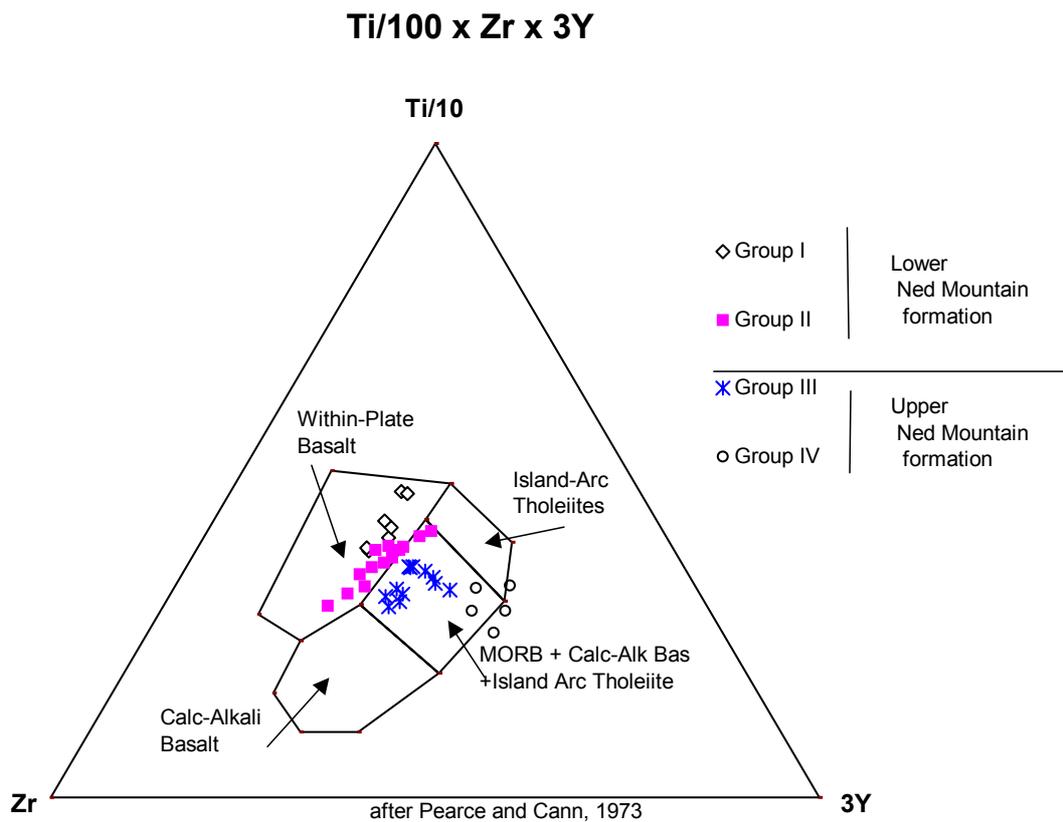


**THE BIRTH OF IAPETUS:
GEOCHEMICAL EVIDENCE FOR LATE NEOPROTEROZOIC RIFTING FROM
THE METAIGNEOUS ROCKS OF THE NED MOUNTAIN FORMATION, MANHATTAN PRONG**

Pamela Chase Brock and Patrick W. G. Brock
Queens College of CUNY, School of Earth and Environmental Sciences, Flushing, N. Y. 11367

The Ned Mountain formation is a unit of Late Neoproterozoic age, positioned stratigraphically between the Grenvillian basement (Fordham Gneiss) and Cambro-Ordovician cover (Inwood Marble, Walloomsac Schist) in the Manhattan Prong (southeastern New York and adjoining Connecticut). The Ned Mountain formation contains abundant, bimodal metavolcanic rocks, which are inferred to be the products of rift-basin magmatism. Ned Mountain formation is the special focus of our ongoing reconnaissance geochemical study, though we aim to characterize, compare, and contrast all of the major metaigneous units of the Manhattan Prong. Our findings so far include: (1) both the mafic and felsic rocks of the Ned Mountain are chemically distinguishable from Fordham Gneiss; (2) metarhyolite of the Ned Mountain shows consistent “intraplate” affinity; (3) mafic rocks of the Ned Mountain are chemically diverse, displaying a wide range of trace-element compositions. Ned Mountain rocks include intraplate tholeiites as well as P-MORB and E-MORB-like lithologies. Stratigraphic constraints within the Ned Mountain formation demand that the intraplate tholeiites, as a group, be older than the P-MORB-types. The best explanation for the observed chemical evolution of the Ned Mountain mafic rocks is progressive melting of a mantle plume. This mantle plume, we infer, triggered the rifting event that opened the Iapetus Ocean.



Rift-related rocks of Late Neoproterozoic age have been mapped in a discontinuous chain along the length of the Appalachians, from Newfoundland (Williams and others, 1985) to Alabama (*e.g.*, Thomas, 1991). However, the

rift-related strata of the Manhattan Prong, the Ned Mountain formation, have only recently been distinguished (Brock, 1989; 1993). This unit was not recognized during the first 110 years of geological investigations in the Manhattan Prong because of the complexity of the Prong's structure, the high grade of Ordovician regional metamorphism, and the many resemblances between Ned Mountain lithologies and those of other stratigraphic units.

Geochemical analysis of the Manhattan Prong's metaigneous rocks provides an independent test for our stratigraphic interpretations. We have found that the Grenvillian-aged mafic rocks of the Manhattan Prong are typically depleted in Nb and Ta; both arc-tholeiite and calc-alkaline metabasalt appear to be present. Associated felsic rocks plot as volcanic-arc granite on a Rb versus Nb+Y diagram. Fordham gneisses share their volcanic-arc affinity with neighboring portions of the Grenville province in the northern Appalachians (*e.g.*, McLelland and Chiarenzelli, 1990).

Lithically varied rift-facies strata of the Ned Mountain formation unconformably overlie the arc-related rocks of the Fordham Gneiss. Despite the sedimentological diversity, the chemical compositions of the mafic rocks relate to their stratigraphic position within the Ned Mountain formation, and are independent of the nature of adjoining lithology. Thus, intraplate tholeiites (Groups I & II, Fig. 1) occur near the base of the sequence, where they are interbedded at some locations with quartz-feldspar-garnet-sillimanite gneisses, at other locations with graphitic, orthoamphibole-bearing basal metasandstones, at still other locations with calc-silicate rocks or quartz-feldspar granofels. The upper part of the Ned Mountain formation consists largely of bimodal metavolcanic sequences, layered metavolcaniclastic rocks, quartz-feldspar granofels, and calc-silicate rocks. All of these lithologies are accompanied by amphibolites with P-MORB or E-MORB chemistry (Groups III & IV, Fig. 1). Basal metaconglomerates with E-MORB-type amphibolitic interlayers sit directly on Fordham Gneiss at some localities; at these places, intraplate tholeiites are absent. Younger portions of the Ned Mountain formation are more broadly distributed than older ones, revealing the Fordham-Ned Mountain contact to be time-transgressive.

Trace-element and REE data further illuminate the origin of the Ned Mountain mafic rocks. An underlying unity appears to be present among the disparate lithologies; most of the intraplate and E-MORB rocks can be understood as products of progressive melting of a primitive source. However, the high Ba/Nb and La/Nb ratios of certain rocks require inputs from either continental-lithospheric mantle or substantial crustal contamination. Drawing on a combination of chemical (trace-element and REE) and stratigraphic evidence, we propose the following model: First, a primitive-mantle source melted at depth (garnet peridotite field), yielding increasing degrees of melt over time. Later, continental-lithospheric mantle began to melt extensively, and these melts mixed in varying proportions with the primitive-mantle melts. Finally, the primitive source generated melt at shallow depth (spinel peridotite field).

This model envisions a plume origin for the Ned Mountain basalts and for the associated rifting. The region affected by this plume would have been many hundreds of kilometers in diameter, since Ned Mountain-like intraplate tholeiite has been reported north into Quebec (*e.g.*, Vermette and others, 1993), and at least as far south as the Pennsylvania/Maryland border (*e.g.*, Smith and others, 1991). Rift-related igneous activity in the Manhattan Prong continued to at least 562±5.5 Ma (Rankin and others, 1997), and was followed by development of the Cambro-Ordovician carbonate bank; the Iapetus Ocean had been born.

ACKNOWLEDGMENTS

XRAL Laboratories performed the chemical analyses; funding for the analytical work was provided by PSC-CUNY grant #669223. Many of the samples were collected in the course of our mapping for the STATEMAP project, which was supported by the New York State Geological Survey and the United States Geological Survey.

REFERENCES

- Brock, P. C., (1989), Stratigraphy of the northeastern Manhattan Prong, Peach Lake quadrangle, New York-Connecticut, *in* Weiss, D., ed., Field Trip Guidebook, New York State Geological Association, 61st Annual Meeting, 1-27.
- Brock, P. C., (1993), Geology of parts of the Peach Lake and Brewster quadrangles, southeastern New York and adjacent Connecticut, and basement blocks of the north-central Appalachian, [Ph.D. thesis], City University of New York, 494 p.
- McLelland, J. M., and Chiarenzelli, J. R., (1990), Geochronological studies in the Adirondack Mountains and the implications of a Middle Proterozoic tonalitic suite, *in* Gower, C. F., Rivers, T., and Ryan, B., eds., Mid-Proterozoic Laurentia-Baltica, Geological Association of Canada Special Paper 38, 175-194.

- Pearce, J. A, and Cann, J. R., (1973), Tectonic setting of basic volcanic rocks determined using trace element analyses, *Earth and Planetary Science Letters*, 19, 290-300.
- Rankin, D.W., Tollo, R.P., Aleinikoff, J.N., and Ayuso, R.A., (1997), Manhattan Prong A-type metagranites with feldspar Pb isotope affinity to Laurentia and zircon ages of ~563 Ma: support for late Neoproterozoic Iapetan rifting. *Geological Society of America Abstracts with Programs*, 29, 74.
- Smith, R. C., II, Berkheiser, S. W., Jr., and Barnes, J. H., (1991), Pennsylvania's version of the Catoclin metabasalt story, *in* Sevon, W. D., and Potter, N., Jr., eds, *Guidebook for the 56th Annual Field Conference of Pennsylvania Geologists*, 5-20.
- Thomas, W. A., (1991), The Appalachian-Ouachita rifted margin of southeastern North America, *Geological Society of America Bulletin*, 103, 415-431.
- Vermette, D. R., Hébert, R, and Bergeron, M., (1993), Petrological and geochemical characteristics related to early rifting of Iapetus Ocean, Quebec Appalachians, *American Journal of Science*, 293, 81-110.
- Williams, H., Gillespie, R. T., and Van Breemen, O., (1985), A late Precambrian rift-related igneous suite in western Newfoundland, *Canadian Journal of Earth Sciences*, 22, 1727-1735.