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THE HURRICANE MOUNTAIN FORMATION MÉLANGE AND UNCONFORMABLY OVERLYING LOWER TO MIDDLE ORDOVICIAN VOLCANICS, BRASSUA LAKE AND MOOSEHEAD LAKE QUADRANGLES

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INTRODUCTION

Significance of mélange is central to development of accretionary tectonic theory despite the fact that dynamic processes internal to developing mélanges remain poorly understood. Inasmuch as the observation of mélange in the making is elusive, inference as to the origin of mélange in the geologic record — particularly the early Paleozoic — must be integrated from a diversity of structural and lithologic data. The purpose of this trip is to examine the Hurricane Mountain Formation within a logistically tractable, small portion of its regional extent. This necessarily restricts observation of the variety of clasts that occur in the unit throughout its strike belt, as well as of lithic variation in the matrix. Other varieties are described. Determination of depositional vs. tectonic modes of emplacement of clasts is hindered by subsequent structural modification during the Acadian orogeny, but nonetheless the early structural history of the Hurricane Mountain Formation must be gleaned in large measure from the modes of origin and emplacement of its clasts.

The relationship of pre-Silurian terranes bordering the Hurricane Mountain Formation remains speculative. Zen (1983) proposed that Taconian subduction took place along a lineament defined in part by the Lobster Mountain anticlinorium in which the Hurricane and its bordering pre-Middle Ordovician units lie. Geologic relationships in the Brassua Lake — Moosehead Lake part of the Lobster Mountain anticlinorium argue for inception of a mélange-forming event in later Cambrian, but not later than earliest Ordovician (Tremadocian) time. There is no evidence for further folding until the Acadian, inasmuch as Lower and Middle Ordovician (Boucot, 1969) and Upper Ordovician (Neuman, 1973) strata responded to Acadian deformation in virtually every respect similarly to Silurian and Lower Devonian strata overlying them. Together they form one structural package of singly-deformed and similarly-deformed rock. Similarity of pre-Middle Ordovician strata on each side of the Hurricane strike belt, projected northeasterly, as in the Caucomgomoc — Munsungun, and Weeksboro — Lunksoos anticlinoria, clouds the recognition of pre-Hurricane Mountain terranes, and heightens the probability that similar strata represent similar environments of deposition in different terranes, or that subsequent large-scale tectonic transport may have emplaced portions of one terrane upon another throughout

FIGURE 1 EXPLANATION

Silurian and Devonian	DSu	Silurian and Devonian metasedimentary rocks undivided
	~~	*unconformity*
Lower, Middle, and Upper Ordovician	Ok, Olm	Lobster Mountain Volcanics (Olm); mafic to intermediate volcanic and volcaniclastic rocks. Kennebec Formation (Ok); felsic volcanic and volcaniclastic rocks
	~~	*unconformity*
Upper Cambrian(?) to Lower Ordovician(?)	O€dr	Dead River Formation. Green slate, phyllite, and graywacke; commonly graded-bedded.
Cambrian(?)	€h	Hurricane Mountain Formation. Gray to dark gray, rusty-weathering metasiltstone and subordinate phyllite, showing flaser bedding and complex (commonly hackly) microstructure. Cf. fig. 2 explanation for other lithic varieties.

GEOLOGIC OUTLINE MAP OF LOBSTER MOUNTAIN ANTICLINORIUM, EASTERN BRASSUA LAKE AND WESTERN MOOSEHEAD LAKE QUADRANGLES

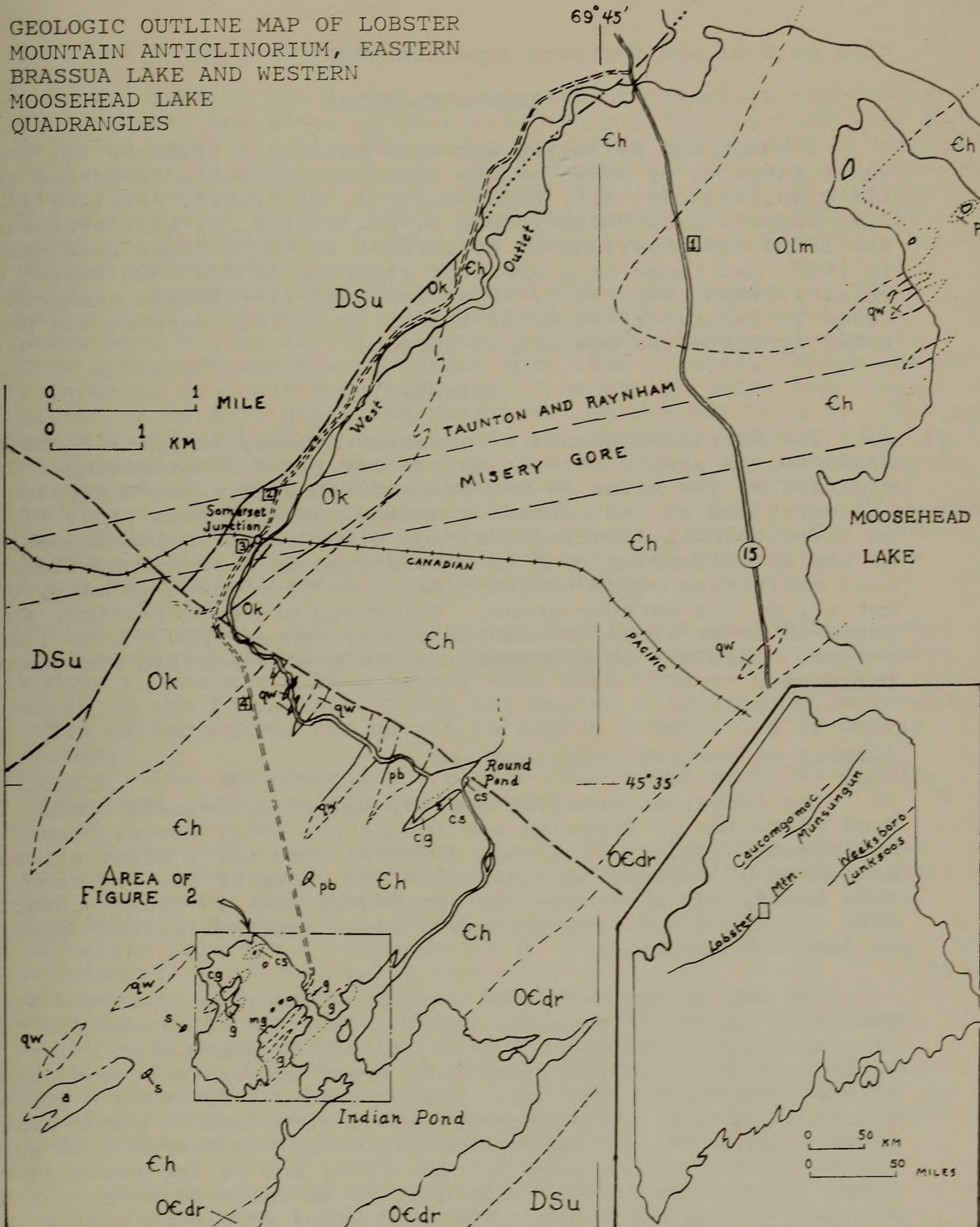

Figure 1

this part of the northern Appalachians.

ACKNOWLEDGMENTS

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DESCRIPTION

The Hurricane Mountain Formation (Boone, in prep; Boone and Boudette, in prep.) forms a narrow outcrop belt extending from the vicinity of the Maine — New Hampshire boundary northeastward to the north end of the Lobster Mountain anticlinorium (fig. 1). It is lithologically distinctive from other pre-Silurian formations of the anticlinorium, and is interpreted as a tectonostatigraphic unit exhibiting characteristic features of mélange in many, but not all of its outcrop areas. Thickness of the formation, as measured in major limbs of Acadian folds, ranges from 850 to 1000 meters. This can be regarded only as a post-Acadian structural thickness.

Summary of contact relationships

The formation overlies the volcanigenic, less-deformed Jim Pond Formation of Cambrian age (Boudette, 1982; Boone, Boudette and Moench, 1981). It grades downward into thick olistostromal sequences of feldspathic quartzite and wacke of the Jim Pond in some areas, but in others, it apparently lies in fault contact with volcanics and volcaniclastic rocks assigned to the upper third of Jim Pond Formation.

The top of the Hurricane Mountain Formation is marked by gradation across thicknesses ranging from one or two meters to approximately 20 meters into the dominantly green, but color-veriegated slate and phyllite, and minor quartzite at the base of the Dead River Formation. Sparse graded beds of 10 - 30 cm thickness provide stratigraphic facing direction at the contact in several, widely dispersed localities in the Pierce Pond quadrangle (Boone, unpub. map; Lyttle, 1976) and in The Forks quadrangle (Burroughs, 1979). The contact is inferred to be diachronous younging to the southwest. The Dead River Formation is likely of late Cambrian to early Ordovician (pre-Arenigian) age; although pervasively polydeformed, it is not as intensely deformed as the Hurricane Mountain Formation. The Hurricane Mountain Formation is thus bounded by significantly less deformed pre-Middle Ordovician units.

Internal characteristics

The bulk of the formation consists of metasiltstone (about 70 percent), and slate or phyllite. This lithic mixture will be referred to as matrix, whether or not it is accompanied by clasts of internal or exotic origin. Both monomictic as well as polymictic assemblages are found in clast-bearing areas of outcrop. The question of whether these assemblages define structural or stratigraphic horizons within the formation is examined in a subsequent paragraph.

Matrix Conservatively estimated at least 95 percent of the matrix rock is devoid of well-defined bedding. Flaser-like pseudobeds appear as thin laminae and lenses ranging in length from a few centimeters to rarely more than a meter. These define a layering manifested by subtle differences in color and composition of metasiltstone and phyllite. Matrix may be gray, lacking sulfide and carbonaceous material, but commonly is dark gray, pyritic with consequent rusty weathering, and variably, but not intensely carbonaceous. Much smaller lenses, of a few millimeters to a centimeter in length, consist of light gray to buff, chalky weathering, finegrained felsic volcaniclastic rock. These are a common feature of the matrix, although such material perhaps accounts for a percent or less of matrix composition.

A structural characteristic of matrix not shared by clasts is a pervasive development of intersecting micro-fractures which endows the matrix with a hackly microstructure — one of the hallmarks of the formation. Where not healed by subsequent metamorphism or tectonism, the matrix is highly friable and is easily eroded.

Clasts Both endogenous and exotic rock types occur as clasts, rafts, and blocks within the mélange.

Endogenous clasts consist mainly of feldspathic sandstone and wacke. As quartz granules are characteristic of both types, the field term quartzwacke is used here in a collective sense. Variation in timing of lithification and disruption of clast materials relative to deformation of matrix resulted in a spectrum of geometric and structural relationships: from clasts of lithified quartzwacke with sharp, angular to rounded outline, to those that were probably semi-lithified at the time of emplacement (lumpy in outline, with gradationally sharp to diffuse boundaries), to quarter- to half-meter thick lenses showing pull-apart structure, to massive beds of quartzwacke. It is indeterminate whether the massively bedded areas themselves represent olistoliths or whether they represent detrital sediment deposited in situ.

Another possibly endogenous lithology consists of thinly bedded to laminated calcite-ankerite-rich metalimestone. The bedded carbonates show the same gradational relationships to matrix as does quartzwacke, but they are much less common. Rare fragments of cherty fine-grained quartzite also may be endogenous.

A rock type in the mélange that is difficult to class as being endogenous, exotic, or even as part of the Hurricane Mountain Formation, is massive brown slate with undeformed cleavage. Several outcrop areas of such slate, each commonly spanning a distance of 300 to 500 meters, have been found at widely separated localities along the strike belt of the formation. Each is surrounded by typical mélange matrix, but contacts have not been observed. Since matrix — as identified by its structural characteristics — rarely consists of slate unaccompanied by metasiltstone, these areas may represent rafts or blocks of slate in which the formation of cleavage predated disruption and emplacement. They thus may have been less prone to the same deformational response as unlithified matrix protolith sediments.[1]

Composition of exotic rock-types that have been found throughout the strike belt of the Hurricane Mountain Formation consist of:

volcaniclastic, arkosic sandstone

metagabbroic and metadiabasic rocks

pillowed and massive mafic metavolcanics

basaltic aquagene metatuff

pyritic, massive metacarbonate rock

amphibolite and greenschist

light gray thickly bedded orthoquartzite

black, carbonaceous orthoquartzite

serpentinite

felsic metavolcanics

chert

alkali granite

All but four have been recognized in the mélange in the Brassua Lake quadrangle; mafic varieties are commonest at Indian Pond. Here, as elsewhere, metagabbroic and metadiabasic rocks appear to occur both as intrusive bodies (dikes and sills) and as dismembered blocks. Evidence in support of each mode of occurrence will be examined.

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1 It is conceivable that the brown slate is a post-Lower Ordovician, pre-Acadian formation preserved only in widely separated synclinal keels, only within the Hurricane strike belt. Similar outcrop areas of green slate, however, are found in the Dead River Formation. It therefore seems more likely that each slate lithology is integral to its bounding formation despite the curious lack of evidence of polydeformation.

Pre-mélange metamorphism and deformation of metabasaltic rock

On islands of Indian Pond and surrounding mainland, blocks of tuffaceous greenstone, greenschist, and amphibolite show varied degrees of deformation that roughly correlate with their metamorphic grades. Insofar as is presently known, the ambient metamorphic grade of rocks in the Lobster Mountain anticlinorium, as recorded by white mica -- Fe-chlorite-rich assemblages in the Hurricane Mountain matrix and Dead River Formation, is lowest greenschist facies. No change from this assemblage, or change in grain-size of Hurricane matrix is detectable adjacent to the metabasaltic blocks showing higher grade metamorphic assemblages (Frost, 1977; Frost and Boone, 1978).

Fine-grained greenstone, which in some localities shows well preserved accretionary lapilli amid other primary textures of water-sorted tuff, is composed of the common assemblage

actinolite - chlorite - albite - quartz - Fe^{3+}oxide - pumpellyite or epidote $\pm$ white mica $\pm$ calcite

In one block at Round Pond (northeast of Indian Pond) assemblage (a) grades into rock containing the assemblage

actinolite - barroistic hornblende - chlorite - albite - epidote - quartz - hematite $\pm$ pumpellyite

Na in M4 is close to 0.75, from calculation of stoichiometry according to the method of Laird and Albee (1981) (Pflumio, 1983, unpub. ms.). Rocks containing this assemblage show a slightly coarser, porphyroblastic texture, with incipient tectonite fabric. According to Laird's (1980) grouping of oxide components, this is a c + 1 (and probably disequilibrium) assemblage (excluding pumpellyite). Similar chlorite-amphibole-bearing greenstone and greenschist occur on islands in the western part of the cove shown in figure 2. On one island, metabasalt dikes cut foliated greenstone and are themselves foliated. The foliation is approximately normal to that in the enclosing wall rock, and the mineral assemblage is dominated by relict pyroxene and plagioclase that is variably replaced by chlorite and unidentified (zeolitic ?) minerals, but in which actinolite and other amphiboles are lacking.

A block of metabasaltic rock 0.75 mile (1.3 km) long, 0.5 mile (0.8 km) west of Indian Pond is made up of amphibolite gneiss with highly contorted foliation and knots of pegmatitic albite. Alternating fine- and coarse-grained layers consist of the assemblage

Tschermakitic hornblende - albite - MgAl-rich chlorite - quartz - sphene - ilmenite.

Assemblages (a) through (c) record a transition between the biotite-albite and garnet-albite zones of a medium-pressure facies series (cf. Laird, 1980); a low-pressure series is excluded because a progression from albite to oligoclase.....etc. is not recorded in the metamorphic progression to amphibolite gneiss.

Tectonic sequence vs. geographic restriction of clast types

The metabasaltic (greenstone to amphibolite) blocks of the Indian Pond area are roughly colinear in the middle of the Hurricane Mountain Formation belt, but other varieties of clast lithologies are not restricted to a tectonostratigraphic horizon. Quartzwacke clasts provide an example in the opposite extreme, for these are found at all positions relative to top and apparent base of the unit, and at all localities along its strike. Restriction to part of the strike belt may apply to some clast varieties as, for example, black and light gray quartzites in the southwestern Pierce Pond quadrangle, and most of the metabasaltic and meta-gabbroic varieties in the Brassua Lake quadrangle segment of the formation. Since the erosion surface provides only a two-dimensional examination of the unit, one may imagine that the total variety of clasts in a given geographic locale might be augmented were it possible to restore the section up-dip or examine the formation at depth. It is premature and probably false, therefore, to presume that the quartzites or the meta-basaltic greenstones represent different provenances separated by the strike distance between each group of clasts.

Operating on the simple premise that clast variety along the total strike belt gives a reasonable integration, the observation may be made that striking similarities outweigh a few notable differences in the lithologies of the Hurricane Mountain Formation, the Chase Brook Formation (Hall, 1970), and parts of the Grand Pitch Formation (Neuman, 1962; 1967). Pollock (1982, and this volume) describes similar mélange characteristics in the Hurd Mountain Formation of the Caucomgomoc Lake area. The relationship between these units is presently the subject of further study.

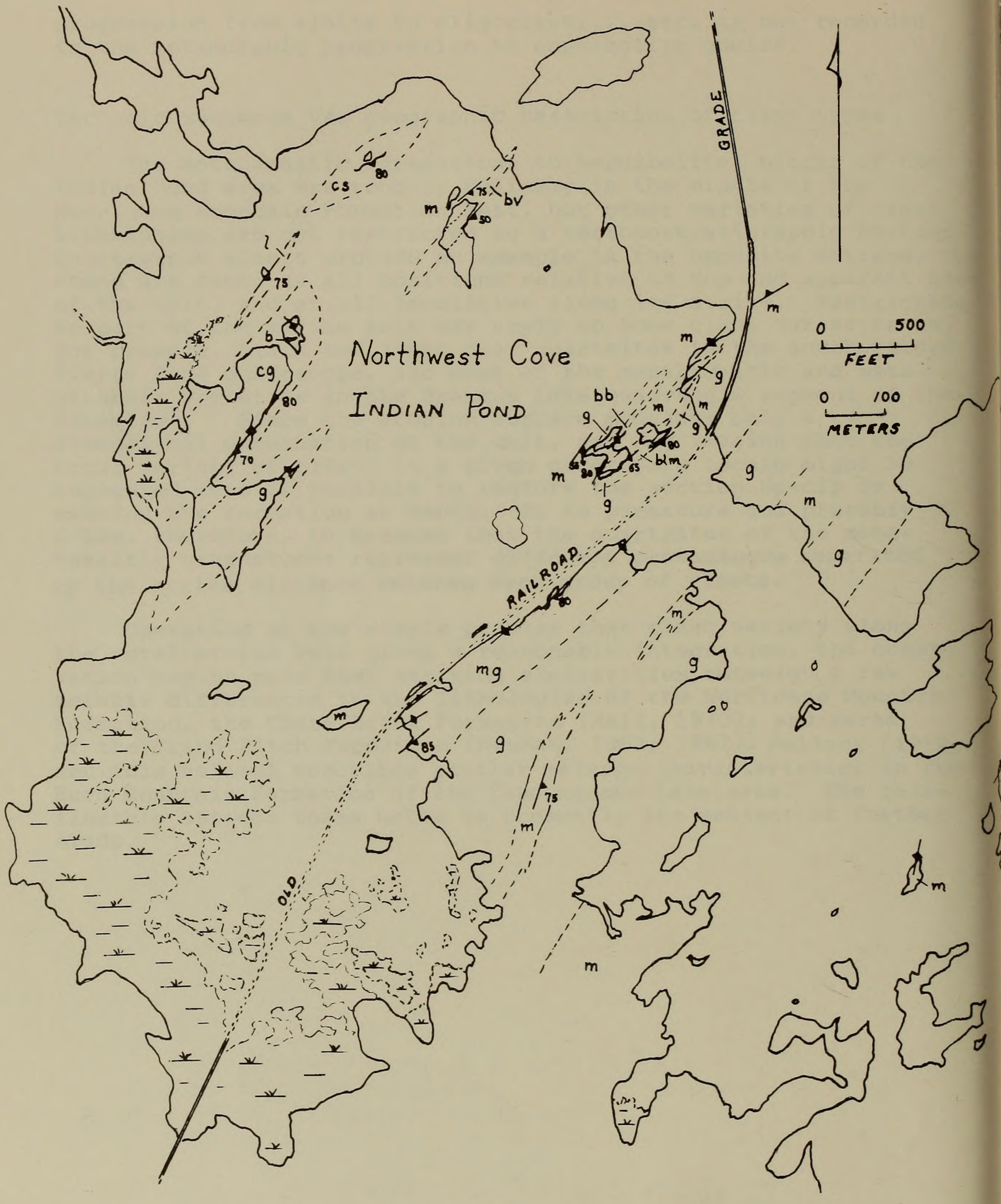


Figure 2. Lithologic relationships in Hurricane Mountain Formation, northwest cove of Indian Pond

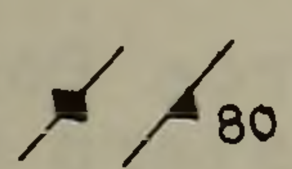
FIGURE 2 EXPLANATION

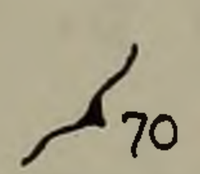
Hurricane Mountain Formation

Cambrian (?)

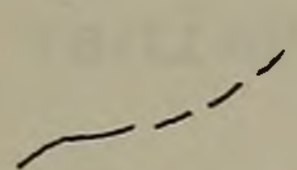
m	Common matrix assemblage: rusty and non-rusty weathering, dark gray metasiltstone; black, light gray and light greenish gray phyllite
mg	Mélange matrix with abundant gabbro and basalt clasts, dikes, and sills
blm	Bluish gray metasiltstone
l	Rusty weathering, laminated chloritic metalimestone
b	Metabasalt
bv	Metabasalt, grading into bedded, calcitic, mafic volcaniclastics
bb	Metabasalt breccia
g	Fine - to medium - grained metagabbro
cg	Chlorite-actinolite greenstone and fine-grained greenschist; locally gradational into relict metabasalt
cs	Fine - to medium grained, well foliated, chlorite-actinolite-rich greenschist

Structure Symbols





Vertical or steeply dipping late cleavage in matrix; estimated average orientation of earlier, pre-mélange foliation in greenstone and greenschist



Contact; dashed where inferred

Bearing and plunge of small scale folds in matrix foliation

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Road Log, Trip

Moosehead Lake and Brassua Lake 15' quadrangles

Mileage

Interval	Cumulative	
	00.0	Greenville Proceed west on State Rte. 15 toward Rockwood
13.0	13.0	Bridge crossing East Outlet of Moosehead Lake
3.8	16.8	Stop 1. Outcrops at crest of hill. Plagioclase-phyric volcanics assigned to Lobster Mountain and Kennebec Formation volcanic sequences
1.2	18.0	Bridge crossing West Outlet of Moosehead Lake
0.2	18.2	Turn left (south) on unpaved road. From here to Indian Pond, several access roads branch off westward; continue straight on main road, however, along the west side of the West Outlet
0.2	18.4 (approx.)	Enter Brassua Lake 15' quadrangle
3.8	22.2	Stop 2. Outcrops on west side of road, just south of Taunton & Raynham — Misery Gore twp. line. Lower to Middle Ordovician brachiopods recovered here from felsic metatuffs of Kennebec Formation (Boucot, 1969, p. 54-55)
0.5	22.7	Somerset Junction; Canadian Pacific R.R. overpass
0.05	22.75	Road intersection and bridge on left, but continue straight on main road
0.1	22.85	Stop 3. Typical exposures of cleaved felsic volcaniclastics of Lower to Middle Ordovician Kennebec Formation. Exposures

		on each side of Outlet show moderately dipping beds cut by steeply dipping spaced cleavage
0.25	23.1	Road intersection; keep left
0.2	23.3	Cross old railroad bridge
0.25	23.55	Well cleaved, dark red, green & white volcaniclastics of Kennebec Formation

(From here to Indian Pond, road is in disrepair; proceed with caution)

0.3	23.85	Stop 4. Hurricane Mountain Formation. Typical matrix lithology, showing strongly cleaved, rusty weathering, dark gray metasiltstone and gray metaquartzwacke. Exposures of the contact between the Kennebec and Hurricane Mountain formations have not been found in the Brassua Lake and Moosehead Lake quadrangles, but 16 miles along strike northeastward, volcanics associated with the Lobster Mountain volcanic sequence overlie in exposed angular unconformity the Hurricane Mountain Formation. The Kennebec and Hurricane are inferred to be separated here by the same unconformity. Structural contrast between singly deformed Lower to Middle Ordovician rocks above, and polydeformed rocks of Cambrian to possibly Tremadocian age below the unconformity suggests the intervening early deformation is Penobscottian (cf. Neuman, 1967).
1.0 0.3	24.85 to 25.15	Abundant outcrops of Hurricane Mountain Formation; lithology similar to previous outcrops
1.0	26.15	End of road at east shore of northwest cove of Indian Pond. Weather permitting, embark by canoe to examine shoreline and island outcrops showing lithic variations and structural contrasts between mafic rocks (clasts and intrusives) and matrix of a mélange facies of the Hurricane Mountain Formation (map, fig. 2)
		Return to Greenville