T2.2 THE AVALON AND MEGUMA ZONES

A fault across Nova Scotia, from Cobequid Bay to Chedabucto Bay, neatly divides the province into two geological zones which are fundamentally different from one another. In 1978, Williams divided the Appalachians into five tectonostratigraphic zones, named for their distribution in Newfoundland.[1] From north to south across Newfoundland and Nova Scotia, they are Humber, Dunnage, Gander, Avalon and Meguma. He placed the northern boundary of the Avalon Zone through Fortune Bay, Newfoundland, and north of the Caledonian Highlands in southern New Brunswick. The south boundary is the Cobequid-Chedabucto Fault, so the whole of Cape Breton and northern Nova Scotia fell within the Avalon Zone. It appears as part of "Avalonia," (see Figures T2.1.4 and T2.2.2a) which also included southern Britain and northern France.[2] Prior to the Devonian Period, the Avalon and Meguma zones developed in different areas and later came into contact along the Cobequid-Chedabucto Fault. (The fault system also has other names: Glooscap Fault; Minas Geofracture.)

In the last fifteen years, Barr, Jamieson, Raeside and others have accumulated evidence to show that, in Cape Breton, the Avalon Zone is limited to the southern part of the island (see Figure T2.2.1). In the interim, also, the term "terrane" has come into use to describe the zones. A terrane is a distinct region or

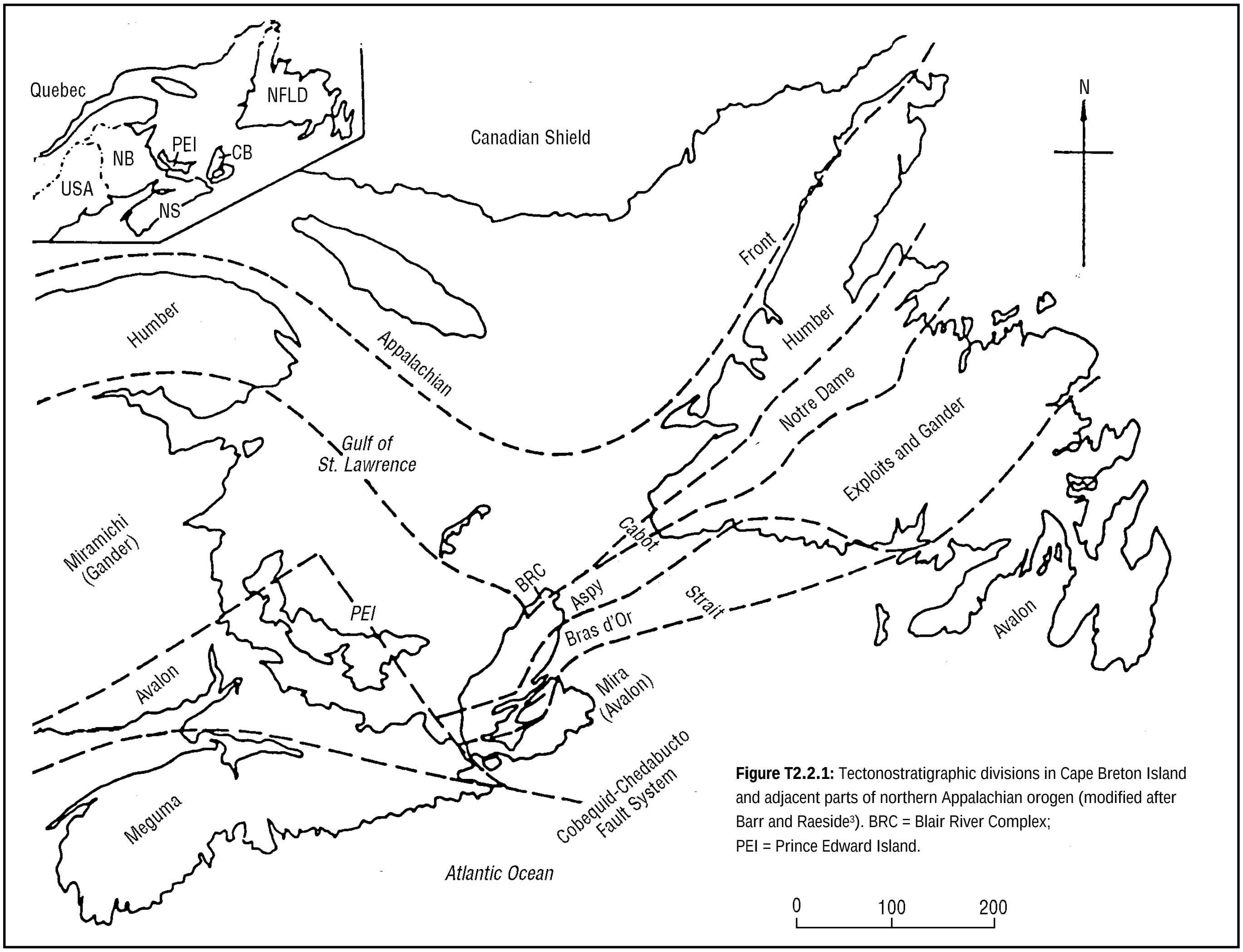


Figure T2.2.1: Tectonostratigraphic divisions in Cape Breton Island and adjacent parts of northern Appalachian orogen (modified after Barr and Raeside[3]). BRC = Blair River Complex; PEI = Prince Edward Island.

group of rocks with common stratigraphic units and origin. The northwestern areas of Cape Breton Island are composed of two other terranes — the Aspy and Bras d'Or—and a small fragment of the Precambrian Shield (the Blair River Complex).

AVALON ZONE

Distribution of Strata

Rocks of the Avalon Zone outcrop north of the Cobequid-Chedabucto Fault. They range in age from Precambrian to Devonian and are found in three areas: the Cobequid Highlands, the Pictou-Antigonish Highlands (Districts 310, 320) and in Cape Breton (Regions 100, 200 and Districts 310, 330). They occur in fault-bounded blocks which stand out in the landscape as prominent ridges because the rocks are resistant to weathering and because they have been pushed up relative to their surroundings.

Earliest Record

Precambrian rocks are found in all three areas and, with the exception of volcanic deposits in southern Cape Breton, are severely altered. Granites were intruded late in the Precambrian and again in Devonian time. Some of the rocks have been metamorphosed to high grade.

Northern Cape Breton consists of three parts, which have different metamorphic histories and ages. They are the Blair River Complex (at the northern tip of Cape Breton), the Bras d'Or terrane (Ingonish to East Bay) and the Aspy terrane (between the two).

The Blair River Complex consists of quartzo-feldspathic and amphibolite gneisses and minor amounts of calcareous rocks; these have been intruded by anorthosite, syenite and granite. The Pb/U (zircon) radiometric age of the syenite is about 1,000 million years. The Complex has a late-Grenvillian metamorphic age and resembles Grenville rocks of the Canadian Shield.

The Aspy terrane consists of volcanic and sedimentary rocks now metamorphosed to greenschist and amphibolite facies (i.e., low- to high-grade phyllites and schists). The Pb/U age is 430–440 million years, i.e., Ordovician-Silurian. It is separated from the Bras d'Or terrane by a shear zone up to 800 m wide.

The Bras d'Or terrane consists of sedimentary and volcanic rocks, generally metamorphosed only to relatively low grade, that were intruded by diorite and granite. The granites have Pb/U (zircon) ages of 555–565 million years, and so are Early Cambrian.

On the basis of age, of composition, and of magnetic and seismic continuity across Cabot Strait, the Blair River Complex is correlated with the Humber Zone in Newfoundland. This means the edge of the Precambrian part of the continent (Laurentia) extends as far south as northern Cape Breton. The Aspy and Bras d'Or terranes are correlated with the rocks of central Newfoundland; the Dunnage Zone does not appear in Cape Breton. These correlations remove northern Cape Breton from the Avalon Zone and redefine that zone to include only the Mira terrane, which is the part of Cape Breton south of the Boisdale Hills and Bras d'Or Lake (Figure T2.2.1). The northern mainland remains in the Avalon.

The Avalon Zone in southern Cape Breton contains late Precambrian volcanic rocks that were intruded by diorite and granite. Following an interval when those rocks were being eroded, red sandstones and conglomerates were deposited upon them, and followed by grey shales and siltstones of Early Cambrian age. During the remainder of Cambrian time, shales and siltstones were deposited in a marine basin that gradually deepened and then shoaled again, as is indicated by a disconformity (indicating a period of non-deposition) beneath the Late Cambrian shales and limestones. The fossils include brachiopods, crinoids, trilobites and graptolites. Comparison of this assemblage with those found elsewhere indicates that the Avalon Zone was associated with Europe and Africa (i.e., Gondwana) during the Cambrian period.

In the Pictou–Antigonish area, Cambrian rocks were deposited as lavas and volcanic ash interbedded with sands and muds. They include beds of oolitic hematite. Late Ordovician volcanism is indicated by the Bear Brook Formation, and ash beds show that the activity continued into Silurian time. The oldest sediments of the classic exposures near Arisaig are Silurian. The Arisaig Group has abundant fossils of great variety and is composed mainly of shales and fine-grained sandstones, deposited in a sea that gradually became shallower. In the upper part of the group there are Middle Silurian red beds (Moydart Formation) that indicate fluvial or estuarine deposition. Similar conditions returned in Early Devonian time (Knoydart Formation), and both formations contain abundant fossil fish spines and plates. The similarity of the fossil faunas to those of northern Europe is one of the reasons for believing that Avalonia and Baltica were close together in Silurian time (see Figure T2.2.2. a & b).

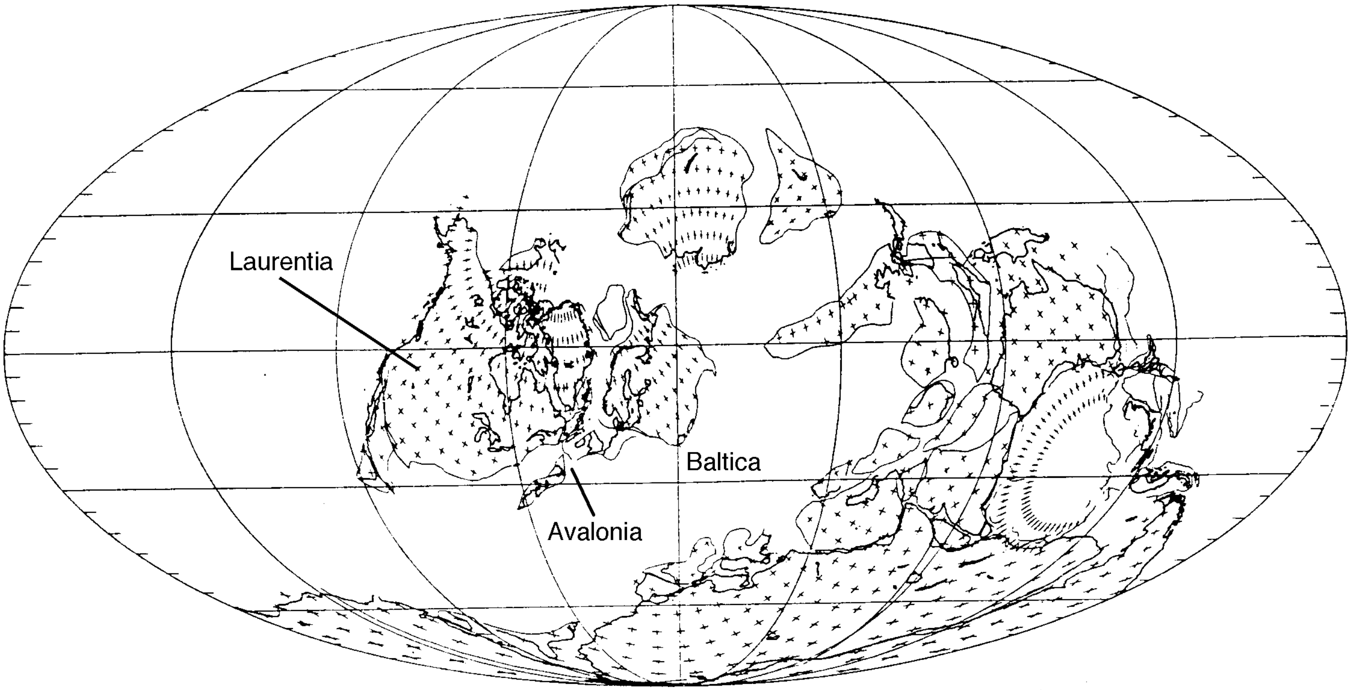


Figure T2.2.2a: Location of continents during the Middle Silurian. Nova Scotia was part of the subcontinent Avalonia attached with parts of Europe (Baltica) to the continent Laurentia. (Reprinted from McKerrow and Scotese[2], with permission of the Geology Society Publishing House.)

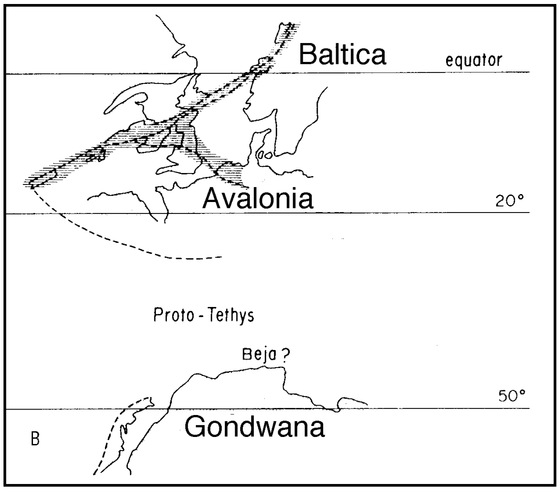


Figure T2.2.2b: Relative position of Avalonia and Baltica to the continent of Gondwana (South American and Africa) during the Middle Silurian. (Modified after J.P. Lefort[4])

In the Cobequids, the Silurian rocks are dominantly volcanic, and the interbedded sedimentary rocks are similar to those of the upper part of the Arisaig Group. The Devonian rocks are also similar to those of the Antigonish area.

The overlying Carboniferous rocks are discussed in T2.4. The Avalonian rocks were metamorphosed at different times, as shown in Figure T2.2.3.

MEGUMA ZONE

Regional Geologic Setting

The Meguma Zone occupies the southern mainland of Nova Scotia and extends seaward beneath younger sedimentary rocks. To the south and southeast it underlies the Scotian Shelf (Districts 910, 920, 930) and the continental shelf southeast of Cape Breton; to the east it underlies the tail of the Grand Banks of Newfoundland; and to the northwest it underlies the Bay of Fundy (Unit 912). Its total area is approximately 200 000 km^2. The base of the succession is unknown because of intrusive granites; the top is an erosional and angular unconformity representing the Acadian Orogeny. Geochemical and geophysical data suggest that the Meguma Zone *in toto* has been thrust over a southward extension of the Avalon Zone. Composite thickness of the stratigraphic succession exceeds 23 km; however, nowhere do all of the units occur at one locality, nor are their thicknesses constant.

Stratigraphy

The sedimentary rocks of the Meguma Zone consist almost entirely of fine-grained sandstones and shales. Minor amounts of volcaniclastic, conglomeratic and carbonate rocks are significant locally. The Meguma stratigraphic succession consists of three major groups of sandstone that alternate vertically with two thick groups of shale. Together they form two supergroups.[5] The basal Meguma Supergroup underlies most of southern Nova Scotia. An erosional remnant of the overlying Annapolis Supergroup occurs only along the northwestern margin of the Zone. The stratigraphic succession is also divisible by unconformities. These are indicated by local erosional and angular discordances but mainly by subaerial volcaniclastic rocks. The intervening four stratigraphic sequences each begins with basal sandstone, followed by black shale and capped by siltstone and/or sandstone. Igneous activity ends each sequence, usually as subaerial volcaniclastics but also as extrusive or intrusive sheets.

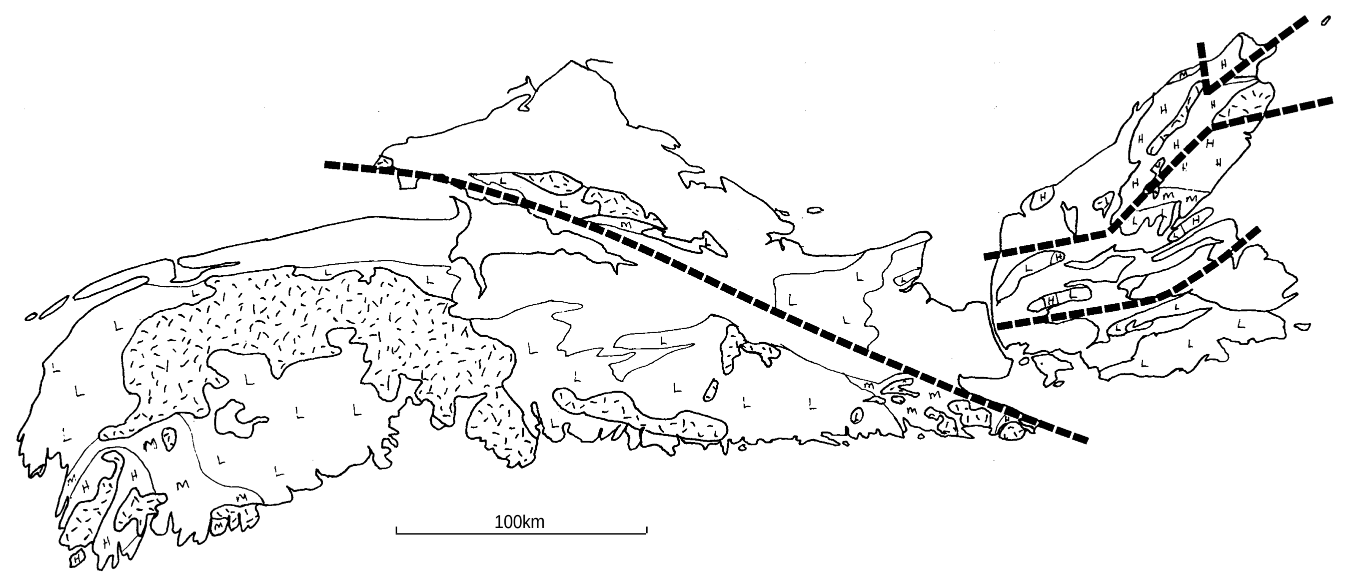
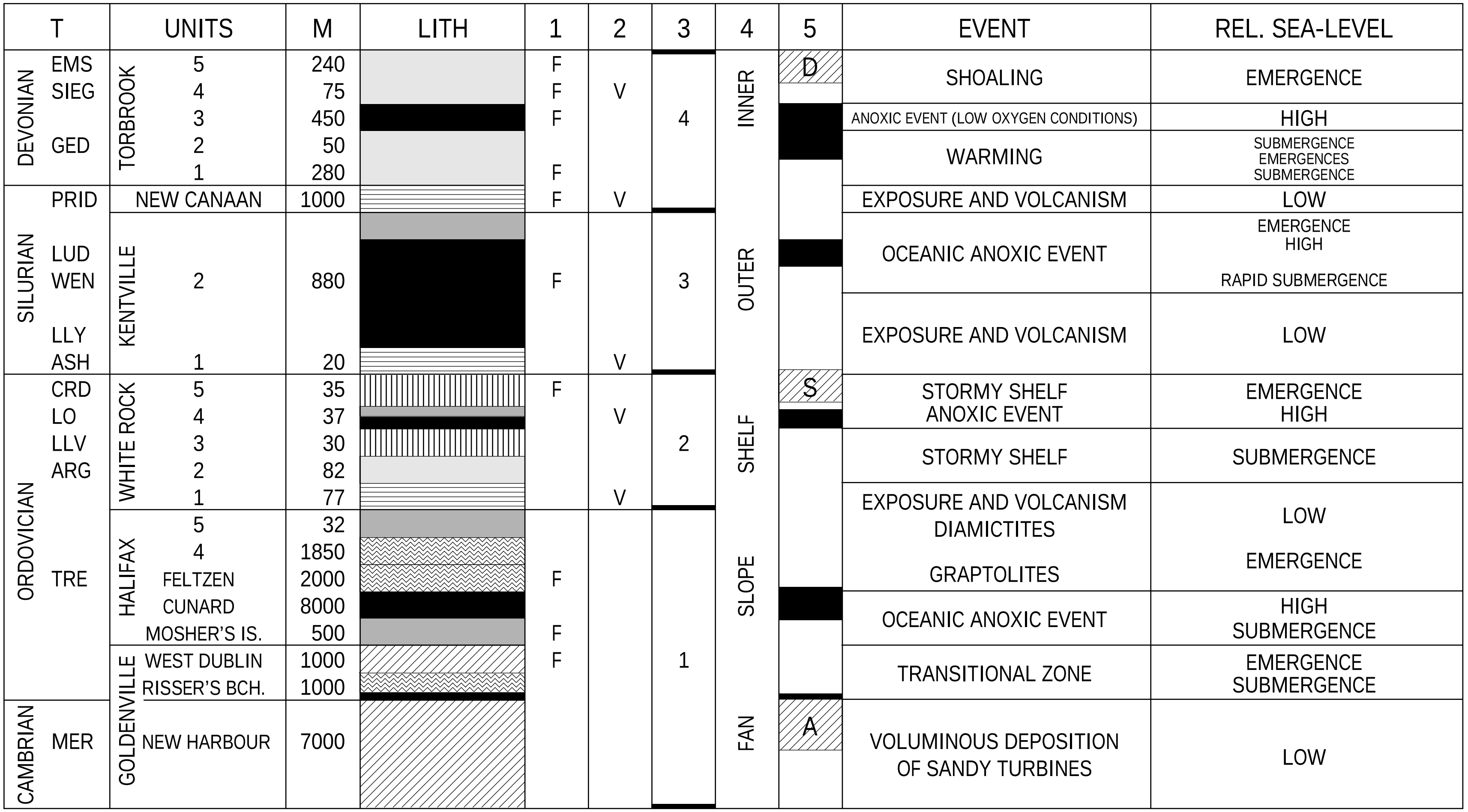


Figure T2.2.3: Metamorphism and Devonian plutonism in Nova Scotia. L—low-grade metamorphism; M—medium-grade metamorphism; H—high-grade metamorphism; stippled—Devonian granite. The age of metamorphism in the Meguma and Aspy terranes is Devonian; in the Bras d'Or terrane it is Cambrian; in the Avalon terrane it is late Precambrian; and in the Blair River Complex it is mid-Proterozoic.

Sandstones of the Meguma Supergroup are different from those of the overlying Annapolis Supergroup. Both are metamorphic quartzites, but the Meguma sandstones were originally mixed feldspathic, quartz-rich sands and mud, perhaps with some volcanic debris. They occur as thick strata showing limited graded bedding, sole marks and, in places, horizontally directed burrows. Regional analysis of sandstone composition, texture and sedimentary structures shows that paleocurrents flowed from the present south-southeast. On the other hand, sandstones of the Annapolis Supergroup are dominantly quartzose, with small mud content. Sedimentary structures include abundant cross-stratification and vertically directed burrows. Paleocurrent patterns are almost random. The sandstones of the two supergroups record different environments. Those of the Meguma are the products of turbidity flows in deep water, channel complexes of submarine-fan systems.[6] The source area was to the present south-southeast and continental in size. Sandstones of the Annapolis Supergroup are the result of traction currents on a shallow-water continental shelf. Random paleocurrent patterns and the nature of bed forms in the sandstones suggest that cyclonic storms generated currents.[7]

The two major slates of the supergroups are black, carbon-rich and graptolitic. The base of the lower slate has a regionally extensive, thin, laminated, silty slate (the Mosher's Island Formation — see Figure T2.2.4). Significantly, it has a high metal content, including manganese, lead, copper, zinc and barium.[8] The thick remainder of the lower zone has sandstone layers that decrease in abundance and thickness upwards in the stratigraphic succession. Sedimentary structures also change from graded to cross-stratification. The upper slate is almost silt-free in its lower portion, but silt laminae increase in abundance and thickness upwards. The uppermost part is dominantly silt, so that colour changes to grey or green. Black slates of the Meguma Supergroup record a prograding wedge complex that shoaled upwards from the toe of a continental slope to an outer shelf.[7] In contrast, the main black slate of the



T		UNITS		M	LITH	1	2	3	4	5	EVENT	REL. SEA-LEVEL
DEVONIAN	EMS	TORBROOK	5	240		F		4	INNER	D	SHOALING	EMERGENCE
	SIEG		4	75		F	V					
			3	450		F				■	ANOXIC EVENT (LOW OXYGEN CONDITIONS)	HIGH
	GED		2	50						■	WARMING	SUBMERGENCE EMERGENCES SUBMERGENCE
			1	280		F						
SILURIAN	PRID	NEW CANAAN		1000		F	V				EXPOSURE AND VOLCANISM	LOW
	LUD WEN	KENTVILLE	2	880		F		3	OUTER	■	OCEANIC ANOXIC EVENT	EMERGENCE HIGH RAPID SUBMERGENCE
	LLY ASH		1	20			V				EXPOSURE AND VOLCANISM	LOW
ORDOVICIAN	CRD	WHITE ROCK	5	35		F		2	SHELF	S	STORMY SHELF ANOXIC EVENT	EMERGENCE HIGH
	LO		4	37			V			■		
	LLV		3	30							STORMY SHELF	SUBMERGENCE
	ARG		2	82								
			1	77			V				EXPOSURE AND VOLCANISM DIAMICTITES	LOW
	TRE	HALIFAX	5	32				1	SLOPE			
			4	1850								
			FELTZEN	2000		F					GRAPTOLITES	EMERGENCE
			CUNARD	8000						■	OCEANIC ANOXIC EVENT	HIGH SUBMERGENCE
			MOSHER'S IS.	500		F						
		GOLDENVILLE	WEST DUBLIN	1000		F					TRANSITIONAL ZONE	EMERGENCE SUBMERGENCE
			RISSER'S BCH.	1000						■		
CAMBRIAN	MER		NEW HARBOUR	7000					FAN	A	VOLUMINOUS DEPOSITION OF SANDY TURBINES	LOW

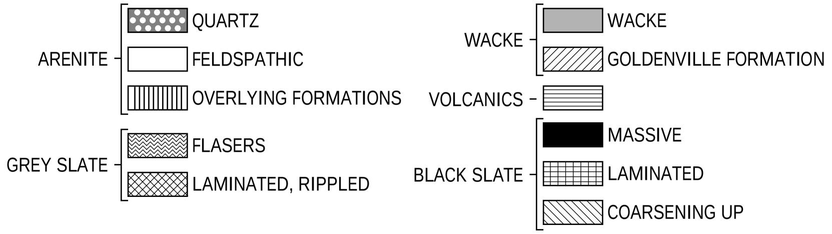


Figure T2.2.4: Summary and relationships of event stratigraphy and relative sea-level changes in the Meguma Zone. T refers to geologic time, and M to maximum measured thicknesses in metres. Major events are listed in the lithology column and columns 1 through 5: the lithology column gives predominant lithologies represented by patterns (to the left); column 1 indicates fossil-bearing intervals; column 2 shows episodes of volcanism; column 3 identifies unconformities by horizontal heavy lines (Meguma sequences are numbered); column 4 summarizes general, depositional environments; and column 5 displays (1) times of global anoxic events (black) and (2) major Paleozoic glacial episodes (A is for Andean; S, for Saharan; and D, for Devonian). Major events and relative sea-level changes in the Meguma Zone are listed in the next two columns.[7]

Annapolis Supergroup represents a deepening of water on a shelf. Both major slates and minor ones in the Annapolis Supergroup record global oceanic low-oxygen conditions (see Figure T2.2.4).

Volcaniclastic and conglomeratic sediments are minor but significant components in the Meguma Supergroup. The volcanic rocks can be locally thick, as along the boundary of the two supergroups. There, 10–30 m of basaltic pillow lavas overlie 10–50 m of acidic tuffs formed from airborne volcanic ash. Laterally, continuous layers of tuff are common. A significant volcanic event occurred in the western part of the Meguma Zone to form the base of sequence four (see Figure T2.2.4). Quartzose sandstones, marbles and slates containing boulders occur with the volcanic rocks. Most of the volcaniclastics are water-laid, but their thickness and lateral extent, and the presence of large boulders, suggest at least nearby exposure to the air. These rocks coincide with angular and erosional unconformities.

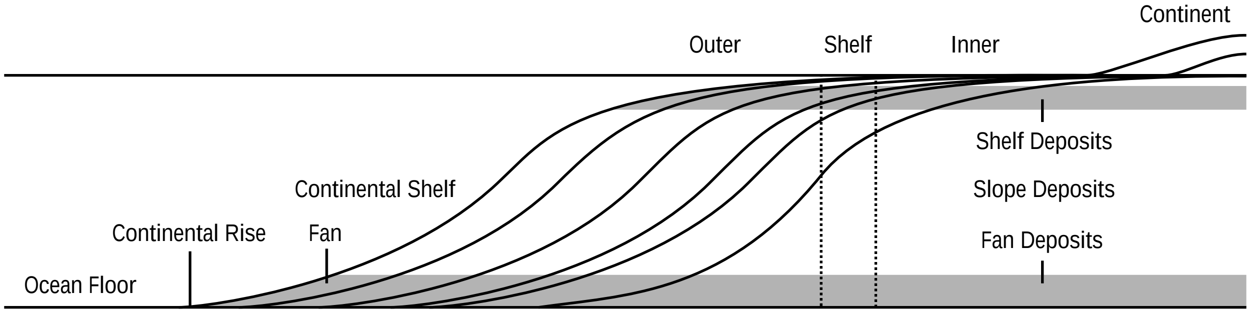
Skeletal fossils become abundant only in the upper groups of the Meguma Zone, although trace fossils are common throughout. The oldest fauna occurs at one locality near the Goldenville-Halifax contact. There, transported, broken trilobite fossils are Early Middle Cambrian in age.[9] Elsewhere in this Zone and in the thick overlying slate, fossil graptolites and acritarchs date sequence one (the Meguma Supergroup) as earliest Ordovician. In the Annapolis Supergroup, sequence two (White Rock Group) contains shells of possible Late Ordovician age. Sequence three is Late Silurian, as shown by graptolitic and shelly fauna. Shelly fossils are abundant in sequence four (Torbrook Group) and give an Early Devonian age. Thus, strata of the Meguma Zone range in age from possibly Late Middle Cambrian through Early Devonian. Three unconformities interrupt this record in the Early Ordovician, Late Ordovician and Late Silurian.

Derivation

The Meguma Zone is a good example of a terrane, at least until Carboniferous time. A terrane is a fault-bounded rock body of regional extent, characterized by a geologic history different from that of adjoining terranes. It is an exotic fragment of continental material added to ancestral North America by continental collision. The Meguma terrane is unlike the adjacent Avalon terrane in terms of sediments, metamorphism and formation of metallic minerals. The great problem with terranes is their source. The volume of Meguma sediments equals a block with the combined area of Portugal and Spain and a height of 5 km. This sediment is the product or erosion of a large southeastern continent, clearly not the Avalon terrane or even North America. The Meguma terrane is a fragment of that continent's margin, from rise to slope to shelf (see Figure T2.2.5). The source of the sediments must have been Gondwana. Two specific areas of Gondwana are likely. These are northwest Africa (North Gondwana) and northwest South America (West Gondwana).

The following is a summary of the North Gondwana hypothesis. From Cambrian through Early Devonian time, a vast, northward-directed dispersal system carried sediment across the North Gondwana margin. This drainage system was the size of the present Mississippi River complex. Headwaters in the south tapped fine-grained sandstones produced by Late Proterozoic glaciation and moun-

Figure T2.2.5: As a broad generalization, the rocks of the Meguma Zone accumulated on an advancing continental shelf, as old deposits of submarine fans on the continental rise were buried under sediments deposited on the continental shelf. In detail the process was complicated by periods of low sea level and emergence of the shelf and slope.



tain building. Erosional remnants of this source rock exist now as buttes and mesas over much of southern Mali. Marine submergences from the north twice interrupted the northward transport of sands. The resulting stratigraphic record across the West African Craton and North Gondwana consists of three thick sandstones with intervening thick, marine shales. They are identical in time and lithology to those of the Meguma Zone. Rifting along the North Gondwanan margin created a plethora of microcontinents or microplates. Several have the same stratigraphic record, e.g., Saudi Arabia and the Welsh Basin. In particular, first the Avalon terrane collided with ancestral Atlantic Canada. Next, part of the continental margin of northwest Africa thrust over the Avalon during Middle Devonian collision between Africa and southeastern Atlantic Canada.

The following is a summary of the West Gondwana hypothesis. The Meguma terrane was deposited in an intramontane basin (intradeep) within or marginal to northwestern South/Central America. The Meguma fossil faunal and detrital zircon data indicate Gondwana affinities but are not more specific. Analysis of the distribution of distinctive Avalonian Cambrian–Ordovician strata, containing a unique Avalonian fauna and source regions for detrital zircons that occur in the Georgeville Group, suggests a western South American provenance. If the Meguma terrane was carried passively with the Avalon terrane, a South American source is also indicated. The intradeep interpretation implies that the basal thick sandstone of the Meguma Supergroup is associated with a Cambrian orogen. Orogens of this age are rare but are present in the Pampean Orogen (southwest Argentina). Transfer of the Meguma terrane from Gondwana to Laurasia about 400 million years ago is compatible with Laurasia–South America collision in the Silurian–Devonian rather than the Laurasia–Africa collision in the Early Carboniferous.

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Associated Topics

T2.1 Introduction to the Geological History of Nova Scotia, T2.3 Granite in Nova Scotia

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