canada Creek and Williams Brook exhibit distinct HFS element ratios.

CLASSIFICATION: KIMBERLITES, ORANGEITES, OR LAMPROITES?

Are these unusal rocks really kimberlites? Over the years they have been referred to as "serpentine bodies" (Vanuxem, 1842), peridotites (Williams, 1887a), 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)

70

Kimberlites are currently divided (somewhat arbitrarily) into two groups (Smith et al., 1985; Skinner, 1989). 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 (or the "lamprophyric kimberlites" of Wagner (1914)). The two groups of kimberlites display subtle differences in their mineralogical composition (Smith et al., 1985; Skinner, 1989; Mitchell, 1995; Tainton & Browning, 1991).

The current formal definition for Group I kimberlites states that they "are volatile-rich (dominantly carbon dioxide) potassic, ultrabasic rocks commonly exhibiting a distinctive inequigranular texture resulting from the presence of macrocrysts (large crystals, typically 0.5–10 mm diameter) and, in some cases, megacrysts (larger crystals, typically 1–20 cm) set in a fine grained matrix" (Le Maitre et al., 2002). Some of the minerals from the macrocryst–megacryst association are mantle and crustal xenocrysts that were sampled and carried up by the kimberlitic fluid.

There is no formal definition at this moment for Group II kimberlites because they are less well studied. They were originally named "micaceous kimberlites" by Wagner (1914) and later "orangeites" (Wagner, 1928). According to Le Maitre et al. (2002), Group II kimberlites "belong to a clan of ultrapotassic, peralkaline volatile-rich (dominantly H_2O) rocks, characterized by phlogopite macrocrysts and microphenocrysts, together with groundmass micas." Mitchell (1986, 1995) argues that Group II kimberlites are not true kimberlites, but a distinct group of rocks. He suggests that they should be called "orangeites" to recognize their fundamentally different mineralogical character. According to Mitchell (1995; p.14) orangeites can be distinguished from kimberlites by "the absence of monticellite, magnesian ulvospinel, and Ba-rich micas belonging to the barian phlogopite-kinoshitalite series." In addition, orangeites can be distinguished from alnoites, lamprophyres and many other alkaline rocks by their lack of "melilite, alkali feldspar, plagioclase, kalsilite, or nepheline" (Mitchell, 1995; p.14). If these criteria are applied, then the central New York dikes would not be considered true (Group I) kimberlites; they would be classified as orangeiites. However, in terms of bulk chemical composition, the dikes often plot between the fields of kimberlites and orangeites (as defined by South African intrusions), with slightly more overlap with the Group I kimberlite field for most elements (Figure 13).

Lacking any widely accepted criteria for identifying and classifying this complex clan of igneous rocks, and the ambiguous petrographic and chemical features of the central New York dikes, we have chosen to refer to them as "kimberlitic" or "kimberlite-like", rather to call them kimberlites and imply that they are true analogues of group I kimberlites.
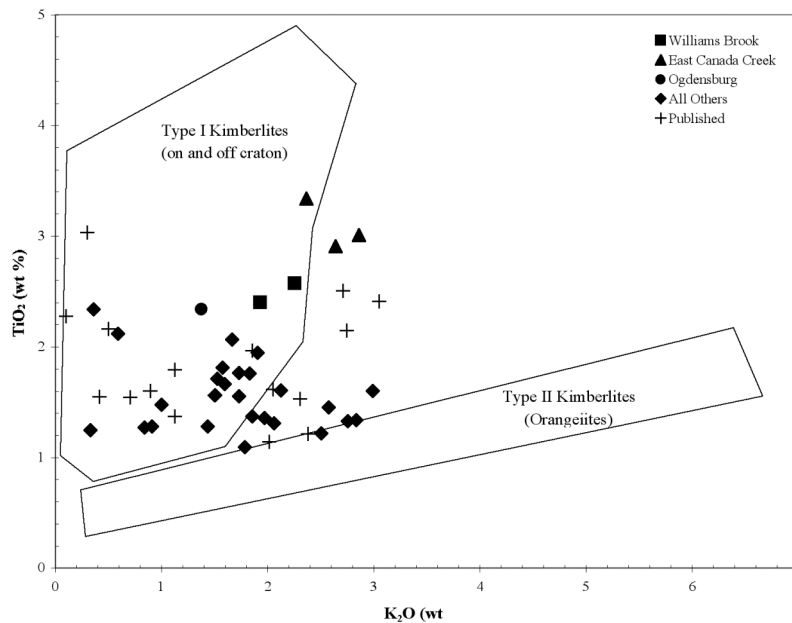

FIGURE 13—TiO_2 vs. K_2O concentrations in New York kimberlitic rocks. Fields for Group I and Group II kimberlites are from Mitchell (1995).

GEOGRAPHIC DISTRIBUTION AND AGES OF KIMBERLITIC ROCKS IN EASTERN NORTH AMERICA

Kimberlitic rocks in the eastern part of North America have been described from Tennessee (Safford, 1869; Gordon, 1927; Hall and Amick, 1944; Meyer, 1976), Kentucky (Diller 1885; Crandall 1887), Virginia (Sears and Gilbert, 1973), Pennsylvania (Kemp and Ross, 1907) and New York. These rocks are poorly exposed and occur as dikes, small diatremes, and pipe-like structures (Kentucky). The largest dike currently known in eastern North America is in Masontown, PA where it can be traced along strike for over 4 km.

These rocks were originally referred to as "mica peridotites", but mineralogically and texturally they can all be broadly classified as kimberlites. Dikes from all of the areas contain macrocrysts of olivine (usually highly serpentinized), phlogopite, pyrope garnet, and Cr-rich diopside, set in a strongly altered and calcite-rich groundmass. Distinct, mantle-derived ultramafic xenoliths are very rare; compositions of the observed macrocryst phases suggest many grains are from disaggregated garnet lherzolite (and possibly spinel lherzolite) xenoliths.

Even though there are many difficulties and uncertainties related to establishing the real age of the kimberlitic rocks of eastern North America, a compilation of the data published by Hall and Amick (1944), Zartman et al. (1967), Sears and Gilbert (1973), Pimentel et al. (1975) and Heaman and Kjarsgaard (2000) suggest a general trend toward progressively younger ages from south to north: Tennessee 225 to 350 Ma; Kentucky 257 to 275 Ma; Pennsylvania ~185 Ma; New York ~145 Ma. If valid, this apparent progressive age trend might be the continental expression of the northward migration of the opening of the Atlantic basin during this time (Taylor, 1984). A much more comprehensive study of all of the eastern North American dikes involving modern radiometric dating techniques is needed to test this hypothesis.

The kimberlitic rocks of New York are an important part of the record of Mesozoic tectonic and magmatic activity in eastern North America. They have fascinated and intrigued geologists since their discovery in 1837. Poor exposures along with extensive alteration and contamination have made unraveling their story an extremely difficult task. This report presents new whole-rock and mineral data that have made it possible to discern subtle differences between the clusters of dikes in central New York. At the completion of this study, we hope to be able to say a bit more about the age and origin of these unusual rocks.

ACKNOWLEDGEMENTS

REFERENCES CITED

Barnett, V.H., 1905, Notice of the discovery of a new dike at Ithaca, New York: American Journal of Science, v. 19, p. 210.

Basu, A.R., Rubury, E., Mehnert, H.H., and Tatsumoto, M., 1984, Sm-Nd, K-Ar and petrologic study of some kimberlites from eastern United States and their implication for mantle evolution: Contributions to Mineralogy and Petrology, v. 86, p. 35-44.

Broughton, J.G., 1950, Observations on the intrusion of rock salt by peridotite: Eos, Transactions American Geophysical Union, v. 31, p. 229-233.

Clement, C.R., 1982, A comparative geological study of some major kimberlite pipes in the Northern Cape and Orange Free State. University of Cape town, Cape Town.

Crandall, A.R., 1887, Report on the geology of Elliot County; also, notes on the trap dikes of Elliot County, Kentucky: Kentucky Geological Survey, v.13, 198 p.

Darton, N.H., and Kemp, J.F., 1895a, A new intrusive rock near Syracuse: Geological Society of America Bulletin, v. 6, p. 477-478.

—, 1895b, A newly discovered dike at DeWitt, near Syracuse, New York: American Journal of Science, v. 49, p. 456-462.

Dawson, J.B., 1980, Kimberlites and their xenoliths: New York, Springer-Verlag, 252 p.

Dawson, J.B., and Stephens, W.E., 1975, Statistical classification of garnets from kimberlites and associated xenoliths: Journal of Geology, v. 83, p. 589-607.

Diller, J.S., 1885, Dikes of peridotite cutting the Carboniferous rocks of Kentucky: Science, v.5, p,65.

Filmer, E.A., 1939, New peridotite dikes of Ithaca: Pan-American Geologist, v. 72, p. 207-214.

Foster, B.P., 1970, Study of the kimberlite-alnoite dikes in central New York (Finger Lakes region). SUNY at Buffalo, Buffalo, NY (Master's),

Gordon, C.H., 1927, Mica-peridotite dike in Union County, Tennessee: Geological Society of America Bulletin, v.28, p.125-216.

Hall, G.M., and Amick, H.C., 1944, Igneous rocks areas in the Norris Region, Tennessee: Journal of Geology, v.52, P.622-625.

Heaman, L.M., and Kjarsgaard, B.A., 2000, Timing of eastern North American kimberlite magmatism: continental extension of the Great Meteor hotspot track?: Earth and Planetary Science Letters, v.178, p.253-268.

Hogeboom, W.L., 1958, The petrology of the Green Street peridotite dikes in Syracuse, New York. [M.Sc. thesis]: Syracuse University, Syracuse, NY. 95p.

Hopkins, T.C., 1914, The geology of the Syracuse Quadrangle [New York]: Bulletin - New York State Museum, v. 171.

Hunt, T.S., 1858, Contributions to the History of Ophiolites. Part II.: American Journal of Science, v. 26, p. 234-240.

Ilupin, I.P., and Lutz, B.G., 1971, The chemical composition of kimberlite and questions on the origin of kimberlite magmas: Sovietskaya Geol., v. 6, p. 61-73.

Kay, S.M., and Foster, B.P., 1986, Kimberlites of the Finger Lakes region: New York State Geological Association, Field Trip Guidebook, v. 58, p. 219-238.

Kay, S.M., Snedden, W.T., Foster, B.P., and Kay, R.W., 1983, Upper mantle and crustal fragments in the Ithaca kimberlites: Journal of Geology, v. 91, p. 277-290.

Kemp, J.F., 1891, Peridotite dikes in the Portage sandstones near Ithaca, New York: American Journal of Science, v. 42, p. 410-412.

Kemp, J.F., and Ross, C.G., 1907, A peridotite dike in coal measures of southwestern Pennsylvania: New York Academy of Science Annals, v.17, p.509-518.

Kraus, E.H., 1904, A new exposure of serpentine at Syracuse, New York: American Geologist, v. 33, p. 330-332.

Le Maitre, R.W., Streckeisen, A., Zanettin, B., Le Bas, M.J., Bonin, B., Bateman, P., Bellieni, G., Dudek, A., Efremova, S., Keller, J., Lameyre, J., Sabine, P.A., Schmid, R., Sorensen, H., and Woolley, A.R., 2002,

Igneous rocks; a classification and glossary of terms; recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks Edition: 2: Cambridge, Cambridge University Press, 236 p.

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

—, 1888, The matrix of diamond: Geological Magazine, v. 5, p. 129-131.

Martens, J.H.C., 1924, Igneous Rocks of Ithaca, New York, and Vicinity: Geological Society of America Bulletin, v. 35, p. 305-320.

Matson, G.C., 1905, Peridotite dikes near Ithaca, New York: Journal of Geology, v. 13, p. 264-275.

Maynard, J.E., and Ploger, L.W., 1946, A study of the Salt Springs Road peridotite dike in Syracuse, New York: American Mineralogist, v. 31, p. 471-485.

Meyer, H.O.A., 1976, Kimberlites of the continental United States: A review: Journal of Geology, v. 84, p. 377-402.

Miller, D.S., and Duddy, I.R., 1989, Early Cretaceous uplift and erosion of the northern Appalachian Basin, New York, based on apatite fission track analysis: Earth and Planetary Science Letters, v. 93, p. 35-49.

Mitchell, R.H., 1986, Kimberlites: Mineralogy, Geochemistry, and Petrology: New York, Plenum Press, 442 p.

—, 1995, Kimberlites, Orangeites, and Related Tocks: New York, Plenum Press, 410 p.

Newland, D.H., 1931, An occurrence of peridotite near Ogdensburg, New York: Bulletin - New York State Museum, v. 286, p. 113-117.

Pimentel, N., Bickerman, M., and Flint, N.K., 1975, A new K-Ar date on the Masontown dike, southwestern Pennsylvania: Pennsylvania Geologist, v.6, p.5-7.

Safford, J. M. (1869) Geology of Tennessee; Mercier, Printer to the State, Nashville.

Schneider, P.F., 1902, New exposures of eruptive dikes in Syracuse, N Y: American Journal of Science, v. 14, p. 24-25.

Schneider, P.F., 1903a, Notes on some eruptive dikes near Ithaca [New York]: Proceedings of the Onondaga Academy of Sciences, v. 1, p. 130-136.

—, 1903b, The geology of the serpentines of central New York: Proceedings of the Onondaga Academy of Sciences, v. 1, p. 110-117.

Sears, C.E., and Gilbert, M.C., 1973, Petrography of the Mt. Horeb Virginia kimberlite: Geological Society of America Program with Abstracts, v.5, p.434.

Sheldon, P.G., 1921, A new dike near Ithaca, New York: Science, New Series, v. 53, p. 20-21.

—, 1927, On the association of faulting with dike intrusion: Journal of Geology, v. 35, p. 353-367.

Skinner, E.M.W., 1989, Contrasting group I and group II kimberlite petrology; towards a genetic model for kimberlites, *in* Ross, J., Jaques, A.L., Ferguson, J., Green, D.H., O'Reilly, S.Y., Danchin, R.V., and Janse, A.J.A., eds., Fourth international kimberlite conference: Perth, Australia, Geological Society of Australia, Sydney, N.S.W., Australia, p. 528-544.

Smith, B., 1909, Dikes in the Hamilton shale near Clintonville Onondaga County, New York: Science, v. 30, p. 724.

Smith, B., 1931, Notes on the Clintonville dikes, Onondaga County, New York: Bulletin - New York State Museum, v. 286, p. 119-122.

Smith, C.B., Gurney, J.J., Skinner, E.M.W., Clement, C.R., and Ebrahim, N., 1985, Geochemical character of southern African kimberlites: a new approach based upon isotopic constraints: Transactions Geological Society of South Africa, v. 88, p. 267-280.

Smyth, C.H., 1892, A third occurrence of peridotite in central New York: American Journal of Science, v. 43, p. 322-327.

—, 1893, Alnoite containing an uncommon variety of melilite: American Journal of Science, v. 46, p. 104-107.

—, 1896, Note on recently discovered dikes of alnoite at Manheim, New York: American Journal of Science, v. 2, p. 290-292.

—, 1898, Weathering of alnoite in Manheim, New York: Geological Society of America Bulletin, v. 9, p. 257-268.

—, 1902, Petrography of recently discovered dikes in Syracuse, New York, with note on the presence of melilite in the Green Street dike: American Journal of Science, v. 14, p. 26-30.

Tainton, K., and Browning, P., 1991, The relationship between Group-2 kimberlites and lamproites; an example from the northern Cape Province, South Africa: European Union of Geosciences Terra Abstracts, v. 3, p. 17-18.

Taylor, L.A., 1984, Kimberlitic magmatism in the eastern United States: Relationship to mid-Atlantic tectonism: Proceedings of the Third International Kimberlite Conference, v.1, p.417-424.

Van Tyne, A.M., 1958, Petrology of the Euclid Avenue peridotite intrusive. [M.Sc. thesis]: Syracuse University, Syracuse, NY. 144p.

Vanuxem, L., 1837, First annual report of the geological survey of the third district, New York: Albany, 265 p.

—, 1839, Third annual report of the geological survey of the third district, New York, 283 p.

—, 1842, Geology of New York; Part III, Comprising the survey of the third geological district: Albany, NY, W. and A. White and J. Visscher, 306 p.

Wagner, P.A., 1914, The diamond fields of South Africa: Johannesburg.

—, 1928, The evidence of the kimberlite pipes on the constitution of the outer part of the Earth: South African Journal of Science, v. 25, p. 127-148.

Wells, J. W., 1961, Unpublished New York State bedrock geology maps: in Broughton, J. G., Fisher, D. W., Isachsen, Y. W., and Richard, L. V., eds., Geologic Map of New York, Finger Lakes Sheet: New York State Museum and Science Service Map and Chart Series #5.

Williams, G.H., 1887a, On the serpentine (peridotite) occurring in the Onondaga salt group at Syracuse, New York: American Journal of Science, v. 34, p. 137-145.

—, 1887b, On the serpentine of Syracuse, N.Y.: Science, v. 9, p. 232-233.

—, 1890a, Note on the eruptive origin of the Syracuse serpentine (with discussion by James Hall and J. F. Kemp): Geological Society of America Bulletin, v. 1, p. 533-534.

—, 1890b, Origin of serpentine of Syracuse, New York: American Geologist, v. 5, p. 118.

Winter, J.D., 2001, An Introduction to Igneous and Metamorphic Petrology: Upper Saddle River, NJ, Prentice Hall, 697 p.

Zartman, R.E., Brock, M.R., Heyl, A.V., and Thomas, H H., 1967, K-Ar and Rb-Sr ages of some alkalic intrusive rocks from central and eastern United States: American Journal of Science, v.265, p.848-870.

ROAD LOG FOR FIELD TRIP A-3

KIMBERLITIC ROCKS OF NEW YORK

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Start at McDonald's parking lot on RT 13 just south of intersection with RT 281 on SW outskirts of Cortland.
		Follow Route 13 to Ithaca.
7.4	7.4	Turn right at light in village of Dryden. Stay on RT 13.
13.4	6.0	Turn left at light onto RT 366 (Dryden Rd).
17.4	4.0	Continue straight on Hoy Rd onto Cornell campus (RT 366 bears off to left)
17.7	0.3	Turn left onto Campus Rd.
18.2	0.5	Bear left onto Stewart Ave. Continue downhill on Stewart.
18.4	0.2	Turn right onto E. Buffalo St.
19.6	1.2	Intersection of RT 89 and RT 96. Continue straight on RT 96 north (Cliff St.)
28.7	9.1	Turn right onto Taughannock Park Rd. (Sign for Taughannock Falls State Park)
29.6	0.9	Stop 1. Pull off and park in gravel turn off on right side of road next to creek. Follow foot-path south down to stream bed.

STOP 1. TAUGHANNOCK FALLS STATE PARK

The entire stream valley is part of Taughannock Falls State Park. No hammering or collecting is allowed

At least three small (2-8cm wide) dikes are exposed on the north bank of the creek underneath a small poplar tree, slightly west of the parking area. Foster (1970) identified and mapped out 10 dikes in the streambed over a distance of ~ 800m. Erosion and sampling over the past 30+ years has made it increasingly difficult to locate half of these dikes.

The dikes intrude the Devonian West River Shale (Genesee Group), and follow the prominent N-S joints. The tendencies of the dikes to occur in clusters, to contain xenoliths of the local country rock, and to pinch out along strike, are all displayed nicely here.

Petrographically, the Taughannock Creek dikes contain the best preserved macrocryst assemblage of all the NY kimberlites, with unaltered olivine, phlogopite, pyrope garnet, Cr-bearing diopside, and various spinels being relatively common. The groundmass of the dikes is composed of varying proportions of serpentine, calcite, phlogopite, perovskite, apatite and magnetite. Relative to the other central NY dikes, the groundmass of the Taughannock Creek dikes is relatively calcite-rich.

The bulk chemistry of the Taughannock dikes is quite variable, but they tend to have relatively low SiO_2 contents and relatively high CaO, P_2O_5, Sr and Zr concentrations compared to other NY state kimberlites (Table 2).

29.6	0.0	Turn around and return to RT 96.
30.5	0.9	Turn left onto RT 96 S (Cliff St.)
38.2	7.3	Stop 2. Pull off in parking area on right side of road just north of intersection with Hopkins Rd. Hike up stream ~ 50m. Dike is well exposed on north wall of creek bed.

STOP 2. Williams Brook

*** Unusual and nicely exposed dike. Please do not hammer on outcrop. Collect only loose pieces found in streambed***

As noted by Kay & Foster (1986), the Williams Brook dike is the largest dike in the Cayuga lake region, with a width of ~3.7m. The contacts with the surrounding shale are not exposed along the eastern margin, and only poorly exposed on the western margin. Little to no thermal effects are visible.

The dike is petrographically and chemically distinct from all of the other Cayuga region dikes. It is very dark colored and dense, with abundant large (2-12mm) black serpentine pseudomorphs after olivine macrocrysts. Large phlogopite macrocrysts are also common, but in contrast to the Taughannock Creek dikes, no garnet, pyroxene, or spinel macroscrysts are observed. Some samples contain up to 10% unaltered olivine. The groundmass is similar to the other Cayuga area dikes, although perovskite and phlogopite are somewhat more abundant.

Chemically, the Williams Brook dike is unlike any of the other Ithaca region dikes (Table 2). It has a relatively high TiO_2 content, and relatively low Ba, Sr, and Zr concentrations. The bulk composition of the Williams Brook dike is most similar to the northernmost Ogdensburg dike.

38.2	0.0	Continue south on RT 96.
39.8	1.6	Intersection with RT 13N and RT 34 N. Turn left onto RT 34N (Meadow St.)
41.4	1.6	Take exit for RT 34N (Stewart Park / Auburn). Turn left at stop sign onto RT 34N.
47.1	5.7	Turn left onto RT 34B toward King Ferry.
47.7	0.6	Turn left onto Portland Point Rd.
48.1	0.4	Stop 3. Turn left into Hanson (South Lansing) rock quarry (just past rock conveyor that crosses over the roadway).

STOP 3. PORTLAND POINT QUARRY

Private Property. Contact Hanson Aggregates New York for permission to enter quarry

Two dikes were discovered in the Hanson Aggregates (former Portland Point) limestone quarry. One dike (5 to 7 cm wide) was found cutting the floor, and another, (12 to 20 cm wide) is exposed in the west wall of the quarry. Both strike N-S, have near vertical dips, and are strongly altered. They contain upper crustal xenoliths of both limestone and shale. Large serpentine pseudomorphs after olivine are common in some portions of the

dikes, but are absent in others. Pyrope garnets are very rare, but when present they contain unusually high amounts of chromium (5.77% Cr_2O_3). Calcite and serpentine are the most common minerals in the groundmass.

In 1947 a dike cutting the halite in the underground works of the Cayuga Rock Salt Company (just below the Portland Point limestone quarry) was discovered. The dike, studied by Broughton (1950), occurred at a depth of 0.4 mile, and was exposed underground for 300 feet. The dike is an extension of one of the dikes exposed in the overlying limestone quarry, and had been predicted by the local mine geologists.

48.1	0.0	Leave quarry. Turn right onto Portland Point Rd.
48.5	0.4	Turn right onto RT 34B.
49.6	0.7	Junction with RT 34. Continue straight on RT 34 toward Genoa.
55.4	5.8	Turn right onto Locke Rd.
56.5	1.1	Bear left; stay on Locke Rd.
59.3	2.8	Turn right onto RT 90 at stop sign.
60.8	1.5	Village of Locke. Turn left onto RT 38 (Main St).
64.5	3.7	Village of Moravia. Turn right onto RT 38A north (E Cayuga St).
76.0	11.5	Continue straight on RT 359.
77.7	1.7	Turn left onto RT 41A (West Lake Rd.)
83.5	5.8	Turn right onto US 20 (West Genesee St.)
83.6	0.3	Village of Skaneateles. Continue east on US 20.
88.7	5.2	Turn left onto Williams Rd.
89.0	0.3	Stop 4. Park along side of road near Melody Meadows Farm

STOP 4. CLINTONVILLE

** Private property. Please ask permission to access ravine from property owner. Please do not hammer on outcrop. Collect only loose pieces found in streambed**

The Clintonville dikes were discovered nearly 100 years ago (Smith, 1909). While only two dikes were originally identified, subsequent workers (Hopkins, 1914; Smith 1931) described a total of six dikes exposed over a distance of ~75m in the small ravine.

The dikes range in width from 2 to 30 cm, and all are nearly vertical with a N6-12°E strike. The dikes cut through shales of the Devonian Skaneateles Formation (Hamilton Group). What is most striking about the Clintonville dikes is the dramatically different degree of weathering and alteration exhibited by immediately

adjacent dikes. Two of the largest dikes exposed on the southern wall of the ravine are only centimeters apart, but one is completely altered to a soft yellow clay/hydroxide mixture while the other remains fairly coherent and is composed primarily of serpentine and calcite.

The fresher dikes contain macrocrysts of phlogopite, and nice euhedral pseudomorphs of olivine, along with scarce macrocrysts of diopside and spinel.

The bulk composition of the least altered Clintonville dikes closely approximates the "average" composition of all of the NY kimberlites.

89.0	0.0	Turn around and return to US 20.
89.4	0.4	Turn left onto US 20 (east).
89.7	0.3	Turn left onto RT 174 (Sevier Rd.)
92.0	2.3	Turn right onto RT 175E / RT 174
93.5	1.5	Bear right and stay on RT 175E (W Seneca Turnpike)
101.7	8.2	Turn left and stay on RT 175E (South Avenue)
103.6	1.9	Turn right onto W. Kennedy St. / RT 175
104.2	0.6	Turn left onto S. Salina St / US 11
105.7	1.5	Turn right onto James St / RT 5
		(Note: City fountain and park will be on your left; large white Post-Standard Building will be in front of you just past the intersection).
106.4	0.7	Turn right onto Lodi St. (Note: Large Regency Towers Apt. building will be at on your right).
106.5	0.1	Turn left onto Green Street.
106.6	350 ft.	Stop 5. Park in parking lot on your left. Walk uphill to vacant lot immediately adjacent to parking lot. Blocks of kimberlitic material are exposed in the slope to the north.

STOP 5. GREEN STREET

Only a few blocks remain of what was probably the very first kimberlite discovered in New York State. Please do not hammer on, or remove, any of the remaining large pieces

The Green Street, or "Foot-street road serpentinite", was first described by Vanuxem in 1839, although it was reportedly discovered by Oren Root in 1837 (Williams, 1887a). The Green Street dike is part of a cluster of relatively small to moderate sized (5 cm up to 10 m wide) dikes (and sill offshoots?) that run NNW from Green Street in the south to Griffith Street in the north. Excavations in this area over the years encountered the serpentinite in at least five separate localities (see Figure 1b). The actual number, size, and orientation of intrusions are not known. All intrude Silurian dolostones and shales of the Syracuse Formation (Salina Group), and many contain abundant crustal xenoliths. Most xenoliths are from the local country rock, although lower crustal metamorphic rocks (gneisses and amphibolites) are also found.

As with all the kimberlitic rocks, samples of the Green St.–Griffith St. intrusions are quite variable in color, texture, and mineralogy. During the early excavations, it was reported that the local children collected "rubies" (pyrope garnets) and "emeralds" (Cr-bearing diopsides) up to 1 cm in diameter (Williams, 1887a). Other macrocrysts reported include phlogopite, olivine, orthopyroxene, clinopyroxene, feldspar, garnet and spinel (Hogeboom, 1958). We have only observed phlogopite, olivine and spinel macrocrysts in the samples currently available for study. The matrix is composed of phlogopite, serpentine, calcite, magnetite, apatite, and perovskite. Smyth (1902) reported the presence of melilite, but this has not been confirmed.

106.6	0.0	Turn right out of parking lot onto Green St.
106.65	0.05	Turn left onto Lodi St.
107.1	0.45	Turn left onto Erie Blvd East.
109.6	2.5	Turn right onto Thompson Rd.
109.9	0.3	Turn right onto Springfield Rd.
110.0	0.1	Stop 6. Turn left into LeMoyne College Physical Plant parking lot. Hike up hill to Dewitt reservoir. Blocks of kimberlitic material are common along the slopes of the reservoir.

STOP 6. DEWITT RESERVOIR

Private property. Contact LeMoyne College security for permission to hike on trails up to reservoir. Abundant material is available for collecting on the banks of the reservoir, although please leave the larger blocks intact for future field trips

Other than the few small blocks on Green St., this is the only other kimberlitic material in the Syracuse region that is still exposed and accessible. The "dike" was discovered in 1894 by P. F. Schneider, and first described by Darton & Kemp (1895a.b). According to the contractor engaged in the initial excavation of the reservoir, blocks of the kimberlitic 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, 1895a,b; p.456). Some of the individual blocks were reported to be 20' x 50', indicating that the original intrusion was a very large dike or possibly a diatreme or sill.

What is most striking about the DeWitt material is the abundance of dark, dense, relatively hard rocks. In fact, some of the "surplus" blocks excavated from the reservoir were "crushed and used for road material in DeWitt with satisfactory results" (Schneider, 1903b).

The freshest samples contain abundant, well-defined pseudomorphs of serpentine after olivine and rare macrocrysts of phlogopite and pyrope garnet. The matrix consists largely of phlogopite, serpentine, calcite, magnetite, and perovskite.

		To get onto the NY Thruway (I-90)
110.0	0.0	Leave parking lot. Turn right (east) onto Springfield Rd.
110.1	0.1	Turn left onto Thompson Rd.

112.7	2.6	At Carrier traffic circle, take 2nd exit for I-90 tollbooths (Exit 35).

To return to Cortland / SUNY Cortland

110.0	0.0	Leave parking lot. Turn right (east) onto Springfield Rd.
110.1	0.1	Turn left onto Thompson Rd.
110.6	0.5	Take the ramp onto I-690 W
113.6	3.0	Take the exit for I-81 S toward Binghamton. (Note: Exit will be on your left). Stay on I-81 S
144.3	30.7	Take Exit 12 (Homer / Cortland) off of I-81 S.
144.8	0.5	Follow signs for US-11 S / RT 41 S and merge onto US-11 / RT 41. Stay on US-11 / RT 41 into downtown Cortland.
146.9	2.1	Turn right onto Groton Ave / RT 222
147.3	0.4	SUNY Cortland Campus will be on your left (south).

END OF FIELD TRIP