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*Paleogeographic Implications of Ordovician Shelly Fossils in the Magog Belt of the Northern Appalachian Region**

ROBERT B. NEUMAN

INTRODUCTION

ORDOVICIAN BRACHIOPODS and other shelly fossils from a wide range of rock types at scattered localities from Maine to Newfoundland permit assignment of some specific events and details to Kay's (1951, fig. 1) graphic paleogeographic rendition of this region. Kay's subdivision of the Appalachians into two parts—the Champlain and Magog belts—corresponds to the distribution of dominantly carbonate rocks and detrital-volcanic rocks, respectively. This review is confined to the Magog belt southeast of the Green Mountain-Sutton Mountain anticlinorium and its presumed counterpart in Newfoundland, the Long Range (Williams, 1964, p. 1142).

European genera not generally found in North America characterize the fossil assemblages. Some forms are newly discovered, such as a new species of *Tritoechia* named for Professor Marland Billings and described herein. Other representative specimens are illustrated on the accompanying plates.

Although a few Ordovician fossils had been found in this area before World War II, the pace of geologic investigations in both the United States and Canada was much quickened after the war; most of the fossil discoveries have been made during this more recent work. These fossils are not easily found, as most of them occur in unlikely rocks such as tuff and conglomerate,

and some are considerably deformed. Because the fossils at many places are fragmentary, many large collections of rock were needed; much credit is therefore due the observant and persevering geologists whose collections make this review possible.

Pre-Silurian rocks form a minor part of the total exposed bedrock outcrop area of the Magog belt. They occur in anticlinal outcrop areas of different sizes, isolated from each other by intervening younger sedimentary rocks, plutonic rocks, and bodies of water. Only a small part of the pre-Silurian outcrop area is demonstrably of Ordovician age; the remainder is either assignable to the Precambrian or Cambrian, or is of uncertain age. Ordovician slate and shale containing graptolites but no brachiopods or other shelly fossils are more common than rocks that have shelly fossils; consequently, the area known to be underlain by Ordovician rocks that contain shelly fossils is an infinitesimally small percentage of the entire belt.

Ten localities are in the northern half of Maine; a few are known in New Brunswick, Quebec, and Newfoundland; and one poorly preserved collection has been found in Nova Scotia. Direct superposition of two zones was seen at only one place, Intricate Harbour, New World Island, Newfoundland. At a few places a sequence has been pieced together by geologic mapping, but most localities are isolated and their relative ages are inferred from their fossils. In addition, a few localities have yielded too few

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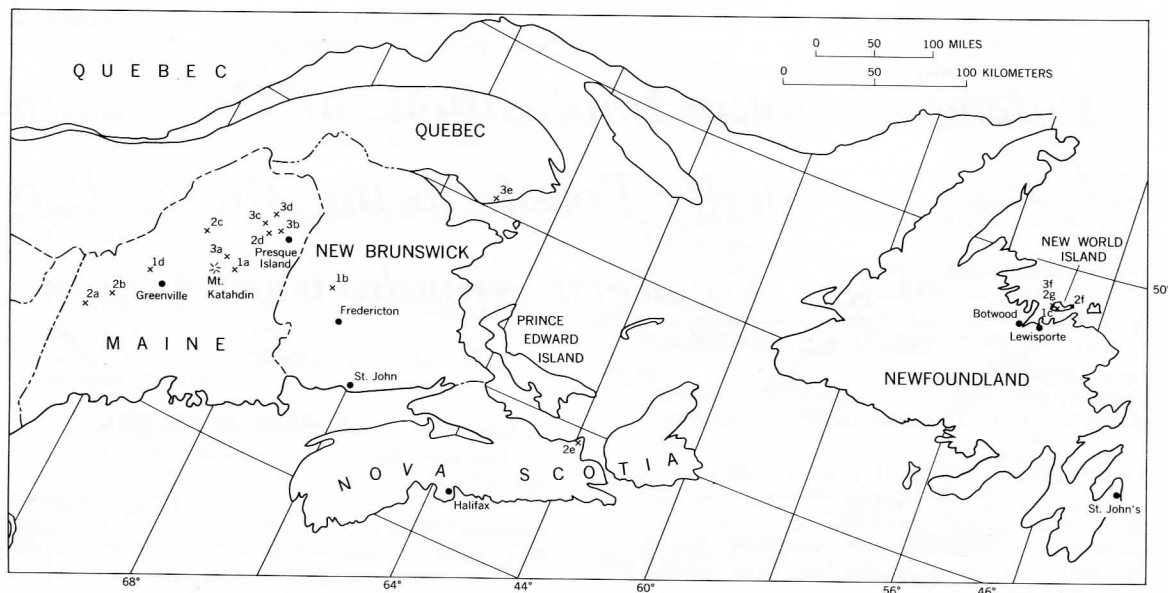


FIGURE 3-1. Index map of southeastern Canada and Maine showing localities of Ordovician shelly fossils in the central Magog belt.

specimens to furnish useful information, and no doubt some have been overlooked.

GENERAL COMPOSITION OF THE SHELLY FOSSILS

The assemblages of Ordovician shelly fossil genera in the Magog belt are more like those in Europe than they are like those elsewhere in North America. European subdivisions of the system are therefore more applicable than the North American ones. The older assemblages consist of unique associations of genera not known to coexist elsewhere, together with new genera not yet recorded from outside this area. Younger assemblages reflect the well-established trend toward cosmopolitanism with decreasing age in the Ordovician; nevertheless, in addition to some of the more cosmopolitan genera, other genera of both brachiopods and trilobites found here have not hitherto been found in North America.

In contrast with most North American assemblages but in common with many European ones, the number of genera at individual localities in the Magog belt is greater than at most other places in the Appalachians or in the midcontinent region, where relatively few genera are present throughout the Ordovician. Thus, correlations are more readily made with the Old World, even though many of these are uncertain, and few can be confirmed by associated graptolite faunas or by superposition of successive zones.

ROCKS OF ARENIG TO LLANDEILO AGE

Occurrences

Correlated with confidence. *Shin Brook Formation*, Shin Pond and Island Falls quadrangles, Penobscot and Aroostook Counties, Maine (1a of Fig. 1) (Neuman, 1964, 1967; Ekren and Frischknecht, 1967). Most of the formation is crystal tuff, with lesser amounts of flows, volcanic sandstone, and conglomerate. It unconformably overlies the Lower Cambrian(?) Grand Pitch Formation, and is overlain by metadiabase whose age is not well established.

ORDOVICIAN	Britain		North America		Central Magog belt
	UPPER	Ashgill	UPPER	Richmond	3
				Maysville	2
				Eden	
LOWER	UPPER	Caradoc	MIDDLE	Barneveld	
				Wilderness	1
				Porterfield	
	LOWER	Llandeilo	LOWER	Ashby	
				Marmor	1
				Whiterock	
		Arenig		Canadian	

FIGURE 3-2. Ordovician subdivisions in Britain and North America (after Whittington, 1966, Table 1) and equivalents in the central Magog belt.

TABLE 3-1. Brachiopods in rocks of Arenig to Llandeilo age in Maine, New Brunswick, and Newfoundland. Localities plotted on Figure 1. "sp" indicates uncertain specific identification of specimens belonging to the genus.

	1a Shin Brook Formation, Maine	1b Hayesville and Napadogan quads., New Brunswick	1c New World Island, Newfoundland
<i>Multispinula</i> sp.			X
<i>Productorthis mainensis</i> Neuman	X	sp	X
<i>Orthambonites robustus</i> Neuman	X	X	sp
<i>Valcourea</i> sp.		X	X
<i>Platystrophia</i> sp.	X		
<i>Tritoecchia billingsi</i> Neuman	sp	X	X
<i>Platytoecchia boucoti</i> Neuman	X		sp
new genus aff. <i>Oslogonites</i>			X
<i>Polytoecchia</i> sp.	X		
<i>Porambonites</i> sp.			X
<i>Christiania</i> sp.			X
<i>Eoplectodonta</i> sp.			X
syntrophid, new genus		X	
<i>Eodalmannella</i> sp.		X	X

Fossils in the Shin Brook Formation, in addition to brachiopods tabulated in Table 3-1, are: siliceous monaxon sponge spicules and root tufts; bryozoans—*Batostoma* sp. and *Nicholsonella* sp.; gastropod—*Leseurilla* sp.; and trilobites—*Geragnostus* sp., *Ampyx* sp., *Nileus* sp., *Annamitella? borealis* Whittington, *Iliaenus* (s. l.) sp., *Raymondaspis* sp., *Hibbertia?* sp., and an undetermined miraspinid.

Unnamed formation, principally calcareous siltstone, Hayesville and Napadogan quadrangles, York County, New Brunswick (1b of Fig. 3-1) (Robb, 1870, p. 189-190; Poole, 1958, 1960, 1963). This unit is underlain by quartzite and slate similar to the Grand Pitch Formation, and is overlain by a heterogeneous unit consisting of graywacke, chert, red and green iron formation, volcanic rocks, and slate near the base that contains graptolites including *Climacograptus bicornis* (Hall) (W. H. Poole, written communication, 1967). Brachiopods (Table 3-1) are the most abundant fossils, associated with subordinate amounts of bryozoans and pelmatozoan debris.

Unnamed formation, Village Cove, New World Island, Twillingate quadrangle, Newfoundland (1c of Fig. 3-1) (Williams, 1963). Fossiliferous volcanic sandstone is part of Williams's (1963) map unit 4 consisting of volcanic and sedimentary rocks; relations of the fossiliferous rocks to the unfossiliferous rocks enclosing them are not known. A few trilobites, including *Annamitella?* sp. and a harpid, are associated with the varied brachiopod assemblage indicated in Table 3-1.

Provisionally correlated. *Kennebec Formation*, Brassua Lake quadrangle, Somerset County, Maine (1d of Fig. 3-1) (unpublished geologic quadrangle map; see Boucot, 1961, p. 183). The rock was described as "... massive felsite and rhyolite tuff ...". It is underlain by rocks classified as undifferentiated sedimentary rocks of Cambrian or Ordovician age, but contact relations are unknown, and is overlain by undifferentiated strata of Silurian or Devonian age, probably unconformably (Boucot, 1961, p. 178). The following fossils were identified by Boucot (written communication, 1967): dasycladacean alga—*Mastopora* sp. (Boucot and Yochelson, 1966, p. A15); brachiopods—*Orthambonites?* sp., *Valcourea* sp., *Sowerbyites* sp.; gastropod—*Loxoplocus* (*Lophospira*) sp.; trilobite—*Isotelus?* sp.

Age Considerations

When the Shin Brook Formation and its fossils were originally described (Neuman, 1964), no correlatives in the region were known, and neither the brachiopods nor the trilobites (Whittington, in Neuman, 1964, p. E-25 to E-34) permitted a positive age assignment. At that time, as now, the Shin Brook fossil assemblage was found to consist of some forms known elsewhere in Lower Ordovician rocks (Arenig or Canadian), and others known elsewhere from the Middle Ordovician (Llanvirn to Caradoc; Marmor to Porterfield), but not older. The age assignment of the Shin Brook, arrived at by compromising the conflicting evidence, was considered to be either late Canadian or Whiterock by Neuman (1964, p. E24), or somewhat less equivocally Whiterock by Whittington (in Neuman, 1964, p. E34).

Four of the genera (and probably species) of the Shin Brook assemblage were found on New World Island, Newfoundland. Five of the 7 additional forms from New World Island (*Valcourea*, *Porambonites* with obscure cardinal process, *fide* Spjeldnaes, 1957, p. 217, *Christiania*, *Eoplectodonta*, and *Eodalmannella*) are characteristic of Llanvirn or younger rocks; *Tritoecchia* and the undescribed genus similar to *Oslogonites* are more typical of the earlier Ordovician. Kay (1967, p. 588) considers this assemblage "... of late Chazy (Valcourean) age similar to [that] near the top of the Whiterock Stage" in central Nevada." Kay (1967, p. 588) also reported that cephalopods, identified as ellesmeroceratids of probable Gasconade age by Flower, were found in limestone

PLATE 3-1. Brachiopods from older Ordovician rocks on New World Island, Newfoundland. These and other fossils listed in the text occur together at the locality indicated by an F symbol on the geologic map of the Twillingate quadrangle (Williams, 1963), $\frac{1}{2}$ mile (0.8 km) northwest of Village Cove. Specimens accessioned by the Geological Survey of Canada (GSC). Photographs by C. F. Buddenhagen IV.

(1) *Productorthis mainensis* Neuman: a-d, rubber replica of an external mold, dorsal, ventral, side, and posterior views, respectively, GSC 23294, $\times 2$; a-g, silicified dorsal valve, external, posterior, and internal views, respectively, GSC 23295, $\times 2.5$. Specimens of this species from this locality are better preserved than those from the Shin Brook Formation in Maine. Note the long carinate cardinal process and the absence of a chilidium.

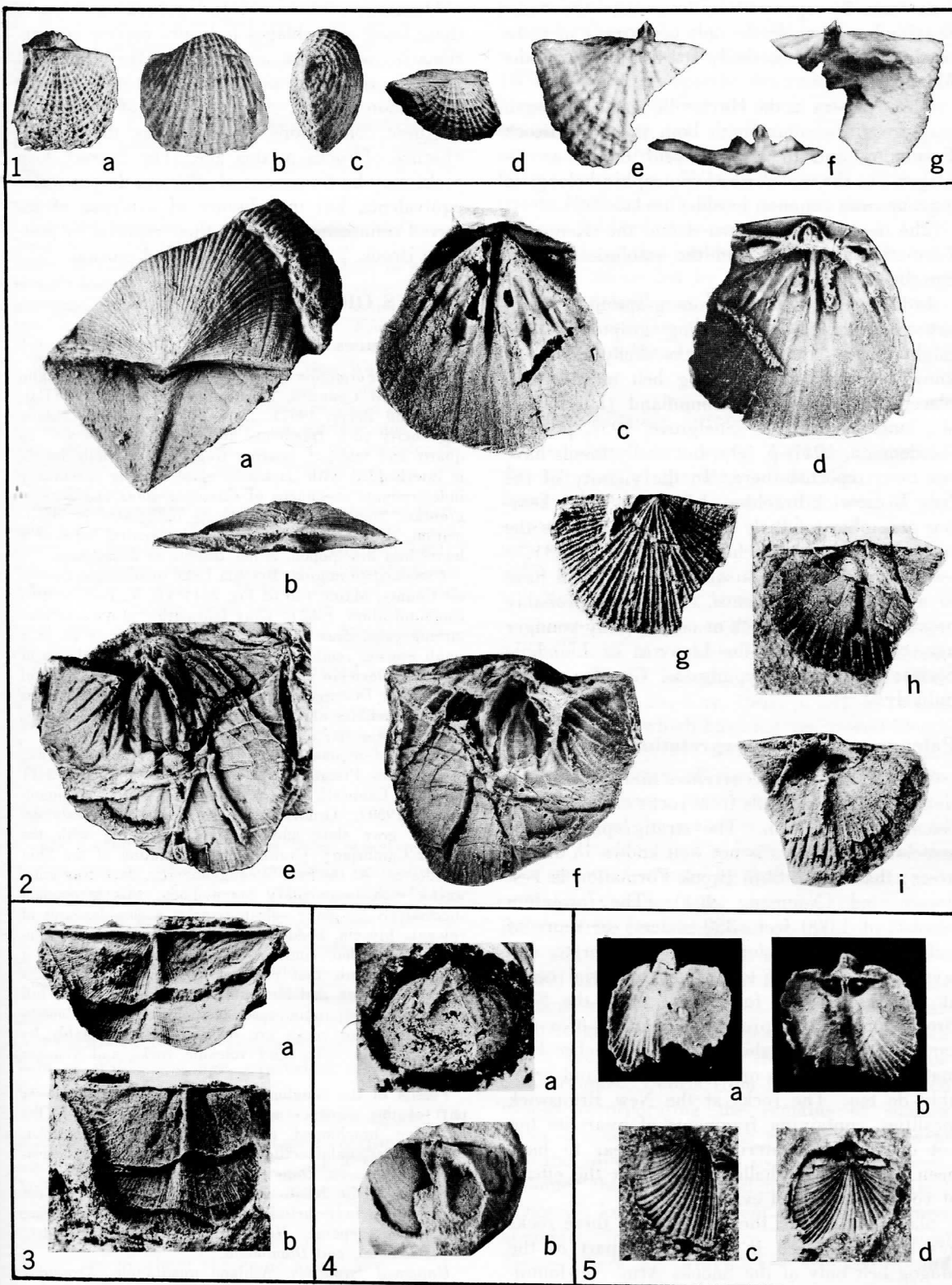
(2) *Tritoechia billingsi* Neuman, new species: a, b, paratype, rubber replica from external mold, posterior view of ventral and dorsal valves, GSC 23297, $\times 2$; c, d, holotype, internal mold and rubber replica of dorsal valve, GSC 23296, $\times 2$; e, f, paratype, internal mold and rubber replica of ventral valve, GSC 23298, $\times 2$; g-i, paratype, dorsal valve, rubber replica from external mold, internal mold, and rubber replica from internal mold, respectively, GSC 23299, $\times 2$. The presence of a chilidium in this species distinguishes it from all others known to me. Ventribi-convex, parvicostellate shells having radially striated interareas, the dorsal about $\frac{1}{4}$ the length of the ventral. Notothyrial platform supported above shell floor by median septum which extends about midway into shell; cardinal process short and bladelike in smaller specimens, but bulbous in larger ones. In small specimens chilidium covers only apical part of notothyrium, but in large ones, such as in Figure 2b, at least half of the notothyrium is covered. Unsupported stout brachio-phores and associated shallow sockets extend outward from the margins of the notothyrium and merge with shell floor toward the posterolateral extremities of the shell. Ventral valve unexceptional for the genus, its interarea planar or slightly concave, and having an arched pseudodeltidium; no specimens at hand preserve evidence of the foramen, although presumably one perforated the apex of the pseudodeltidium. Dental plates of small specimens short and erect, but in larger ones they advance into the valve along the margins of the muscle field. Muscle impressions poorly differentiated, but anterior end of thickened muscle field of large specimens nearly straight.

The New Brunswick specimens also display a chilidium like these, but the single dorsal valve known from the Shin Brook Formation lacks the relevant part of the shell so that the presumption that it too is conspecific cannot be confirmed.

(3) *Valcourea* sp.; a,b, ventral valve, rubber replica of external mold, and internal mold, GSC 23300, $\times 2$.

(4) *Christiania* sp.; a, ventral valve, internal mold, GSC 23301, $\times 2$; b, dorsal valve, partially preserved silicified specimen and impression of exterior, GSC 23302, $\times 2$.

(5) *Eodalmarella* sp.; a-d, articulated specimen, ventral and dorsal views of internal and external molds, GSC 23303, $\times 2$. This genus has hitherto been recorded only from rocks of Llanvirn age in Czechoslovakia.



fragments incorporated in lava near the rocks bearing brachiopods, the only occurrence of rocks of this age bearing shelly fossils known in the Magog belt.

Three genera in the Hayesville and Napadogan map-areas are common to both the Shin Brook Formation and the New World Island assemblages, but the undescribed syntrophid belongs to a group most common in older rocks.

The few fossils known from the Kennebec Formation do not aid in the resolution of the age problem.

Independent evidence from graptolites is not yet available. Rocks bearing graptolites that might be the equivalent of the shelly rocks are known in the central Magog belt only at one place, Snooks Arm, Newfoundland (lat. 55°42' W., long. 49°51' N.) (Snelgrove, 1931, p. 488; Ruedemann, 1947, p. 59), but shelly fossils have not been reported there. In the vicinity of the New Brunswick brachiopod localities, slate bearing graptolites of early Caradoc age overlies the rocks bearing the brachiopods (Poole, 1963).

Thus firm correlation of these rocks will have to await further evidence. They will probably prove to be of Whiterock or only slightly younger age, correlative with the Llanvirn or Llandeilo Series; an age as young as Caradoc seems unlikely.

Paleogeographic Interpretation

Three of the four occurrences under consideration have yielded fossils from rocks of dominantly volcanic composition. The stratigraphy of the associated sequences is not well known in all the areas; that of the Shin Brook Formation is best documented (Neuman, 1964). The formation consists of 1,000 feet (350 meters) or more of tuff, tuffaceous sandstone and conglomerate, and lava flows; clasts of terrigenous material occur at the base of the formation. Thus the Shin Brook apparently represents a segment of a volcanic island and its shore, as the Kennebec Formation and the rocks on New World Island probably do too. The rocks at the New Brunswick localities, containing fragments of quartzite but not of volcanic material, also appear to have been deposited in shallow water, but the effects of volcanism are not evident there.

Slate probably of the same age as these rocks has been identified in the central part of the Magog belt only at the Snooks Arm, Newfoundland, locality already referred to. Along the eastern and western margins of the belt are other occurrences of such slate, but in entirely different stratigraphic associations.

Occurrence of brachiopod genera common to these fossil assemblages indicates marine connections between them and suggests that the shoal water in which the organisms lived merged with a common seaway. Interpretation of the nature of these connections is limited by the general absence of rocks of this age. The Snooks Arm rocks may be a remnant of offshore, deeper water equivalents, but the absence of evidence of inferred connections suggests their removal by post-Shin Brook, pre-Caradoc uplift and erosion.

ROCKS OF CARADOC AGE

Occurrences

Dixville Formation?, Cupsuptic quadrangle, Franklin and Oxford Counties, Maine (2a of Fig. 3-1) (Harwood and Berry, 1967). Dark-gray graywacke containing cherty rock fragments and slate chips as well as quartz and feldspar, bearing fragments of shelly fossils, is interbedded with dark-gray slate bearing specifically indeterminate specimens of *Climacograptus* and *Dicellograptus*. Shelly fossils are nearly obliterated by deformation, and unidentifiable except for ventral valve of a leptestid brachiopod, either *Bilobia* or *Diambonia*.

Unnamed formation, Brassua Lake quadrangle, Somerset County, Maine (2b of Fig. 3-1) (E. V. Post, written communication, 1962). Gray feldspathic graywacke containing calcareous siltstone pebbles appears to be in a small erosion remnant above gray slate of Cambrian or earlier Ordovician age, and below calcareous siltstone of Silurian or Devonian age. Brachiopods in the calcareous siltstone pebbles and in graywacke are: *Glyptorthis* sp., *Platystrophia* sp., and *Leptellina* sp.

Unnamed sequence, Spider Lake and Churchill Lake quadrangles, Piscataquis County, Maine (2c of Fig. 3-1) (Hall, in Caldwell, 1966, p. 42-50, and written communication, 1960). Ordovician rocks overlie complexly deformed gray slate and siltstone correlated with the Lower Cambrian? Grand Pitch Formation of the Shin Pond area. At the base is conglomeratic, dark-gray graywacke with fragmentary brachiopods; this is overlain successively by mafic volcanic rocks, a complex unit of volcanic breccia, bedded chert, sandstone and conglomerate, slate that contains *Climacograptus bicornis*, a black slate unit that contains *Orthograptus truncatus* var. *intermedius*, and by a unit consisting of felsitic tuff and chert containing severely deformed brachiopods. The Ordovician rocks are overlain unconformably by Silurian sedimentary and volcanic rocks and younger units.

Fossils in the conglomeratic graywacke in the lower part of the sequence at several localities include the following brachiopod genera: *Nicolella*, *Glyptorthis*, *Skenidioides*, dalmanellid indet., *Rhynchotrema*, *Sowerbyella*, *Leptellina*, *Diambonia*, and *Catazyga*.

Fossils in the felsitic tuff in the upper part of the sequence include heliolid corals and the following brachiopod genera: *Hesperorthis*, dalmanellid indet., *Eoplectodonta*, and *Diambonia*.

Unnamed formation, Ashland quadrangle, Aroostook County, Maine (2d of Fig. 3-1) (Neuman, 1963). Exposures, confined to the floor of a single gravel pit, include dark-gray, tuffaceous and conglomeratic mudstone, granule and boulder conglomerate, and green concretionary mudstone and siltstone. Fossil list is revised and

supplements that of 1963; selected species illustrated on Plate 3-2, Figs. 5-7 show their remarkable preservation.

Corals—*Catenipora* sp., unidentified rugose and tabulate corals; brachiopods—*Cyrtonotella* sp., *Nicolella* cf. *N. actoniae* (Sowerby), *Boreadorthis* sp., *Chaulistomella* sp., *Glyptorthis* sp., *Skenidioides* sp., *Howellites* sp., *Triplecia* cf. *T. insularis* (Eichwald), *Oxoplectra* sp., *Catazyga* sp., *Chonetoides* sp., *Christiania* sp., *Leptellina* sp., *Diambonia* sp., *Sampo* sp., *Eoplectodonta* sp., *Ptychoglyptus* sp., and *Leptaena* sp.; graptolite—*Amplexograptus* sp.

Unnamed formation, Cape George, Antigonish County, Nova Scotia (2e of Fig. 3-1) (Boucot and others 1959). Hematitic, calcareous quartzite occurs in blocks in fault breccia and in boulders in Carboniferous conglomerate, but is not known elsewhere. Brachiopods, revised from study of the collections, are: *Kjaerina* sp., rhynchonellid, indet., and an indeterminate atrypacean.

Unnamed formation, Cobbs Arm, New World Island, Twillingate quadrangle, Newfoundland (2f of Fig. 3-1) (Williams, 1963). Impure limestone, part of a unit that consists of volcanic rocks, argillite, siltstone, and sandstone as well as limestone, contains the brachiopods *Hesperorthis* sp., *Valcourea* sp., *Refinesquina* sp., and *Cyclospira* sp.

Unnamed formation on the northwest shore of Intricate Harbour, New World Island, Twillingate quadrangle, Newfoundland (2g of Fig. 1) (Williams, 1963). Gray, fossiliferous, pebbly siltstone containing the fossils listed here is overlain by 75 feet (25m) of polymict boulder conglomerate which is in turn overlain by a much more pebbly mudstone containing Ashgill-age fossils that are listed on p. 44.

Corals: *Catenipora* sp. and unidentified rugose and tabulate corals; brachiopods—*Boreadorthis* sp., *Glyptorthis* sp., *Ptychopleurella* sp., *Platystrophia* sp., *Atelelasma?* sp., *Howellites* sp., *Christiania* sp., *Diambonia* sp., *Sampo* sp., *Eoplectodonta* sp., and *Leptaena* sp.; and unidentified trilobite fragments.

Age Considerations

The Caradoc age of six of these seven occurrences can be deduced from their brachiopods with reasonable confidence (The exception is the Nova Scotia locality, 2e, whose fossils are few and poorly preserved.) Their relative ages within the Caradoc can also be estimated.

The Cobbs Arm, Newfoundland, assemblage is unlike any known elsewhere in the northern Appalachians, but its genera suggest a Porterfield or Wilderness age, equivalent to the lower Caradoc.

Graptolites of Berry's (1960) zones 12 and 13 associated with the brachiopod-bearing graywacke in the Spider Lake-Churchill Lake area, Maine, establish a middle Caradoc age for these rocks; presumably the similar graywackes with similar fragmentary fossils in northwestern Maine are of about the same age.

The tuffaceous beds in the Spider Lake-Churchill Lake area, the rocks in the Ashland gravel pit, and beds at Intricate Harbour, Newfoundland, that contain the fossils listed here are

probably of younger Caradoc age. Although the generic suite of the rich assemblage at Ashland is similar to that of the Girvan district, Scotland (Williams, 1962), specific determinations of the Maine fossils have not yet been made; generic comparisons are not significant because many genera range through more than one part of the Girvan succession. Most of the genera of the Intricate Harbour suite listed here are the same as those at Ashland. Inasmuch as the beds at Intricate Harbour that yielded these fossils are conformably succeeded by beds yielding fossils of probable Ashgill age, listed below, it seems reasonable to estimate that the Caradoc part here, and thus at Ashland, represents a segment of late Caradoc time.

Paleogeographic Interpretation

The absence of early Caradoc-age rocks through most of the Magog belt, also noted by Berry (this volume), suggests that most of the area stood above sea level at this time. This interpretation is consistent with post-Shin Brook uplift and erosion that is deduced from the distribution of the older Ordovician rocks.

The single occurrence of rocks assigned to the early Caradoc is a crossbedded, impure limestone on New World Island; purer limestone (Williams, 1963, p. 28; Kay, 1967, p. 591-592) that contains fossils which have not yet proved identifiable occurs nearby. Such limestone is unique in the Ordovician of the Magog belt, and its presence indicates that if there was a general withdrawal of the sea or emergence of the land in early Caradoc time, at least a small part of the area remained covered by shallow water.

Middle Caradoc seas were apparently deep, judging from the widespread occurrence of black slate and chert (Berry, this volume). The interbedded graywacke contains large proportions of siliceous volcanic fragments together with scattered fragmentary brachiopods and other fossils which indicate their derivation from local volcanic islands. Debris from the erosion of such islands incorporating the remains of shallow water benthonic organisms was probably swept into the adjacent deep sea by turbidity currents. Although the location of islands and their extent is not yet known, they seem to have been most abundant in northwestern and north-central Maine where the graywackes are known and where Ordovician volcanic rocks are abundant. Study of the stratigraphy of the graywackes and their sedimentary structures may permit delineation of the islands.

PLATE 3-2. Caradoc and Ashgill age brachiopods from Maine and Newfoundland. Photographs by R. H. McKinney.

(1) *Retrorsirostra* sp.; a,b, dorsal valve, internal mold and rubber replica made from external mold, USNM 159951, $\times 1.5$. USGS loc. 3889-CO at Pond Pitch, East Branch of the Penobscot River, Traveler Mountain quadrangle, Maine.

(2) *Cryptothyrella* sp., mold of ventral valve, GSC 23527, $\times 2$. Northwest shore of Intricate Harbour, Twillingate quadrangle, Newfoundland.

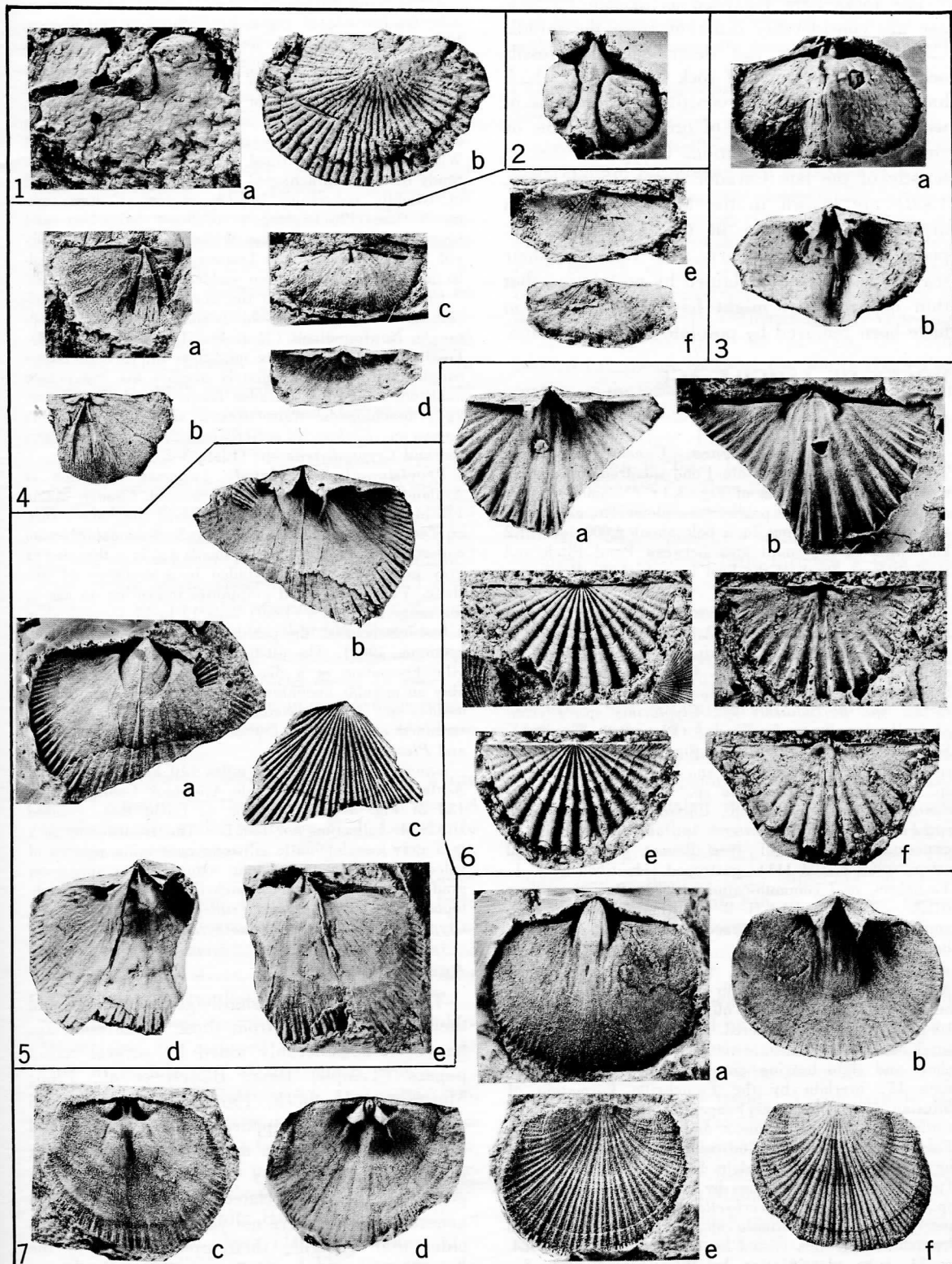
(3) *Schizophorella* sp.; a,b, dorsal valve, internal mold and rubber replica, USNM 159952, $\times 2$. USGS loc. 3889-CO.

(4) *Eochonetes* sp.; a,b, dorsal valve, internal mold and rubber replica, GSC 23528, $\times 2$; c-f, ventral valve, internal and external molds and rubber replicas, respectively, GSC 23529, $\times 2$. Same locality as Figure 2. The canals that pierce the interarea are seen as bridges of matrix in 4c.

(5) *Boreadorthis* sp.; a-c, ventral valve, internal mold, rubber replica, and part of rubber replica made from external mold, respectively, USNM 159953, $\times 1.5$; d,e, dorsal valve, rubber replica and internal mold, USNM 159954, $\times 1.5$. USGS loc. 4112-CO, floor of gravel pit 5.6 miles east of Ashland, Maine.

(6) *Nicolella* cf. *N. actoniae* (Sowerby); a,b, ventral valve, rubber replica and internal mold, USNM 159955, $\times 1.5$; c-f, dorsal valve, external and internal molds, and rubber replicas, respectively, USNM 159956, $\times 1.5$. USGS loc. 4112-CO.

(7) *Howellites* sp.; a,b, ventral valve, internal mold and rubber replica, USNM 159957, $\times 2$; c-f, dorsal valve, internal mold, rubber replica, external mold and rubber replica, respectively, USNM 159958, $\times 2$. USGS loc. 4112-CO. Fossils from this locality are very well preserved permitting the observation of such details as punctae which are preserved as a mat of hairlike spines of matrix on internal and external molds.



The rocks here regarded as of late Caradoc age are considerably different from the middle Caradoc-age rocks just described. The fossils occur in a wide range of rock types, all of which have abundant volcanic constituents, but none of which displays evidence of turbidity currents or similar kinds of redeposition. Graptolites characteristic of the late Caradoc (zone 15 of Berry, 1960) are known in the Magog belt only in argillaceous limestone in the Aroostook-Matapedia anticlinorium (Berry, this volume); their scarcity seems best explained by postulating that thin deposits that might have contained them have been removed by post-late Caradoc erosion.

ROCKS OF ASHGILL AGE

Occurrences

Correlated with confidence. *Unnamed formation*, Traveler Mountain and Shin Pond quadrangles, Penobscot County, Maine (3a of Fig. 3-1) (Neuman, 1967). A succession of varied polymict conglomerate, graywacke and siltstone crops out in a belt about 4,000 feet (1.2 km) wide in the small area between Pond Pitch and Haskell Rock Pitch of the East Branch of the Penobscot River and immediate vicinity.

The fossils from several localities through this belt are: corals (identified by W. A. Oliver, Jr., written communication, 1961)—*Catenipora* sp., *Acidolites* sp. and petraiid corals, genera and species undetermined; brachiopods—*Orthambonites* sp., *Nicolella* sp., *Hesperorthis* sp., *Boreadorthis* sp., *Glyptorthis* sp., *Ptychopleurella* sp., *Retrorsirostra* sp. (Plate 3-2, Fig. 3-1), *Schizophorella* sp. (Plate 3-2, Fig. 3-3), *Horderleyella* sp., *Laticrura* sp., *Reuschella* sp., *Vellamo* sp., *Triplecia* sp., *Oxoplecia* sp., *Leangella* sp., *Sampo* sp., *Eoplectodonta* sp., *Strophomena* sp., *Christiania* sp., *Leptaena* sp., *Fardenia* sp., *Rhychotrema* sp., and *Catazyga* cf. *C. anticostiensis* (Billings) (see Boucot in Boucot and others, 1964, p. 108-111); gastropod (identified by E. L. Yochelson, oral communication, 1963), *Pterotheca* sp.; trilobites (identified by H. B. Whittington, written communication, 1963), *Sphaerocoryphe* cf. *S. thompsoni* Begg and *Diacalymene* sp.

Pyle Mountain Argillite, Presque Isle quadrangle, Aroostook County, Maine (3b of Fig. 3-1) (Boucot and others, 1964). The rock is olive-colored argillite, greenish-gray where unweathered, underlain without structural contrast by volcanic rocks with interbedded dark chert and slate bearing graptolites of Berry's (1960) zone 13; overlain by the Frenchville Formation of Silurian (late Llandovery) age but the nature of the contact is equivocal (Boucot and others, 1964, p. 32). Fossils (occurrences at individual localities are listed by Boucot and others, 1964, p. 21-22) are: brachiopods (preliminary determinations by Neuman)—*Skenidioides* sp., *Leangella* sp., *Sowerbyella* sp., an undetermined plectambonitid, *Christiania* sp., and an undetermined leptaenid; trilobites (listed by Boucot and others, 1964, p. 21, from identification by Whittington)—*Trinodus* sp., *Remopleurides* sp., *?Symphysops* sp., *Tretaspis* sp., *Novaspis* sp., *Dionide* sp., *?Raphiophorus* sp., *Pseudosphaerexicus* sp., *Dindymene* sp., *Platylichus* sp., and *Carmon* sp.

White Head Formation, Gaspé County, Gaspé Peninsula, Quebec (3e of Fig. 3-1) (Schuchert and Cooper, 1930; Cooper and Kindle, 1936, and accompanying papers; P. J. Lespérance, written communications, 1964-1967). The formation consists of thin-bedded, fine- to coarse-grained, more or less argillaceous limestone, and calcareous siltstone; its stratigraphic relations to enclosing formations are uncertain. Fossils from the White Head are described in the papers cited above. Study of recent brachiopod collections by Neuman, and of trilobite collections by Lespérance (written communication, 1967), largely confirms Schuchert and Cooper's correlation of the White Head with the Ashgill Series. According to Lespérance, however, one collection from this formation yielded Caradoc graptolites.

Unnamed formation on the northwest shore of Intricate Harbour, New World Island, Twillingate quadrangle, Newfoundland (3f of Fig. 1) (Williams, 1963). Fossils occur in a pebbly mudstone interbed in coarse conglomerate that immediately overlies the less pebbly mudstone containing Caradoc fossils already listed (loc. 2g); brachiopods—*Retrorsirostra* sp., *Dalmanella* sp., *Sampo* sp., *Eochonetes* sp. (Plate 3-2, Fig. 4), *Leptaena* sp., and *Cryptothyrella* sp. (Plate 3-2, Fig. 2).

Provisionally correlated. *Unnamed formation* at Ashland, Ashland quadrangle, Aroostook County, Maine (3c of Fig. 3-1) (Collection of David Roy, Mass. Inst. of Technology, 1966, assigned U. S. National Museum collection no. 13030). Shelly fossils are in a thin bed of gray pebbly mudstone included in a sequence of siltstone. Poorly preserved graptolites indicating an age in the range of Berry's (1960) zone 12 to 15 occur in slate a few feet beneath the pebbly mudstone (Berry, written commun., 1967). The siltstone is overlain by the Frenchville Formation at a discordant contact that is probably an angular unconformity. Brachiopods are: *Skenidioides* sp., *?Horderleyella* sp., *Hirnantia* sp., an undetermined enteletacean, *Leptaena* sp., *Cryptothyrella* sp., and *Plectothyrella* sp.

Unnamed formation, 6.5 miles (10 km) northeast of Ashland, Ashland quadrangle Aroostook County, Maine (3d of Fig. 3-1) (collection of David Roy, assigned U.S.N.M. collection no. 13031). The fossiliferous rock is a gray conglomeratic siltstone containing pebbles of volcanic rocks in a sandstone sequence that apparently grades upward into the Frenchville Formation. Brachiopods are: *Hirantia* sp., *Triplecia* sp., *Oxoplecia* sp., *Cryptothyrella* sp., and *Plectothyrella* sp.

Age Considerations

The recognition of Ashgill-age assemblages and their discrimination from those of Caradoc age has been considerably aided by several recent papers (Temple, 1965; Bassett et al., 1966; Marek and Havlíček, 1967). From these and earlier works it is apparent that Caradoc- and Ashgill-age rocks have many brachiopod genera in common, and many species of the common genera are closely related. A few brachiopod genera, however, have not yet been found in beds older than Ashgill; their presence led to the Ashgill age assignment of most of the assemblages listed above.

Thus, *Retrorsirostra*, *Schizophorella*, *Hirnantia*, and *Fardenia* are the key elements of the

assemblage from Penobscot County, Maine, in assigning it an Ashgill age; this assignment is confirmed by the trilobite, *Sphaerocoryphe* cf. *S. thompsoni*. Most of the genera found there, however, are common in beds of Caradoc age, and some range well into the Lower Silurian.

Similarly, the *Eoconetes* as well as the *Retrorsirostra* and *Cryptothyrella* date the New World Island assemblage. This date is consistent with the occurrence of these fossils in rocks in sequence above those containing a late Caradoc assemblage.

Neither of these assemblages, however, can be correlated with any of the established subdivisions of the Ashgill Series. The fossils at several different levels through a wide outcrop belt in Penobscot County suggests that more than one subdivision may be represented, but these have not yet been distinguished.

The trilobites of the Pyle Mountain Argillite have not yet been intensively studied. Whittington (*in* Boucot and others, 1964, p. 21) noted that most of the genera occur also in the Upper Ordovician rocks of Poland. Kielan examined some of the Maine specimens briefly, and commented on the probable specific identity of some forms with Polish species that she had studied (Kielan, 1960). All the genera from the Pyle Mountain occur only in rocks dated as lower or middle Ashgill in Poland; upper Ashgill equivalents of the *Dalmanitina* beds have not been identified in Maine.

The stratigraphic succession within the White Head Formation on the Gaspé Peninsula and its correlation are under study by P. J. Lespérance (written communication, 1967) and his colleagues. Although ages from late Caradoc through late Ashgill have been inferred from paleontologic evidence, complex structure has destroyed direct evidence that might be obtained from superposed strata. The Caradoc graptolites occur in a structurally disjunct body of shale; some of the more certainly Ashgill-age trilobite assemblages are assigned by Lespérance to the early or middle part of that epoch, and assemblages containing *Dalmanitina* are assigned to its later part. Other assemblages, as well as those found in the Matapedia Group farther southwest, have fossils that do not permit discrimination between Caradoc or Ashgill ages, and some limestone mapped as White Head contains fossils of Silurian (lower to upper Llandovery) age.

The two localities in the Ashland quadrangle, Maine, have yielded assemblages that may be of early Llandovery rather than Ashgill age. Discrimination between these is difficult (Boucot and

Johnson, 1964, p. 2), but the Ashland collections lack the genera most indicative of a Silurian age, and are thus provisionally assigned to the Ashgill.

Paleogeographic Interpretations

The wide range of rock types and fossil assemblages of Ashgill age indicates that paleogeography of the Magog belt consisted of a complex pattern of contrasting elements that in places changed rapidly through the epoch. The variety of rocks containing Ashgill-age fossils along the East Branch of the Penobscot River, Maine, ranging from fine-grained calcareous siltstone to boulder conglomerate, indicates rapidly changing local tectonic controls. By contrast, the thin-bedded calcareous rocks of the White Head Formation on the Gaspé Peninsula are contiguous with similar rocks as old as late Caradoc and as young as Silurian (late Llandovery) (Pavrides and Berry, 1966, p. B53, Lespérance, written communication, 1967); thus the calcareous rocks of the Aroostook-Matapedia belt (Pavrides and others, 1964) represent a stable paleogeographic element that changed little through a long span of time.

A problem similar to those already posed for older, erratically distributed marine Ordovician rocks is repeated here: although marine interconnections are implied by the fossils, the connections are not preserved. Whereas coarse-grained rocks of Ashgill age may have been connected by thin, fine-grained deposits that have been completely removed, they seem more likely to have accumulated in local, tectonically controlled troughs that were arms of a sea whose main body presumably lay to the southeast. This suggestion is derived from consideration of the limited occurrence of Lower Silurian (upper Llandovery) conglomerate above the Ashgill-age rocks in the East Branch of the Penobscot River area (Neuman, 1967). These Silurian rocks probably represent such an arm; the main body of this sea is recorded by a broad outcrop belt of contemporaneous Silurian rocks on the southeast that extends for many miles along the northeast-southwest structural trend. A comparable seaway of Ashgill age is suggested by the calcareous rocks of the Aroostook-Matapedia belt in which the Ordovician rocks plunge beneath present erosion levels in eastern Maine (Pavrides and others, 1964, p. C30), but may re-emerge farther southwest (Ekren and Frischknecht, 1967, p. 15) and then continue an unknown distance along strike below the surface. Local tectonic control of sedimentation was also suggested for these rocks in Newfoundland (Kay, 1967, p. 589).

The White Head Formation of the Matapedia Group and the Carys Mills Formation of the Meduxnekeag Group (Pavrides, *in* Cohee and West, 1966) seem to record the floor of a segment of the sea that persisted from Middle Ordovician (Caradoc) time through most if not all of the Early Silurian. Pavrides (*in press*) suggested that these rocks in Maine might be comparable to the "calcareous flysch" of the Carpathian Mountains of Poland (Dzulynski and others, 1959, p. 1095–1096). However, the limestone beds of the "calcareous flysch" are graded calcarenites that differ from "normal flysch" only in the chemical composition of the constituent particles of the sandstone layers; such graded calcarenites are rare in the Carys Mills. Although the Carys Mills possesses abundant flute casts, convolute structures, and occasional burrows, these features are common in several sedimentary environments; furthermore, the argillaceous layers between limestone beds are lighter-colored than those normally associated with acknowledged "flysch" deposits. In addition, the White Head Formation at the northeastern end of the Aroostook–Matapedia outcrop belt displays few if any of these distinctive sedimentary structures, and its thin-bedded argillaceous limestones are typical of shallow water deposition.

The calcareous rocks of the Aroostook–Matapedia belt seem more likely to have been deposited on a platform within an elongate trough. Deeper troughs flanking the platform may have served as traps for most of the terrigenous clastic debris originating from adjacent sources, probably islands. Trapped debris of this kind may be represented by the Chandler Ridge Formation (Pavrides, *in* Cohee and West, 1966, p. A54–A55), which lies at the western border of the outcrop of calcareous rocks, although similar sandstone forms thin units at several places across the belt (Pavrides, 1965, p. 19).

The lithologic contrast between the Pyle Mountain Argillite and the conglomeratic rocks to the west in the Ashland quadrangle provisionally assigned an Ashgill age are consistent with such an interpretation, especially if they prove to be contemporaneous. If so, the conglomeratic rocks may represent entrapped coarse debris in contrast to the fine-grained Pyle Mountain.

SUMMARY

Abundant and varied fossils of marine benthonic organisms imply that the rocks that contain them were deposited in shallow to moderately deep water rather than at abyssal depths. Consideration of the composition of such rocks,

together with their geologic and spatial relations to the contrasting graptolitic facies and to unfossiliferous equivalents, yields some acceptable paleogeographic interpretations, while others are prohibited. Although the suggestions offered here are based on but a few bits of evidence, this evidence suggests that the main outlines of the principal paleogeographic features appear to be significantly different from one to another of three phases of the Ordovician, and tectonic events seem to have separated these phases.

The oldest Ordovician rocks in the central Magog belt (Arenig to Llandeilo age) include shelly deposits in volcanic ejecta which record the presence of volcanic islands from north-central Maine to northern Newfoundland. Graptolitic facies of this age, known only in northern Newfoundland, may represent the interconnections between islands, now largely removed. A Middle Ordovician tectonic event is implied, during which the thinner deposits and much of the volcanic material were removed by subaerial erosion, leaving only small and isolated remnants.

Rocks containing lower Cardoc fossils are virtually absent from the area. Middle Caradoc rocks, largely dark pelites containing graptolites, are widespread, but graywacke having large amounts of volcanic debris and scattered shells is interbedded with pelite at several places in northwestern Maine. Such relations seem most likely to record sediment derived from volcanic islands and swept into deeper water. Thus marine connections between islands are better demonstrated in this segment of the Ordovician than in earlier or later parts. The known distribution of middle Caradoc graywacke probably represents but a fraction of their actual distribution; however, present knowledge indicates that they are more restricted than are the earlier Ordovician shell-bearing volcanic rocks. Although this difference in distribution may reflect the distribution of volcanoes in these parts of the Ordovician, the picture will remain unsatisfactory until the widespread unfossiliferous volcanic rocks attributed to the Ordovician can be ascribed to a specific part of the system. The study of the distribution and composition of fossiliferous rocks of volcanic derivation may help in better discriminating these less well-dated rocks.

The oldest rocks of the Aroostook–Matapedia belt of calcareous rocks are of middle Caradoc (zone 13 of Berry, 1960) age, suggesting that this major feature, which persisted well into the Silurian, came into being at this time. Although the shallow-water origin of the rocks in this belt is questioned (Pavrides, *in press*), the rocks are

conspicuously different from those that surround them, both in their composition and in their temporal and areal continuity. Thus the Aroostook-Matapedia belt represents a stable paleogeographic element whose origin seems to date from about the time of sliding of the Taconic allochthon (Zen, 1967, p. 68); the tectonic significance of this coincidence, however, remains to be appraised.

Other paleogeographic realignments, perhaps coincidental with the Taconic orogeny, seem more evident from the kinds of rocks dated as late Caradoc and Ashgill, and from the general absence of pelitic facies of these ages. Interconnections linking late Caradoc and Ashgill shelly rocks may have been through ephemeral arms of the sea extending from the Aroostook-Matapedia belt onto the axial part of the Magog belt. Tectonic control of the coarse-grained rocks bearing the shelly fossils is suggested by their conglomeratic nature, and by the coincidence of such Ashgill-age rocks with very similar rocks of Llandovery age that overlie them in one small area in Maine. Thus the major elements of Early Silurian paleogeography seem to have been established in Late Ordovician time.

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