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A GEOTRAVERSE THROUGH THE APPALACHIANS OF NORTHERN NEWFOUNDLAND

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Abstract. A geotraverse across the Appalachian Orogen in the northern part of Newfoundland is presented as a cross-section, and is supplemented by shorter cross-sections for parts of the traverse. The stratigraphy of the rocks depicted on the cross-sections is outlined in a chart. The geology is reviewed in the framework of seven tectonostratigraphic zones, two of which, at either end of the geotraverse, are platforms with little deformed sedimentary rocks lying on exposed or inferred continental basement. The five zones in between form a section all the way across the variably deformed and metamorphosed rocks of the orogen. Most of the zone boundaries are faults. Stratified rocks exposed in the orogen range in age from late Precambrian to Carboniferous. Carboniferous strata are mostly gently inclined, or locally folded. They were deposited in basins along a large-scale zone of right-lateral strike-slip faulting, connected with continental collision in the Southern Appalachian segment of the orogen. An alkaline granite of Carboniferous age is known from the eastern platform zone. Rocks of all zones on the traverse have been affected to some degree by compressive deformation of Acadian (medial Devonian) age, which is interpreted as due to the collision of the Avalonian continental fragment with North America along the Northern Appalachian segment of the orogen. Granitoid plutons emplaced during this collisional event are abundant in all five central zones and occur in the western parts of the eastern (Avalon) platform, but are not found in the western platform. Pre-Acadian events within the orogen are responsible for most of the tectonostratigraphic variations used to define the zones. The best known of these events is the medial Ordovician Taconian Orogeny, an island-arc collision with the western platform, accompanied by obduction of a well-preserved ophiolitic nappe. This platform was a passive continental margin before the Taconic event and was formed by rifting in the late Precambrian. A less well understood tectonic event (or events) was responsible for pre-late Ordovician deformation and regional metamorphism of rocks in the zone adjacent to the eastern Avalon platform. The latter also underwent rifting in the late Precambrian. Metamorphism is generally of low grade along most of the traverse, except in the two zones adjacent to each platform, where it reaches amphibolite facies. Ductile deformation consists mostly of simple inclined to upright folding and cleavage in the low-grade zones, but is polyphase with large early recumbent folds in the two more highly metamorphosed terranes. Plutons older than Devonian, probably of island-arc origin, are known in places from the central zones. Most mafic-ultramafic plutonic associations are now interpreted as variably dismembered ophiolite complexes many of which were tectonically emplaced during the early to medial Ordovician. This orogenic belt was the first to be recognized explicitly, by Wilson (1966), as the result of the opening and closing of a major ocean. Its more detailed history amply confirms this general notion, even though many detailed aspects remain to be resolved.

Introduction

The island of Newfoundland provides along its northern coasts probably the best exposed cross-section of any in the Appalachian-Caledonian System. This region has been the subject of many recent studies which have provided considerable information towards the solution of many of the perplexing problems of the development of orogenic belts. Because

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exposure is locally so good, the relationships between major elements in the belt are apparent, and the internal details of development of these elements can be readily studied. Although the excellence of exposure has been used by some to elevate the Newfoundland cross-section to the status of a type section for the Appalachians there is no reason why all elements recognizable here should be present elsewhere or why some elements present elsewhere should be found in Newfoundland. Details of the character of the orogen do change along its length but the overall character remains much the same (Bird and Dewey, 1970; Williams, 1978). The bounding platforms are clearly continuous over considerable distances, particularly on the northwest, but subdivisions of the terrane between these platforms, and its width, show considerable variation along the length of the orogen.

The Appalachian System in Newfoundland has been subdivided in a variety of ways by recent workers (Williams, 1964a; Kay and Colbert, 1965; Kay, 1967; 1972; Poole, 1967; Poole, et al., 1968; Bird and Dewey, 1970; Dewey and Bird, 1971; Williams, et al., 1972, 1974). All workers recognize three fundamental elements of the system: (1) the Western Platform, consisting of autochthonous and allochthonous early Paleozoic rocks underlain by Grenvillian basement; (2) the Avalon Platform or Zone consisting of late Precambrian sedimentary and volcanic sequences overlain by a shallow-water Cambro-Ordovician succession; and (3) a Central Mobile or Volcanic Belt consisting mainly of Ordovician and Silurian volcanic and sedimentary rocks of eugeosynclinal aspect, but including older rocks on its margins (Figure 1). Metamorphic grade is generally low except on the margins of the Central Mobile Belt in the north and along its extension in the southern part of the island, where it becomes considerably narrower. Continental basement rocks are only recognizable on the margins of the Central Mobile Belt and are replaced by a locally exposed ophiolitic basement in the central part of this element. At the southwestern tip of the island the eugeosynclinal rocks of the Central Mobile Belt are absent and the basement complexes of the Western Platform and the eastern margin of the Central Mobile Belt are only separated by a zone of mylonite (Brown, 1973).

Mainly because of problems of access, little detailed study has been done across the southern coastal section of the Newfoundland Appalachians. This paper will present data from the northern cross-section of the System. The main line of section ABCD (Plate 1) has been supplemented by shorter sections to the north and south where different elements or more detailed information is available.

For the purposes of description the region has been divided into seven zones characterized by different Ordovician or older depositional and/or structural development (Figure 1). With the exception of parts of the boundary between the Botwood and Gander Zones all other zone boundaries are marked by faults across which correlation is difficult.

Geophysical Characteristics of the Orogen

Marine seismic refraction surveys off the western and northern coasts of Newfoundland (Ewing, et al., 1966; Sheridan and Drake, 1968) indicate that in western Newfoundland the crust is from 30 to 40 km thick, consists mostly of the major continental crustal layer with compressional wave velocity of about 6.1 km/sec overlying an upper mantle with the usual compressional wave velocity of about 8 km/sec. In contrast, along the northern coast of the island, offshore from the region that consists of ophiolite and arc-type volcanic rocks, the crust is thicker (about 45 km), and overlies an upper mantle with compressional wave velocity of about 8.5 km/sec. The crust here consists of three layers with velocities 7.5-7.7, 6.0-6.3, and 4.7-4.8 km/sec, from base to top.

Gravity data from Newfoundland (Weaver, 1967) generally reflect this same contrast in crustal character between the Western Platform and the Central Mobile Belt. They also indicate that the Avalon Zone and the eastern part of the Gander Zone contrast with the Central Mobile Belt and that crust here is probably again of continental character. Gravity profiling by Miller and Deutsch (1976) and Miller (1977) has been interpreted to show that dense (oceanic?) crust underlies the region from the boundary of the Notre Dame and Exploits Zones to the Baie Verte Ultramafic Belt in the Fleur de Lys Zone. It is probable from earlier studies (Weir, 1970) and those of Miller (1977) that the crust changes its character from oceanic to continental along or close to the western boundary of the Gander Zone.

Extension in detail of the major tectonic features of the Newfoundland Appalachians onto the adjacent continental shelf is presently far from clear from geophysical studies. Haworth (1977) has proposed that the boundary between the Gander and Avalon Zones (the Dover Fault) represents the ancestral continental equivalent of the Charlie Fracture Zone. Magnetic and gravity trends on the continental shelf northeast of Newfoundland (Jacobi and Kristofferson, 1976) suggest continuation of the ultramafic rocks of the Baie Verte Ultramafic Belt and the Betts Cove Ophiolite Complex in a northeasterly direction for distances of 150 km and beyond. Gravity trends indicate that the crustal character of the Notre Dame and Gander Zones extends northeastwards for similar distances.

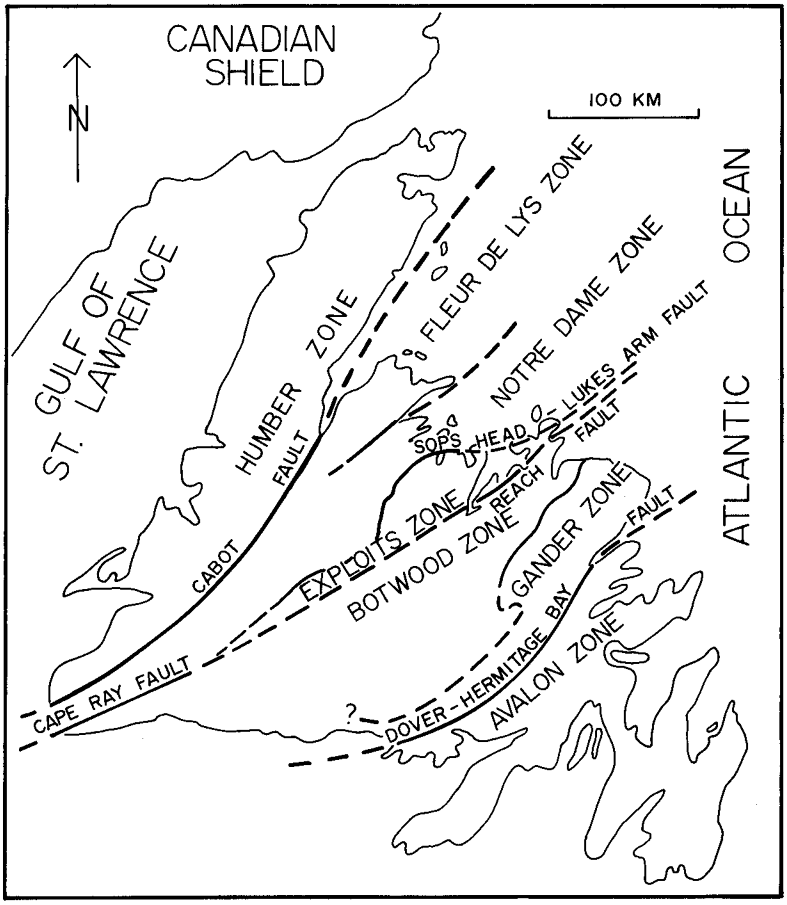

Figure 1. Outline map of Newfoundland showing the boundaries and distribution of the tectonostratigraphic zones.

Definition of the Zones

Whereas early Ordovician and older rocks of the Newfoundland Appalachians show considerable variations in thickness, facies, style of deformation and metamorphism across the orogen, Caradocian and younger rocks do not display the same variation. This is particularly true of Silurian rocks. These pre-Caradocian variations form the basis for subdivision of the orogen into seven tectonostratigraphic zones (Figure 1) that not only provide the basis for description but also serve to accentuate the major differences in development from place to place.

In general, the effects of two orogenic episodes are widely recognized within the Appalachians of Newfoundland. The Taconian orogenic episode was responsible not only for the emplacement of allochthons onto the platform of the Humber Zone but also for deformation and regional metamorphism, locally to amphibolite facies, in the Fleur de Lys Zone. Although the timing of final emplacement of the Taconian allochthons is medial Ordovician, crustal instability and deformation probably extended into the late Ordovician farther to the east. The Acadian orogenic episode has affected early Devonian and older rocks throughout the orogen, including some of the autochthonous and allochthonous rocks of the Humber Zone. Metamorphic grade is generally low and resulting folds are upright. In the east, rocks of the Gander Zone have been intensely deformed and metamorphosed, locally to the amphibolite facies, before deposition of adjacent medial and possibly early Ordovician rocks of the Botwood Zone. Although this deformation and metamorphism may be early Ordovician and thus broadly Taconian, part or all of it may be considerably older, of possible Cambrian or late Precambrian (Hadrynian) age. There is evidence of localized Late Precambrian deformation and granitic plutonism in the adjacent Avalon Zone, but most of the folding in this zone is of the Acadian orogenic episode. Evidence for pre-early Ordovician deformation can also be found locally in the Notre Dame Zone. Acadian structures appear to have had modest effects on older deformed elements of the orogen.

Most mafic-ultramafic complexes along the

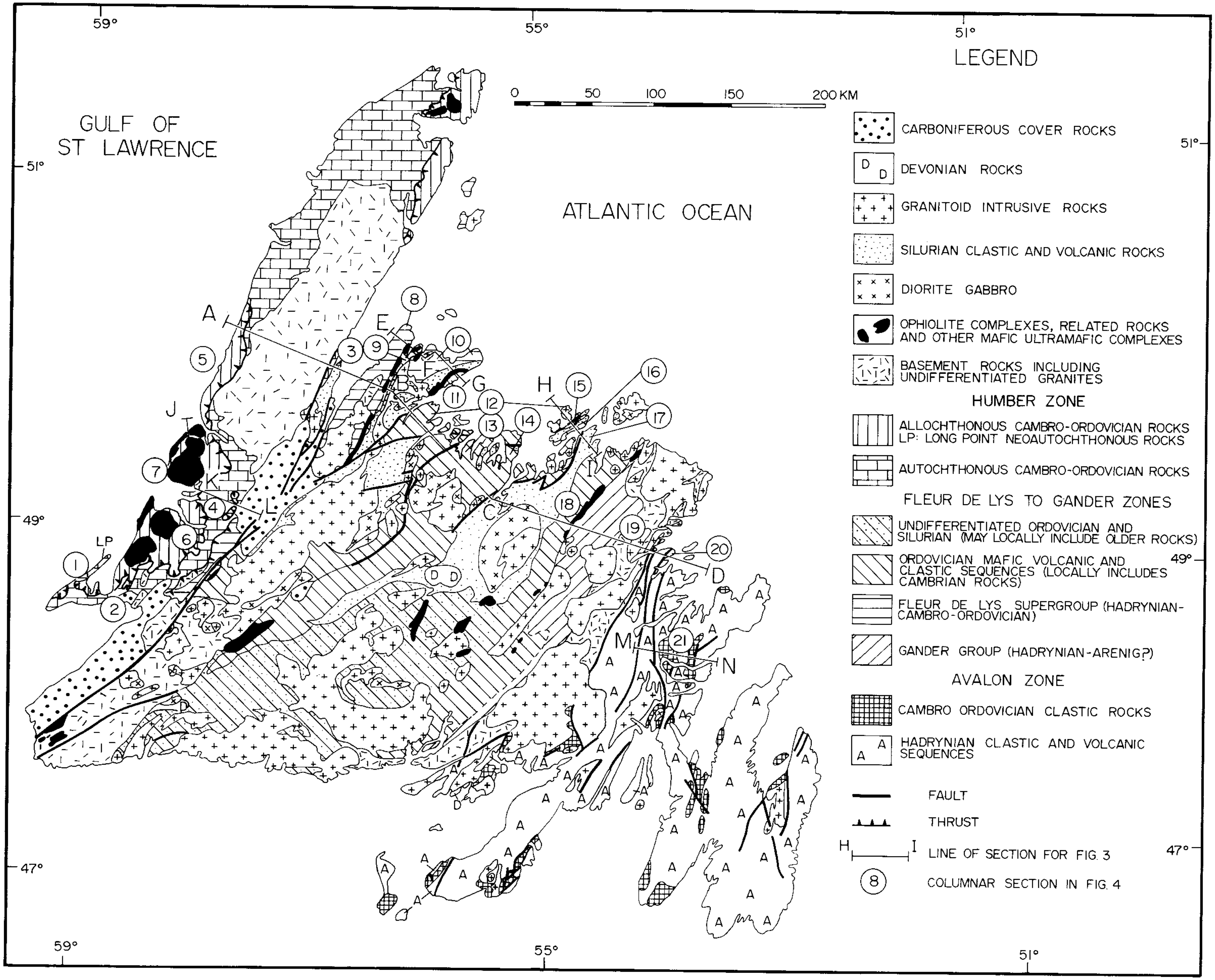

Plate 1. Simplified geologic map of Newfoundland showing the geographic position of the lines of section of Plate 2, and the places from where the stratigraphic data shown in Plate 3 are derived. Simplified from Williams (1967b).
(See insert in pocket in back of book for color presentation.)

line of the geotraverse are now widely accepted as ophiolites, and it is likely that others in the central and southwestern part of the island (Plate 1) have a similar origin as remnants of oceanic crust and upper mantle. Carboniferous rocks, mostly deposited in fault-controlled basins, are only locally folded. They represent post-orogenic deposits as far as development of this part of the Appalachian Orogen is concerned.

The definitive characteristics of each zone are as follows:

(a) The Humber Zone is characterized by a Grenvillian-age crystalline basement unconformably overlain by a Cambro-Ordovician clastic and carbonate sequence containing trilobite and graptolite faunas of the Pacific faunal province. The carbonates represent the most northeasterly extension in North America of the carbonate terrane that flanks the whole Appalachian System from Newfoundland to Alabama. This autochthonous sequence is locally overlain by allochthonous Cambro-Ordovician clastic and carbonate rocks which were originally deposited to the east of the Humber Zone. Latest Precambrian (Hadrynian) clastic rocks may occur at the base of this sequence. They are in turn structurally overlain by allochthonous ophiolite complexes and by smaller slices of mafic volcanic and plutonic rocks. The allochthons were emplaced into their present position in medial Ordovician time. The southerly Humber Arm Allochthon is locally unconformably overlain by neoautochthonous carbonates of late medial Ordovician age. Deformation and metamorphism in the Humber Zone is generally slight, but the rocks of the eastern parts of the zone are tightly folded and weakly metamorphosed. Higher grade metamorphic rocks characteristic of the Fleur de Lys Zone are thrust over the autochthonous to parautochthonous carbonates in the eastern parts of this zone. The eastern boundary of the Humber Zone is defined by the Cabot Fault System.

(b) The Fleur de Lys Zone is characterized by a thick, dominantly clastic metasedimentary sequence in upper greenschist to amphibolite facies that is complexly deformed. They are generally considered to range from late Precambrian (Hadrynian) to Cambro-Ordovician in age and are assigned to the Fleur de Lys Supergroup. This Supergroup occurs in an eastern and western area within the zone, separated by a steep belt of dismembered ophiolite complexes and associated mafic volcanic rocks of presumed Ordovician age. The western Fleur de Lys is almost entirely metasedimentary and is underlain by an older gneissic basement, whereas the eastern Fleur de Lys contains metasedimentary rocks overlain by mafic and silicic metavolcanic rocks that are absent to the west. It is probably underlain in the east by a mafic and ultramafic basement. Metamorphism of the Fleur de Lys is demonstrably older than deposition of Siluro-Devonian volcanic rocks and of Ordovician? clastic sediments associated with the ophiolite belt. It is probably of early Ordovician age. Tight Acadian folding and low greenschist facies metamorphism has affected younger rocks. The southeastern boundary of this zone is marked by faults.

(c) The Notre Dame Zone is characterized by an ophiolite basement of late Cambrian-early Ordovician age which is exposed on its western edge. The upper part of this basement also occurs at isolated localities elsewhere in the zone. The ophiolite is overlain by a thick sequence of mafic volcanic rocks and associated volcaniclastics of early Ordovician age. Older mafic and silicic volcanic rocks, including pillow lavas intruded by trondhjemite, represent remnants of an older, probably Cambrian terrane that occurs as isolated blocks within the zone. The rocks of these older blocks are locally intensely deformed and metamorphosed to amphibolite facies. Silurian to Devonian clastic and subaerial volanic rocks locally unconformably overlie the Ordovician rocks. In general, however, metamorphism in this zone is weak (low greenschist facies), deformation is restricted to open to tight folds with sporadic cleavage, and both are largely considered to be of Acadian age. The southeastern boundary of this zone is marked by the Sops Head-Lukes Arm Fault.

(d) The Exploits Zone is characterized by early Ordovician sequences of sedimentary and mafic volcanic rocks similar to those of the Notre Dame Zone but with sediments greatly predominating over mafic flows. The sequence may extend down into the Cambrian. The basement of the Exploits Zone is not exposed. The Ordovician sequences are overlain by a thin but extensive medial Ordovician black shale and argillite which passes up into late Ordovician-early Silurian quartzofeldspathic turbidites overlain by paraconglomerates, shallow-water sandstones, and mixed mafic and silicic volcanic rocks with associated red beds. In the northeastern part of this zone the early Ordovician to Cambrian succession is represented by the Dunnage Melange. Metamorphism is in subgreenschist to low greenschist facies. Cleavage and locally tight folding affects Ordovician and Silurian rocks and is generally considered to be of Acadian age. The southeastern boundary of the Exploits Zone is marked by the Reach Fault.

(e) The Botwood Zone lacks an exposed basement in the northwest and is characterized by a medial and possibly early Ordovician, dominantly clastic sequence with, in most places, only minor volcanic rocks. The Ordovician succession is dominantly turbiditic with olistostromes, overlain by Caradocian black shales. It rests upon rocks of the Gander Zone to the east with locally derived coarse conglomerates. The Ordovician rocks pass upwards into Silurian shallow-water clastics with minor mixed volcanic rocks overlain by more marine clastics and finally red beds. Cleavage and tight folding affects the whole succession and is of Acadian age. Metamorphism is in the low greenschist facies. The eastern boundary of the Botwood Zone is generally defined by a fault but locally an unconformity with underlying rocks of the Gander Zone can be recognized.

(f) The Gander Zone is characterized by a thick sequence of complexly deformed dominantly clastic metasedimentary rocks of the Gander Group, similar in general aspect to much of the Fleur de Lys Supergroup of the Fleur de Lys Zone. Metamorphism is in the greenschist to amphibolite facies. The Gander Group is structurally overlain by mafic and ultramafic rocks with associated pillow lavas in the northwest, which are generally considered to represent an ophiolite complex, and which locally separates the Gander Group from rocks of the Botwood Zone. The metasedimentary rocks pass eastwards into metasedimentary gneisses and migmatitic gneisses that are locally recognized as basement to the zone. The deformation and metamorphism of the Gander Zone predates deposition of the Arenigian?-Llanvirnian rocks of the Botwood Zone but its exact age is uncertain. The eastern boundary of the Gander Zone is marked by mylonites and other cataclastic rocks of the Dover-Hermitage Bay Fault.

(g) The Avalon Zone lacks an exposed granitic basement in Newfoundland and is characterized by late Precambrian (Hadrynian) mafic and silicic volcanic rocks and marine clastic rocks locally containing impressions of soft-bodied organisms. The youngest late Precambrian (Hadrynian) rocks are red beds with local mixed mafic and silicic volcanic rocks. These are overlain with local angular unconformity by a shallow marine Cambro-Ordovician shale and sandstone sequence containing a trilobite fauna characteristic of the Atlantic faunal province. Devonian rocks in the southwestern part of the zone indicate that gentle to tight folding and cleavage formation was of Acadian (Middle Devonian) age. Metamorphism is weak, of sub-greenschist to low greenschist facies. The Avalon Zone represents an extensive element on the southeastern side of the Appalachian orogen in North America that can be followed intermittently southwestwards to the Carolinas.

Description of the Zones

The development of the zones, from west to east, is summarized below with reference to the section of the geotraverse (Plate 2*) and the stratigraphic sections (Plate 3). Relationships outside the area of the geotraverse will only be referred to where they have direct relevance to the development of the zone as a whole. All quoted K/Ar and Rb/Sr isotopic ages have been adjusted for the recent change in decay constants (Steiger and Jager, 1977; Dalrymple, 1979).

Humber Zone

Introduction

The Humber Zone forms the western margin of the Appalachian orogen in Newfoundland (Plate 2, sections AB and JKL). A crystalline basement of 1.0± Ga. age (Grenville) is overlain unconformably by a shallow water clastic and carbonate sequence of early Cambrian to early medial Ordovician age that was deposited on a passive (Atlantic-type) continental margin. Deeper water flysch of medial Ordovician age stratigraphically overlying these rocks reflects the approach and overthrusting of allochthonous, dominantly clastic sedimentary rocks of inferred late Precambrian and Cambrian through early Ordovician age, and a well-preserved ophiolite complex nappe above them. The allochthonous sediments are interpreted to be deep water equivalents of the platform rocks, originally deposited to the east on the continental lower slope and rise. The ophiolite suite is interpreted as a sample of the oceanic crust and upper mantle from outboard of the site of initial subduction in the early Ordovician Appalachian ocean. The arrival of these allochthonous thrust slices is dated as late medial Ordovician by neoautochthonous shallow water carbonates that unconformably overlie the allochthonous rocks in one place. Early Devonian red beds disconformably overlie the neoautochthon and are folded with it (Acadian folding) but Carboniferous red beds in most of the Humber Zone are flatlying or only gently folded. In the eastern part of the Zone, the Ordovician and older rocks there are strongly folded, foliated, and metamorphosed to greenschist facies. On Traverse section AB, medial to late Silurian shallow marine-terrestrial sediments and volcanics are preserved in this eastern part of the Zone. Deformation and metamorphism decreases in a general sense to the west and north. North of Traverse section AB, Cambro-Ordovician platform sedimentary rocks to the west of the Long Range are essentially flatlying.

Stratigraphy

This is summarized on columns 1-7 of Plate 3. The crystalline basement rocks of Precambrian age are mainly exposed in the Long Range Mountains, crossed by Traverse section AB, and in the Indian Head Range near the site of column 2. In the Long Range, they consist mostly of granitic gneisses and foliated granites with minor quartzofeldspathic metasediments and amphibolitic gneisses (Clifford, 1969). In the Indian Head Range similar rocks are accompanied by anorthosite (Riley, 1962). K/Ar age determinations give cooling ages in the range 790-860 Ma. for the Indian Head Range (Dallmeyer, 1978) and 955-970 Ma. for micas from the Long Range (Lowdon, et al., 1963). A

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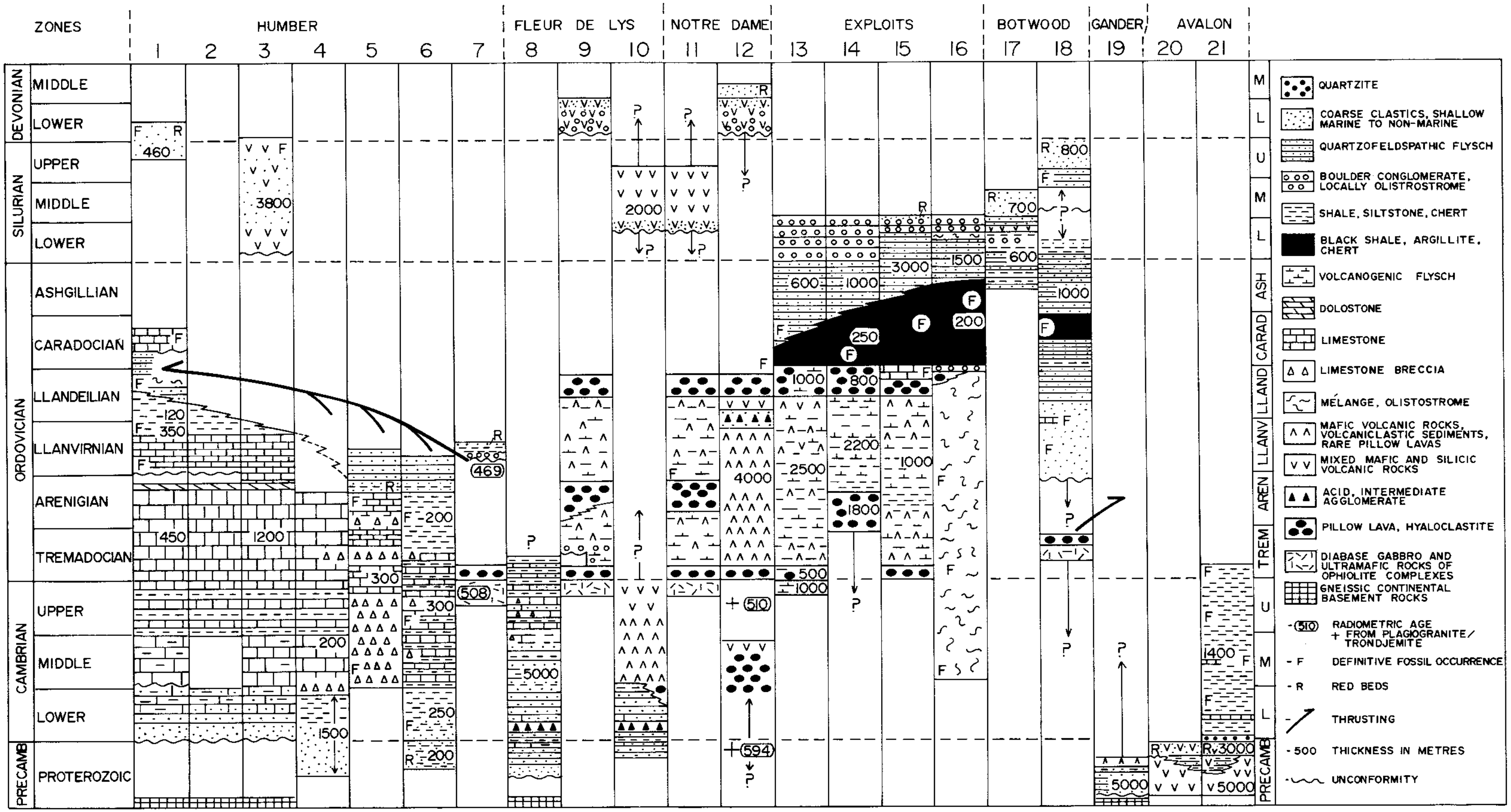

Plate 3. Simplified stratigraphic columns for the lines of section of Plate 2. Sources of information given in the text. (See insert in pocket in back of book for color presentation.)

single Rb/Sr whole-rock isochron from a foliated granite in the Long Range gives an age of 1106±90 Ma. (Pringle, et al., 1971), perhaps more closely approximating the age of active tectonism at the start of uplift and cooling. Although the Long Range crystalline basement has traditionally been regarded as autochthonous, it is bounded on the west by the Long Range Thrust (Plate 1; section AB, Plate 2). It occupies a position comparable to basement massifs elsewhere along the western edge of the Appalachians that are known (Ratcliffe, 1975) or suspected of being overthrust for significant distances (Rowley, 1981) with respect to the intact continental crust of North America.

The stratigraphy of the Cambro-Ordovician shallow-water clastic-carbonate sequence on the Port au Port Peninsula (Rodgers, 1967; Stevens, 1967) is shown in Columns 1 and 2 (Plate 3). This is the best known and best exposed fossiliferous section near the line of traverse. The section in column 3, the Coney Arm Group from Western White Bay near section AB, is unfossiliferous (Lock, 1972), and its age is inferred by lithologic correlation with the Port-au-Port sections. The section in column 4, derived from autochthonous to parautochthonous rocks near Corner Brook (Bruckner, 1966; Lilly, 1963), is also unfossiliferous in the lower part. All these sections can be divided into a basal part containing shallow water quartzo-feldspathic clastic rocks resting unconformably on the crystalline basement, passing upward gradationally into a largely shallow water carbonate accumulation (St. George Group). A disconformity probably due to temporary eustatic sea-level fall is recorded in the medial Cambrian of the Port au Port area, but otherwise essentially continuous slow subsidence and deposition is recorded in this Zone up through the early Ordovician. The carbonates contain much dolostone, and they are ubiquitously dolomitised at the top of the St. George Group (Lilly, 1963). The medial Cambrian hiatus is overlain by a thin development of dominantly arenaceous rocks which pass upward into late Cambrian carbonates with some shales. In column 4, the basal clastics are much thicker than in the other sections (Bruckner, 1966).

Outside the area of the traverse, at the north end of the Long Range (Clifford, 1965) and on Belle Isle (Williams and Stevens, 1969) a swarm of northnortheast-trending diabase dykes cuts the crystalline basement and were feeders to basalt flows that lie above a small thickness of coarse clastics and underneath arkosic sandstones of late early Cambrian age. The latter are equivalent to the base of the section in the Port au Port area. The early Cambrian volcanics of northern Newfoundland are interpreted as due to rifting of the continental crust prior to ocean opening and the development of the rifted edge into a passive continental margin (Bird and Dewey, 1970). Their composition (Strong and Williams, 1972; Strong, 1974) is compatible with this interpretation.

Isotopic dating of the dikes has yielded variable results. Pringle, et al., (1971) report ages ranging from 766 to 876 Ma. while Wanless earlier reported a single age of 341 ± 100 Ma., clearly the product of later alteration. Stukas and Reynolds (1974b) present data that suggests an age of intrusion about 615 ± 10 Ma. and evidence that the older ages reported by Pringle et al. (1971) were due to excess argon.

The top of the Cambro-Ordovician carbonates of the St. George Group is marked by an erosional disconformity and karsted surface, above which Llanvirnian (late early Ordovician) limestones of the lower Table Point Formation are found (Columns 1 and 2, Plate 3). These cannot be separately distinguished from the older carbonates of the Coney Arm Group in the area of Western White Bay (Column 3) (Lock, 1972). The limestones of the lower Table Point are succeeded upward (in the area of columns 1 and 2) by interbedded calcarenite to micrite lime turbidites in dark shales which in turn are overlain by black graptolitic shales, the middle and upper divisions of the Table Point respectively. These are inferred from the contained faunas to be diachronous facies, younger in the west than in the east, at least for the area near Hare Bay, well north of section AB (Fahraeus, 1970). In the Coney Arm Group (column 3, Plate 3) the passage from carbonates below to derivatives of black shales (now fine-grained schists) above, has been documented by Lock (1972). The bedded carbonateshale middle division in the area of Column 1 (Plate 3) contains thick, rapidly deposited limestone breccia/conglomerate horizons that indicate contemporary erosion of uplifted blocks of Table Point limestone, thought to be evidence of block faulting of the now more rapidly subsiding platform (Stevens, 1976; N. James, pers. comm., 1981). This sequence of units above the disconformity on the St. George Group indicates initial uplift and then rapid subsidence so that a sequence of increasingly deep water facies succeed one another at any one place. The diachronous development across what was previously all a shallow carbonate sea indicates retreat of the reef front from east to west through the late early Ordovician. All these effects are explained by the encroachment of a subduction zone and island arc upon the passive rifted continental margin by eastward subduction of the oceanic crust outboard of the continental margin (Stevens, 1970). This causes the passage of a flexural bulge westward across the outer part of the margin and is followed by subsidence of the margin as its outer edge becomes loaded by the approaching subduction complex and volcanic arc. A thicker sequence of turbidite greywackes and shales of Llanvirnian to early Caradocian age (Mainland sequence, Stevens, 1970, 1976) exists above the thin black shales of the upper Table Point. They are overlain conformably by the Long Point Formation (Rodgers, 1965) which consists of basal shallow water limestones overlain by greenish shales and calcareous sandstones. This unit is also of early Caradocian (medial Ordovician) age (Fahraeus, 1973). It is important in the regional geology because it also, in the same area, unconformably overlies the western edge of the allochthonous Humber Arm thrust sheets (Stevens, 1970; column 1, Plate 3). It is therefore neoautochthonous with respect to the thrust sheets and dates their final emplacement (Stevens, 1970). It is overlain in a structurally conformable way by red sandstones, calcareous sandstones and mudstones of the late Silurian-early Devonian Clam Bank Formation. The contact is probably a disconformity but is not exposed. Elsewhere, near the site of Column 2, (Plate 3) early Carboniferous sediments are locally exposed at the edge of the St. Georges Basin, where they contain evaporites (gypsum) as well as clastic rocks.

Within the thrust sheets of the Humber Arm Allochthon (Williams, 1975), the sedimentary rocks are assigned to the Humber Arm Supergroup (Stevens, 1970; Plate 3, columns 5 and 6). Column 5 summarizes the stratigraphy of the Cow Head Group, which occurs in a small imbricated slice in the northern area of the Allochthon near the western end of section AB (Plate 2). This Group consists of a very thin sequence of spectacular coarse, channelized carbonate breccias interstratified with carbonate turbidites and shales. It ranges in age from mid-Cambrian to late early Ordovician, and is overlain by easterly-derived quartzofeldspathic flysch of very early medial Ordovician (late Arenigian-early Llanvirnian) age (Kindle and Whittington, 1958).

Column 6 summarizes the stratigraphy of the main part of the Humber Arm Allochthon as developed in the Bay of Islands area (Bruckner, 1966; Stevens, 1970, 1976). This sequence, the Curling Group, preserves a relatively thin column of deep-water sediments ranging from below early Cambrian up to at least late early Ordovician age. Like the platform sequence of columns 1-4, it has a dominantly quartzofeldspathic lower unit with turbiditic arenites and some coarser beds in green and red mudrocks. Granitic clasts in these sediments are probably derived from Grenville basement, and mafic volcanic clasts from the mafic volcanics known from the base of the sequence on the platform (Stevens, 1970). Limestone clasts in conglomerates near the top of this division contain early Cambrian trilobites, indicating the development of the carbonate bank on the platform and transport of detritus into deep water farther offshore. At Hare Bay, well north of traverse AB, a thicker section of the lower quartzofeldspathic unit is developed. Some of this may very possibly be older than anything preserved in the Curling Group. It contains, locally, some mafic volcanic flows and minor intrusions, probably correlative with the mafic volcanics also preserved on the platform in this northern area below early Cambrian arkoses (Stevens, 1970; Smyth, 1971). Above the lower quartzofeldspathic unit in the Curling Group, there is a section consisting largely of calcarenite to micrite turbidites in black shale, with less abundant pebbly limestone breccia beds in places. It ranges in age from medial Cambrian to medial early Ordovician (Stevens, 1976). The carbonates in this section are all in a deep-water resedimented facies originally deposited east of the carbonate bank and are a more distal facies than the Cow Head breccias. They are capped by a black and green shale unit of late Tremadocian to mid-Arenigian age, which in turn is overlain by quartzofeldspathic turbidites and shales (flysch) that are of late Arenigian and perhaps younger age (Stevens, 1976; column 6, Plate 3). There were derived from the east, and indicate this by the serpentine and chromite detritus contained within the turbidites, eroded from an already moving and uplifted ophiolite nappe, a remnant of which now structurally overlies the Humber Arm Allochthon. The age of the basal flysch is younger in originally more westerly sections (compare columns 5 and 6 with column 1) reflecting the progressive movement of the area of flysch deposition towards and over the older carbonate platform during obduction of the ophiolite (Stevens, 1970; Church and Stevens, 1971; Dewey and Bird, 1971) and arc-continent collision (Nelson and Casey, 1979). Volcanics reported as interstratified with the allochthonous flysch (Williams, 1973) are in tectonic contact with the rocks below (Kidd and Idleman, 1982) although they are conformably overlain by flysch. These volcanics and the overlying flysch comprise a separate thrust slice; in structurally lower slices the succession passes up from Tremadocian-Arenigian shales to flysch without any trace of volcanics.

The highest allochthonous thrust slices in the area (Williams, 1973, 1975) are mostly volcanic and plutonic rocks of the Bay of Islands ophiolite complex. These rocks represent an exceptionally well preserved slice of oceanic crust and upper mantle (Stevens, 1970; Church and Stevens, 1971; Dewey and Bird, 1971; Casey et al., 1981). The westernmost part of the ophiolite slice (Little Port Slice; Williams, 1975) is interpreted as remnants of rocks developed in a ridge-ridge transform fault and oceanic fracture zone (Karson and Dewey, 1978). Broadly speaking, the ophiolite section consists of peridotite (mainly harzburgite) up to about 7 km in original thickness, overlain by layered ultramafic and gabbroic rocks, then massive gabbros with minor trondhjemites, totalling about 4 km thickness. These gabbros are succeeded by about 1 km thickness of diabase in a unit of sheeted dikes and these have a gradational upper contact with up to about 600 m of pillow lavas (Casey, et al., 1981). The fracture zone rocks consist mostly of amphibolites, greenschists, amphibolitized gabbros, and trondhjemitic plutons. Alkaline volcanic rocks and associated sediments of the Skinner Cove Formation (Williams, 1973, 1975) are now thought to be part of a separate but still oceanic crustal-derived slice (Williams, 1975; Kidd and Idleman, 1982). The age of the Skinner Cove volcanics is probably "early Ordovician" (Williams, 1975), but at present it is not closely constrained. Sediments previously reported to lie conformably above the ophiolite pillow lavas have recently been shown to lie unconformably on the ophiolite (Casey and Kidd, 1981). These mafic breccias and olistostromic shales of the Crabb Brook Group (Plate 3, column 7) are of Llanvirnian age and are interpreted to have been deposited on the ophiolite while it was being obducted. The Bay of Islands ophiolite complex itself is dated by a U/Pb zircon age from trondhjemite of 504± 10 Ma. (Mattinson, 1976). Zircons from trondhjemite in the transform-fault-derived Little Port Slice give an undistinguishable age of 508± 5 Ma. (Mattinson, 1975). These are confirmed by two Sm/Nd internal isochrons on pyroxene gabbro from the ophiolite, giving ages of 508± 6 and 501± 13 Ma. (Jacobsen and Wasserburg, 1979). The ages are probably close to the Cambrian-Ordovician boundary, but correlation between the fossil-defined stages and the numerical time scale is as yet not very precise in this portion of the Phanerozoic.

Structure

In the extreme western portions of this zone, near the traverse and the locations of columns 1 and 2, the autochthonous platform rocks are only very gently folded (Plate 2, sections AB and JKL); north of section AB on the west coast of Newfoundland, they are essentially flat-lying. In a general way rocks of this zone become in outcrop more obviously and strongly deformed to the east. In central parts, near the site of column 6 (Plate 1) and east of line JK, rocks of both autochthonous platform and Humber Arm Allochthon show in outcrop open to close folds with a single axial surface cleavage. Folds plunge gently and trend generally northnortheast. West along the general direction of the traverse, folds are more open and rocks lack any cleavage, for example in the vicinity of Cow Head (Plate 1, column 5). To the east, near the Humber Gorge (Plate 1, column 4 and section KL) the rocks, especially the platform carbonates and the underlying clastics, are tightly and complexly folded, with multiple foliations and pervasive crenulation. The foliations in general tend to dip moderately to steeply eastward, and the folds are overturned to the west here and in an equivalent position along strike in western White Bay on traverse AB (column 3, Plate 2) (Lock, 1969b; Lilly, 1967). However, places where east-vergent folds accompany west-dipping cleavage exist in several parts of the Humber Arm Allochthon west of the Humber Gorge area (Lilly, 1967).

On a larger scale, the most major structures in this zone are the thrusts that lie at the base of the various allochthonous slices (Williams, 1975), particularly the one at the base of the ophiolite slice. These thrusts are mostly marked by zones of melange (Stevens, 1970) and they are known to be of pre-early Caradocian age since rocks of early Caradocian age (Long Point Formation) unconformably overlie both the Humber Arm Allochthon and the autochthonous platform sequence. They are therefore part of the Taconic Orogeny (Rodgers and Neale, 1963). The earliest thrust is that marked by the basal metamorphic aureole of the ophiolite, consisting of a thin zone of polydeformed amphibolites and greenschists, and which represents the initial detachment surface of the ophiolite nappe (Williams and Smyth, 1973; Malpas, 1979). An Ar^{40}/Ar^{39} age on amphiboles in the metamorphic rocks (Dallmeyer and Williams, 1975) gives 469± 5 Ma. while several K/Ar ages (Archibald and Farrar, 1976) give a combined age of 462± 9 Ma. The fossil-defined stages of the early Ordovician are not currently tied to the numerical time scale with any certainty (in fact this age has been used by some to define one point of correlation). However, this age could be somewhere in the Arenig. The oldest flysch (containing ophiolite detritus) is of late Arenigian age (Stevens, 1976) in the area of the geotraverse, which is used as a younger age limit on the time of initial transport. Displacements on these thrusts are probably substantial; analogy with present-day continental margins suggests that 100-300 km displacement between allochthonous continental rise sediments and the underlying platform is quite probable. Comparable displacements are also possible on thrusts marked by melange zones within the allochthonous sediments. The ophiolite and allochthonous sediments are thought to have been, in broad terms, assembled by thrust accretion stacking (Stevens, 1970), whereby progressively lower slices were attached to a moving allochthon. However, the fact that the initial detachment surface and the ophiolite complex are folded and cut by later thrusts (Casey and Kidd, 1981) shows that a protracted and more complicated history of thrusting was involved. The present disposition of the Humber Arm Allochthon in a broad synclinorial structure (Plate 2, sections AB, JKL) is due to late folding and thrusting that involved the Grenville continental basement. The Long Range Thrust (Plate 2, section AB) may have developed at this time, but age constraints on this fault are not tight. In the eastern part of this zone in the Humber Gorge area (column 4, Plate 1; Plate 2, section KL) polydeformed quartzofeldspathic schists similar to rocks of the Fleur de Lys Zone are in probable thrust contact over platform carbonates of the St. George Group. In western White Bay (area of column 3, Plate 1; section AB), the platform carbonates and quartzites lie unconformably on the Grenville basement and define a steep zone. Serpentine-bearing melange (Williams, 1977a) above these rocks defines the basal thrust of allochthonous rocks. Both allochthonous and autochthonous rocks are here strongly deformed with tight to isoclinal early folds and phyllitic schistosity, affected by a widespread later crenulation and kink bands (Lock, 1969b). In this area the Cambro-Ordovician rocks are adjoined (Lock, 1969a) and perhaps unconformably overlain (Williams, 1977a) by medial to late Silurian terrestrial and shallow marine rocks. These possess only a single steep cleavage axial surface to large-scale upright gently-plunging tight folds. Some of the fabrics in the Cambro-Ordovician rocks here are therefore pre-Silurian, or Taconic in age. The folds in the Silurian rocks are probably of Acadian age (Lock, 1969a) since adjacent Carboniferous rocks (Plate 2, section AB), while strongly folded, are not cleaved. The age of folding in most of the Humber Zone is not well-constrained because of a lack of widespread Silurian and younger rocks. The large monoclinal fold that affects the late Silurian Clam Bank Formation near column 1 (Plate 1) may be of Acadian or Carboniferous age. The same might be said of many structures, especially in the eastern part of the zone, although much is probably due to the Taconic episode.

Metamorphism and Plutonism

Metamorphism in much of the Humber Zone is low grade to non-existent. Rocks in the western part are essentially unmetamorphosed and in a general way the sedimentary rocks gradually increase in metamorphic grade to the east. In the central and eastern part of the Humber Arm Allochthon slaty cleavage is developed and the rocks are in sub- to low-greenschist facies. East of the Allochthon in the area of columns 3 and 4 (Plates 1, 2) carbonates are now fine-grained marbles, and pelitic rocks are phyllites to fine-grained schists in greenschist facies. The age of this metamorphism is probably at least partly late Ordovician, but constraints on this are poor, since adjacent Silurian rocks in the area of column 3 also show low grade metamorphism, although of slightly lower grade than adjacent Cambro-Ordovician rocks. The matamorphism must pre-date Carboniferous rocks since they do not show its effects and contain metamorphic detritus.

Metamorphic rocks of allochthonous origin occur in the Humber Zone in association with the Bay of Islands Ophiolite Complex. The thin polydeformed mafic granulites, amphibolites and greenschists of the basal "aureole" of the ophiolite represent deformed oceanic crustal rocks attached to the base of the slab of oceanic lithosphere as it started its transport (Malpas, 1979). Amphibolites and greenschists and local mafic granulites of the Little Port Complex (Karson and Dewey, 1978) are interpreted to have formed in an oceanic transform fault zone. Greenschist and local amphibolite facies metabasites (generally not foliated) at the top of the ophiolite section are interpreted as having formed from ocean floor hydrothermal metamorphism at a spreading ridge (Dewey and Bird, 1971; Williams and Smyth, 1973; Casey, et al., 1981).

Plutons of Paleozoic age are scarce in the Humber Zone, except in the ophiolite complex. Plutonic rocks form the bulk of the Bay of Islands ophiolite complex, described above under stratigraphy. Harzburgites with minor dunites and orthopyroxenites represent old oceanic upper mantle rocks; gabbroic rocks and layered ultramafic rocks at their base lie above the harzburgites and represent the lower part of the oceanic crust. The sheeted diabase dike complex lies above the gabbros and fed pillow lavas which overlie it; these form the upper part of the crustal section. Minor quartz-dioritic to trondhjemitic plutons and agmatites in the upper gabbros and lower dikes are comagmatic with the ophiolite suite (Church and Stevens, 1971; Dewey and Bird, 1971; Williams, 1973; Malpas and Stevens, 1976; Church and Riccio, 1977; Casey, et al., 1981). Trondhjemite-tonalite plutons intrude the Little Port Complex and are cut by diabase dikes. Both are thought to be derived from magmatism at a ridge-transform intersection (Karson and Dewey, 1978). One probable Acadian granitic pluton intrudes Silurian volcanics and sediments in the area of column 3 (Plate 1) (Lock, 1969b) and is cut by a Carboniferous fault. The Coney Head Complex, a tonalitic plutonic body in this area of section AB, is interpreted by Williams (1977) as a transported pluton like those in the Little Port Complex.

Nature of the Boundary with the Fleur de Lys Zone

On section AB, the contact with the Fleur de Lys Zone is a large strike-slip fault zone occupied by folded and faulted Carboniferous red beds. Substantial displacement is possible across this zone, the Cabot Fault of Wilson (1962). No definite evidence is known from the vicinity of the traverse as to the sense or amount of displacement, but evidence from elsewhere in the northern Appalachians indicates that right-lateral displacement is required. (Bradley,1982). The same fault zone passes across the end of section JKL, but on this section polydeformed metaclastic rocks similar to those of the Fleur de Lys Zone are in probable overthrust relationship to rocks of the Humber zone. This is likely, in a general sense, to have been the original relationship between the two zones before Carboniferous faulting modified the situation.

Fleur de Lys Zone

Introduction

The Fleur de Lys Zone includes some of the most complex geology along the geotraverse. A few key relationships in this zone are unclear and in dispute in part because many of the rocks are complexly deformed and metamorphosed, and also because there are no known fossil localities and isotopic age studies have in some cases given debatable, indeterminate, or contradictory information.

In general, on the line of the traverse (Plate 2, sections ABC, EFG), this zone is divided in two by the Baie Verte Lineament, a narrow zone of mafic volcanic and volcaniclastic rocks bordered discontinuously on its western side by dismembered ophiolites. To the west of the Baie Verte Lineament (or Baie Verte Ultramafic Belt), the western division of the Fleur de Lys Supergroup (Church, 1969) consists of polyphase deformed, mostly quartzofeldspathic metasedimentary schists overlying a remobilized granitoid gneissic basement (DeWit, 1972, 1980; Bursnall and DeWit, 1975) of presumed Grenville age. To the east of the Baie Verte Lineament, the eastern division of the Fleur de Lys Supergroup (Church, 1969) also consists of polyphase deformed quartzofeldspathic metasedimentary schists at the base, overlain by extensive mafic metavolcanics, in turn succeeded by silicic metavolcanics. The mafic metavolcanics are intruded synkinematically by a large granodiorite (Burlington Granodiorite) that occupies a major portion of the exposure of the eastern zone. It is pre-Devonian in age as it is overlain unconformably by Devonian subaerial volcanics and clastics along the east side of the Baie Verte Lineament. Other mafic and silicic volcanic rocks exposed on the eastern edge of this Zone have been correlated with these Devonian rocks, and with the deformed silicic metavolcanics that appear to have been deformed with rocks intruded synkinematically by the Burlington Granodiorite. This impossibility can be resolved in several ways, by breaking either of the correlations of the silicic volcanics or by postulating the existence of two similar granodiorite plutons of different ages. Miscorrelation of the volcanics seems more likely, but this problem is discussed in more detail below.

An important division in the pre-Silurian geology of the Appalachian Orogen is crossed within the Fleur de Lys Zone, that of rocks originally deposited above continental basement, seen in the western Fleur de Lys Zone, and rocks deposited above oceanic basement, seen in the Baie Verte Lineament, and in places within the eastern Fleur de Lys Zone (Bird and Dewey, 1970). This boundary represents the now highly modified and originally complex passage from continental lithosphere of North America to oceanic lithosphere, originally established by late Precambrian rifting.

Stratigraphy

The stratigraphy of the western Fleur de Lys Zone is summarized by DeWit (1980) (column 8, Plate 3). A quartzofeldspathic gneissic basement is overlain locally by a thick basal conglomerate (DeWit, 1974), once (Church, 1969; Harland, 1969), but no longer, regarded as a possible tillite. The conglomerate is overlain by a very thick homogeneous unit of quartzofeldspathic metaclastic rocks (Seal Cove Group) now psammitic and pelitic schists. Both these and the basement contain abundant amphibolite layers, originally basaltic dikes, sills and flows (DeWit, 1972, 1980). These clastic and volcanic rocks are correlated with the basal quartzofeldspathic clastic and volcanic sequence of late Precambrian-Cambrian age on the platform and allochthon in the Humber Zone. They represent rapid sedimentation and vulcanism synchronous with rifting of the continental lithosphere prior to ocean opening in the earliest Cambrian. Above the Seal Cove Group there is a thin, lithologically more variable sequence mostly of metasedimentary rocks. In the west they are referred to the Bear Gove Group by DeWit (1972, 1980), and in the east and northeast to the Rattling Brook Group (Bursnall and DeWit, 1975). They consist largely of pelitic to psammitic quartzofeldspathic mica schists, some rich in garnet and magnetite. In the Bear Cove Group, graphitic schists containing thin metaquartzites, pelitic mica schists with marble beds, carbonate breccia with pelitic matrix and some blocks several meters across, pebbly psammites with mafic volcanic, vein quartz and granitic clasts, and mafic metavolcaniclastic rocks are present. In the Rattling Brook Group to the east, carbonates and quartzites are very rare, and mafic metavolcaniclastic rocks, locally interstratified with quartzose metasediments, are more abundant

(Kennedy, 1971; Bursnall, 1976; Kidd, 1974). Bursnall and DeWit (1975) suggested that this sequence extended up into the early Ordovician, but it most closely correlates, in lithologies and their sequence, with only the early Cambrian part of the Curling Group in the Humber Arm Allochthon, with the exception of the mafic metavolcaniclastic schists.

Although these volcaniclastic schists do have zones within their eastern outcrop that contain deformed ophiolitic fragments and structural indications of high strain (Kidd, 1974; Bursnall, 1976) interpreted as thrusts containing melange (Williams, 1977b), the proposal to include all the mafic schists in the Birchy Complex (Williams, et al., 1977) obscures the fact that they contain recognizable volcaniclastic beds interstratified conformably with pelitic and psammitic schists and metaquartzites of the Rattling Brook and Bear Cove Groups (Kidd, 1974; DeWit, 1972). While some of the mafic schists may have a tectonic significance like that of the basal aureole to the Bay of Islands Ophiolite Complex, it is clear that a large portion of them, below the first melange zone, are an integral part of the Fleur de Lys Supergroup stratigraphy. The age and tectonic significance of the volcanism represented by these mafic schists is unknown; it could be connected with rifting in the early Cambrian, or with island arc volcanism in the early Ordovician, or with intraplate volcanism any time in between. They are, however, in relative terms, the youngest unit in the western Fleur de Lys Supergroup succession.

The eastern division of the Fleur de Lys Supergroup is divided (Church, 1969) (column 10, Plate 3) into a thick basal unit of quartzofeldspathic psammitic schists that are probably the equivalent of the Seal Cove Group in the western Fleur de Lys, although they do not contain many metabasite layers. A somewhat more pelitic upper portion, containing minor graphitic schists and metaquartzites, is structurally overlain by a thick unit of mostly mafic metavolcanic and metavolcaniclastic rocks, the Paquet Harbor Group. These metavolcanics have been thought to conformably overlie the quartzofeldspathic schists below, but recent discovery of metamorphosed ultramafic pods in pelitic schist within the contact zone (J. Hibbard, in prep.) suggests that there may be a major thrust with ophiolitic melange in this position. However, this thrust must predate polyphase deformation and metamorphism in the rocks on either side of it because they show identical structural histories (Neale and Kennedy, 1967; Kennedy, 1975).

The metavolcanic rocks of the Paquet Harbor Group are largely mafic near the base but upward they contain a substantial quantity of more silicic metavolcanic and metavolcaniclastic rocks. This represents a transition into the uppermost unit of the eastern Fleur de Lys, the Grand Cove Group (Church, 1969), which consists of a thick sequence of intermediate and silicic volcaniclastics and volcanics. A U/Pb zircon date from one volcaniclastic rock and a consanguineous porphyry intrusion (Mattinson, 1977) gives an age of 475± 10 Ma. (early Ordovician). This key piece of information rules out correlations of these rocks with supposed Silurian and known Devonian silicic volcanics elsewhere in this zone, even though the Grand Cove Group is supposed (DeGrace, et al., 1976) to form the north limb of a syncline with inferred Silurian/Devonian volcanic rocks (Cape St. John Group) on its south limb. Either the syncline does not exist and there is an as yet undetected structural and stratigraphic break between the Grand Cove Group and the southern part of the area mapped as Cape St. John Group, or the Cape St. John Group is also Ordovician in age. This problem has not been helped by indiscriminate use of the term Cape St. John Group since Church's (1969) prescient proposal of the Grand Cove Group as a separate entity. Many Rb/Sr dates from these two units and equivalent intrusive rocks (Bell and Blenkinsop, 1977; Pringle, 1978) range from a low of 336± 14 up to 444± 50 Ma., and perhaps even older (Bell and Blenkinsop, 1978). Strong and unpredictable disturbance of the isotopic system in these rocks seems indicated, perhaps by a Carboniferous-age event (Mattinson, 1977).

Evidence that the Cape St. John Group (in the sense used by Church, 1969) is Siluro-Devonian in age comes from the existence, near the southeast end of traverse section EFG, of an angular unconformity between subaerial silicic and mafic volcanics with local siliceous arenites (Cape St. John Group) above, and mafic pillow lavas and turbiditic mafic volcaniclastics of the fossil-dated early Ordovician Snooks Arm Group below (Neale, et al., 1975). A similar unconformity (Schroeter, 1971) exists farther southwest towards section BC, where the Cape St. John Group rocks are lithologically extremely similar to the dated early Devonian Mic Mac Lake Group.

This latter unit consists of ignimbrites, subaerial basalt flows, conglomerates and sandstones, lying in a narrow outcrop belt on the east side of the Baie Verte Lineament, crossed by traverse section ABC. The only Rb/Sr isochron from this unit where the analytical data have been published (Pringle, 1978) gives an age of 388± 15 Ma. (early Devonian). The main part of the Mic Mac Lake Group rests with erosional unconformity on the Burlington Granodiorite (Neale and Kennedy, 1967). The Mic Mac Lake and Cape St. John Groups are shown as Silurian on column 10, Plate 3. The western part of the Mic Mac Lake Group rests either conformably or with slight unconformity on mafic pillow lavas and mafic and rare silicic volcaniclastics of the Baie Verte Group (Kidd, 1974, 1977). Both the Mic Mac Lake Group and the Baie Verte Group here share the same main cleavage and tight folding (Neale and Kennedy, 1967; Kidd, 1974, 1977) and hence the Baie Verte Group (presumed to be early Ordovician in age) was not penetratively deformed prior to the Devonian.

The Baie Verte Group, shown in column 9, Plate 3, was initially proposed by Neale and Nash (1963) and suffered later attrition Neale and Kennedy, 1967; Church, 1969) for good structural and lithologic reasons. We regard a more recent proposal (Williams, et al., 1977) to extinguish the name and substitute three others for lithologically identical rock suites as ill-conceived and in violation of normal stratigraphic practice. Along most of the Baie Verte Lineament, the mafic volcanics (pillow lavas) and turbiditic mafic volcaniclastics are in fault contact with dismembered, ophiolite-derived ultramafic and gabbroic plutonic rocks (Kidd, 1974, 1977; Bursnall, 1976). At the north end of the Lineament, in Mings Bight (Kidd, et al., 1978) identical volcaniclastic and volcanic rocks rest conformably and directly on pillow lavas that form the top of an ophiolite complex (column 9, Plate 3), complete with sheeted dikes. This section shows that this oceanic lithosphere must have been generated within or adjacent to an island arc, since coarse volcaniclastics directly overlie the ophiolite pillow lavas. Elsewhere in the Baie Verte Group, clasts and olistoliths of ophiolitic plutonic lithologies in some stratigraphic units indicate nearby, large, submarine fault scarps (Kidd, 1974, 1977), possibly of a transform or large intra-arc transcurrent fault. Remnants of ophiolite complex suites of more than one age may be present in the Baie Verte Lineament. Several lines of evidence suggest this, including the presence of rare, predepositionally foliated quartzofeldspathic phyllite and silicic volcaniclastic boulders in a conglomerate unit (Kidd, 1974, 1977). These imply that the Baie Verte Group sediments were deposited after some deformation of quartzofeldspathic rocks like the Fleur de Lys Supergroup, but the Fleur de Lys contains ophiolite-derived clasts in melange zones that formed before deformation of the melange and the Fleur de Lys rocks. In the same vein, ophiolitic lithologies in the coastal section north of Baie Verte town (section EF in Plates 1 and 2) are fully involved in the Fleur de Lys deformation and metamorphism at the northwest end of the section (Bursnall, 1976) but are identical in lithology and structural style to the Baie Verte Group in the most southerly part. In between, in several fault-bounded slices, the structural characters of the rocks are apparently gradational between those of the two ends (Bursnall, 1976). Isotopic dating or fossil discoveries will be needed to further resolve the situation.

The sediments and volcanics of the Baie Verte Group are lithologically identical, except for being more strongly cleaved and deformed, to the Snooks Arm Group. That Group consists of mafic pillow lavas and volcaniclastics (column 11, Plate 3) conformably overlying the Betts Cove Ophiolite Complex, and situated in the Notre Dame Zone immediately adjacent to the Fleur de Lys Zone on section EFG (Plate 2). The Snooks Arm Group is fossil-dated (Snelgrove, 1931) as Arenigian, and most workers now agree with Dewey and Bird's proposal (1971) that it developed as a marginal, intra-arc basin. The same seems likely to be true for most of the rocks included in the Baie Verte Group, including the Mings Bight (or Point Rousse) Ophiolite Complex.

Structure

In the western Fleur de Lys, the large-scale structure in the middle (Plate 2, section AB) is a large domal, north-plunging anticline, as suggested by Neale and Nash (1963). The gneissic basement occurs in the center and is, in a first-order way, flanked by the older, then the younger metasedimentary units. This anticline appears to be controlled by the last regionally penetrative deformation (D_3) to affect these rocks, which in outcrop is expressed by crenulation schistosity, often conjugate on a large scale, and gently to moderately plunging close to tight folds (DeWit, 1972; Kidd, 1974). Both in this area and to the north, near section EF (Plate 2), earlier large scale and small scale isoclinal folds and schistosity of two generations have been documented in the metasediments (Neale and Kennedy, 1967; Kennedy, 1971; DeWit, 1972, 1980; Bursnall, 1976; Kidd, 1974; Bursnall and DeWit, 1975). Younging evidence is very scarce, but Kennedy (1971, 1975) showed that large scale F_2 folds were originally recumbent and westward facing. Thin, deformed ophiolitic melange zones in the easternmost part of the western Fleur de Lys represent syn- or pre-D_1 ductile high-strain zones (Bursnall, 1976; Kidd, 1974) that developed during transport and westward thrusting of some ophiolite complex (Williams, 1977b).

On section ABC (Plate 2), the eastern margin of the western Fleur de Lys block is a fault (Neale and Kennedy, 1967) inferred by Kidd (1974, 1977) to have been developed during deformation of the Baie Verte Group. Rock along the fault, as well as the Baie Verte Group and adjacent Mic Mac Lake Group (Devonian age) all show a single steep slaty cleavage axial surface to a very tight northnortheast-trending syncline whose axial region was overthrust eastward during the deformation.

Minor subsequent crenulation fabrics are developed in places in these rocks (Neale and Kennedy, 1967; Kidd, 1974). This Acadian deformation has little effect on the western Fleur de Lys (Kidd, 1974). The aureole of a Devonian post-kinematic granite in the Fleur de Lys is truncated by the western boundary fault of the Baie Verte Lineament in the vicinity of section AB (Plates 1 and 2).

To the north near section EFG (Plate 2), the Baie Verte Group on the eastern side of the Baie Verte Lineament also has a single slaty cleavage axial surface to a thrust-disrupted syncline defined by the Mings Bight Ophiolite Complex and overlying sediments and volcanics (Kidd, 1977; Kidd, et al., 1978). Thrusting is to the east-southeast and locally affects the eastern Fleur de Lys in retrograde, brittle thrust zones post-dating regional deformation and metamorphism of the psammitic schists (Kidd, et al., 1978). The deformation here is therefore identical in nature and geometry to that in the Baie Verte Lineament at section AB, where it is known to be post-lower Devonian. On the west side of the Baie Verte Lineament at its northern end (Plate 2, section EF), ophiolitic rocks northeast of the Advocate Mine appear to have been partially or wholly involved in the Fleur de Lys polyphase deformation sequence (Bursnall and DeWit, 1975; Bursnall, 1976). What part of this deformation in the Fleur de Lys in this northern area is Acadian and what part Taconic is difficult to resolve with present data and may well be complicated not only by the presence of ophiolites of two ages, but also by the occurrence of transform-fault-generated ductile fabrics in the ophiolitic plutonic rocks (Kidd, 1974).

In the eastern Fleur de Lys, a polyphase deformation sequence very similar to that in the western Fleur de Lys affects the rocks (Church, 1969; Kennedy, 1975). In outcrop, two generations of isoclinal folds with associated axial surface schistosity can be distinguished. The main schistosity (S_2) trends generally east-west and is for the most part gently inclined. Large-scale tight to isoclinal folds face south. Early D_1 isoclines are rare. In the northwest, a later generation of tight folds and a crenulation cleavage are superimposed on the D_2 structures. Both the tightness of the D_2 and D_3 folds and the intensity of development of their axial surface fabrics become less to the south and southeast. In this direction the S_2 schistosity becomes a crenulation and S_1 schistosity becomes more prominent. The facing and sense of transport of the major F_2 folds are in the opposite sense to those in the western Fleur de Lys. DeGrace, et al. (1976) use a different structural sequence for the eastern Fleur de Lys.

In the southeastern area of the eastern Fleur de Lys, the Cape St. John Group (Siluro-Devonian) volcanics and clastics have a single moderately north-dipping cleavage, best developed in volcaniclastic and sedimentary units but not at all in silicic flows and sills. This cleavage is probably the same as that weakly developed in sedimentary rocks of the Snooks Arm Group and axial surface to the large syncline that affects the latter (Plate 2, section EFG). This fabric is reported by DeGrace, et al. (1976) to be the same as the main schistosity affecting the rocks of the Grand Cove Group (S_1 of Kennedy, 1975). In the light of the early Ordovician age obtained by Mattinson (1977) on the Grand Cove Group this makes all the deformation in the Eastern Fleur de Lys of Acadian age, but presumed Devonian thrusting of the eastern Fleur de Lys rocks in Mings Bight (see above) is post-kinematic with respect to the regionally developed schistosities. Further work will presumably help to resolve this incompatibility, but it seems likely that at least some, if not all of the polyphase deformation and metamorphism affecting the Paquet Harbor and Grand Cove Groups is of pre-Devonian age, despite the young cooling ages recently obtained from them (Dallmeyer, 1977, 1981).

Plutonism

In the western Fleur de Lys metasediments, a few very small syn-kinematic silicic plutonic rocks are known in deformed dikes (DeWit, 1972, 1980; Bursnall and DeWit, 1975). The edge of a small body of tonalitic-granodioritic composition and satellite dikes intrudes rocks of the Rattling Brook Group next to the fault at the western side of the Baie Verte Lineament. It is syn- or pre-D_1 in the structural sequence (Kidd, 1974). Apart from these rocks, plutons in the western Fleur de Lys are all post-kinematic. A small granite at the northern end of the peninsula (Partridge Point Granite) has a K/Ar age of 368± 16 Ma. (in Kennedy, 1971). The Wild Cove Pond Complex is a large composite granite-diorite suite and occupies most of the width of the western Fleur de Lys south of section AB (Plate 1). A K/Ar age of 365 Ma. (reported in Neale and Nash, 1963) has been determined on a granite from this Complex. These are therefore two of the numerous Acadian plutons of the Newfoundland Appalachians.

In the eastern Fleur de Lys, large silicic plutons are abundant, as is confusion about their ages. The Burlington Granodiorite intrudes the Pacquet Harbor metavolcanics syn- or pre-kinematically with respect to the main schistosity and elongation lineation in those rocks (Kidd, 1974; Kennedy, 1975). A Rb/Sr isochron determined on it gives an age of 437± 40 Ma. (Pringle, 1978) and a U/Pb age of 445± 10 Ma. (Mattinson, 1977). Two other plutons in the area of higher metamorphic grade are the synkinematic Dunamagon granite (Kennedy, 1975), giving an Rb/Sr isochron of 427± 10 Ma. (Pringle, 1978) and 435± 15 Ma. age by U/Pb method (Mattinson, 1977). The Cape Brule porphyry is pre-kinematic (Kennedy, 1975) and gives a U/Pb age (Mattinson, 1977) of 475± 10 Ma. Rb/Sr isochrons determined on rocks supposed to be Cape Brule Porphyry (Pringle, 1978; Bell and Blenkinsop, 1977) are much younger and probably due to later thermal disturbance (Mattinson, 1977). These data are consistent with deformation and metamorphism accompanying pluton intrusion into the eastern Fleur de Lys in the time span of about 450-430 m.y. (late Ordovician to early Silurian) which is consistent with much, if not all, of the geological data from the area.

Other intrusions in the eastern Fleur de Lys include the La Scie porphyry, the Redditts Gabbro and the Seal Island Bight syenite. The latter gives a U/Pb age of 435± 15 Ma. (Mattinson, 1977). Rb/Sr isochrons on these rocks appear to reflect later disturbance.

A ring dike and cauldron subsidence-related plutonic complex intrudes the middle of the Burlington Granodiorite (Neale and Nash, 1963; Neale and Kennedy, 1967). It consists largely of quartz-feldspar porphyry and syenite. It is interpreted as the subvolcanic plutonic complex equivalent to the silicic volcanics of the Mic Mac Lake Group (Neale and Kennedy, 1967). A zone several kilometers wide surrounding the oval silicic plutons contains common dolerite dikes cutting the Burlington Granodiorite (Kidd, 1974). They are interpreted as feeders to the mafic flows in the Mic Mac Lake Group. A similar but larger plutonic complex farther south, in the next zone to the east, is known to be of alkaline and peralkaline rocks (Taylor, et al., 1980). Rb/Sr isochrons determined on these (reported in Taylor, et al., 1980) give ages of about 400 Ma., consistent with the idea that they are plutons related to the silicic portion of early Devonian bimodal volcanism.

Metamorphism

In the western Fleur de Lys, metamorphism locally attains amphibolite facies (kyanite and staurolite), although it is in most parts only of upper greenschist to lowest amphibole facies, albeit in coarse-grained schists. Garnet is widespread (Kennedy, 1971; DeWit, 1972, 1980). Lower greenschist facies assemblages occur very close to the eastern boundary with the Baie Verte Lineament, but these are not, except very locally, retrograde assemblages (Bursnall, 1976; Kidd, 1974). Metamorphic peak assemblages correlate with the main S_2 schistosity (Kennedy, 1971) or the S_3 crenulation (DeWit, 1972). Eclogite bodies reported by Church (1969) were found by DeWit (1972) to be localized to the gneissic basement. DeWit and Strong (1975) explained this as due to relatively "dry" metamorphic conditions in the basement allowing pyroxene growth while relatively "wet" conditions in the sedimentary cover required amphibole growth. In the basement generally, metamorphic disequilibrium textures are common (DeWit, 1980) in contrast to the cover, tending to confirm the conditions inferred for eclogite development. Development of andalusite and local metasomatic K-feldspar is known in the narrow aureoles of post-kinematic granitic and dioritic bodies in the western Fleur de Lys south of section AB (Plate 1) (Kidd, 1974).

In the eastern Fleur de Lys metamorphism likewise just reaches into amphibolite facies with kyanite and staurolite known locally (Kennedy, 1975). Most of the rocks in the northwestern part are in upper greenschist to lowest amphibolite facies but the metamorphic grade dies away fairly quickly to the south and east. Peak of metamorphism in the higher grade part of the eastern Fleur de Lys occurred after D_1 and before or during D_2 according to Kennedy (1975). Most of the Grand Cove Group is in mid to lower greenschist facies, and the Cape St. John Group on the southeast side of the zone is in low greenschist to sub-greenschist facies, as are the adjoining rocks in the Notre Dame Zone.

Within the Baie Verte Lineament, rocks are in low greenschist facies and in most places along the western side of the structure contrast markedly with the higher grade of the adjacent western Fleur de Lys rocks. At the northern end of the Lineament near section EFG, a more-or-less gradational sequence occurs from low greenschist facies in the undoubted Baie Verte Group to high greenschist facies and coarsely recrystallized rocks in undoubted Fleur de Lys (Bursnall, 1976). On the eastern side of the Lineament in this section, low greenschist facies Baie Verte Group mafic rocks are thrust over upper greenschist to lower amphibolite facies psammitic schists of the eastern Fleur de Lys (Kidd, et al., 1978). Farther south, near section ABC (Plates 2, 3) the same low greenschist metamorphism associated with one cleavage affects both the mafic rocks of the Baie Verte Group and the adjoining early Devonian Mic Mac Lake Group. The Baie Verte Lineament therefore is a belt of low grade Acadian-age metamorphism within higher-grade presumed Taconic-age polydeformed metamorphic rocks. Dallmeyer (1977) reported Ar cooling ages from both western and eastern Fleur de Lys terrains. Hornblendes and muscovites from the western terrain yield ages ranging from 428 to 394 Ma. and biotites range from 394 to 373 Ma. The early to mid-Silurian time coresponding to the older hornblendes and muscovite cooling ages requires that the Fleur de Lys metamorphism, broadly speaking,is a Taconic event. More study is needed, however, to understand the ages of metamorphism in this area since mineral cooling ages from the eastern Fleur de Lys (Dallmeyer, 1977; 1981), typically in the range 340-365 Ma., are interpreted by him as indicating Acadian metamorphism. We find more plausible the hypothesis that these younger ages from the eastern Fleur de Lys are due to resetting and/or much prolonged cooling because of the Acadian overthrusting from the Baie Verte Lineament eastward onto the eastern Fleur de Lys terrain.

Nature of the Boundary with the Notre Dame Zone

Most of this boundary in the area of the geotraverse is a late steep fault, the Green Bay Fault, with about 20 km right-lateral displacement (Upadhyay, et al., 1971). Carboniferous red beds occur at two places along this fault, one near section BC (Plate 1), suggesting that at least part of its displacement is of this age. Near the east end of section EFG (Plate 1) the boundary has been placed at the fault on the north side of the Snooks Arm Group. This is probably an Acadian structure and most probably is a southward directed thrust (Church and Riccio, 1974), like those seen on the east side of the Baie Verte Lineament. This boundary is hard to trace into the area south of the line of the geotraverse, since that area is full of granitoid plutons.

Notre Dame Zone

Introduction

This zone is characterized by early Ordovician and older island arc volcanic rocks and less abundant volcaniclastic sediments that rest locally upon an ophiolite basement. The Ordovician rocks are unconformably overlain by red beds and subaerial volcanics of presumed late Silurian to early Devonian age in the western part of this zone. Cambrian trondhjemitic granite cutting an older sequence of volcanics which are locally intensely deformed and metamorphosed prior to extrusion of Ordovician lavas is another characteristic feature of the Notre Dame Zone. This zone is separated from the Exploits Zone by the Sops Head-Lukes Arm Fault.

Stratigraphy

The stratigraphy is summarized in Columns 11 and 12 of Plate 3. The oldest rocks of this zone are represented by foliated hornblende trondhjemite/tonalite of the Mansfield Cove Complex and associated pillow lavas that are preserved in an agmatitic complex. All these rocks occur in a fault bounded block where Section BC crosses the more southerly part of this zone (Plate 2). The tonalite has yielded a minimum zircon $^{207}Pb/^{206}Pb$ age of 594± 10 Ma. (Bostock, et al., 1979). The fault block is surrounded by mafic pillow lavas, and less abundant coarse volcaniclastics, and minor silicic rocks, chert and volcaniclastic sediments all of the Roberts Arm Group. Rb/Sr isochron studies of this group and a related pluton (Bostock, et al., 1979) suggest an early to medial Ordovician (pre-Caradocian) age (Nelson and Kidd, 1979). Many earlier workers had favored a Silurian age for these rocks. The Roberts Arm Group and the correlative Chanceport Group (Strong and Payne, 1973; Dean, 1977) are separated from the rest of the Notre Dame Zone by faults, the Lobster Cove and Chanceport Faults (Dean, 1977).

The northern part of this zone in the vicinity of Section BC largely consists of variably, but often strongly, deformed mafic lavas, pillowed in many places, and much less abundant mafic volcaniclastic rocks (Little Bay Head Group). Near section BC, these are interpreted to be overlain by the fossil-dated (Dean, 1970; Boucot, 1973) Catchers Pond Group (Neale and Nash, 1963) of Arenigian age. This mostly contains mafic and silicic flows and volcaniclastics, and is generally less deformed and pervasively altered than many areas of the Little Bay Head Group (Kennedy and DeGrace, 1972). Other apparently less deformed sequences (Western Arm Group, Cutwell Group) are also found within this terrane, and consist largely of equal amounts of mafic volcaniclastics and mafic pillow lavas, with minor silicic volcanics, limestone, and black slate near the top (Marten, 1971; Kean and Strong, 1975). A suggestion of an unconformable relationship between the apparently less and more deformed sequences (Bird and Dewey, 1970) has been disputed (Marten, 1971), but indirect evidence of such a relationship has been documented in the eastern exposures of this zone along the line of section HI (Plates 1, 2) (see below). The Western Arm Group is correlated with the nearby and lithologically very similar Snooks Arm Group, which has yielded a sparse graptolite fauna of Arenigian age (Snelgrove, 1931), the only other datable fauna yet found in this zone. The Snooks Arm Group rests conformably on the Betts Cove Ophiolite Complex (Upadhyay, et al., 1971) which indicates that the basement to this zone, at least locally, is oceanic (Plate 3, Column 11; Plate 2, Section FG. The volcanics in the Western Arm, Cutwell, and Roberts Arm Groups, and in the Snooks Arm Group above the ophiolite base, although they are mostly in greenschist facies, have been shown to have compositions compatible with origin in an island arc tectonic setting. The volcanics of the Little Bay Head Group are tholeiites (Papezik and Fleming, 1967) and their tectonic setting cannot be isolated from the composition. Pillow lavas of the Betts Cove Ophiolite Complex are, in part, basaltic komatiites (Upadhyay, 1978).

Mafic pillow lavas and lesser rhyolites, rhyolite breccias and volcaniclastics of the Sleepy Cove Group form the oldest rocks along section HI (Williams and Payne, 1975) and are probably of Cambrian age (Plate 2). They are highly foliated in the southern part of their outcrop, and locally are metamorphosed to amphibolites. They are geochemically similar to rocks of island arcs (Strong and Payne, 1973; Williams and Payne, 1975). The Sleepy Cove Group has been intruded by the Twillingate "Granite" (tonalite-granodiorite) that has been dated by U/Pb on zircons at 510± 17 Ma., and mafic dikes that cut it post-kinematically have yielded ^{40}Ar/^{39}Ar ages on hornblende of 448± 10 and 482± 9 Ma. (Williams, et al., 1976). These mafic dikes are interpreted as feeders to the adjacent Herring Neck and Moreton's Harbor Groups which consist of mafic dikes and pillow lavas, and minor mafic volcaniclastics that occur to the south and west of the "Twillingate "Granite". A structural unconformity is therefore indicated by the relationships in this area (Williams and Payne, 1975) between these two sets of rocks. The younger volcanics are probably of early Ordovician age based on the ages of the dikes cited above.

The early to medial Ordovician Roberts Arm Group is separated from presumed late Silurian-early Devonian red sandstones and conglomerates of the Springdale Group by an angular unconformity. The Springdale Group occurs only in the western part of this zone near section BC (Plate 2), where it also overlies the Little Bay Head Group with angular unconformity. It consists of a thick section of subaerial bimodal volcanics including much ignimbrite, with lesser red sandstones which are dominant as the top unit in the section. The lithologically correlative Mic Mac Lake Group in the Fleur de Lys Zone has been dated by an Rb/Sr whole-rock isochron of 388± 15 Ma. (recalculated from Pringle, 1978).

Moderately to weakly consolidated Carboniferous sedimentary rocks are preserved in a small area near the line of section BC close to the northwestern boundary of the zone. They consist of about 1400 meters of gently to moderately dipping red conglomerates, sandstones, and limy shales which rest unconformably on adjacent older rocks (Neale and Nash, 1963).

Structure

Foliation in the Mansfield Cove tonalitic pluton and associated deformed mafic rocks (Bostock, et al., 1979) could be of pre-Ordovician age; it is likely to be older than mid-Ordovician since the adjacent Roberts Arm volcanics do not in most places possess any foliation. A similar structural situation exists for the Twillingate pluton and Sleepy Cove Group (Section HI, Plate 2) relative to the adjacent less deformed Moreton's Harbor Group (Williams and Payne, 1975), but there the constraints on the age and distribution of the early deformation are much better preserved. Unfoliated mafic dikes identical to those that feed lavas in the younger Moreton's Harbor and Herring Neck Groups cut a steeply inclined foliation in greenschists and amphibolites of the Sleepy Cove Group, in the southern part near the Chanceport Fault. However, to the north, over a few kilometers, the Sleepy Cove Group becomes less deformed and in places it and the Twillingate pluton appear virtually undeformed. The main steep northeast-trending foliation well developed in part of the Twillingate pluton passes into a crenulation foliation (S_2) in the intruded mafic rocks. The younger volcanic units in the area do not in most places show a cleavage, but stratification is often vertical, implying that they are tightly folded, generally about north-east trending axes. This folding is presumed to be medial Devonian (Acadian) but its age is not tightly constrained here.

To the west, along section BC in the area of western Notre Dame Bay, the Roberts Arm Group shows close to tight upright folds with northeast to east-trending axes. These rocks do not in most places have any well developed foliation. To the north of the Lobster Cove Fault, rocks of the early Ordovician Cutwell, Western Arm and Snooks Arm Groups are affected by the same style of folds mostly trending east to northeast, locally southeast. A steep slaty cleavage is in places weakly to moderately developed in sedimentary rocks but the volcanics are mostly unfoliated. Along the Lobster Cove Fault near Section BC the ?Silurian and early Devonian Springdale Group (Kalliokosi, 1953; Neale and Nash, 1963) is steeply dipping and rests disconformably (Dean and Strong, 1977) or unconformably (Bostock et al., 1979) on the Ordovician Roberts Arm Group. Large-scale northeast-trending open folds that affect the main area of the Springdale Group west of section BC are probably of Acadian age. The relationship cited by Bostock, et al. (1979) and the tighter geometry of the folds in the early Ordovician rocks suggests that some of the folding that affects them is of pre-Acadian age.

The Little Bay Head Group, like the Sleepy Cove Group, shows strongly inhomogeneous deformation (Kennedy and DeGrace, 1972). Zones of high strain that contain a strong, steeply dipping, northeast-trending cleavage or schistosity predate the widely-developed steeply dipping northeast-trending regional cleavage. This regional cleavage can be traced into the early Ordovician volcanic and volcaniclastic rocks of the Western Arm Group, although it is generally more weakly developed in these younger rocks. It is possible that the early high strain zones in the Little Bay Head and Sleepy Cove Groups are of early Ordovician-late Cambrian age, but the major foliations and folds regionally developed in the Notre Dame Zone are most likely of late Ordovician and/or Acadian ages. Minor later crenulations and kink bands are common in the well foliated rocks of the Little Bay Head Group.

Dean and Strong (1977) suggested that some of the major northeast-trending faults in the Notre Dame Zone and the faults that form its boundary with the Exploits Zone are folded, originally southeast-directed, pre-Acadian thrust faults. Other steep faults in this zone, particularly the fault forming the northwestern boundary on section BC (the Kings Points-Green Bay Fault) are likely to have had Carboniferous strike-slip movement. Carboniferous rocks are found in small areas adjacent to the Kings Point-Green Bay Fault, and it is known to offset the large plunging syncline containing the Snooks Arm and Western Arm Groups by about 20 km in a dextral sense.

Metamorphism and Plutonism

Metamorphic grade in the Notre Dame Zone is almost wholly in low greenschist to sub-greenschist facies, except very locally in the older, well-foliated rocks where upper greenschist-lower amphibolite facies has been attained in small areas, and in hornfels close to plutons. The Roberts Arm Group near section BC is in prehnite-pumpellyite facies (Bostock, et al., 1979). Some of this metamorphism is likely to be early Ordovician or older, but the bulk is probably of either Acadian or late Ordovician age, coincident with the episodes of deformation in the zone.

A range of plutonic rocks intrudes this mafic volcanic dominated zone, the oldest of which are the tonalitic bodies dated as late Cambrian at Twillingate to late Precambrian-Cambrian at Mansfield Cove. A small layered gabbro-trondhjemite pluton dated by $^{40}Ar/^{39}Ar$ as 503± 5 Ma. (Stukas and Reynolds, 1974a) intrudes mafic volcanics (possibly Cutwell Group) near section BC, and small dioritic to granitic plutons also occur in this area, intruding the Roberts Arm Group. One of these has been dated (Rb/Sr isochron 464± 13 Ma. by Bostock, et al., 1979), but others not yet dated are in part likely to be Devonian since one at least intrudes the Springdale Group. Granitoid plutons in this zone, as in the adjoining Exploits Zone, tend to be on average more mafic than in adjoining zones, perhaps reflecting the nature of the basement (Dewey and Kidd, 1974). The older tonalite-trondhjemite plutons are interpreted as genetically related to the volcanic rocks they intrude, and both probably formed largely in an island arc above an oceanic foundation. Dikes of a wide range of compositions, from basalt to rhyolite, are very abundant in many parts of the Notre Dame Zone, in contrast to most parts of adjacent zones. In most cases the age of an individual dike is not known with any precision but examples range from pre-dating the earliest foliation to wholly postdating the cleavage in the Ordovician volcanic sequences. No dikes are known to cut the Carboniferous rocks and thus the dikes are probably Devonian or older. Lithological characteristics suggest that many of them are likely to be cogenetic with the Ordovician volcanic rocks.

Nature of the Boundary with the Exploits Zone

Along section HI, the boundary with the Exploits Zone is formed by the Lukes Arm Fault, which trends southwest with a very straight trace. Rocks exposed near the trace suggest that it is a steep zone of late brecciation, and is probably an Acadian and/or Carboniferous fault with some strike-slip displacement. On section BC (Plate 2), the boundary is also occupied by a fault, the Sops Head Fault (Dean, 1977; Nelson, 1981). Although this is also now steeply dipping, the adjacent olistostromic melange (Boone's Point Complex; Helwig, 1967; Nelson, 1981) of late Ordovician-early Silurian age, which contains fragments of mafic volcanic rock, suggests that the boundary here is a folded thrust of late Ordovician-early Silurian age (Nelson, 1981) like the Lobster Cove Fault (Dean and Strong, 1977). The Lukes Arm Fault may be a later structure that cuts this older boundary near section HI. However, olistostromes of similar age near the northern boundary of the Exploits Zone on New World Island (McKerrow and Cocks, 1978, 1980) can be interpreted in the same framework. No undoubted ophiolite complex-derived blocks are present in these olistostromes; all exotic blocks are of mafic and silicic volcanic and volcaniclastic rock, inferred to be derived from the Notre Dame Zone.

Exploits Zone

Stratigraphy

The stratigraphy of the Exploits Zone along the line of the geotraverse is summarized in columns 13-16 of Plate 3, and the disposition of the rocks illustrated in Plate 2, Sections BC and HI. The stratigraphy of the western part of the zone has been summarized by Dean (1977). The lower part of the succession is represented by a thick mixed sequence dominantly of volcaniclastic sediments, shales and cherts, with lesser pillowed and massive mafic and silicic lavas, and locally extensively intruded by gabbro and capped in some places by a mafic lava unit. In the northeast a persistent shallow-water limestone occurs in association with these volcanics (Plate 3, column 15). Black shales with cherts and minor fine-grained greywackes form an extensive unit which ranges from late Llandeilian to early Ashgillian across the zone (Plate 3). These black shales are overlain by thick quartzofeldspathic greywackes generally known as the Sansom Greywacke. They show a north to northwesterly derivation and are overlain by coarse paraconglomerates of the Goldson Group. Greywackes within the Goldson show a similar provenance (Helwig and Sarpi, 1967; Eastler, 1969; Kay, 1976).

In the extreme northeast of this zone (Column 16, Plate 3), the lower part of the succession is represented by the Dunnage Melange, a bouldery mudstone with boulders and larger blocks of greywacke, limestone, argillite, and pillow lava, in a black and green shale matrix (Kay, 1976; Hibbard and Williams, 1979). Fossils from blocks within the Dunnage and from its matrix indicate that it represents an interval from medial Cambrian to early Ordovician (Kay and Eldredge, 1968; Hibbard, et al., 1977) but it may include older rocks and rocks as young as Llandeilian. It is locally conformably overlain by a thin clastic sequence including conglomerates containing pebbles of porphyry similar to small intrusions that occur within the Dunnage. The conglomerates are overlain by the ubiquitous Caradocian black shale. The Dunnage Melange has been interpreted as a gravity slide by Horne (1969) and as a trench accretionary prism deposit by Bird and Dewey (1970), Kay (1972; 1976) and McKerrow and Cocks (1978). Hibbard and Williams (1979) conclude that it was probably deposited as a gravity slide either in a fore-arc trough or in a rear-arc basin. It is interpreted to overlie and to interdigitate with gabbro sill-infested early Ordovician volcaniclastic turbidites farther to the southwest. The Sansom Greywacke that overlies the black shales above the Dunnage extends up into the medial Llandovery in this region. It is overlain or perhaps intercalated with an olistostrome containing blocks of Ordovician rocks. Turbiditic siltstones and paraconglomerates of the Goldson Group overlie the Sansom (McKerrow and Cocks, 1978). Slightly younger Silurian rocks in the western and south-central parts of this zone are represented by shallow-marine clastics overlain by mainly silicic volcanic rocks followed by red beds.

Structure

Slaty cleavage affects most of the rocks of the Exploits Zone. It is generally steep, trends from northeast to east and is considered to be of Acadian age. At the northeastern extremity of this zone the stratigraphic succession occurs as a southeast-dipping and northwest-younging sequence. In places the beds face upwards to the northwest and the cleavage and associated folds are overturned to the southeast (Plate 2, Section HI), indicating that the cleavage was superimposed on originally steeply inclined beds. In some cases, the cleavage may not be coeval with folding, since it is not everywhere an axial plane cleavage, and some folds in this region may be slump folds. It is possible that the cleavage has originated in a wide zone as a response to dextral ductile shear. Crenulations and kink bands locally affect this cleavage. In the central and western part of the zone the large scale upright folds bear a normal relationship to the slaty cleavage (Plate 2, Section BC). The Silurian rocks overlie the late Ordovician conformably. Locally, in the east, a reported unconformity (Kay, 1969) has been reinterpreted as an olistostrome within a conformable sequence (McKerrow and Cocks, 1978).

Cleavage in the Dunnage Melange may be partly the product of soft-sediment deformation but it has generally not proved possible to separate these effects from subsequent cleavage that affects both Ordovician and Silurian rocks. Locally, where folded cleavage occurs in the Dunnage, the older cleavage is cut by porphyry intrusions whereas the younger cleavage post-dates them.

Metamorphism and Plutonism

Metamorphism is in the greenschist to subgreenschist facies except close to granitoid intrusive rocks. The Dunnage Melange is cut by dacite porphyry dikes which have yielded K/Ar ages of 402± 12, 438± 13, 452± 13 Ma., and a remarkable dacite porphyry rich in (mostly altered) ultramafic xenoliths with asbestiform borders gave Rb/Sr ages on biotite of 470 Ma. (using 1.42×10^{-11}/yr decay constant, recalculated from Kay, 1976). It is probable that these intrusions were emplaced during or at the termination of melange formation, since pebbles and boulders of similar porphyry dominate in conglomerates immediately overlying the melange. Gabbros that cut volcaniclastic rocks in parts of the zone are probably also related to medial Ordovician volcanism.

Two relatively large plutons occur in the northern part of the Exploits Zone. The Hodges Hill pluton west of C on the geotraverse (Plates 1 and 2) is a composite gabbro-diorite-grandiorite body that intrudes Ordovician rocks. The Loon Bay Granodiorite (including the Long Island body) which also intrudes Ordovician rocks in the eastern part of this zone is probably of Devonian age. Xenoliths from this pluton have yielded K/Ar whole-rock ages of 372± 10 and 379± 10 Ma. (Kay, 1976). Felsic dikes also of probable Devonian age are found in some places.

Lamprophyre dikes of Jurassic age are widespread in parts of the zone. Associated alkaline ultramafic-mafic stocks occur in two places within the central part of the zone (Strong and Harris, 1974; Helwig, et al., 1974).

Nature of the Boundary with the Botwood Zone

The Reach Fault, which forms the boundary between the Exploits and Botwood Zones in the northeast, has been interpreted as a transcurrent fault by most workers (Williams,et al., 1972, 1974; Kay, 1976) since it is characterized by a wide shatter zone and by lenticles of exotic rock in places along its length. The sense and magnitude of displacement are unknown. It is offset sinistrally by northnortheastward trending faults in several places. It has been correlated with the Cape Ray Fault of southwestern Newfoundland, interpreted as a cryptic suture by Brown (1973) because crystalline basement rocks of the northwest and southeast sides of the orogen are juxtaposed there. This has led others to consider the Reach Fault to mark the line of the main suture in northern Newfoundland (Kennedy, 1975; McKerrow and Cocks, 1977). Ordovician benthic faunas on each side of the fault belong to contrasting faunal provinces (McKerrow and Cocks, 1977), which is the best evidence that the Reach Fault occupies the site of the suture formed by closure of the Appalachian-Caledonian (Iapetus) Ocean. The present fault is probably a transcurrent fault of large offset, and which has severely modified the original Acadian suture zone. It should not be regarded as "the suture", merely as the zone across which the faunas now show a distinct contrast. Brecciated granodiorite in the fault zone is cut by undeformed lamprophyre dikes of presumed Jurassic age.

Botwood Zone

Introduction

The Botwood Zone is bounded on the northwest by the Reach Fault which separates it from the Dunnage Formation (Section HI, Plate 1) in the New World Island area (Williams, 1964b; Kay, 1972). Farther to the southwest the continuation of the Reach Fault separates stratified volcanic and sedimentary rocks of the Exploits Zone from the Botwood Zone.

The Botwood Zone differs from the Exploits Zone not only in Ordovician faunas but also in stratigraphy. The bulk of the Ordovician succession consists of fine-grained slates with minor mafic and silicic volcanic rocks. It contains coarser-grained volcaniclastic sediments near its exposed base. Persistent units of limestone are absent. The Silurian rocks of the Botwood Zone are generally similar to those of the Exploits Zone but volcanic rocks are even less extensive.

Stratigraphy

The Ordovician Davidsville Group rests unconformably upon ultramafic rocks of the Gander Zone on Section CD (Column 18, Plate 3) where coarse conglomerates contain pebbles of schistose serpentinite, gabbro, diabase, dark phyllite, amphibolite and quartzofeldspathic schist together with detrital muscovite, biotite, chromite and garnet, interpreted to be derived from rocks of the Gander Zone (McGonigal, 1973, Kennedy, 1976). These conglomerates pass upwards through interbedded grey slates and felspathic sandstones with conglomerate beds, locally rich in quartz porphyry pebbles, into mafic tuffs overlain by calcareous sandstones and slates containing an Ordovician (Caradocian) brachipod fauna (Jenness, 1958, 1963). These are in turn overlain by a thick sequence of graded grey slates with minor red and green slate interbeds. Detrital mica and chromite are ubiquitous in the coarser sediments. Most of the slates in the Davidsville Group are fine-grained "distal" turbidites. North of section CD other fossil localities in these grey slates and in limestone have also yielded Caradocian faunas (Jenness, 1958, 1963; Bergstrom, Riva and Kay, 1974). Conodonts from this limestone, which occurs in probable fault contact with rocks of the Gander Zone, indicate a late Llanvirnian to early Llandeilian age (Stouge, 1980).

The base of the Davidsville north of the line of section CD is marked by coarse conglomerates containing gabbro, trondhjemite and serpentinite pebbles and boulders derived from adjacent rocks of the Gander Zone. Farther north again, the base of the Davidsville is marked by an olistostromic melange containing a variety of lithologies including pillow lava, limestone, greywacke, gabbro and serpentinite olistoliths. Less commonly, metasedimentary and metavolcanic clasts containing pre-depositional tectonic fabrics and metamorphic mineral assemblages are found within the melange and these have been interpreted by Kennedy and McGonigal (1972), and by Kennedy (1976) to have been derived from the adjacent Gander Group. Pajari, et al. (1979) suggested that these clasts were produced during melange formation, related to emplacement of the ophiolitic rocks of the Gander River Ultramafic Belt (Plate 2). In the extreme north, on the coast, pillow lavas, limestones and limestone breccias, mafic breccias, and mafic volcaniclastics are present within the lower parts of the Davidsville Group.

The Davidsville rocks along section CD are succeeded westwards by graded and cross-bedded buff to grey sandstones with dark slate interbeds, assigned to the Botwood Group. Graptolites from these rocks have indicated an early Ludlovian age (Berry and Boucot, 1970). These rocks are overlain westwards by cross-bedded red sandstones of the Botwood Group. The close proximity of fossiliferous Ludlovian and Caradocian rocks in this region may indicate a disconformity in the sequence but the contact between the two groups is not exposed.

At the southeastern end of Section HI (Plate 2) Silurian rocks of the Indian Islands Group (Williams, 1964b, 1967a, McCann and Kennedy, 1974) are exposed in a syncline (Column 17, Plate 3). The succession may include Ordovician rocks correlative with the Davidsville Group at its base, although the relationship between Ordovician and Silurian in this region has been interpreted as a fault (Williams, 1964). The base of the succession along the traverse consists of black slates and siltstones with thin limestones overlain by grey siltstones and slates with minor limestones. Corals in the limestone beds have been taken to indicate an early Silurian age (Twenhofel, 1947) but preservation is poor and a Late Ordovician age is also possible. Farther to the northwest, these rocks are in faulted contact with unfossiliferous grey to buff slates, siltstones and greywackes containing a diamictite unit. The diamictite comprises finely laminated slates and sandy siltstones containing outsize rounded to subangular clasts (dropstones?) 0.5 to 30 cm in diameter, composed of silicic volcanic rocks, quartz-feldspar porphyry, granodiorite and sedimentary rocks. It has been interpreted as a possible glaciomarine deposit by McCann and Kennedy (1974). This conglomerate unit is considerably thinner on the northwest limb of the syncline (section HI); the conglomerates are here interbedded with greywackes and probable dropstones are absent. The diamictite unit is overlain by siltstones and a volcanic unit of interbedded agglomerate, crystal and lithic tuffs and andesite-dacite flows. The top of the succession is formed by sandstones and siltstones with abundant ripple marks and ripple-drift cross-lamination and local conglomerates with volcanic rock fragments. This uppermost sandstone unit may rest upon a disconformity because the lower members of the unit are absent on the southeastern limb of the syncline. The continuation of these rocks to the northeast on the Change Islands has yielded a shelly fauna indicative of Llandoverian age (Eastler, 1969).

Structure

Slaty cleavage is ubiquitous in rocks of the Botwood Zone along both sections but it is poorly developed to absent to silicic volcanic rocks and siliceous sediments. Pelitic rocks in this zone are typically slates, in contrast with the Exploits Zone where cleavage is generally not as well developed. The major folds shown on Plate 2 (Sections CD and HI) were formed in association with the development of this cleavage. Minor folds are rare in the rocks of the Botwood Zone. The slaty cleavage developed in response to a northwest-southeast shortening and sub-vertical extension strain. Locally, sub-horizontal extension strain in the cleavage becomes dominant and variations in the magnitude of this strain has resulted in local downward-facing folds. Since the slaty cleavage involves rocks as young as Late Silurian it is generally considered to be of Acadian (medial Devonian) age. Locally this cleavage is redeformed by steep crenulation cleavage and also by sub-horizontal crenulations and kink bands.

The melange and locally derived conglomerates at and close to the base of the Davidsville Group suggests that faulting was probably active during sedimentation in this part of the Zone. Most mapped faults appear to be late features. The Reach Fault contains breccias and mylonites along it in the New World Island area. It has probably had a long and complex movement history.

Metamorphism and Plutonism

Regional metamorphism is in the low greenschist to sub-greenschist facies throughout this zone along the traverses. Sericite and chlorite occur ubiquitously in slates, and chlorite, actinolite and epidote occur in mafic rocks. Metamorphism is synchronous with the development of the slaty cleavage. Silurian rocks are intruded by a large composite gabbro-diorite-granodiorite pluton in the western part of Section CD which has led to the development of a narrow aureole of hornfels in the country rocks. This pluton has yielded a Rb/Sr isochron of 393± 30 Ma. (Bell, et al., 1977). A small granitoid pluton also cuts Silurian? rocks at the southeastern end of section HI. Mafic and silicic dikes probably related to volcanism occur in Ordovician and Silurian rocks throughout the zone but they are not numerous. Quartz diorite, granodiorite and quartz monzonite plutons are common in the Davidsville Group north of Section CD. Metamorphic grade in the Davidsville Group on the coast north of Section CD is significantly higher, reaching sillimanite grade locally, but with widespread garnet, andalusite, and cordierite. Ultramafic rocks and gabbros within the Davidsville Group along Section CD are interpreted as faulted against the surrounding rocks. It is possible that some gabbros may intrude the Davidsville but the majority of these rocks are believed to represent faulted extension of the older mafic and ultramafic rocks of the Gander Zone. Lamprophyre dikes of late Jurassic-early Cretaceous age cut Silurian rocks of the Botwood Zone close to the Reach Fault.

Nature of the Boundary with the Gander Zone

The contact between rocks of the Botwood and Gander Zones is interpreted in many places as a fault. However, along the line of section CD, conglomerates at the base of the Davidsville Group rest unconformably on ultramafic rocks of the Gander River Ultramafic Belt. The presence of detritus from this belt, and from other rocks of the Gander Zone, within the Davidsville Group indicates that this zone boundary is essentially marked by an unconformity, although it is now generally modified by faulting (Kennedy and McGonigal, 1972; Kennedy, 1976; Blackwood, 1979). Pajari et al., (1979), in contrast, have considered that the boundary between the Botwood and Gander Zones is essentially conformable. The coarse aspect and locally-derived nature of conglomerates along the contact suggest to us rapid uplift and erosion of the adjacent terrane during deposition of the basal Davidsville sediments.

Gander Zone

Introduction

The Gander Zone is characterized by a thick sequence of dominantly semi-pelitic to psammitic quartzofeldspathic metasediments which have generally been metamorphosed in the upper greenschist to low amphibolite facies. This sequence overlies a sequence of gneisses and migmatites. Granitoid plutons are widespread, particularly in the eastern part of the zone, and ultramafic and mafic plutonic rocks occur as a distinct belt along the western side of the zone and as small bodies within it. The rocks of the Gander Zone show evidence of having been deformed, metamorphosed and eroded in pre-Caradocian time before deposition of adjacent rocks of the Botwood Zone.

Stratigraphy

Gneissic rocks form the base of the succession in the Gander Zone (Kennedy and McGonigal, 1972; Blackwood and Kennedy, 1975). They can be divided into two units along the line of Section CD (Figure 3); a westerly unit of largely semi-pelitic and psammitic metasedimentary gneisses, and an easterly unit of tonalitic migmatites derived from the former (Blackwood, 1977). These gneissic rocks have been suggested to be basement to the eastern side of the Appalachian belt, but isotopic ages confirming this idea are lacking. Blackwood (1978) has considered them to represent higher grade and migmatized equivalents of the Gander Group metasediments exposed farther to the west, following earlier interpretations proposed by Jenness (1963). Hanmer (1981) has elaborated on this interpretation. The age of these gneissic rocks is unknown. They are intruded by a variety of granitoid plutons which have yielded a range of Rb/Sr whole-rock isochrons with ages mostly in the range 345-440 Ma. (Bell, et al., 1977). These plutons post-date the gneissic foliations.

The gneisses are overlain by metasedimentary rocks of the Gander Group (Plate 3, Column 19). The contact is not exposed along Section CD but the relationships across the contact have been interpreted to indicate that the gneiss complex forms a basement to the Gander Group and has suffered major deformation and metamorphism before that of the Gander Group (Kennedy and McGonigal, 1972; Colman-Sadd, 1974; Kennedy, 1976; Blackwood, 1977). This interpretation is based upon contrast in structural complexity between the two units, intrusive bodies that cut the gneisses after the formation of the gneissic foliations but are deformed with the overlying Gander Group and the overprinting of fabrics of the cover rocks upon the gneisses of the basement terrane. It is probable that the present contact between these two units is tectonic, where it is not obliterated by plutons.

The stratigraphy of the Gander Group is summarized in Plate 3, Column 19. The bulk of the succession consists of quartzofeldspathic schists (quartz wackes) locally graded and cross-bedded, with interbedded pelites. Some of the quartz wackes are calcareous and they contain detrital microcline and albite/oligoclase in small quantitites. These are overlain by a thin unit of graphitic schists with thin quartzofeldspathic interbeds which are in turn overlain by mafic schists, possibly containing relict pillow lavas. The Gander Group is unfossiliferous and its exact age is unknown. Since it provided detritus to the overlying Davidsville Group it is of pre-late Llanvirnian age. Changes in sedimentation history of the adjacent Avalon Zone to the east have been interpreted to indicate that the Gander Group was deformed and metamorphosed in late Precambrian (late Hadrynian) time (Kennedy, 1976, 1979; see below). Correlation with similar rocks in an equivalent tectonic position in the Caledonian orogen of the British Isles also lends support to the suggestion that the Gander Group may be Precambrian in age. The clastic rocks of the Gander Group provide no direct indications of provenance except that they had a continental source.

A suggestion of an easterly/southeasterly derivation comes from the occurrence of thicker and coarser (perhaps more proximal) psammitic beds in the eastern part of the area.

The Gander Group is separated from the Ordovician sediments of the Botwood Zone along Section CD by a suite of mafic and ultramafic rocks forming the Gander River Ultramafic Belt (Figure 3). These consist of serpentinites, pyroxenites, gabbros, trondhjemites and pillow lavas, which are now generally regarded as a dismembered ophiolite suite (Kennedy, 1976; 1979; Pajari et al., 1979) although the alternative interpretation of mantle diapirs has also been uttered (Malpas and Strong, 1975). The contact with the Gander Group is not exposed along the line of Section CD, but elsewhere it is considered to be a thrust. The association of melange and ophiolitic rocks at and near this contact suggests that large displacements have occurred between the rocks on either side of the contact zone. Pyroxenites are mylonitized close to the contact. Gabbro and serpentinite also occur as fault-bounded slivers within the Davidsville Group. Rocks of the Gander River Ultramafic Belt have provided detritus to the Davidsville sediments and hence they are of pre-late Llanvirnian age.

Structure

The gneisses of the Gander Zone have been subjected to an involved sequence of deformations. The metasedimentary gneisses and amphibolites that occur both as xenoliths in migmatites and as more extensive regions of non-migmatized rocks have suffered polyphase deformation with the formation of transpositional gneissic layering, which itself has been complexly refolded before the gneissic foliation of the migmatites was formed. All the gneisses are overprinted by a steep cataclastic foliation which is parallel to and intensifies into the cataclastic foliation of the Dover Fault Zone, which forms the southeastern boundary of the Gander Zone. A late foliation also overprints the gneisses close to the contact with the Gander Group. No major fold structures have been recognized in the gneisses but small scale folds are common.

The rocks of the Gander Group along Section CD (Plate 2) are disposed in large-scale generally southeasterly facing folds that are recumbent along the central part of the traverse and become upward facing close to the gneisses. These folds also become upward facing close to the boundary with the Botwood Zone. The folds are the product of the second recognizable deformation which has formed the dominant foliation of the Gander Group. This S_2 foliation and the associated F_2 folds deform an earlier foliation with associated minor folds that have been largely destroyed by subsequent deformation and recrystallization. Later crenulations, crenulation cleavage/schistosity, and kink bands, are superimposed on these major recumbent F_2 folds. No post-F_2 large scale folds have been identified in the Gander Group, but the earliest of the post-D_2 crenulation foliations is folded along with the S_2 foliation close to the contact with the Botwood Zone. This steepening of Gander Group structures is interpreted to be the result of Acadian (medial Devonian) deformation since the Davidsville Group, the basal unconformity and Silurian rocks are also involved within the Botwood Zone. Foliation locally developed in mafic and ultramafic rocks along the western edge of the Gander Zone is tentatively correlated with the main S_2 foliation of the Gander Group, but it may be younger. These rocks were clearly foliated before deposition of the Davidsville Group and were probably overthrust over the Gander Group at much the same time it was itself being deformed. It is also not clear what effect the Acadian slaty cleavage of the Botwood Zone had upon adjacent rocks of the Gander Zone apart from resulting in steepening of earlier structures close to the contact. However, sub-horizontal crenulations on steep foliation surfaces in the Gander Group may be equivalent to similar crenulations on the steep slaty cleavage of the adjacent Botwood Zone. If this is correct, at least the first three deformational episodes of the Gander Group are pre-Acadian. Fragments identified as derived from the Gander Group that occur in melange within the Davidsville Group north of traverse CD support this conclusion.

The mafic and ultramafic rocks on the western edge of the Gander Zone are locally intensely brecciated and cut by diabase. It would appear that this line has been the site of continued movement so that the unconformable relationship between the Botwood and Gander Zones is only locally preserved.

Plutonism

In general, granitoid plutons in the Gander Zone are more potassic than those in the Botwood Zone. The Botwood Zone is characterized by quartz-diorites and granodiorites whereas the Gander Zone contains numerous quartz monzonites and granites (Dewey and Kidd, 1974; Strong, et al., 1974; Jayasinghe and Berger, 1976). Along Section CD the gneisses are cut by two plutons. The most westerly is a massive porphyritic biotite granite that cuts the gneisses post-kinematically and post-dates the late foliation that is superimposed on the gneisses. It has yielded an Rb/Sr isochron of 435± 20 Ma. (Bell, et al., 1977). The more easterly pluton is a coarse megacrystic biotite granite with large K-feldspars which predates the late foliation of the gneisses. It has yielded an Rb/Sr isochron age of 311± 30 Ma. (Bell, et al., 1977) and a U/Pb zircon age of 460± 20 Ma. (Dallmeyer et al., 1981). This pluton is affected by the late cataclastic foliation that passes into the Dover Fault, whereas the more westerly pluton cuts and is therefore later than this foliation. Farther west, a large granitic pluton occurs just south of the line of Section CD, within the Gander Group. It has not been isotopically dated, but it cuts the main S_2 schistosity of the Gander Group metasediments.

The Gander Zone as a whole is characterized by muscovite and/or biotite-bearing granites that are locally garnetiferous. Aplites and pegmatites are particularly rich in garnet. Although some of these bodies are involved in the early deformations of the Gander Group and must thus be older than the Davidsville Group, others occur in the Davidsville rocks, particularly as dikes, and hence must be younger.

Gabbro also occurs locally as small plutons cutting the gneisses of the Gander Zone. The Gander Group also locally contains plentiful amphibolites, the deformed and metamorphosed relicts of mafic sills and dikes. These may be related to mafic metavolcanics in the upper part of the Gander Group.

Metamorphism

Metamorphism in the gneisses of the eastern part of the Gander Zone is generally in the amphibolite facies. Garnet and sillimanite occur in the metasedimentary gneisses and cordierite and andalusite are developed in the aureoles of later granites which cut these gneisses.

Metamorphism in the Gander Group along Section CD is in the mid to upper greenschist facies with biotite, and locally garnet, being present in pelites. South of the traverse the grade is higher, reaching amphibolite facies, with widespread garnet and local staurolite (McGonigal, 1973). The main metamorphic mineral growth occurred between the first and second deformations. Later metamorphism, which also affects the adjacent rocks of the Botwood Zone, locally reaches andalusite and sillimanite grade. In Gander Group rocks this metamorphism post-dates the S_3 crenulation cleavage, whereas in adjacent Davidsville Group rocks it post-dates S_1 slaty cleavage. In both Groups it is overprinted by flat-lying crenulations, the second deformation in the Acadian sequence of structures. Clastic detritus in the Davidsville Group indicates that most of the metamorphism of the Gander Group is of pre-Caradocian age.

Nature of the Boundary with the Avalon Zone

The Gander Zone is in fault contact with the Avalon Zone across the Dover-Hermitage Bay Fault. On the traverse (Figure 3, CD) the fault consists of a mylonite zone 300-500 m wide that has undergone some later brecciation. South of the traverse it is represented by a breccia zone (Blackwood and O'Driscoll, 1976). The development of the fault zone has been recently reviewed by Kennedy et al., (1982). In the north, around the line of traverse CD, the mylonitic foliation on the fault passes laterally into a cataclastic foliation that overprints the gneisses and most of the granites of the Gander Zone. This includes the Lockyers Bay Granite which has yielded the U/Pb zircon isotopic age of 460± 20 Ma. (Dallmeyer et al., 1981). An adjacent granite unaffected by the foliation has yielded an Rb/Sr isochron of 435± 20 Ma. (Bell et al., 1977). The mylonites of the fault zone pass eastward into foliated volcanic rocks of the Precambrian-age Love Cove Group of the Avalon Zone. Phyllites of the Love Cove Group have yielded whole-rock $^{40}Ar/^{39}Ar$ ages of 309± 8, 316± 7, and 352± 10 Ma. (Dallmeyer, et al., 1981a) and U/Pb zircon ages of 590± 30 and 608± 25 Ma. (Dallmeyer, et al., 1981b). The $^{40}Ar/^{39}Ar$ ages can be interpreted to reflect the time of cooling after regional metamorphism and hence after the main movement on the Dover Fault, which is therefore Acadian. However, presence of foliated fragments of Love Cove lithologies in adjacent late Precambrian red beds suggests that earlier movement on this and related faults also occurred (Kennedy, et al., 1981). This is supported by the localization of small mylonitized equigranular granite plutons along the line of the Dover Fault. These have yielded a Rb/Sr whole-rock isochron of 414± 30 Ma. (Blenkinsop et al., 1976). The sense of movement along the Dover-Hermitage Bay Fault is not known directly but, since it brings a gneissic terrane on the western side in contact with a low grade terrane to the east, relative downthrow to the east is indicated. Hanmer (1981) suggested left-lateral strike-slip displacement from indirect evidence. The fault is cut by a large granitoid batholith (Ackley batholith) which gives an Rb/Sr isochron of late Devonian-early Carboniferous age (late Acadian), 357± 10 Ma. (Blenkinsop, et al., 1976). The same authors dated other granites near or on the fault and although the field relations and ages obtained allow alternative interpretations, they suggested that the fault was older than early Ordovician in its southern part. The fault is clearly a major fundamental feature whose latest main movement was of Acadian age (Kennedy et al., 1982, Dallmeyer et al., 1981)

Avalon Zone

Introduction

The Avalon Zone presents strong contrasts with the adjacent Gander Zone to the northwest. Metamorphism is low grade or absent, granitic plutons are rare and deformation is far less complex and intense (Figure 3, sections CD and MN). The Avalon Zone consists predominantly of late Precambrian (Hadrynian) rocks which can be subdivided into a basal unit of volcanic rocks which include basalts, rhyolites, and intermediate rocks overlain by a dominantly sedimentary unit of siliceous siltstones and greywackes which contain a tillite near the base (Bruckner and Anderson, 1971; Williams and King, 1976) and a well-preserved metazoan fauna near the top. Minor volcanic horizons are present. This unit is overlain by a sequence of non-marine cross-bedded red sandstones and conglomerates with local volcanic accumulations which include basalts and rhyolites. This sequence is overlain by shallow water marine sandstones and shales of Cambrian and early Ordovician age. Cambrian rocks contain a well preserved Atlantic trilobite fauna in contrast to the Pacific faunas found in the Humber Zone on the other side of the orogen. The late Precambrian (Hadrynian) red bed sequence rests with angular unconformity on older rocks in the western part of the zone. Cambrian rocks generally rest disconformably upon the red beds but locally, especially in the eastern part of the zone, the Cambrian rests unconformably on older rocks. In particular, the Cambrian rests non-conformably on a late Precambrian granite. No crystalline basement is exposed in the Avalon Zone but geophysical characteristics suggest that it is underlain by continental crust.

Stratigraphy

Intermediate and silicic volcanic rocks of the Love Cove Group (Jenness, 1963) form the base of the succession along Sections CD and MN (Plate 3, Columns 20, 21). They occur in two fault bounded belts and consist of a variety of rhyolites, basalts, andesites, tuffs, and volcaniclastic sediments with minor local conglomerates and other sedimentary rocks. Most of the Love Cove Group is strongly foliated. The Love Cove Group is interpreted to be overlain by the sedimentary rocks of the Connecting Point Group but all recognized contacts are faults in the vicinity of section CD. The Connecting Point Group consists predominantly of dark green and grey shales, siliceous siltstones and greywackes, but local red siliceous siltstones and minor volcanic rocks also occur. The Connecting Point Group is generally only weakly deformed and foliated in comparison with the Love Cove Group. This has led to the suggestion that the two may be separated by an unconformity (Jenness, 1961; Kennedy, 1976). Feldspathic fluvial red sandstones, shales and conglomerates of the Musgravetown Group rest with angular unconformity on the Connecting Point rocks at one locality in the northwestern part of the Avalon Zone (Jenness, 1962). However, south of Section MN, rocks of the Love Cove Group pass apparently conformably up into red beds of the Musgravetown Group (Hussey, 1978, 1979). It is thus probable that on a regional scale there is considerable facies change and that the Groups are, at least partly, lateral equivalents. Coarse conglomerates at the base of the Musgravetown Group contain schistose fragments of Love Cove lithologies, rare fragments of schistose granite, and pebbles of Connecting Point lithogies (Jenness, 1963; Blackwood and Kennedy, 1975; Kennedy, 1976). Detrital muscovite is common in many of the red sandstones and detrital muscovite, garnet and metamorphic rock fragments occur in similar conglomerates correlative with the Musgravetown Group in the eastern part of the Avalon Zone (Papezik, 1973; A.F. King, personal communication). Most of the conglomerates of the Musgravetown Group are rich in silicic volcanic pebbles and pebbles of other rock types are generally rare. The Musgravetown Group has been subdivided into a number of different formations by Jenness (1963) which include a unit of volcanic flows near the base (basalts and rhyolites) with associated tuffs (including ignimbrites) and volcaniclastic sediments in a sequence of red to buff cross-bedded sandstones and conglomerates. Volcanic rocks may occur at other levels in the red bed succession.

The nature of cross-bedding and the presence of mud cracks indicates that the succession is a shallow marine or non-marine deposit. Preliminary studies of provenance within the Musgravetown Group by Jenness have indicated that the sediments are northwesterly to southwesterly derived. The change in sedimentary environment from marine conditions of the Connecting Point Group to the probably non-marine, fluviatile conditions of the Musgravetown Group has been interpreted by Kennedy (1976) to be the result of orogenic activity in the Gander Zone to the west in late Precambrian (late Hadrynian) time.

The Musgravetown Group passes disconformably upwards into quartzites and sandstones along Traverse MN which are conformably overlain by Cambro-Ordovician sedimentary rocks (Plate 3, Column 21). The Cambrian succession consists of red and green shales near the base overlain by pink massive limestone overlain by further red and green shales. Minor limestones occur at several horizons. The lithology of the Cambrian rocks changes from red and green shales to dark grey shales in the mid-medial Cambrian. The base of the medial Cambrian is marked by a manganiferous zone. Medial Cambrian shales pass upwards into dark grey shales with limestone concretions that have yielded late Cambrian to Tremadocian faunas. These are the youngest rocks on Section MN but younger (Arenigian) sandstones and oolitic haematite beds occur farther east in the Avalon Zone (Rose, 1952). In the region of Section MN, mapping by Jenness (1963) showed the Ordovician rocks in contact locally with the Precambrian Connecting Point and Musgravetown Groups. However, poor exposure makes it impossible to distinguish between the possibilities of unconformable or faulted contacts. Medial to late Devonian, and early Carboniferous sedimentary rocks occur locally in the southwestern part of the Avalon Zone (Bradley, 1962; Williams, 1971; Howie and Barss, 1974).

The depositional history of the Avalon Zone in the late Precambrian is marked by a change from marine conditions of the Connecting Point Group, and its equivalent farther east, to non-marine red bed sedimentation (King, 1980). It has been suggested (Kennedy, 1976) that the change might be related to contemporary deformation and metamorphism farther west in the Gander Zone. Detrital metamorphic rock fragments, garnet and muscovite occur in the red beds (Jenness, 1963; Blackwood and Kennedy, 1975; Papezik, 1973), indicating uplift ofa crystalline source, but this has not been definitely identified as either the gneisses or the metasediments of the Gander Zone.

Structure

Rocks of the Avalon Zone are generally folded by tight to close north-northeast trending upright folds. Paleozoic rocks are usually preserved in the cores of the tighter synclines. The intensity of folding and the development of slaty cleavage varies considerably from place to place. Along Sections CD and MN (Figure 3), rocks of the Love Cove Group and, locally, of the Connecting Point Group, are tightly folded and display an associated penetrative slaty cleavage or phyllitic foliation. Folding and cleavage development in the Musgravetown Group in the same region is less intense. The presence of foliated pebbles of Love Cove lithologies in Musgravetown Group conglomerates shows that the Love Cove Group was at least locally foliated in the late Precambrian. This was probably only developed close to the Dover Fault and associated parallel faults within the Avalon Zone, because elsewhere within the Zone both stratigraphic relationships, and isotopic ages (Dallmeyer et al., 1981), indicate that the cleavage was formed in the Acadian orogeny. This cleavage also affects Cambro-Ordovician rocks, and the early Devonian rocks found locally in the southwestern part of the zone (Williams, 1971). The cleavage predates emplacement of a granite that has yielded a Rb/Sr isochron of 326± 5 Ma. (Bell, et al., 1977). The steep cleavage of the Avalon Zone is locally deformed by crenulation cleavages and kink bands, particularly where it is well developed.

The cleavage in the Love Cove Group near the Dover Fault passes laterally into the mylonitic foliation of the fault zone, indicating that the latest major episode of movement on the fault (Acadian) is contemporaneous with cleavage formation in Avalon Zone.

Faults within the Avalon Zone are generally late features. The faults that bound the two belts of Love Cove rocks in the western part of the Avalon Zone have probably had a long movement history as conglomerates in the Musgravetown Group near them are coarser than elsewhere. Fragments of Love Cove and other foliated rocks are numerous in conglomerates close to the faults. The sediments and depositional environment of the Musgravetown Group indicate that faulting was active during accumulation of this sequence.

Block faulting, granitic plutonism, gentle warping and uplift of Precambrian rocks in the eastern part of the Avalon Zone has been termed the Avalonian Orogeny by Lilly (1966). This term has been applied to movements of comparable age elsewhere in the Appalachian Orogen. However, if this late Precambrian activity is related to movements in the Gander Zone where deformation and metamorphism is more intense, another term such as Ganderian (Kennedy, 1975) may be more appropriate.

Metamorphism and Plutonism

Metamorphic grade within the Avalon Zone is generally low except in the aureoles of granitic plutons. The Love Cove Group has been subjected to low greenschist facies metamorphism. Chlorite and sericite are ubiquitous. Younger groups locally contain similar assemblages but are generally non-metamorphic. Prehnite has been identified in late Precambrian (Hadrynian) sandstones near St. Johns (Papezik, 1973) and may be more extensive within the Avalon Zone.

This zone contains scattered granitic plutons of a variety of ages. A small body of riebeckite granite occurs in the Connecting Point Group between the end of Section CD and Section MN (Jenness, 1963). It has generally been considered to be of Devonian age but may be younger since a peralkaline granite in the southern part of this zone has yielded a Rb/Sr isochron of 326± 5 Ma. (Bell, et al., 1977). Between Sections CD and MN a granitoid pluton that cuts the Love Cove and Musgravetown Groups has yielded a Rb/Sr isochron of 352± 10 Ma. (Bell, et al., 1977). South of Section MN Precambrian and Cambrian rocks are intruded by another granitoid pluton that Bell, et al., (1977) have dated by Rb/Sr isochron at 518± 30 Ma.; however, Dallmeyer et al., (1981) have dated the pluton at 580± 20 Ma. by U/Pb zircon analysis and also obtained ^{40}Ar/^{39}Ar cooling ages of 560 and 566± 15 Ma. from it. In the eastern Avalon Zone the Holyrood Granite that cuts Precambrian rocks and is nonconformably overlain by early Cambrian sediments has yielded a Rb/Sr isochron of 594± 11 Ma. (McCartney, et al., 1966). Both these granites are most probably comagmatic in a regional sense with the Love Cove Group volcanics and equivalents.

Discussion

The main aim of this paper is to present the cross-section of the Appalachians in Newfoundland and descriptions of the geology along the section. Interpretation has been deliberately kept to a minimum in the preceding text. This concluding section gives an outline of the currently more plausible interpretations. It is not meant to be a comprehensive, complete review of all previous interpretations. The Appalachian-Caledonian orogen was the first to be interpreted in modern terms, by Wilson (1966), as due to the opening and subsequent closing of a major ocean, in part using evidence from Newfoundland. Subsequent to Wilson's pioneering effort, more detailed interpretations and models of the orogen in Newfoundland have been presented by a large number of authors in a larger number of papers. Many aspects of the models are now regarded as inadequate or oversimplified in the light of present knowledge about the geology, and current models are likely to be superseded for the same reasons.

Beginning in the western part of the orogen in the Humber Zone, rifting of the North American continent is thought to have occurred in latest Precambrian time, based on the age of the basaltic dike swarm in Grenville basement and the occurrence of basalts conformably beneath clastic sediments containing early Cambrian fossils. This interpretation is implied by Dewey (1969) and Stevens (1970), and is explicitly outlined by Bird and Dewey (1970). Subsequent development of the Humber Zone through the early Ordovician involved the establishment of a carbonate platform on the subsiding passive continental margin (Stevens, 1970; Bird and Dewey, 1970). Deep-water sediments of the same age range deposited at the foot of the carbonate bank and on the continental rise are now preserved in the sedimentary thrust slices of the Humber Allochthon (Stevens, 1970). Deformed and metamorphosed equivalents of these deep-water sediments are found in the western Fleur de Lys Zone, but the bulk of the rocks in that zone consist of somewhat older metaclastic rocks and mafic metavolcanics formed during the active rifting of late Precambrian-early Cambrian age (Bursnall and Dewit, 1975; Dewey, 1969). Medial to late Ordovician development of the Humber Zone involves the rapid subsidence of the previously stable carbonate platform, and the progradation of flysch over the continental rise and onto the platform followed closely by the thrust sheets of the Humber Allochthon and the Bay of Islands Ophiolite (Stevens, 1970). This event is interpreted as the result of attempted subduction of the passive continental margin of North America (Stevens, 1970; Church and Stevens, 1971).

Rocks forming much of the eastern Fleur de Lys Zone and most of the Notre Dame Zone are the ?late Cambrian and early Ordovician volcanics and lesser plutonics of the island arc (Bird and Dewey, 1970) formed by the subduction of oceanic lithosphere prior to the collision of the arc with the North American passive margin (Williams and Stevens, 1974; Nelson and Casey, 1979). This island arc is suggested to have been built on an oceanic foundation (Bird and Dewey, 1970; Dewey and Bird, 1971). The oldest, often well-foliated mafic and trondhjemitic rocks of the Notre Dame Zone may be part of old oceanic crust and, in particular, have obtained their foliation and some of their metamorphic character from deformation in oceanic transform fault zones. The Baie Verte Lineament in the Fleur de Lys Zone has been identified by some as the simple root zone for the ophiolite nappes now seen in the Humber Zone, and hence as the suture between rocks of the Cambro-Ordovician continental margin of North America and the volcanic arc (Williams and St. Julien, 1978; Nelson and Casey, 1979). However, relationships of this structure, and those of the Betts Cove Ophiolite Complex, clearly indicate a more complex event, with the likely involvement of basins floored by oceanic crust that opened within the volcanic arc while subduction was taking place (Bird et al., 1971; Dewey and Bird, 1971; Upadhyay et al., 1971; Kidd, 1977; Kidd et al., 1978). These basins were immediately filled by detritus from the adjacent arc volcanoes and by volcanics related to the arc, and they may well have been pull-aparts connected with significant strike-slip faulting along the arc.

The early Ordovician rocks of the Exploits Zone are clastic sediments shed from the main volcanic arc (Bird and Dewey, 1970), probably into a rear-arc basin in which local and small volcanic accumulations related to the arc were built from time to time. At the eastern side of this zone, a lateral equivalent of the arc-derived sediments, the Dunnage melange (Horne and Helwig, 1969), has been a key element in many interpretations as a subduction melange. It is still not clear if this interpretation is valid, or whether this extensive melange should instead be viewed as a large strata-bound olistostrome (Hibbard and Williams, 1979). This particular problem of interpretation is responsible for much of the differences between tectonic models proposed for the pre-medial Ordovician history of central and western Newfoundland.

That history is now seen basically as due to rifting and establishment of a passive continental margin in earliest Cambrian time, and the formation of a major ocean (Appalachian Ocean, or Iapetus) by subsequent sea-floor spreading. Subduction to the east (present direction) within this ocean generated an island arc during early Ordovician, and perhaps latest Cambrian, times. The arc progressively approached the North American passive continental margin and collided with it during the later part of the early Ordovician. Thrust sheets of the Humber Zone, emplaced over the previously passive margin, had come to rest by medial Ordovician time, being overlain unconformably by fossil-dated neoautochthonous sediments (Stevens, 1970). Metamorphism and polyphase deformation within the Fleur de Lys terrain was, broadly speaking, an event coeval with the underthrusting of the continental margin and burial by the thrust sheets, although uplift and cooling lasted for a significant time afterward, as shown by the Silurian and Devonian ages of argon retention in metamorphic minerals. This arc-continent collision is the same that produced the classic Taconic thrusts and allochthons of New York and New England (Bird and Dewey, 1970) although the timing of equivalent events in that region is systematically later than in Newfoundland, requiring a diachronous collision (Rowley and Kidd, 1981).

Pre-medial Ordovician events in the more easterly zones of the Newfoundland Appalachians are less well understood because correlation between the zones is more difficult. The record in the Avalon Zone is most plausibly interpreted as resulting from late Precambrian rifting of continental lithosphere accompanied by extensive bimodal subalkaline vulcanism and plutonism (Strong et al., 1978). Sedimentation that accompanied the rifting is interpreted as due to progradation of major delta complexes into substantial water depths within the rifts, filling them together with the volcanics. Whether the large volumes of clastic sediments had a convergent orogenic source, or were just derived from uplifted rift horst blocks along strike, is not clear. Block faulting and gentle warping of the strata during the rifting explain local unconformities. Subsequent Cambro-Ordovician sedimentation in the Avalon Zone is of tectonically little disturbed shallow marine platform facies.

A significant uncertainty in the interpretation of the Newfoundland Appalachians occurs because correlation between the Gander and Avalon Zones has not proved possible. Kennedy (1976) suggests that the immensely thick quartzofeldspathic clastics of the Gander Group probably developed, like those of the Fleur de Lys Zone, as a prism of sediments at a passive continental margin during and shortly after rifting. Their occurrence adjacent to the rifted Avalon Zone suggests a possible connection but it is likely that faulting has significantly modified the original relationship. Additional uncertainty is also contained in the relationships of the metamorphic rocks of the Gander Zone to the dismembered ophiolites at its western side. It is presumed that eastward thrusting and obduction of these ophiolites and related rocks are connected with the beginning of the major polyphase deformation and regional metamorphism in the Gander Zone. Detritus from both ophiolites and Gander metamorphics are found in sediments of early Ordovician age which locally overlie the ophiolitic fragments unconformably. It is not clear, however, what kind of tectonic event resulted in the ophiolite obduction and dismemberment and, if collision with an island arc was involved, the arc itself has yet to be identified. At least one pluton in the Gander Zone has yielded an early Ordovician isotopic age and was perhaps emplaced, broadly speaking, at the same time as the major metamorphic and deformational event of the Gander Zone. Presumably, uplift and slow cooling followed, but isotopic cooling ages are presently not published for the Gander Zone, nor is there any known detrital evidence suggesting prolonged uplift of these metamorphic rocks.

The pre-medial Ordovician rocks of the Gander Zone and at least the eastern part of the Botwood Zone are taken as belonging to the Avalonian side of the system, because Cambrian and early Ordovician faunal provinciality (McKerrow and Cocks, 1976; 1977) require that a major ocean separated them from the Exploits and more westerly Zones. The faunas suggest that this ocean was of significant width, although shrinking, through the Silurian (McKerrow and Cocks, 1976). Rocks of medial Silurian to early Devonian age in the Notre Dame, Fleur de Lys and Humber Zones are mostly shallow marine or subaerial clastics, and volcanic rocks of calc-alkaline or alkaline affinity, which overlie older rocks with profound angular unconformity. Late Ordovician and early Silurian sediments in the Exploits and Botwood Zones are by contrast thick, deep-water, basin-filling greywackes, shales and olistostromes overlain by turbiditic conglomerates which conformably overlie medial Ordovician and older rocks. They are capped by shallow marine red beds with limited calc-alkaline volcanics. These sequences can be interpreted to show deposition and subduction-related and/or strike-slip pull-apart vulcanism within or on the border of orogenic lands created by the Taconic arc collision. Deposition in the Exploits and western Botwood zones during late Ordovician-early Silurian time may have occurred in marine borderland basins of California-type (Kidd, et al., 1977). These rocks are therefore consistent with the continued existence of an ocean, but only to the southeast of both the Exploits Zone and the northwestern part of the Botwood Zone. Contemporary late Ordovician-early Silurian convergent tectonism between the rocks of the Notre Dame and Exploits Zones (Nelson, 1981) is also consistent with plate convergence during this time (perhaps very oblique to the margin) across the northwestern edge of the still shrinking northern Appalachian ocean. Some workers, for example Williams (1979; 1980) suggest that the Appalachian ocean in the Newfoundland sector was essentially closed by the late Ordovician. The faunal evidence makes this unlikely, and Williams arguments do not take account of the effects of possible large strike-slip displacements, subparallel to orogenic zones, in removing or duplicating tectonic assemblages. The potentially great significance of this problem was first emphasized by Kay (1972).

Upright folding and mostly mild metamorphism of medial to late Devonian age affects all zones of the orogen near the line of section. This Acadian orogenic event is attributed, following Dewey (1969), Bird and Dewey (1970) and McKerrow and Ziegler (1972) to continental collision between the Taconic-modified margin of North America and the Avalonian continental fragment. While some authors point to the Reach Fault itself as occupying the site of the Acadian suture, it is alternatively possible that faults and highly strained rocks within the middle of the Botwood Zone are the suture zone, since the stratigraphy of early to medial Silurian rocks is similar in the western Botwood Zone and the adjacent Exploits Zone. This collision is likely to have been between irregularly-shaped continental margins (Dewey and Kidd, 1974), and the line of the main section crosses an area that was between promontories. The rocks near the section were not as strongly deformed as those in other places along strike, for example in southwestern Newfoundland, where a cryptic suture is reported (Brown, 1973, following Burke and Dewey, 1973).

The Acadian collision resulted in extensive granitoid plutonic activity in all Zones except the Humber Zone. The plutons tend to be on average of more silicic compositions in the marginal Fleur de Lys and Gander Zones, interpreted as underlain by deformed continental basement, and somewhat less silicic in the central zones, interpreted to be underlain by a deformed oceanic foundation (Dewey and Kidd, 1974). This contrast has been interpreted as evidence for partial melting of crustal materials by self-heating and conduction following collisional crustal thickening (Dewey and Kidd, 1974).

McKerrow and Ziegler (1972) present an elegant scheme whereby the Avalon terrain was impacted against North America by the South American part of Gondwanaland. The major part of Gondwana is then proposed to have moved away and rotated counter-clockwise until the late Carboniferous Alleghenian collision of the African part of Gondwana with North America along the southern Appalachian segment of the orogen. During the Acadian and Carboniferous events, major strike-slip faulting in the central zones of the orogen is likely to have occurred, and if it was part of the major plate motion represented by the proposed movement of Gondwanaland, it would be of right-lateral offset. The Dover-Hermitage Bay Fault may have been the locus of extensive strike-slip motion, possibly left-lateral (Hanmer, 1981), although this motion would have had to predate the late Devonian (Ackley) batholith that cuts the fault. Palaeomagnetic data (Kent and Opdyke, 1978; van der Voo et al., 1979) have suggested large left-lateral offsets, but this has not yet been confirmed by geological evidence, which suggests dextral displacements, at least for the Carboniferous (Bradley, 1982), with major strike-slip faulting, secondary pull-apart basin formation, and local compressional folding seen in western Newfoundland.

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