

GEOCHEMISTRY OF THE SCHISTS OF CENTRAL PARK, NEW YORK CITY.

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INTRODUCTION

On the Geologic Map of New York (Fisher and other, 1970) the bedrock of Central Park is described as Manhattan Schist with the exception of minor unexposed Inwood Marble along the northern edge of the park. More recently, however, the Manhattan Schist has undergone several reinterpretations (particularly Baskerville and Mose, 1989; Hall, 1980; Merguerian and Baskerville, 1987; and Taterka, 1987) which have resulted in much more complexity than previously thought. Most recent geologic interpretations of Central Park include at least two early Paleozoic mica-schist formations, such as the Hartland Formation and the Manhattan C Formation, that are separated by a major terrain suture; Cameron's Line. The meta-sediments southeast of Cameron's Line have been interpreted as having been deposited as deep water eugeosynclinal rocks, and to the northwest of the line as miogeosynclinal shallow water (continental shelf) to transitional rocks.

Our investigation was designed to assess the extent to which differences in the depositional environment of the sedimentary protoliths are reflected in the chemical composition of the various schist units exposed in Central Park. Our preliminary data, however, do not provide any geochemical basis for distinguishing among the schist units and instead support previous interpretations that the bedrock of Central Park is dominated by a single schist. Minor differences in accessory mineral content may have been controlled by variations in the depth reached during the metamorphism of a single thick shale unit before it was abducted and transported westward as a set of allochthonous overthrust slabs.

GEOLOGIC SETTING

One of the first geologic studies of the New York City area (Merrill, 1890) includes a lithologic description of Manhattan including the Manhattan Schist that makes up most of the island. Merrill's description of the Manhattan Schist remained largely unchanged until it was subdivided by Hall (1968) into the Manhattan A (a sillimanite-garnet-muscovite-biotite schist), Manhattan B (a dark amphibolite, not continuous), and Manhattan C (a garnet-muscovite-biotite schist). The age of the Manhattan Schist was recognized by Hall (1968) as Mid-Ordovician, unconformably overlying Cambro-Ordovician Inwood Marble. A Mid-Ordovician age was confirmed by Ratcliffe and Knowles (1969) based on a palmatozoan in the basal marble of the schist. Reinterpretations (Hall, 1976; Merguerian and Baskerville, 1987; Taterka, 1987; and Baskerville, 1989), however, suggest that much of what was mapped as Manhattan Schist may be older than Mid-Ordovician. These older eastern, deep-water formations were overthrust to a position above the Inwood and the younger (Manhattan A) schist. Merguerian and Sanders (1991) on the basis of lithostratigraphic evidence subdivide the Manhattan Schist into upper, middle and lower units. Each of the units are kyanite-sillimanite grade amphibolite facies mica-quartz-plagioclase-garnet schists that plunge to the south.

The lowest but youngest unit (Manhattan A) is exposed in northern Manhattan, but probably not in Central Park. Merguerian and Sanders (1991) interprets the lower unit as an autochthonous unit that is part of a

miogeosynclinal (shallow water) basement-cover sequence deposited on the Proterozoic crust of the New England Appalachians.

The middle but oldest unit (Manhattan B&C) is interpreted by Merguerian and Sanders (1991) as a Waramaug and Hoosac Formation correlative, composed of metamorphosed Cambrian to Ordovician sediments and minor volcanics deposited in the transitional slope and rise environment of the lower Paleozoic shelf edge of ancestral North America. The middle unit comprises the bulk of the exposed schist of Manhattan including the northern Central Park area (Taterka, 1987). It is referred to as the Manhattan Formation by Taterka (1987), and this report.

The upper unit is described by Merguerian and Sanders (1991) as identical to the Hartland Formation. They interpret its protolith as eugeosynclinal deep-oceanic shale and interstratified volcanic rock formed adjacent to North America during the Early Paleozoic. The upper unit is mapped as Hartland Formation by Baskerville (1989), Taterka (1987), and this report. On Taterka's (1987) geologic map of Central Park the Hartland formation is exposed throughout the southern half of the park (Figure 1).

The Manhattan Formation and the Hartland Formation are separated by Cameron's Line which is a major tectonic suture that has superposed meta-eugeoclinal rocks atop meta-miogeoclinal (continental shelf) rocks (Merguerian, 1983). Rocks north of Cameron's Line (Figure 1) are metased miogeoclinal units (Baskerville and Mose, 1989; Hall, 1976). Rocks south of the line are an eugeosynclinal (deep water) sequence, deposited on oceanic crust which accreted to North America during the Taconic orogeny (Jackson and Hall, 1982). Taterka (1987) extends Cameron's Line through the Reservoir near the middle of Central Park (Figure 1).

Hartland Formation - Merguerian and Sanders (1991) describe the Hartland Formation as "gray-weathering, fine to coarse grained, well layered muscovite-quartz-biotite-plagioclase-garnet schist, gneiss, and granofels with cm and m scale layers of greenish amphibolite + garnet". They were originally interlayered shale, graywacke, and volcanoclastics (Gates and Martin, 1976) that have been metamorphosed to at least sillimanite grade (Baskerville and Mose, 1989). Serpentinites from Hartland Terrane rocks suggests an association with oceanic ophiolites (Baskerville, 1989). The Hartland Formation correlates with Ravenswood Granodiorite (Baskerville and Mose, 1989) that was isotopically dated as Early Ordovician (Mose and Baskerville, unpublished).

Manhattan Formation - Merguerian and Sanders (1991) describe the middle unit of the Manhattan Schist (the Manhattan Formation) as a "rusty to maroon weathering, medium to coarse-grained, massive biotite-muscovite-plagioclase-quartz-garnet-kyanite-sillimanite gneiss and schist". The Manhattan Formation is therefore distinguished from the Hartland largely on the basis of its accessory kyanite and sillimanite content although both minerals are also found in the Manhattan A.

Three informal members of the Manhattan Formation have been identified by Taterka (1987). The lowermost 110th St Member is a smooth, brown-weathering, garnet-mica schist. The overlying Blockhouse Member is a gray garnet-mica-kyanite-magnetite schist. The East Meadow Member is a brownish-gray, garnet-mica-kyanite schist that appears to be a layer within the Blockhouse.

Taterka (1987) finds some similarity between the 110th St Member and the Middle Ordovician Walloomsac Schist. He, therefore, proposes an alternative correlation of the 110th St Member with the Walloomsac Schist (a Manhattan A correlative) as "... supported by the position of the 110th St. Member below rocks which are undoubtedly Manhattan Formation (i.e. Blockhouse Member) and above the contact with the Inwood Marble as reported in excavations on 110th

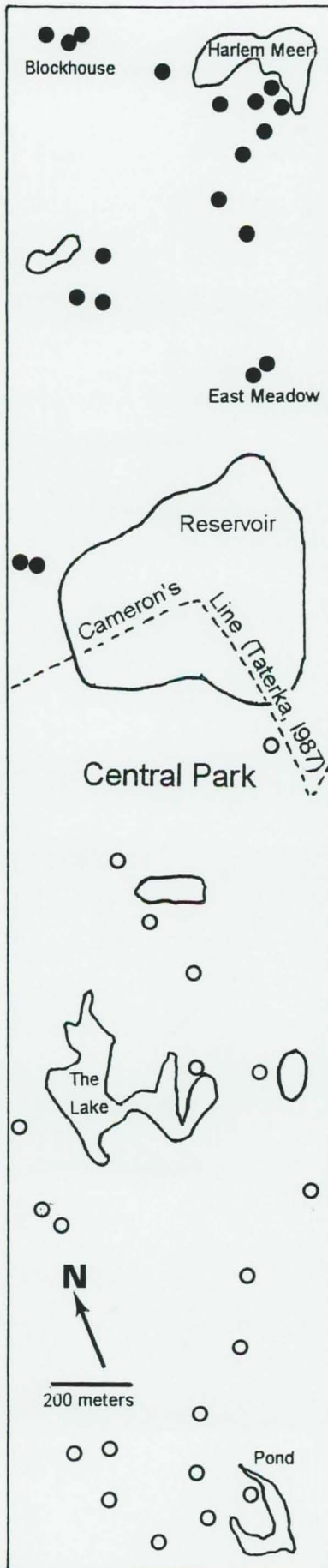


Figure 1. Map of Central Park, New York with sample locations.

Table 1. Chemical analyses of the schists of Central Park.

samples	North Central Park		South Central Park	
	19 av.	range	20 av.	range
Wt.%				
SiO ₂	59.21	47.11-68.42	59.31	47.85-75.72
TiO ₂	1.3	0.81-2.04	1.23	0.66-1.78
Al ₂ O ₃	17.51	13.56-25.1	17.32	10.9-23.01
FeO _t	7.35	4.72-11.68	7.42	3.72-11.58
MnO	0.11	0.02-0.19	0.11	0.08-0.2
MgO	3.52	2.51-4.53	3.54	1.19-5.56
CaO	1.44	0.41-3.08	1.14	0.27-2.21
Na ₂ O	1.92	0.32-3.26	1.57	0.31-2.63
K ₂ O	3.97	2.24-6.02	4.56	1.23-6.69
P ₂ O ₅	0.18	0.1-0.28	0.19	0.07-0.4
LOI	3.01	1.52-5.12	3.16	1.6-6.83
Total	99.52		99.55	
PPM				
Cr	105	50-154	121	45-363
Ni	38	13-60	47	15-71
Rb	105	77-132	122	65-181
Sr	189	20-342	141	15-222
V	153	88-194	160	67-230
Zr	275	166-563	235	158-456

Table 2. Chemical analyses of shales and schists.

samples	NASC	Martinsburg	Manhattan	Hartland
	shales	Shale	Formation	Formation
	40	10	3	3
Wt.%				
SiO ₂	64.8	59.61	57.36	64.31
TiO ₂	0.7	0.79	1.16	0.88
Al ₂ O ₃	16.9	16.62	15.43	14.32
FeO _t	5.66	6.04	7.47	6.06
MnO	0.06	0.1	0.09	0.08
MgO	2.86	3.31	4.35	3.26
CaO	3.63	2.35	3.29	1.52
Na ₂ O	1.14	1.03	0.98	1.59
K ₂ O	3.97	3.41	4.19	3.44
P ₂ O ₅	0.13	0.15	0.15	0.16
LOI	0	5.73	4.74	3.69
Total	100	99.14	99.21	99.31
PPM				
Cr	125	85	87	96
Ni	58	54	29	28
Rb	125	129	121	117
Sr	142	80	271	215
V	n.a.	143	150	79
Zr	200	151	276	296

St. (Charles Baskerville, pers. comm., 1987) and as shown on the geologic map of New York (Fisher and others, 1970)."

SAMPLING AND ANALYSIS

The early Paleozoic schists of Central Park are well exposed through thin glacial sediment. Most exposures are glacially polished with noticeable weathering confined to a thin (<3 cm thick) surface layer and joint surfaces. Weathered surfaces are brown and friable and were easily avoided during sampling. Thirty-nine samples that include each of the schist types described by Taterka (1987) were collected and chemically analyzed for this report (Figures 1 and 2 and Table 1). Exposures of amphibolite and pegmatite are also common throughout the park but are not described in this report.

Representative samples of Manhattan Formation and Hartland Formation from locations outside Central Park were collected and analyzed for purposes of comparison. Each of the Manhattan and Hartland exposures described by Merquerian and Baskerville (1987) and Baskerville (1987) were examined. Table 2 includes analyses of samples of Hartland Formation and Manhattan Formation collected from exposures at Boro Hall Park in the Bronx near the intersection of the Cross Bronx Expressway (I-95) and Third Avenue.

Ten samples of middle Ordovician Martinsburg shale were also collected and analyzed for comparison (Table 2). The Martinsburg samples were collected from sites near the Delaware River along Route 46 in New Jersey.

Each sample was stained for K-spar with Sodium-Cobaltinitrite. Thin sections were cut from representative samples and splits were ground into fine power and prepared for analysis. XRF data (Tables 1 and 2) were determined with a Rigaku wave-length dispersive spectrometer. Calibration curves were based on USGS standards GSP-1, AGV-1, G-2, W-1 and BCR-1 that were replicated during each sample run.

ANALYTICAL RESULTS

The chemical range of samples from the northern half of Central Park completely overlaps the range from the southern half (Table 1 and Figure 2). There are no apparent chemical trends when plotted on N-S lines through Central Park, and no chemically distinctive clusters of samples were identified anywhere in the Park. Most variations in the chemical composition of the schist correlate with random variations in biotite and feldspar content. Samples relatively rich in biotite are enriched in K₂O, FeO, MgO, Cr, Ni and Rb, whereas samples relatively rich in feldspar are enriched in Na₂O, Al₂O₃, and Sr.

The average composition of schist collected from northern and southern Central Park (Table 1) resembles the North American shale composite (NASC, Table 2). The schists of Central Park are somewhat enriched in FeO and depleted in CaO compared to the NASC, the Martinsburg Shale (Table 2), and most of the collections of analyzed shale and metamorphosed shale listed by Gromet and others (1984) and Shaw (1954). However, there is no chemical evidence that would preclude a rather typical shale as the protolith of the Central Park schists. Several studies including Shaw (1954) indicate that the chemical composition of shale remains largely unchanged during regional metamorphism apart from a decrease in volatile content.

The sample populations representing the Manhattan and the Hartland Formations (Table 2) are too small to be truly representative, but on the basis of available data it appears that the Central Park schist averages compare more closely with the Manhattan Formation than with the Hartland

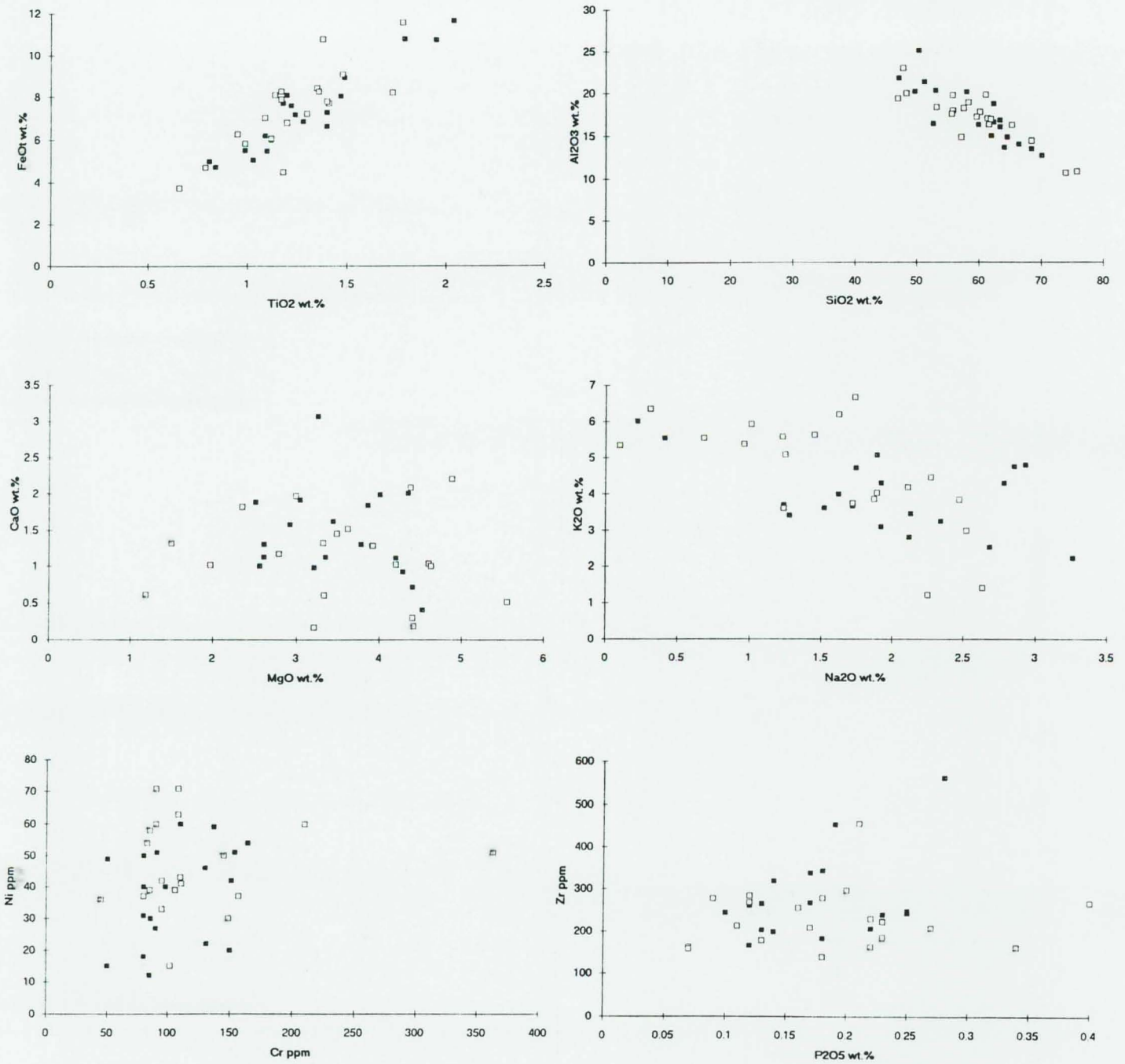


Figure 2. Variation diagrams for samples plotted onto Figure 1. North of Cameron's Line = ■ ; South = □ .

Formation, particularly SiO₂, TiO₂, FeO, and Zr. Concentrations of CaO and Sr, however, compare more closely with the Hartland Formation, although CaO and Sr are highly variable and strongly influenced by slight variations in feldspar content. Sr is particularly enriched in K-feldspar and it may be of significance that K-feldspar is absent from stained slabs of Hartland Formation collected at Boro Hall Park but constitutes up to 4 volume percent of the Manhattan Formation samples collected there. K-feldspar was found in trace amounts in most samples of schist from Central Park, again up to 4 volume percent.

INTERPRETATION

It is well known that the mineralogy and chemical composition of sediments are controlled largely by provenance and depositional environmental factors. It might, therefore, be expected that any given miogeosynclinal sediment derived from a crystalline continental platform source might be expected to consist of a mineral assemblages somewhat unlike that of a typical eugeosynclinal sediment derived from an island arc source. However, on the basis of the geochemical data presented in Table 1 and Figure 2 it is unlikely that the rocks of northern Central Park were deposited in a sedimentary environment or were derived from a source unlike the rocks of southern Central Park. Our evidence indicates that they are chemically indistinguishable.

We, therefore, can offer no geochemical basis for distinguishing between the schist of southern Central Park mapped as Hartland and the schist of northern Central Park including any of the three informal members of the Manhattan Formation of Central Park (Taterka, 1987), despite major differences in the depositional environments proposed in most recent geologic reports.

We also find no compelling reason to exclude the Martinsburg Shale as a possible stratigraphic correlative of the schists of Central Park. The mid-Ordovician Martinsburg in New Jersey is over 3,000 m thick and it is not unlikely that it originally extended several km east of New Jersey where it would have become subjected to the same Taconic compression that metamorphosed the schists of New York City. It may not be possible to determine the extent of westward transport of the allochthonous overthrust slabs but they might not have moved very far before reaching Central Park from a similar metasedimentary source. Although the schists on Manhattan are divided into three distinct sillimanite-grade lithostratigraphic units they are each mineralogically similar and are mapped only on the basis of subtle differences in minor mineral content. They are each mica-plagioclase-quartz schists and variations in minor minerals may be a function of subtle variations in depth of burial of virtually the same shale.

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