Geoscience Canada

Recent Advances and the Interpretation of Geological Structure of New Brunswick

N. Rast and P. Stringer

Volume 1, Number 4, November 1974

URI: https://id.erudit.org/iderudit/geocan1_4art03

See table of contents

Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

Explore this journal

Cite this article

Rast, N. & Stringer, P. (1974). Recent Advances and the Interpretation of Geological Structure of New Brunswick. *Geoscience Canada*, *1*(4), 15–25.

Article abstract

The paper reviews the Precambrian and Paleozoic stratigraphy and structure of New Brunswick against the background of the theory of plate tectonics. The major subdivisions of the Appalachian-Caledonian orogenic belt are examined and a conclusion is reached that as a result of successive Penobscot, Taconic and Acadian orogenic disturbances parts of Paleoamerica and Paleoeurope are so sutured that the formerly intervening oceanic crust has either been entirely obducted onto the continents or subducted below them. The evolution of the orogenic belt in New Brunswick and adjacent regions can be explained with reference to the formation of successive volcanic arcs.

Recent Advances and the Interpretation of Geological Structure of New Brunswick

N. Rast and P. Stringer
Department of Geology
University of New Brunswick
Fredericton, New Brunswick

Summary
The paper reviews the Precambrian and Paleozoic stratigraphy and structure of New Brunswick against the background of the theory of plate tectonics. The major subdivisions of the Appalachian-Caledonian orogenic belt are examined and a conclusion is reached that as a result of successive Penobscot, Taconic and Acadian orogenic disturbances parts of Paleoamerica and Paleoeurope are so sutured that the formerly intervening oceanic crust has either been entirely obducted onto the continents or subducted below them. The evolution of the orogenic belt in New Brunswick and adjacent regions can be explained with reference to the formation of successive volcanic arcs.

Introduction
Until the middle sixties the geology of New Brunswick has been, on a scientific level, explored in the main by the officers of the Geological Survey of Canada, and much of it was summarized by Howie and Cumming (1963). The achievements and insights of the G.S.C. have been ably expounded by Poole (1967), himself a major contributor, and Poole *et al.* (1970). The New Brunswick Research and Productivity Council has produced a complete bibliography which covers this period until 1968 and the findings are represented on a 1:500,000 map compiled by Potter, Jackson and Davies (1968). The map includes the results of all large-scale investigations of the Geological Survey of Canada, the Department of Natural Resources of New Brunswick, the efforts of research students of Canadian and American universities, the explorations by oil and mining companies and by many individuals who took interest in the Province. Since then, I.G.C. Guidebooks by Poole and Rodgers (1972), Potter, Bingley and Smith (1972), van de Poll (1972) and McAllister and Lamarche (1972) added further information. The pace of research and development, however, has been such that it appears timely to analyse the most recent advances in the context of geological and geophysical insights on international level. In particular the well known recognition of the tripartite distinction of: (1) the Laurentian Platform, (2) the Orogen, (3) the Avalon Platform, can now be further explored to establish the geological history of the orogenic belt as a whole.

In this paper the effort has been divided so that one of us (N. Rast) has been responible for the southern part of the Province while the other (P. Stringer) considers the north. Yet, in an endeavour to understand the geology of the Province we inevitably transgress outside it.

An Outline of Stratigraphy and Structure
Stratigraphically the solid sedimentary or meta-sedimentary rocks of the Province involve a succession of Precambrian, Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Triassic rocks. In various parts of the Province these successions differ, and the differences can be summarized in comparative sections (*Fig. 1*) showing the successions in New Brunswick and adjoining regions. In preparing stratigraphic columns in the first place we used the vertical scale proportionate to time rather than thickness, and then constructed the sections as shown by allowing for thickness variations of Ordovician to Devonian strata.

Precambrian rocks. Throughout northern and central New Brunswick there is a general lack of obvious basement rocks. In the Miramichi anticlinorium at the bottom of the so-called lower sedimentary unit of the Tetagouche Group (Helmstaedt, 1971, p. 9) there are gneissose rocks and associated schists and quartzites which may be a part of the basement, in which case they would correlate with the lower part of the Fleur de Lys Supergroup of Newfoundland. This point is of some importance since one of the problems that has so far received no attention is the fate of the products of erosion from the Grenville mainland in Hadrynian times. The exposed wide belt of Grenville rocks adjacent to the Appalachian Orogen belongs to amphibolite and granulite facies. The implication is that the Grenville rocks have been eroded to depths of 15-20 kms, and at present there is no obvious position for the resultant clastic wedge except at the bottom of the Appalachian orogenic belt marginal to the known edge of the Grenville basement. In Newfoundland and the British Isles the products of erosion from the Canadian – Greenland shield are present as the Fleur de Lys and Moine – Dalradian successions respectively. Thus although at present Hadrynian rocks adjacent to the Laurentian Platform are unrecorded from the mainland of North America it seems likely that they will be found below the deformed and metamorphosed Lower Paleozoic formations.

In southern New Brunswick, a full succession of Precambrian (Hadrynian and probable Neohelikian) has been recognized. The succession is better developed in Cape Breton Island, and its upper part in the Avalon peninsula of Newfoundland. Consequently, by extension, southern New Brunswick Precambrian rocks are often referred to as the Avalon Platform. The succession in New Brunswick consists of the lower, Greenhead Group of carbonates, sandstones and gneisses, and the upper, Coldbrook Group of acid and intermediate volcanics, and

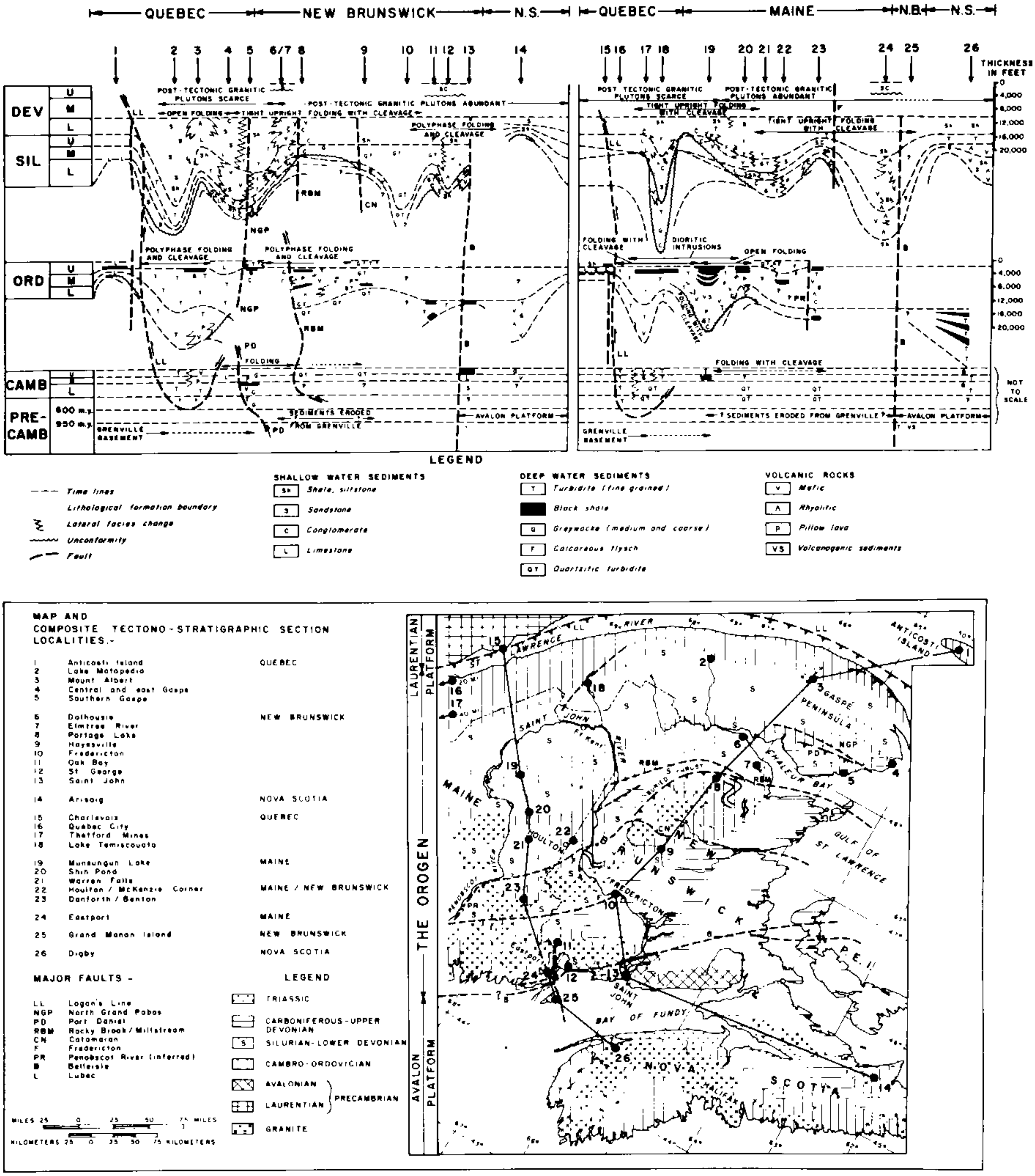

Figure 1
Map and comparative stratigraphic sections across New Brunswick and adjoining areas, Northern Appalachians.

associated thin sediments. Hofmann (1974) suggests a probable Neohelikian age for the Greenhead Group. Most acid volcanic rocks of the Coldbrook Group are ignimbrites and therefore mainly terrestrial. This, however, is not the case in the lateral correlatives of Cape Breton Island and Newfoundland where thick flyschoid sediments occur. The Avalon Platform rocks are abruptly cut off by the Belleisle fault (Fig. 1), and have not been recognized anywhere to the northwest.

Cambrian rocks. In northern New Brunswick there are no indisputable Cambrian rocks, although in easternmost Gaspé peninsula Middle and Upper Cambrian platform carbonates are present, and in southern Gaspé a polydeformed complex greywacke succession (Maquereau Group) of uncertain age may be Cambrian and would then correlate with the lithologically similar part of the Fleur de Lys Supergroup. It is the presence of this supergroup in a position between Newfoundland and northern New Brunswick that has led H. Williams *et al.* (1972, p. 195) to correlate the Tetagouche Group of the Miramichi anticlinorium with the Fleur de Lys Supergroup of Newfoundland.

In southern New Brunswick the fossiliferous Middle Cambrian shales with limestones are separated from Coldbrook volcanics by a 2000 feet thick succession of conglomerates, red beds, and quartzites of undetermined age (Cambrian? – Precambrian?) often referred to as the Etcheminian. The Cambrian succession proper is best exposed around the city of Saint John, where its upper part consists of interbedded slates and greywackes gradationally succeeded by black *Dictyonema*-bearing shales of lowermost Ordovician age. Elsewhere in southern New Brunswick black shales of the so-called Charlotte Group are considered as Ordovician but may also be in part Upper Cambrian.

In Maine and other parts of New England, often unconformably underlying Lower Ordovician rocks, there are outcrops of a banded sequence of graded quartzites and pink, green and grey shales and siltstones. These rocks in eastern Maine have been called Grand Pitch Formation in Shin Pond (Neuman, 1967) and also occur at Danforth (Larrabee *et al.*, 1965). Neuman also thinks that lithologically similar rocks form the lower part of the Tetagouche Group. The age of these rocks is debatably uppermost Precambrian or Lower Cambrian and on lithological grounds and the presence of *Oldhamia* they have been provisionally correlated with the "Bray Series" of southern Eire, where these rocks are also near to the late Precambrian platform of Anglesey and the English Midlands. Thus they are related to the Avalon rather than the Laurentian Platform.

Penobscot Disturbance. In eastern and southern Maine Neuman (1967), Gates (1969) and Hall (1969) refer to a stratigraphic break between the supposed Cambrian Grand Pitch Formation and Ordovician strata. The structural evidence for the interpretation of the break comes from Neuman who records that the Grand Pitch Formation suffered inter-penetrative deformation prior to the deposition of the Ordovician. Hall (1970) recognizes N – S trending "Penobscot" folds with attendant cleavage. The evidence for a distinct orogenic phase is at present inconclusive, although there are other localities (e.g., Hayesville sheet, New Brunswick and eastern Gaspé peninsula) where Ordovician rocks rest with a possible break on older strata.

In Newfoundland (Kennedy *et al.*, 1972) there is strong evidence for a late Cambrian orogenic episode which in the British Isles is known as the Grampian (Rast and Crimes, 1969). In these localities the rocks involved in the deformation are mainly the Fleur de Lys and the Moine – Dalradians, the latter having yielded Cambrian fossils (Downie *et al.*, 1971) towards the top. It seems not impossible to envisage Penobscot movements as time equivalents of the Grampian episode which affected the northeastern part of the Appalachian/Caledonian orogen.

Ordovician rocks. In northern New Brunswick only Middle and possibly Upper Ordovician rocks have been recognized, although the latter are known from northeast Maine (Pyle Mountain Argillite) and the Gaspé peninsula (White Head Formation). The upper part of the Carys Mills Formation of Maine and its equivalent in New Brunswick, Matapédia, and Gaspé, is Silurian, and its lower part is Caradocian. From a thick sequence of calcareous turbidites in between no fossils have been obtained, but because so far no break has been recorded, by implication a part of the Carys Mills Formation is Upper Ordovician. The connection from these rocks into the central New Brunswick Ordovician belt of the Chaleur Bay synclinorium and the Miramichi anticlinorium is badly known. The earliest Ordovician strata are Arenig (Neuman, 1972) on the southeastern flank of the Miramichi anticlinorium. In the Bathurst Camp region no fossils earlier than Berry's Zone 11 (Dean, reported in Helmstaedt, 1973) are known. The lower unit of the Tetagouche Group *sensu stricto* is at present of debatable age and may include rocks ranging from the Precambrian to the Lower Ordovician. Arenig fossils have recently been found at the top of the lower unit south of Tetagouche Falls (L. R. Fyffe, personal communication). The thickest middle part of the Tetagouche Group consists of the economically important volcanic rocks of the Bathurst Camp, and here the only fossils are found in the overlying black shales, including the famous locality assessed by Reudemann (*in* Alcock, 1935, p. 17). The late Middle Ordovician black shales are lithological correlatives of the Normanskill and higher Middle Ordovician black shale of New England and New York, and date the cessation of the Middle Ordovician acid and intermediate volcanicity of the island arc type.

At the southwest end of the Miramichi anticlinorium, Ordovician shales and greywackes containing extensive pillow lavas and some acid pyroclastics have been mapped (Anderson, 1968) and long ago, Bailey (reported in Hahn, 1912, p. 135) discovered here *Dictyonema* *flabelliforme* (Eichwald) var. *sociale* (Salter) of Tremadocian age. Thus these rocks are probably older than the black shales of the Bathurst Camp.

The Ordovician strata of southern New Brunswick have yielded only fossils indicative of Lower Ordovician age. In Saint John the Tremadocian black shales follow those of the Upper Cambrian. On Cookson Island Lower Ordovician graptolite-bearing black slates are in a faulted contact with the Llandovery Oak Bay conglomerates which are assumed to have rested unconformably on the Ordovician. The dark argillites and greywackes of the Charlotte Group are often included in the Ordovician, but there is no faunal control. Thus at present the evidence is that all these rocks may be Lower Ordovician, and there may have been a continuity of deposition with central New Brunswick. The spread of Lower Ordovician black shales is also well known in the British Isles. Extensive tracts of metamorphosed black clastics are known from southern Maine where the Ordovician age is often assumed. In southern Nova Scotia the Halifax black slates have also yielded Tremadocian fossils. In Cape Breton Island Tremadocian strata (McLeod Brook Formation) are present, but the Middle Ordovician is missing. In Arisaig presumed Upper Ordovician ignimbrites rest on the eroded surface of the Brown's Mountain Formation of unknown age. Thus a regionally significant spread of Lower Ordovician black shales is associated with the southeastern part of the Appalachian – Caledonian orogen. At the same time substantially different flysch sedimentation was taking place along the Laurentian Platform indicating asymmetry in the geological development of the two platforms.

Taconic orogeny. The most pronounced manifestations of the Taconic orogeny are in Quebec immediately to the north of New Brunswick. St.-Julien *et al.*, (1972) and Zen (1972) describe nappes and overthrust ophiolites from Thetford mines, and in this general region it is widely recognized that Middle Ordovician polyphase deformation (e.g., Carrara and Fyson, 1973) is overprinted by Acadian structures. In northern New Brunswick the deformed Lower and Middle Ordovician rocks (Tetagouche Group, Madawaska Lake ? Formation, etc.) are juxtaposed with the Carys Mills Formation which has not been deformed in pre-Acadian times. In Bathurst Camp Helmstaedt (1973) recognizes a sequence of polyphase deformation which he attributes to the late Ordovician and early Silurian. Such a complex history of deformation is, however, not recorded from adjacent parts of Maine.

Throughout the Middle Ordovician of northern New Brunswick and Maine extensive volcanic formations of island arc type are noted in Bathurst Camp, Winterville, Castle Hill, Munsungun Lake and Shin Pond. It is the cessation of this volcanic episode at the end of the Middle Ordovician and the spread of a mantle of black shales over the region that we correlate with the onset of the Taconic orogeny, which then caused deformation, uplift and substantial erosion until transgressive Upper Llandovery sediments spread unconformably over the whole region.

In southern New Brunswick the evidence for Taconic movements is restricted to Cookson Island where the Silurian Oak Bay conglomerate is in an unconformable or fault contact with Lower Ordovician black graptolitic shales. Also the uppermost Ordovician ignimbrites in Pictou, Nova Scotia rest with a strong unconformity on the land surface of Brown's Mountain strata.

Silurian rocks. In the aftermath of Taconic orogeny, Llandovery sediments spread over both the Laurentian and the Avalon platforms. This event marks the first occasion of the development of matching episodes of sedimentation and erosion on both of the Appalachian platforms (McKerrow and Ziegler, 1972). Until Llandovery times, as is clear from Figure 1 and our description, the histories of the Laurentian and the Avalon platforms were different throughout late Precambrian to Cambro-Ordovician times. This asymmetry is especially pronounced with respect to the Ordovician volcanic island arc being restricted to northern New Brunswick and the absence in southern New Brunswick of a zone of overthrusting equivalent to that in Quebec.

The well-known irregularity of the Lower Silurian transgression indicates the tectonic instability of the shelves on which it was deposited. Consequently in northern New Brunswick, Silurian sediments indicate derivation from differing sources (Hamilton-Smith, 1971). The Llandovery sediments of the Aroostook – Matapédia anticlinorium, however, grade downwards into the Ordovician (Carys Mills Formation).

In central New Brunswick the evidence for the Lower Silurian is poor although some Silurian flyschoid greywackes and slates (Taxis River Grits) have been claimed to be at least partly Llandovery. In fact, the available graptolites are entirely of Ludlovian and Wenlockian ages (Poole, 1958; Gordon and Cumming, 1966). Unlike the Silurian succession in the Aroostook – Matapédia anticlinorium, these rocks have no manganiferous deposits and are almost entirely non-calcareous. They form a 50 miles broad elongate belt of rocks known as the Fredericton trough in New Brunswick and the central slate belt in Maine (Rodgers, 1970); McKerrow and Ziegler (1971) refer to them as oceanic sediments. The trough is margined by pene-contemporaneous volcanics to the southeast of island arc type (St. George and Eastport areas). Symmetrically disposed volcanics of the same age also exist in northern New Brunswick and Gaspé (Chaleur Bay Group and Mount Alexandre Formation). This situation tends to confirm the proposed oceanic trough on the site of the Fredericton greywacke belt (McKerrow and Ziegler, 1971).

Devonian rocks. Devonian sedimentary rocks in New Brunswick are in general restricted to the south and north, although a few small outliers of Devonian sediments and volcanics occur to the northwest of Fredericton. Devonian rocks are conformable with the underlying Silurian, although local unconformities exist and are sometimes referred to as the "Salinic phase". In Maine, the Lower Devonian sedimentary and volcanic rocks are better known (Neuman, 1967; Hall, 1970) while island arc type volcanicity is prevalent in Maine, northern and central New Brunswick, and Gaspé, and in the former locality it is associated with flysch-type sediments (Hall *et al.*, 1972).

In New Brunswick, little Middle Devonian sediments are exposed, except in the extreme north, although some are present in Maine (W. Forbes, personal communication). Upper Devonian red beds on the other hand are present mainly in southern New Brunswick, and represent a molasse-type sedimentation which succeeded the Acadian orogeny.

Acadian orogeny. Throughout New Brunswick, Maine and Gaspé, Acadian structures (folds with steep axial planes and sub-vertical cleavage) have governed the disposition of the rocks. In detail there are variations, Acadian polyphase deformation *sensu stricto* exists only in the south (Ruitenberg, 1968; Brown, 1972; and Donohoe, 1973). Furthermore, over most of the area the steep Acadian cleavage parallels the axial planes of folds. However, in some localities (e.g., Chaleur Bay and western Gaspé, Bridgewater quadrangle in Maine, and the Passamaquoddy Bay area) cleavage is independent of fold axial planes and has a much more regular NE - SW trend (Stringer, 1974).

The precise dating of the Acadian orogeny is at present a matter of great difficulty. Both in southern and northern New Brunswick and Maine it is pre-Upper Devonian. On paleontological grounds Boucot *et al.*, (1964) suggest that it may be late Lower Devonian. The isotopic ages of post-Acadian granitic plutons fall within the range of 410 to 360 m.y. (Fairbairn, 1971). Recent determinations indicate 390 – 400 m.y. as the more probable dates (Naylor *et al.*, 1974). Although various workers recognize several phases of Acadian movements, none involving inter-penetrative deformation affect the dated late Devonian rocks.

The isotope dating is done principally on Devonian granites. As Fairbairn (1971) points out, there is a series of intrusions straddling Acadian events. The earliest granodiorites have been involved in both folding and cleavage deformation (e.g., north-eastern part of the Pokiok massif) and the latest are entirely post-tectonic. In southern New Brunswick the late post-tectonic granites (e.g., St. George massif) cut earlier but still generally post-tectonic gabbros (Bays of Maine complex). No undoubtedly syntectonic Acadian granites so far have been demonstrated.

Carboniferous rocks. The Carboniferous succession of basal volcanics and succeeding red beds of the Mississippian and Pennsylvanian ages throughout central and northern New Brunswick is very gently folded or almost flat. The rocks have been dated on spores and plants to include formations ranging from Tournaisian to and including Stephanian. Possibly Permian rocks occur in Prince Edward Island. The thickest sequence is in the Moncton basin to the south where the rocks are moderately folded but uncleaved. In southernmost New Brunswick a belt of very strongly deformed Carboniferous strata fringes the Bay of Fundy and seems to continue into Nova Scotia and Cape Breton Island. These rocks are lithologically similar to the rest of the New Brunswick Carboniferous succession. Throughout New Brunswick there is well-documented evidence of an unconformity separating the Mississippian from the Pennsylvanian strata. In southern New Brunswick the latter in places overstep directly onto the Precambrian.

Appalachian-Variscan orogeny. The deformed belt of southern New Brunswick Carboniferous has had various interpretations (*in* Rast and Grant, 1973), the most recent of which is consistent with the flat-lying polyphase foliation which affects the rocks, and claims full-scale orogeny by comparison with the pre-Drift position of the British Isles. The Pennsylvanian rocks in general are free from polyphase deformation, except in Black Bay near St. Martin's Head where first phase Variscan structures are refolded. Furthermore, the first cleavage (S_1) which apparently affects the Mississippian and Pennsylvanian rocks alike is also present in the breccia associated with the marginal overthrusts of the orogenic belt, and is deformed by later folds and crenulations (S_2, S_3).

Triassic rocks. Triassic rocks are found only in southern New Brunswick where they are conglomerates and sandstones on the northwest shore of the Bay of Fundy, and largely basaltic lavas on the southeast shore and on Grand Manan Island (Klein, 1962, and Sanders, 1971). The sedimentary rocks of the northwest shore occur in isolated fault-bounded blocks, in some of which thicknesses approaching several miles have been measured, which is particularly significant in view of the prevailing opinion that all of these rocks are Upper Triassic.

Post-Triassic deformation. Triassic strata show signs of surprisingly vigorous deformation. Steep dips up to vertical occur in the Lepreau area of southern New Brunswick, and gentler synclines and anticlines are widespread (Stringer and Wardle, 1973). In places evidence of crude cleavage has been obtained, and faulting on different scales is common. Nevertheless, the state of deformation is much less than in the adjacent Carboniferous, let alone the older rocks.

Possibly the latest Triassic event is the intrusion of the Caraquet dyke (Burke *et al.*, 1973) which on magnetometric evidence is of a considerable continuity and crosses the whole province into Maine.

Major Structure and Significance of Faults

The main structures in New Brunswick are summarized in *Figure 2*. The dating of the fold episodes is reasonably easy to establish; faults, however, are probably polygenetic and suffered displacement in different times. Some of the faults appear to separate blocks with different geological histories. In relation to the Appalachian Orogen of

New Brunswick and Gaspé three important fault zones of this kind are here selected: (a) Logan's Line, (b) Rocky Brook – Millstream fault and (c) Belleisle fault.

Logan's Line is a curved fault continuing from Lake Champlain, N.Y. to the easternmost part of the Gaspé peninsula. It consists of a series of overthrusts representing the front of the Appalachian Orogen and separating the Ordovician flysch from the penecontemporaneous platform carbonates. The break itself must have been initiated during the Taconic orogeny (St.-Julien *et al.*, 1972). The curvature of the fault is probably original like the curved Hermitage flexure in Newfoundland. As a model, we would like to propose that all strongly curved or sinuous faults in northern Appalachian are Taconic in age. The hades of such faults, however, can be a function of Acadian movements steepening or even overturning them.

The Rocky Brook – Millstream fault is a composite fracture zone with sub-parallel reversed and normal faults. The age of normal faulting cannot easily be evaluated although it is post-Lower Devonian since the fault can be traced south-westwards across the Siluro-Devonian rocks of the Chaleur Bay synclinorium into the Aroostook – Matapédia anticlinorium (*Fig. 2*) and it is pre-Mississippian since the unfaulted outlier (Plaster Rock) rests across it. The thrust component at present is largely suppositional, but it is suggested by analogy with Maquereau (Port Daniel fault). If it exists in New Brunswick, its trace would underlie the unconformable Lower and Middle Silurian rocks. The post-Silurian faulting, as for instance on the Bay of Chaleur coast, separating the Ordovician and Silurian rocks (near Beresford), is interpreted by us as regeneration of movement on those portions of the thrust which have been upturned by the Acadian orogeny. Furthermore, even during Silurian times the trace of the Rocky Brook – Millstream fault appears to separate areas of different sedimentation.

The third variety of faults, represented by the Belleisle fracture zone of southern New Brunswick, are nearly straight. The Belleisle fault probably originated in Silurian times. It is at present a composite fracture zone with many lenticles of rocks ranging from Precambrian to Mississippian involved in it. Sometimes it has been correlated with the Lubec fault but as shown on the map (*Fig. 2*) it probably corresponds to another fracture positioned in eastern Campobello Island and off-shore. This is supported by band-by-band correlations across the Oak Bay fault in Passamaquoddy Bay and also by the curving aeromagnetic anomaly which is associated with the Precambrian and follows the fault on the mainland (Cumming, 1967). The latest movement on the fault of high angle reverse type is Lower Carboniferous.

In New Brunswick Silurian rocks are restricted to the northwest side of the Belleisle fault which is not true for the Lubec fault. Finally, in one of the lenticles of the fault in Deadman Harbour a thick mélange of various blocks of Lower Paleozoic sediments and igneous rocks has recently been identified (Rast and Grant, 1974). The mélange overlies Upper Silurian greywackes and is comparable in its diverse lithology to the Dunnage mélange in Newfoundland interpreted by Marshall Kay (1972) as a subduction zone rock. A similar interpretation is suggested for this mélange and it seems therefore possible that the Belleisle fault at least in part follows the Silurian subduction zone suture, thus separating the Silurian oceanic realm from its platform counterpart to the southeast.

In summary it must be pointed out that the curvature of the major faults affecting the Appalachian Orogen decreases to the southeast. The significance of this pattern can be interpreted on the assumption that the orogen had been squeezed against the North American continent, and therefore fractures near to the Laurentian Platform are likely to be more curvilinear than those away from it. In support of this hypothesis we can point out that the trends of the major folds also follow the same variations. Clearly the local pre-Taconic trend of the Avalon Platform had been approximately straight.

Interpretation and Continental Relationships

The basic regional model for the northern Appalachians has been proposed by Dewey (1969) and Bird and Dewey (1970) in terms of a collision of two plates (Europe – North America) with continental borders. Schenk (1971) also proposed that the southern part of Nova Scotia was part of Africa. Shackleton (1974) maintains that Africa was not involved in a major continental collision until the Variscan orogeny, which is not inconsistent with Schenk's idea since it is quite possible that southern Nova Scotia was a part of the African plate and was joined to the American plate during the Variscan orogeny. Since the granites and deformation in southern Nova Scotia are identical with the mainland of North America, it is also possible that southern Nova Scotia originated as a block from a position in the Gulf of Maine. That the Avalon Platform of New Brunswick, Newfoundland and the Midlands of England was probably a continuous structure is argued by Rast *et al.*, (1974).

Within the frame of two continental borders (Avalon and Laurentian) are situated the deformed Lower Paleozoic and Devonian rocks of the Appalachian Orogen. Within this belt ophiolite representatives of the suggestedly consumed ocean floor form only very small outcrops indicating that the ocean has been almost entirely subducted during the Appalachian – Caledonian cycle. Only in Newfoundland and parts of southern Quebec allochthonous masses of such ophiolites are observed as the principal evidence of the Taconic orogeny. The present width of the belt therefore must have an essentially sialic basement which represents the juxtaposed continental rises and shelves of Paleoeurope and Paleoamerica. This sialic basement consists of two essential parts: the Grenville gneissose basement of the Laurentian Platform and the unknown granitic(?) crust overlain by the Grand Pitch Formation or its presumed equivalents of the Avalon Platform. In Europe this crust is in part represented by Rosslaire complex (Eire), Malvernian gneisses and

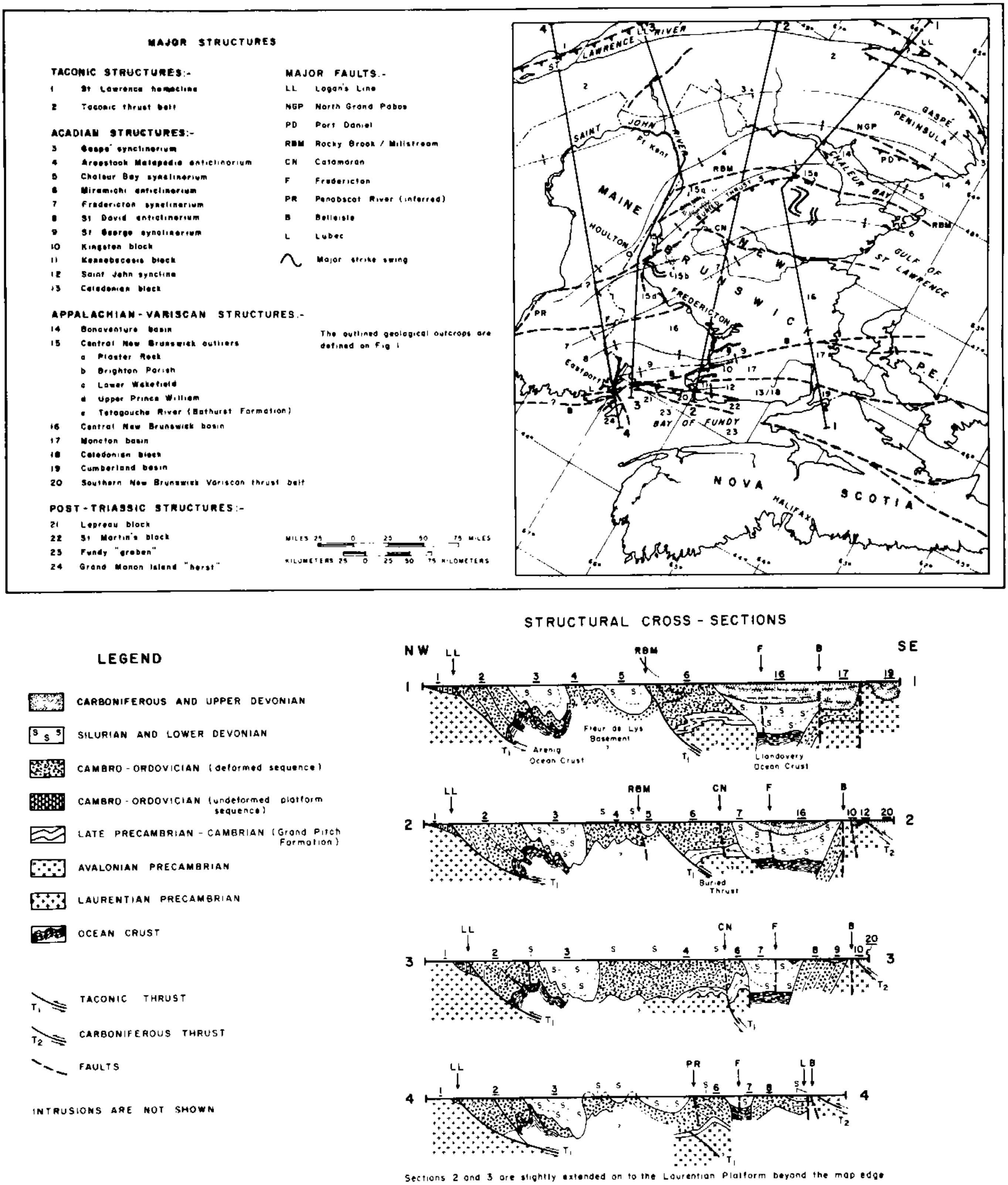

Figure 2
Structural sections across New Brunswick and adjoining regions, Northern Appalachians.

Anglesey metamorphics and granites.

Overlying the two crusts there are: Fleur de Lys Supergroup of Newfoundland, the Quebec Supergroup of flyschoid strata in Gaspé, and further south the pre-Oak Hill sedimentary rocks of Vermont resting on Grenville, while the Grand Pitch rocks are usually covered by later Lower Ordovician volcanogenic sediments. On the Avalon Platform proper a thick Hadrynian volcanic sequence is overlain by fairly thin Cambro-Ordovician strata. At the edge of the platform with an apron of Grand Pitch deposits there are extensively developed Middle Ordovician basalts, andesites and rhyolites of island arc type. The Middle Ordovician island arc, well represented in Maine and New Brunswick and probably continuous with the Buchans of Newfoundland, is in northwest New Brunswick and northeast Maine divided into two parts by the Aroostook – Matapédia belt (*Fig. 3*). We interpret this as a result of Middle and late Ordovician Taconic overthrusting when the rising overthrust Miramichi part of the arc supplied sediments to a foredeep in which a vast thickness of somewhat calcareous flyschoid Ordovician and Silurian deposits accumulated. Thus the Taconic orogeny involved at first formation of overthrust ophiolites succeeded shortly afterwards by the rising of the arc. We would suggest that both phenomena arose due to resistance of the aforementioned thick pile of deformed Precambrian to Ordovician erosion products of the Laurentian Platform.

It is noticeable that the Miramichi part of the island arc shows polyphase Taconic deformation (Helmstaedt, 1973) while this is absent from the Maine part of the arc where no evidence of Taconic overthrusting exists. Thus we suggest an association between Taconic overthrusting and regions of polyphase deformation. The events pertaining to Taconic orogeny are shown in *Figure 4*. In our interpretation we have used the model proposed by Moberly (1972) who, with reference to the present day Pacific arcs, suggested that they migrate in the direction away from the continents,

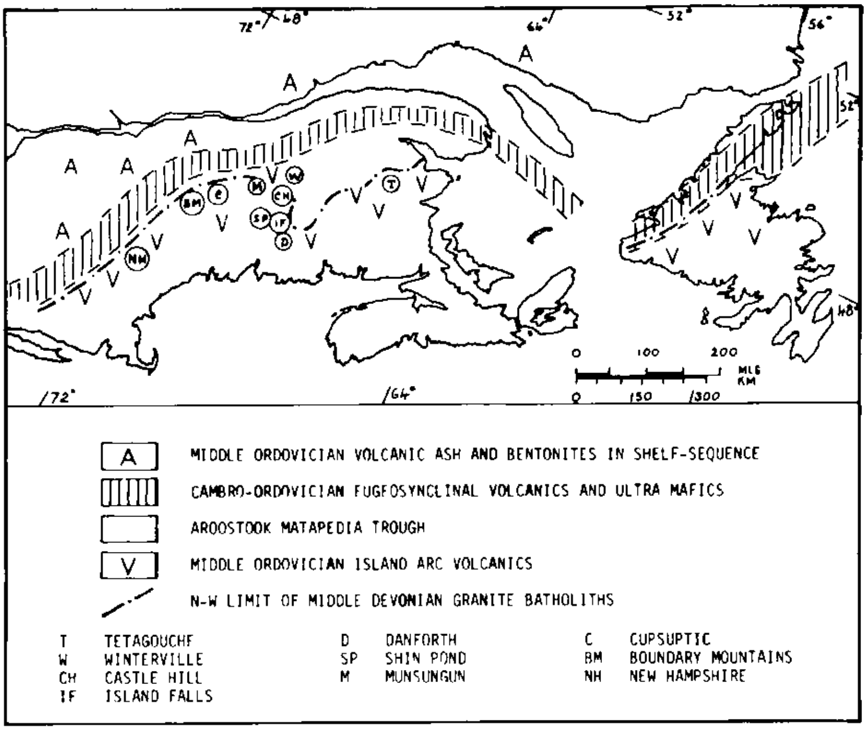

Figure 3
Middle Ordovician volcanic island arc and associated structures.

thus causing the generation of inland seas behind them.

The extended inland sea behind the Miramichi arc was evidently the site of the Silurian small(?) ocean (Fredericton trough) which during the Upper Silurian had marginal island arcs represented by the Gaspé – Chaleur Bay volcanics on the American side and the Eastport – St. George volcanics on the other side. In this respect we follow the general interpretation of McKerrow and Ziegler (1972). We also assume that by Devonian times the small ocean was consumed. We interpret Devonian andesites in the same light as the Midland Valley of Scotland andesites as post-orogenic volcanics produced in the process of melting of subducted slabs.

During the Variscan movements the Nova Scotia block was either (as suggested before) a part of a plate which collided with North America or a rigid North American block which was involved in continental compression by the African or even South American plate (cf. Zietz and Zen, 1973). From then on to the Triassic times the Proto-Atlantic ocean was closed. The late Triassic deformation heralded the opening of the Atlantic.

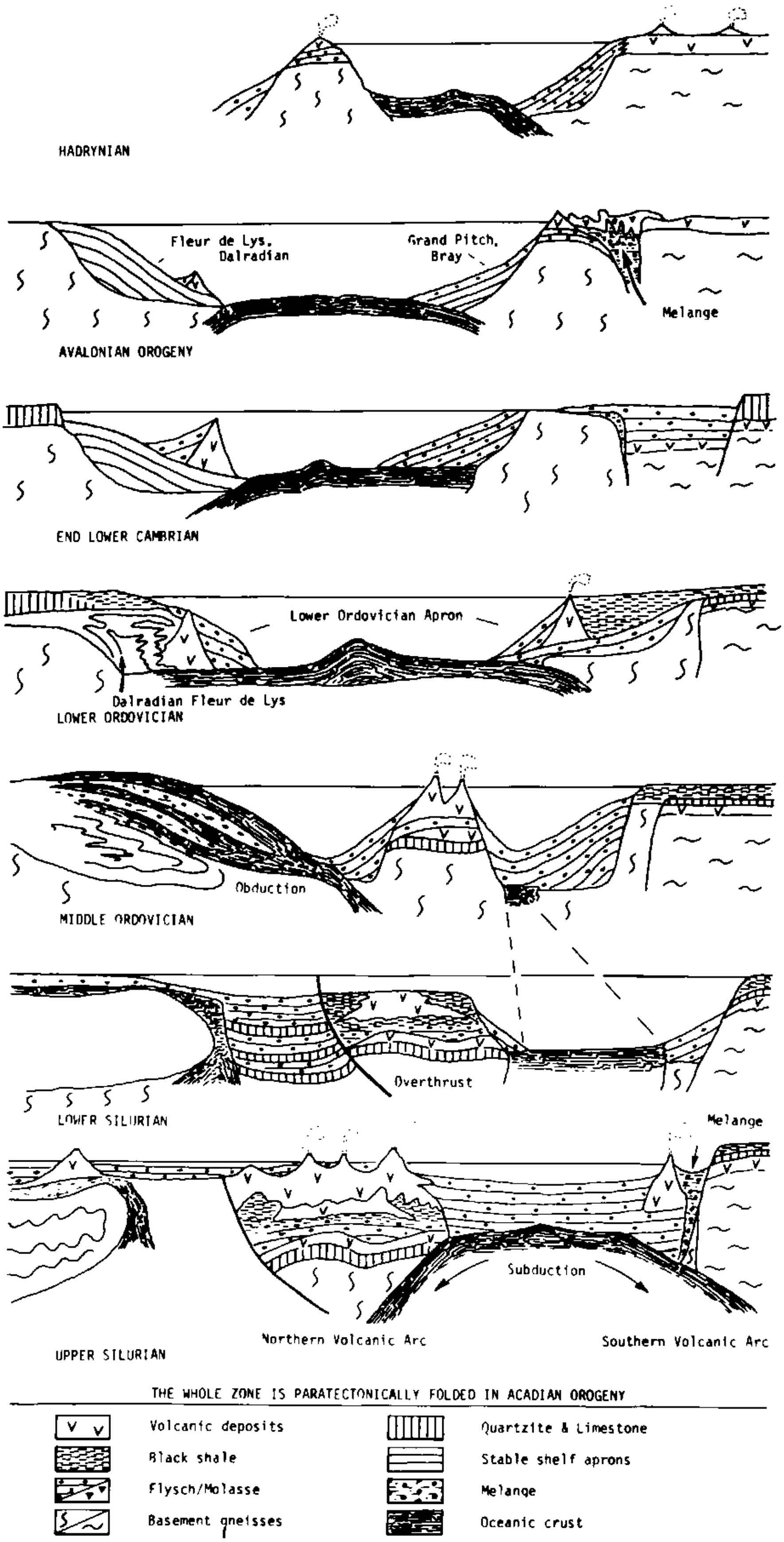

Figure 4
Plate tectonic interpretation.

References

Alcock, F. J., 1935, Geology of Chaleur Bay Region: Geol. Surv. Can., Mem. 183.

Anderson, F. D., 1968, Woodstock, Millville and Coldstream map-areas, Carleton and York Counties, New Brunswick: Geol. Surv. Can., Mem. 353.

Bird, J. M., and J. F. Dewey, 1970, Lithosphere plate – continental margin tectonics and the evolution of the Appalachian orogen: Geol. Soc. Am. Bull., v. 81, p. 1031-1060.

Brown, R. L., 1972, Appalachian structural style in southern New Brunswick: Can. Jour. Earth Sci., v. 9, p. 43-53.

Burke, K. B. S., J. B. Hamilton and V. K. Gupta, 1973, The Caraquet dike: its tectonic significance: Can. Jour. Earth Sci., v. 10, p. 1760-1768.

Boucot, A. J., M. T. Field, R. Fletcher, W. H. Forbes, R. S. Naylor and L. Pavlides, 1964, Reconnaissance bedrock geology of the Presque Isle quadrangle, Maine: Maine Geol. Surv. Quad. Mapping Ser. 2.

Carrara, A. and W. K. Fyson, 1973, Taconic and Acadian folds in northern and western Gaspé Peninsula: Can. Jour. Earth Sci., v. 10, p. 498-509.

Cumming, L. M., 1967, Geology of the Passamaquoddy Bay region, Charlotte County, New Brunswick: Geol. Surv. Can. Paper 65-29.

Dewey, J. F., 1969, Evolution of the Appalachian/Caledonian orogen: Nature, v. 222, p. 124-129.

Donohoe, H. V., 1973, Acadian orogeny in coastal southern New Brunswick, *in* N. Rast, ed., N.E.I.G.C. 1973 Field Guide to Excursions, p. 71-80.

Downie, C., T. R. Lister, A. L. Harris and E. J. Pettis, 1971, A palynological investigation of the Dalradian rocks of Scotland: Inst. Geol. Sci., Rept. no. 7.

Fairbairn, H. W., 1971, Radiometric age of mid-Paleozoic intrusives in the Appalachian-Caledonides mobile belt: Am. Jour. Sci., v. 270, p. 203-217.

Gates, O., 1969, Lower Silurian – Lower Devonian volcanic rocks of New England coast and southern New Brunswick: *in* Marshall Kay, ed., North Atlantic – geology and continental drift: Am. Assoc. Petroleum Geol. Mem 12, p. 484-503.

Gordon, A. J. and L. M. Cumming, 1966, Mactaquac-Woodstock section of the Saint John River: New Brunswick Dept. Nat. Res., Min. Res. Branch, Unpubl. Rept.

Hahn, F. F., 1912, On the Dictyonema-fauna of Navy Island, New Brunswick: Ann. N.Y. Acad. Sci., v. 22, p. 135.

Hall, B. A., 1969, Pre-Middle Ordovician unconformity in northern New England and Quebec: *in* Marshall Kay, ed., North Atlantic – geology and continental drift: Am. Assoc. Petroleum Geol. Mem. 12, p. 467-476.

Hall, B. A., 1970, Stratigraphy of the southern end of the Munsungun anticlinorium, Maine: Maine Geol. Surv. Bull. no. 22.

Hall, B. A., S. G. Pollock and K. M. Dolan, 1972, An early Acadian flysch basin margin-delta complex in the Northern Appalachians: the Lower Devonian Seboomook Formation and Matagamon sandstone, northern Maine: 24th, Internat. Geol. Cong., Abstracts, p. 187.

Hamilton-Smith, T., 1971, Paleography of northwestern New Brunswick during the Llandovery: a study of the provenance of the Siegas Formation: Can. Jour. Earth Sci., v. 8, p. 196-203.

Helmstaedt, H., 1971, Structural geology of Portage Lakes area, Bathurst-Newcastle district, New Brunswick: Geol. Surv. Can. Paper 70-28.

Helmstaedt, H., 1973, Structural geology of the Bathurst-Newcastle district: *in* N. Rast, ed., N.E.I.G.C. 1973 Field Guide to Excursions, p. 34-43.

Hofmann, H. J., 1974, Stromatolites from the Proterozoic Green Head Group, New Brunswick: *in* Geol. Assoc. Can./Min. Assoc. Can., Joint Annual Meeting Program, abstracts and 3rd circular, Authors abstracts, p. 43.

Howie, R. D. and L. M. Cumming, 1963, Basement features of the Canadian Appalachians: Geol. Surv. Can. Bull. no. 89.

Kay, Marshall, 1972, Dunnage mélange and Lower Paleozoic deformation in northeast Newfoundland: 24th Internat. Geol. Cong., Section 3, p. 122-133.

Kennedy, M. J., E. R. W. Neale and W. E. A. Phillips, 1972, Similarities in the early structural development of the northwestern margin of the Newfoundland Appalachians and Irish Caledonides: 24th Internat. Geol. Cong., Section 3, p. 516-531.

Klein, G. de V., 1962, Triassic sedimentation, Maritime Provinces, Canada: Geol. Soc. Am. Bull., v. 73, p. 1127-1145.

Larrabee, D. M., C. W. Spencer and D. J. P. Swift, 1965, Bedrock geology of the Grand Lake area, Aroostook, Hancock, Penobscot, and Washington counties, Maine: US Geol. Surv. Bull. no. 1201-E.

McAllister, A. L. and R. Y. Lamarche, 1972, Mineral deposits of southern Quebec and New Brunswick: 24th Internat. Geol. Cong., Field Excursion A-58.

McKerrow, W. S. and A. M. Ziegler, 1971, The Lower Silurian paleography of New Brunswick and adjacent areas: Jour. Geol., v. 79, p. 635-646.

McKerrow, W. S. and A. M. Ziegler, 1972, Silurian paleographic development of the Proto-Atlantic Ocean: 24th Internat. Geol. Cong., Section 6, p. 4-10.

Moberly, R., 1972, Origin of lithosphere behind island arcs, with reference to the western Pacific: Hawaii Inst. Geophys. Contr. no. 423, p. 145-165.

Naylor, A. L., R. Hon and P. D. Fullagar, 1974, Age of the Katahdin Batholith, Maine: Geol. Soc. Am. Northeastern Section, 9th Annual meeting, Abs. with Programs, v. 5, no. 1, p. 59.

Neuman, R. B., 1967, Bedrock geology of the Shin Pond and Stacyville quadrangles, Penobscot County, Maine: US Geol. Surv. Prof. Paper 524-I.

Neuman, R. B., 1972, Brachiopods of early Ordovician volcanic islands: 24th Internat. Geol. Cong., Section 7, p. 298-302.

van de Poll, H. W., 1972, Stratigraphy and economic geology of Carboniferous basins in the Maritime Provinces: 24th Internat. Geol. Cong., Field Excursion A-58.

Poole, W. H., 1958, Napadogan, York County, New Brunswick: Geol. Surv. Can. Map 11-1958.

Poole, W. H., 1967, Tectonic evolution of the Appalachian region of Canada: *in* E. R. W. Neale and H. Williams, ed., Geology of the Atlantic region: Geol. Assoc. Can. Spec. Paper 4, p. 9-51.

Poole, W. H., B. V. Sanford, H. Williams and D. G. Kelly, 1970, Geology of southeastern Canada: *in* R. J. W. Douglas, ed., Geology and economic minerals of Canada: Geol. Surv. Can., Econ. Geol. Rept. no. 1, p. 227-304.

Poole, W. H. and J. Rodgers, 1972, Appalachian geotectonic elements of the Atlantic Provinces and southern Quebec: 24th Internat. Geol. Cong., Field Excursion A63-C63.

Potter, R. R., H. V. Jackson and J. L. Davies, 1968, Geological map, New Brunswick: N.B. Dept. Nat. Res. Map N.R.-1.

Potter, R. R., J. M. Bingley and J. C. Smith, 1972, Appalachian stratigraphy and structure of the Maritime provinces: 24th Internat. Geol. Cong., Field Excursion A57-C57.

Rast, N. and T.P. Crimes, 1969, Caledonian orogenic episodes in the British Isles and northwestern France and their tectonic and chronological interpretation: Tectonophysics, v. 7, p. 277-307.

Rast, N. and R. H. Grant, 1973, The Variscan Front in southern New Brunswick: *in* N. Rast, ed., N.E.I.G.C. 1973 Field Guide to Excursions, p. 4-11.

Rast, N. and R. H. Grant, 1974, An early Acadian mélange in southern New Brunswick: *in* Geol. Assoc. Can./ Min. Assoc. Can. Joint Annual Meeting Program, Abstracts and 3rd Circular, Authors Abstracts, p. 71.

Rast, N. B. H. O'Brien and R. J. Wardle, 1974, Relationships between Precambrian and Paleozoic rocks of the Avalon platform in N.B. and their lateral equivalents in the N.E. Appalachians and British Isles: *in* Geol. Assoc. Can./Min. Assoc. Can. Joint Annual Meeting Program, Abs. and 3rd circular, Authors Abs., p. 71.

Rodgers, J., 1970, The Tectonics of the Appalachians: Wiley-Interscience.

Ruitenberg, A. A., 1968, Geology and mineral deposits, Passamaquoddy Bay area: N.B. Dept. Nat. Res., Min. Res. Branch, Rept. of Investigation no. 7.

St.-Julien, P., C. M. Hubert, W. B. Skidmore and J. Béland, 1972, Appalachian structure and stratigraphy in Quebec: 24th Internat. Geol. Cong., Field Excursion A56-C56.

Sanders, J. E., 1971, Triassic rocks, northeastern North America: regional tectonic significance in light of plate tectonics: Geol. Soc. Am. Abs. with Programs, p. 781-783.

Schenk, P. E., 1971, Southeastern Atlantic Canada, northwestern Africa, and continental drift: Can. Jour. Earth Sci., v. 8, p. 1218-1251.

Shackleton, R. M., 1974, Late Precambrian rocks of Wales, Brittany and the Iberian peninsula: *in* Geol. Assoc. Can./Min. Assoc. Can. Joint Annual Meeting Program, Abs. and 3rd circular, Authors Abs., p. 85.

Stringer, P., 1974, Two phases of Acadian deformation in northeast New Brunswick: *in* Geol. Assoc. Can./Min. Assoc. Can. Joint Annual Meeting Program, Abs. and 3rd circular, Authors Abs., p. 90.

Stringer, P. and R. J. Wardle, 1973, Post-Carboniferous and Post-Triassic structures in southern New Brunswick: *in* N. Rast, ed., N.E.I.G.C. 1973 Field Guide to Excursions, p. 88-95.

Williams, H., M. J. Kennedy and E. R. W. Neale, Co-ordinators, 1972, The Appalachian structural province: *in* R. A. Price and R. J. W. Douglas, ed., Variations in tectonic styles in Canada: Geol. Assoc. Can. Spec. Paper 12, p. 181-261.

Zen, E-an, 1972, The Taconide zone of the Taconic orogeny in the western part of the northern Appalachian orogen: Geol. Soc. Am. Spec. Paper 135.

Zietz, I and E-an Zen, 1973, Northern Appalachians: Geotimes, v. 18, p. 24-28.

MS received, June 17, 1974.