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THE STRUCTURAL EVOLUTION OF THE NORTHERN SEGMENT OF THE DUNNAGE ZONE–GANDER ZONE BOUNDARY, NEWFOUNDLAND

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ABSTRACT

Detailed mapping and structural analyses including investigation of sense-of-shear indicators, have been carried out along the Dunnage–Gander zone boundary. The portion of the boundary studied separates the Exploits Subzone from the Gander Lake Subzone between Gander Lake to the south and Musgrave Harbour to the north.

Deformation events recorded by structures along and adjacent to the boundary are divided into three groups. The oldest structures, for which kinematic indicators exist, developed through ductile strike-slip and oblique-slip motion. Dextral predated sinistral displacement; however, more than two episodes of ductile strike-slip and oblique-slip movement may have occurred. Structural features in rocks along the shores of Ragged Harbour indicate that some of the movement was contemporaneous with Siluro-Devonian plutonism.

Low-angle normal motion resulted in the development of mylonite, which overprints steeply dipping fabrics. The relative timing of low-angle normal ductile shear and ductile-brittle to brittle faulting is unknown. The latter postdates the cooling of a Devonian granite, but is otherwise unconstrained in age. Notable among the southeast faults are north-trending normal faults (west-side-down) and the most common west- to northwest-trending dextral strike-slip faults. Both sets may be related to the Atlantic opening.

It is here suggested that the present form of the Exploits–Gander Lake subzone boundary is largely the result of at least two episodes of strike-slip and oblique-slip motion.

INTRODUCTION

The Dunnage Zone has been divided into the geologically distinct Notre Dame and Exploits subzones (Williams, H. *et al.*, 1988). The Gander Zone has been separated into the Mt. Cormack, Meelpaeg and Gander Lake subzones (Williams, H. *et al.*, 1988). The Exploits–Gander Lake subzone boundary, with which this study is concerned, represents the easternmost Dunnage–Gander zone boundary. It is most clearly defined to the north, where much of the steeply dipping contact is bordered, on the Exploits side, by the Gander River complex (GRC; O'Neill and Blackwood, 1989: formerly the Gander River Ultramafic Belt of Jenness, 1958; Blackwood, 1978, 1982). Where present, the GRC is imbricated with the Weir's Pond Formation, the basal division of the Davidsville Group of the Exploits Subzone (O'Neill and Blackwood, 1989), and is juxtaposed against the Gander Group of the Gander Lake Subzone (Figure 1).

Interpretations of the structural history of the Exploits–Gander Lake subzone boundary vary. Kennedy and McGonigal (1972) proposed that the Davidsville Group was deposited unconformably on the deformed and metamorphosed Gander Group, and cited as evidence the presence of detrital biotite and garnet, and mafic schist and psammite fragments in basal conglomerate of the Davidsville Group. Uzuakpunwa (1973) examined the Gander and Davidsville groups and associated igneous rocks in the Ladle Cove–Ragged Harbour–Island Pond area. He concluded that the Gander Group had acquired a composite fabric before juxtaposition against the Davidsville Group, and noted that the metamorphic fragments in the melange of the Davidsville Group have folds, which predate incorporation of the fragments. Also, he considered the melange, which contains blocks of serpentinized dunite breccia, mafic pillow lava and hornblende gabbro, to be tectonic, and to have formed during thrusting of the Davidsville Group onto the Gander Group. The two groups were interpreted as being separated by either a melange, an ultramafic belt or a fault, and he mapped a narrow band of intensely foliated phyllite in the Ragged Harbour River area.

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[1] Lithoprobe Contribution Number 205

[2] Newfoundland Mapping Section

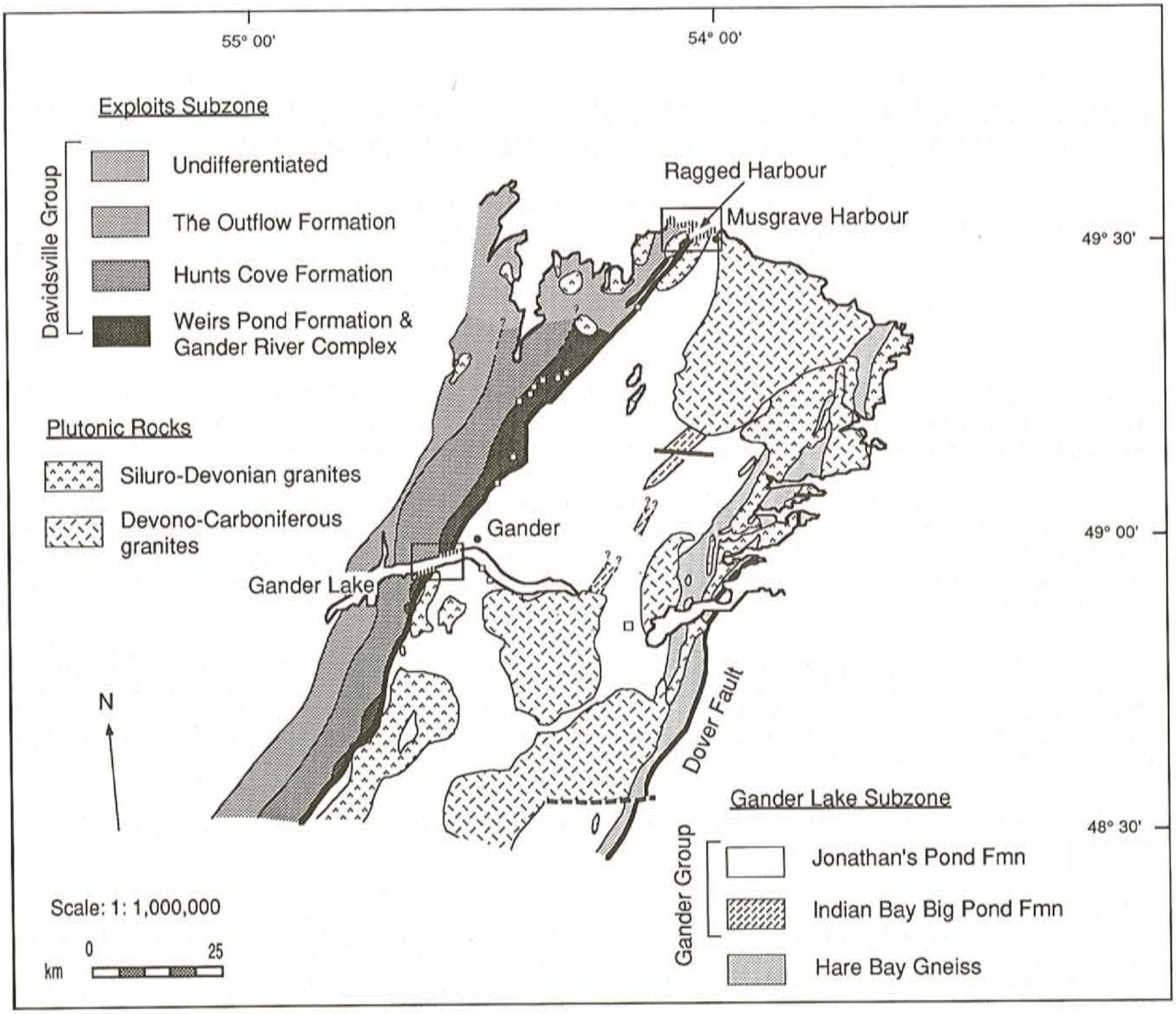


Figure 1. *Simplified map of the northern Dunnage–Gander zone boundary. Detailed structural information was collected from areas indicated by small squares and traverses marked by striped lines (within boxes).*

The two very different interpretations of the boundary as an unconformity and as a tectonic contact also appear in more recent literature. The Carmanville area was the focus of a number of studies (Currie and Pajari, 1977; Pickerill *et al.*, 1978, 1981; Pajari and Currie, 1978; Pajari *et al.*, 1979 and Currie *et al.*, 1979, 1980a, b). Currie and Pajari (1977) concluded that the basal part of the Davidsville Group, near Carmanville, forms part of an allochthonous sheet, spatially associated with an olistostromal melange at its base. Pajari *et al.* (1979) interpreted this melange, which they described as containing granule- to kilometre-size fragments in a shale matrix, to be ophiolitic. The shale matrix has been shown since, in places, to consist of shale clasts, and at least some of the olistostrome horizons mapped by Pajari *et al.* (1979) are clast-supported conglomerates (Williams, 1983). Pajari *et al.* (1979) suggested that olistostrome formation may have commenced as early as the Arenig and that fragments in the olistostrome were derived mainly from early Paleozoic oceanic crust and volcanic rocks (now represented by the GRC), which Pajari *et al.* (1979) interpreted as having been obducted eastward over the eastern continental margin of the Iapetus Ocean. Currie and Pajari (1977) also describe rocks exposed along Ragged Harbour River that contain a mylonitic foliation. They note that complex relict fold structures in rocks of the Gander Group do not occur in the Davidsville Group, 'possibly indicating a structural discontinuity between Gander and Davidsville sequences'.

Blackwood (1978) noted that the nature of the contact between the Davidsville and Gander groups is enigmatic where the GRC is present. Where the GRC is absent, near Island Pond in the Carmanville area and south of Gander Lake, the contact relationships between the Davidsville and Gander groups have been interpreted as conformable (Currie and Pajari, 1977; Blackwood, 1982). Blackwood (1982) suggested that the GRC was nonconformably overlain and bounded to the west by the Davidsville Group, which he interpreted as a submarine fan with distal deposits in the east and proximal in the west. Spatially restricted proximal conglomerates, which occur in the basal Davidsville Group, were, in his model, a product of erosion of ophiolitic basement, which was uplifted along wrench–transform faults. He proposed (in contrast to Currie *et al.*, 1979) that this initial uplift was due to 'oceanic disturbances' (rather than obduction) and interpreted the faulted contact between the GRC and the Gander Group as a major west-dipping thrust, along which the complex was emplaced above the Gander Group during later, regional deformation. Pajari *et al.* (1979) also described the contact between the GRC and the Gander Group as a fault.

Piasecki (1988), based on preliminary work northeast of Weir's Pond, suggested that the contact between the Gander and Davidsville groups is defined by a kilometre-wide mylonite zone, in which kinematic indicators imply south- to southwest-directed movements of the Davidsville Group over the Gander Group.

Research on the nature of the Exploits–Gander Lake subzone boundary, by one of us (LBG), was undertaken as part of a Lithoprobe East project to understand the structural evolution of the eastern and western margins of the Dunnage Zone. Detailed mapping and structural analyses of key areas, including investigation of sense-of-shear indicators, have been carried out along the north and south shores of Gander Lake and along the north coast (Figure 1). Structural information has also been collected from a number of points within, adjacent to, and to the east of the boundary zone (Figure 1). Preliminary results from ongoing analyses of microstructures and textures are also presented.

STRUCTURAL HISTORY

The events recorded by structures along the Exploits–Gander Lake subzone boundary in the study area are:

1) strike-slip and oblique-slip motion, with both dextral and sinistral displacement; contemporaneous with and post-dating Siluro-Devonian plutonism;

2) locally developed low-angle normal movement; and

3) high- to moderate-angle brittle-ductile to brittle faulting; postdates Devonian plutonism.

More detailed discussion of each of the main deformation events follows.

STRIKE-SLIP AND OBLIQUE-SLIP MOTION

Within the study area, the Exploits–Gander Lake subzone boundary and adjacent structures generally dip steeply to the northwest and are locally vertical. Sense-of-shear indicators generally indicate strike-slip or oblique-slip movement and show that the boundary zone has experienced both sinistral and dextral strike-slip displacement.

Our use of stratigraphy of rocks along and adjacent to the boundary will follow O'Neill and Blackwood (1989). From south to north in the study area (Figure 1), the following observations have been made.

On the south shore of Gander Lake, the boundary zone lies within a region where rocks are locally highly strained; although strain is distributed heterogeneously within this region, we will refer to it as a high-strain zone. To the west of the high-strain zone, rocks of the Davidsville Group display a moderately developed, moderately westward-dipping foliation and locally exhibit a poorly developed, down-dip mineral lineation. A steeply to moderately west-dipping foliation, into which the cleavage appears to be transposed, is developed eastward toward the boundary, within the high-strain zone (Figure 2, solid circles). This foliation generally contains a mineral lineation, which is locally defined by the long axes of stretched pebbles (Figure 2, solid squares). Apparent strain partitioning among different rock types in the Davidsville Group results in a variation in orientation of this stretching lineation, which on average plunges moderately to the north, but may plunge shallowly or steeply. Locally, two mineral lineations are present, and the steeper is inferred to be a relic of the older fabric. Sense-of-shear indicators are confined to deformed quartz veins, which do not record a consistent movement sense. Offset of quartz veins in this region of the Davidsville Group, generally indicates a strike-slip component of movement that is sinistral. The dip-slip component is determined to be west-side-up (reverse) in an area where the lineation has a northerly plunge and west-side-down (normal) in an outcrop where the mineral lineation plunges southward. In one location, a dextral strike-slip component is indicated. In an other locality, where the lineation is nearly down-dip, deformation of a quartz vein indicates normal motion. These apparently contradictory observations suggest the possibility of both multiple episodes of deformation and multiple generations of quartz veins. Microstructural and textural analyses, necessary to determine the significance of these complex field observations, is in progress. Similarly oriented foliations and lineations are found within rocks of the Gander Group adjacent to the boundary (Figure 2, solid circles and squares). Isoclinal, intrafolial folds in an older foliation, which are present in these rocks are however, absent in the Davidsville Group. This suggests that the high-strain zone overprinted Gander Group rocks that were already very well foliated. As mentioned previously, the high-strain zone is heterogeneous. The fabric within an area of lower strain (Figure 2, open circles and squares) is similar to that in adjacent, more strongly deformed rocks, though it dips less steeply.

On the north shore of Gander Lake, metamorphic rocks of the Jonathans Pond Formation are separated from ultramafic rocks of the GRC by a break in outcrop. The ultramafic rocks are cut by numerous slickensided surfaces

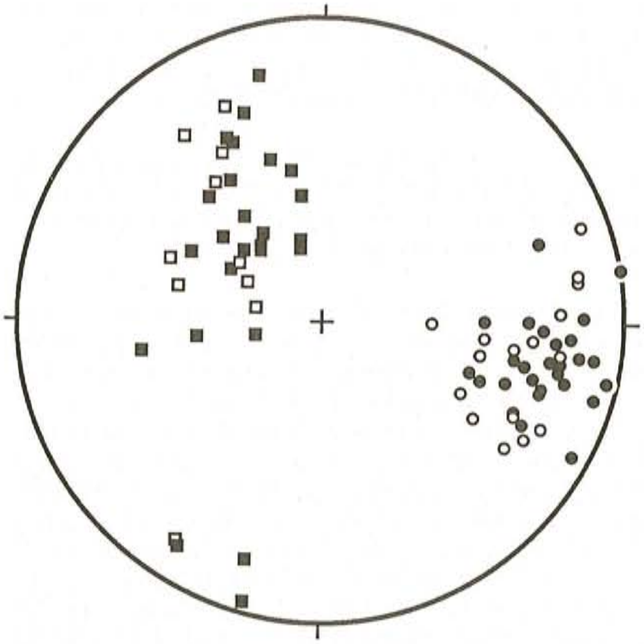


Figure 2. *Lower hemisphere, equal-area plot of structural elements, south shore of Gander Lake. Circles represent poles to foliation; squares are lineations. Black fill = fabric in highly strained rocks of the Davidsville and Gander groups and white fill = fabric of less deformed rocks of the Davidsville Group. See text for further explanation.*

and are typically non-foliated. In contrast, rocks of the Jonathans Pond Formation exposed closest to the boundary exhibit a well-developed, moderately westerly dipping foliation and nearly down-dip mineral lineation. Preliminary petrographic study of a rock sample from this part of the Jonathans Pond Formation, shows that the foliation and associated extensional lineation formed during normal shear with a small sinistral component of motion. This movement sense is indicated by the orientation of shear bands relative to C-surfaces and by a deformed carbonate vein. Whether normal shear is coupled with the strike-slip and oblique-slip movements recorded elsewhere along the boundary, or is related to younger extension (see following section), is presently unknown.

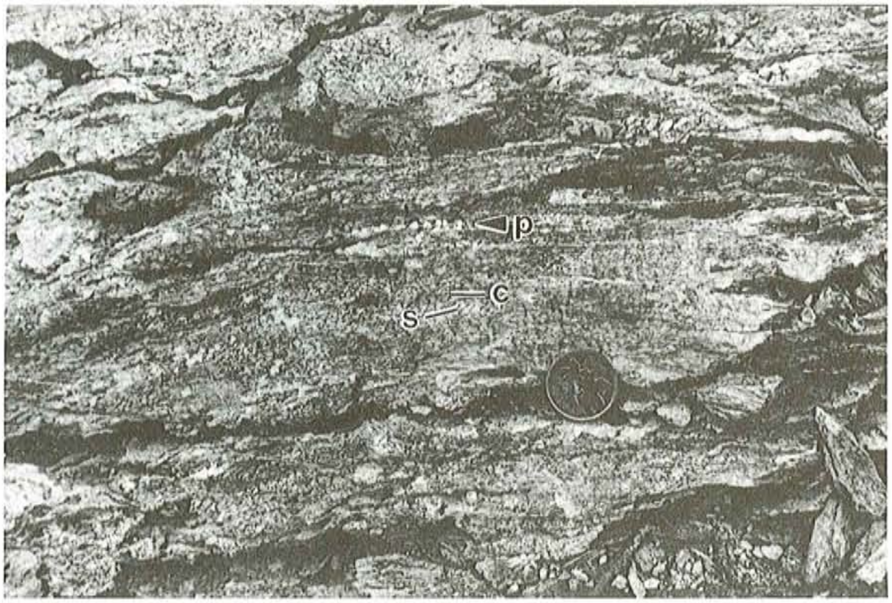
Within the Weir's Pond map area, high-strain zones are developed in both the GRC and the Weir's Pond Formation. In both a sheared trondhjemite-rich conglomerate in the west and a deformed gabbro farther east, kinematic indicators record dextral strike-slip movement. The deformed conglomerate occurs within a high-strain zone that extends a minimum of 0.75 km along strike; ultramafic rocks of the GRC are also highly deformed within this zone. Sense-of-shear indicators in both the gabbro (Figure 3a) and the conglomerate include S- and C-surfaces (cf. Berthe *et al.*, 1979) and C and C' (shear band) surfaces. A subhorizontal stretching lineation is found within the C-surfaces (Figure 3b). S-surfaces in the gabbro were later folded, indicating reactivation of the C-surfaces during sinistral strike-slip motion (Figure 3c). Therefore, an episode of sinistral strike-slip motion postdated dextral strike-slip motion; the folds indicate only a small amount of sinistral displacement in this area.

The GRC is absent along part of the boundary in the Carmanville map area and the Davidsville Group is in direct contact with the Gander Group. Preliminary investigation of this portion of the boundary indicates that a moderately to steeply northwest-dipping foliation is developed in rocks of both groups (Figure 4). A shallowly plunging mineral lineation (Figure 4) is present in the plane of this foliation within quartz-rich rocks of the Gander Group only. Well-developed shear bands in pelitic rocks of the Gander Group and a strongly deformed quartz vein in the Davidsville Group both record sinistral strike-slip motion. The shallow southwest plunge of the locally developed mineral lineation suggests the possibility of a small west-side-down dip-slip component to the movement. The boundary between the Davidsville and Gander groups, where the GRC is absent, is clearly tectonic.

Rocks on the eastern and western shores of Ragged Harbour, as well as in areas in adjacent Musgrave Harbour, exhibit evidence of several deformation events, some of which were contemporary with granitic plutonism. Metasedimentary rocks, migmatites and leucocratic granites are intimately intermingled and deformed. The metasedimentary rocks in this area have experienced a higher grade of metamorphism than elsewhere along the northern Exploits–Gander Lake subzone boundary. Biotite is ubiquitous and garnet is common; andalusite and sillimanite are found locally on the northwest shore and sillimanite is common on the northeast shore of Ragged Harbour. Some xenoliths in highly deformed granite in Musgrave Harbour contain kyanite, which is overprinted by sillimanite. Kyanite has also been found near Wing Pond, in the Gander Lake Subzone, within a high-strain zone (O'Neill and Lux, 1989) that extends at least as far south as Square Pond (see O'Neill, *this volume*). Andalusite is common within the Wing Pond Shear Zone (Plate 1), which is also locally associated with leucocratic granite and contains evidence of oblique-slip movement.

The earliest phases of deformation, for which clear evidence is present in the Ragged Harbour and Musgrave

Figure 3. *High-strain zones in the GRC; a) View is parallel to the lineation and at right angles to the foliation. The orientation of S-relative to C-surfaces (marked) indicate dextral displacement. Note extended plagioclase porphyroclasts (p). Dark zones parallel to C-surfaces are ultramylonite; b) Lower hemisphere, equal-area projection: circles are poles to foliation and squares are lineations. Black fill = fabric in deformed gabbro; white fill = fabric in deformed trondhjemite and ultramafic rock; c) Viewed parallel to the lineation and at right angles to the foliation. Folds with sinistral asymmetry (f) are developed mainly in S-surfaces (S- and C-surfaces are marked).*



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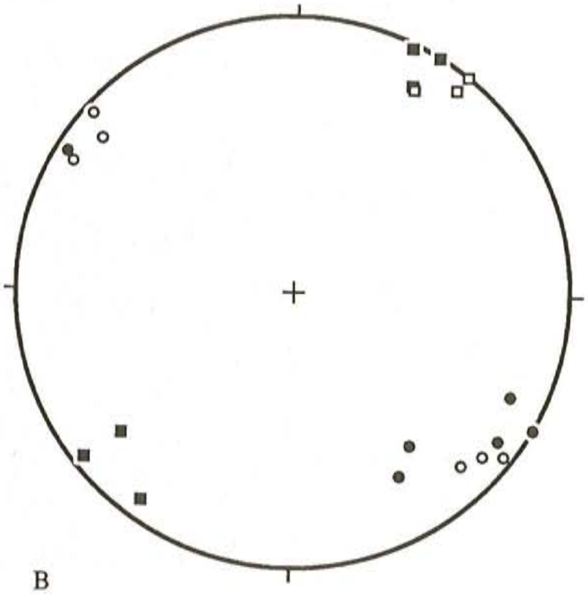

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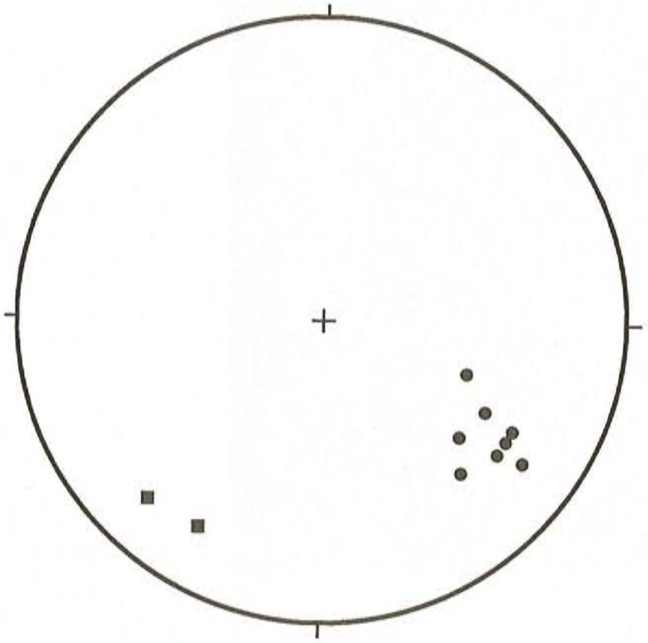

Figure 4. *Lower hemisphere, equal-area projection of fabric elements at Gander–Davidsville group contact. Poles to foliation are represented by circles; lineations are plotted as squares.*

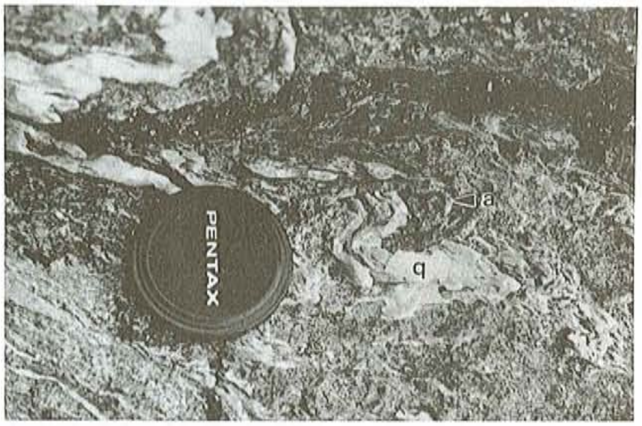

Plate 1. *High-strain zone near Square Pond, showing folded andalusite porphyroblast (a) and typical dextral asymmetry of folded quartz vein (q). Viewed at right angles to foliation and ~45° from lineation.*

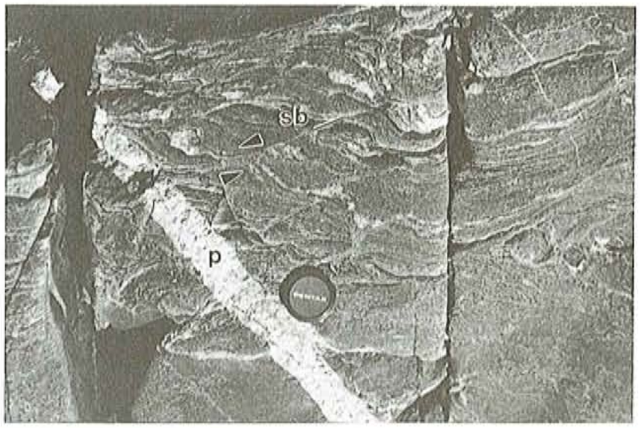

Plate 2. *Shear bands (sb) developed in migmatite near Musgravetown Harbour indicate a sinistral component of shear. Viewed ~45° from lineation (which plunges to the right in the photograph) and at right angles to foliation. Segregation of leucosomes along shear bands is evident (lighter zones at 'l' to the right of sb). Crosscutting pegmatite vein (P) is undeformed.*

Harbour area, were strike-slip and oblique-slip movements resulting in the development of steeply dipping foliations and subhorizontal to moderately plunging mineral lineations. Steep mineral lineations are found locally. Evidence for synplutonic deformation includes leucocratic granite intrusions exhibiting parallel magmatic and tectonic fabrics and multiple phases of intrusion, with granites of different ages showing variably developed, but consistently oriented foliations. Migmatites near Musgrave Harbour contain leucosome segregations along shear-band boundaries (Plate 2); the shear bands indicate oblique-slip movement with sinistral and reverse components. Sense-of-shear indicators elsewhere include offset veins, shear bands and drag folds (e.g., Plate 3). Sinistral strike-slip motion with virtually no component of dip-slip movement is recorded at Ragged Point, where a nearly vertical foliation contains a subhorizontal mineral lineation (Plate 3). Kinematic indicators at several localities within the White Point Complex of Currie *et al.* (1980b), along the east and west shores of Ragged Harbour, indicate dextral strike-slip motion and oblique movement with a component of dextral displacement. Overprinting relationships confirm the observation made to the south that sinistral strike-slip motion postdated dextral movement along the Exploits–Gander Lake subzone boundary.

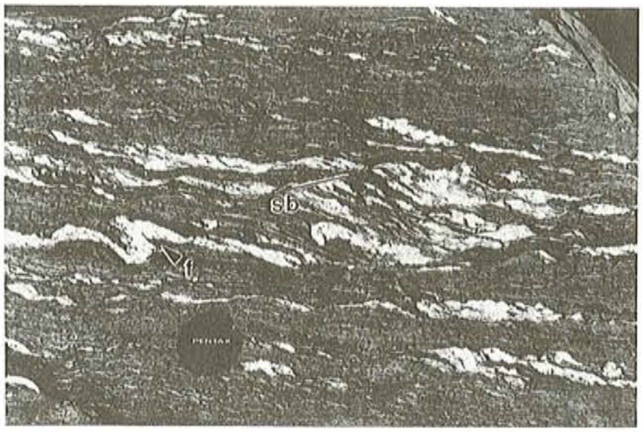

Plate 3. *Mylonite at Ragged Point is viewed parallel to lineation and at right angles to foliation. Asymmetric drag folds in granite veins (f) and movement on shear bands (sb) indicate sinistral shear.*

LOW-ANGLE NORMAL MOVEMENT

On the east shore of Ragged Harbour, south of the town of Ragged Harbour, evidence of ductile normal movement with a variable component of sinistral motion is preserved in granite of the White Point Complex. Deformation of leucocratic granite has resulted in the development of C-surfaces that strike north-northeast and dip, on average, 45° to the east. S-surfaces indicate normal to oblique displacement (Figure 5). This fabric locally overprints the steeply dipping foliation typical of the area (see above). In the area of overprinting, the younger foliation is broadly folded, suggesting a dome shape, which results in some scatter in the orientations of poles to foliations (Figure 5). The relative age of this low-angle normal movement with respect to faults in the area is unknown; emplacement and cooling ages of the granite mylonite would provide constraints on the timing of this deformation episode.

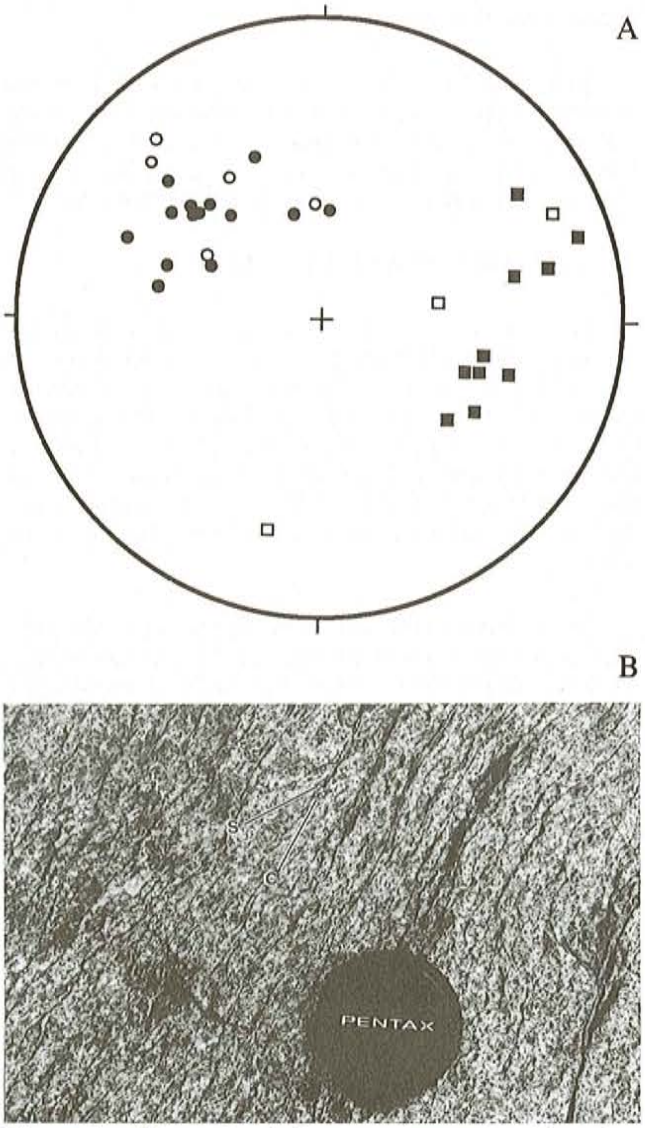

Figure 5. *a) Lower hemisphere, equal-area plot of lineations (squares) and poles to C-surfaces (circles) in granite mylonite (black fill) and included metasedimentary screens (white fill). b) Granite mylonite south of Ragged Harbour viewed parallel to lineation and at right angles to foliation. The plane of the photograph is tilted anti-clockwise; the foliation in the outcrop dips 47° to the southeast (left in photograph). S- and C-surfaces, as marked, indicate normal movement.*

Extension that may be related to low-angle normal motion is recorded elsewhere by a locally developed, shallowly dipping cleavage, along which older foliations are either flattened or offset in a normal sense.

FAULTS

Moderate- to high-angle brittle-ductile to brittle faults crosscut fabrics developed during strike-slip and oblique-slip motions. They occur in west-, northwest-, north- and northeast-trending sets. West-trending faults are the most common; the others appear to occur in roughly equal numbers. The offset along most northeast-trending faults cannot be determined. For the purposes of discussion, the remaining faults will be grouped into roughly northerly trending and west- to northwest-trending sets. Both usually contain multiple sets of slickenside striae and are often associated with quartz fibres. If more than one set of slickenside striae is present, one is generally shallowly plunging and one is commonly steeply plunging, indicating the importance of both strike-slip and dip-slip motion along the faults.

Offset along these faults is commonly difficult to ascertain. Where it is possible to elucidate sense of movement, the northerly trending faults are commonly normal faults and the west- to northwest-trending faults are typically dextral strike-slip faults. However, the relations mentioned above indicate that many of these faults have been reactivated at least once in their history. West- to northwest-trending sinistral strike-slip and normal faults, and north-trending sinistral strike-slip and reverse faults, have been noted. Many of these faults may not be exposed because these fault zones are easily eroded and the outcrop in this region is so poor. It is also important to note that these faults are much more common in the southern portion of the area studied; this may be because the structural level exposed along the north coast is much deeper than that farther south (as indicated by the high-grade metamorphic rocks and migmatites that outcrop along Ragged Harbour).

The northerly trending normal faults and west- to northwest-trending dextral faults have a definite influence on the present distribution of rock units.

Northerly Trending Normal Faults

The normal faults are distinctive in that they commonly dip steeply (locally are vertical) and displacement may be sufficient to juxtapose rocks of substantially different metamorphic grade. The best exposed example is located at Ladle Point, on the east side of Aspen Cove. The fault surface is nearly vertical (dipping westward), is locally associated with a quartz vein and contains nearly down-dip slickenside striae. The sense of movement on this fault is west-side down. Rocks that are deformed, but exhibit no macroscopically visible metamorphic minerals and preserve primary structures, are dropped down next to their andalusite-bearing equivalents along this fault. Northerly trending normal faults indicate east-west extension, which may be associated with Atlantic opening.

West- to Northwest-Trending Dextral Strike-Slip Faults

Dextral strike-slip motion along west- to northwest-trending faults affected the Devonian Deadmans Bay Granite near the fish plant at Musgrave Harbour. Zones of brittle-ductile foliation (Plate 4), a few metres wide, become brittle toward the centre. These zones crosscut a magmatic foliation, indicating that this phase of deformation postdated cooling of the pluton and was therefore Devonian or younger in age. Northerly trending aplite dykes crosscut the brittle-ductile foliation and are slightly dextrally offset by the centrally located brittle faults. This may indicate a substantial temporal difference between brittle-ductile and brittle deformation, or that initially brittle-ductile deformation became progressively brittle and more localized in space. The normal fault at Ladle Point (mentioned above) is also dextrally offset by a high-angle, west-trending fault containing well-developed sub-horizontal slickenside striae. The Gander Lake fault (McGonigal, 1973) also dextrally offsets the GRC. Although it was described previously as a normal fault, offset of metasedimentary rocks of the Davidsville Group along a lake-parallel fault on the south shore of Gander Lake suggests that it belongs to this class of faults. West and northwest geographical trends (e.g., the orientation of the north coast and the trend of bays on the eastern margin of the Gander Lake Subzone) probably reflect this common fault attitude. Apparent offset of geological features may also be explained by these faults (as suggested by the heavy dashed line in Figure 1).

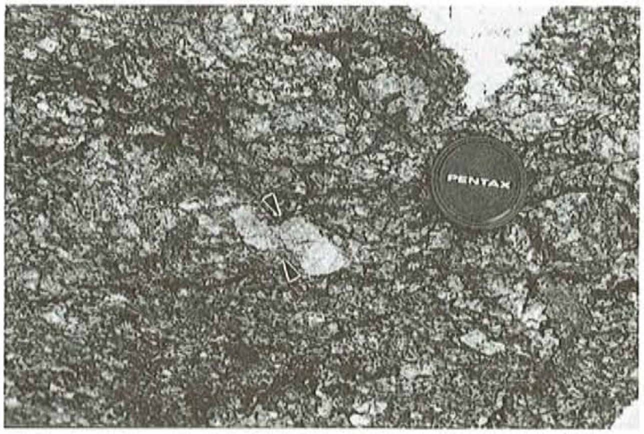

Plate 4. *Deformed granite viewed parallel to lineation and at right angles to brittle-ductile foliation in Deadmans Bay pluton, near fish plant at Musgrave Harbour. Direction of slip on fracture in feldspar (arrows), interpreted as movement along a shear band, suggests dextral displacement on main foliation surfaces.*

These dextral strike-slip faults are similar in trend and character to faults described in southern New Brunswick (Leger and Williams, 1986), northern Newfoundland (Williams, P. *et al.*, 1988), Nova Scotia (Williams and Hy, 1990) and throughout eastern Canada (Miller, 1990) and may similarly represent transfer faults associated with Atlantic opening.

Significance of High-Angle Faults

The brittle structures discussed here are important for two reasons. First, they can accomplish a significant amount of lateral and/or vertical shuffling of lithological units. Where there is a strong component of vertical displacement, this can result in dramatic lateral changes in metamorphic grade. Second, rotation of rocks along faults may result in significant changes in orientation of both bedding and foliation surfaces. For example, foliations in the Ragged Harbour area appear locally to be rotated into parallelism with brittle and brittle-ductile, dextral strike-slip faults.

Lithological boundaries are commonly faulted because of strong rheologic contrasts. Considering the poor outcrop in the area, the potential for rotation of structures across fault surfaces, and fault displacements, high-angle faults could mask or erase evidence of previous structural events.

PEGMATITE AND APLITE DYKES

Pegmatite dykes (Plate 2) on the east coast of Ragged Harbour crosscut the Siluro-Devonian leucocratic granitoids and fabrics developed during strike-slip and oblique-slip motion, and are generally little deformed to undeformed. As there is evidence for more than one episode of both intrusion and strike-slip motion, it is likely that there is more than one generation of pegmatite dykes. The dykes are deformed within the low-angle normal shear zone and are cut by the brittle faults.

Aplite dykes cut the Deadmans Bay Granite in Musgrave Harbour and are therefore younger than the pegmatite dykes. As mentioned previously, they truncate brittle-ductile foliation but are displaced along brittle faults. Where they are undeformed, or little deformed, both pegmatite and aplite dykes generally strike northerly and dip steeply. Although crosscutting relationships indicate that pegmatitic and aplitic dykes were intruded at different times, they both reflect approximately east-west extension. Dates on pegmatite and aplite emplacement would constrain the timing of the latest deformation in the area.

DISCUSSION

Boundaries between rocks of the Gander and Dunnage zones are geometrically diverse. In southern Newfoundland, the boundary is represented by the Bay d'Espoir shear zone (Colman-Sadd, 1980; Piasecki, 1988), which juxtaposes a thin sliver of probable Gander Zone rocks against rocks of Dunnage Zone affinity. Piasecki (1988) suggested that movement along the Bay d'Espoir shear zone involved sinistral strike-slip motion in zones of steep foliation coupled with west-southwest-directed movement of the Dunnage Zone over the Gander Zone in zones of shallow foliation. In south-central Newfoundland, the Mt. Cormack and Meelpaeg subzones form two tectonic windows through overlying

Exploits Subzone rocks and are locally bordered by Dunnage Zone ultramafic rocks (Colman-Sadd and Swinden, 1984; Williams, H. *et al.*, 1988). Colman-Sadd and Swinden (1984), Williams, H. *et al.* (1988) and Williams and Piasecki (1990) state that structural relationships along the Mt. Cormack and Meelpaeg subzone boundaries indicate that the Exploits Subzone, in part, overlies the Gander Zone and that these boundaries are fundamentally thrust surfaces. Colman-Sadd and Swinden (1984), Piasecki *et al.* (1990) and Williams and Piasecki (1990) suggest that later deformational events, including strike-slip and dip-slip motions, have modified structures in these areas.

In contrast to the other boundaries, there is no evidence along the Exploits—Gander Lake subzone boundary that the Exploits overlies the Gander Lake Subzone; the boundary generally dips steeply. The present structures and preserved sense-of-shear indicators chiefly record strike-slip and oblique-slip motion. A possible exception is the exposure of rocks adjacent to the Exploits—Gander Lake subzone boundary on the north shore of Gander Lake, where kinematic indicators observed in thin section, indicate normal motion, which may be related to younger extension. Zones which record oblique-slip motion may, as noted previously, contain evidence for a reverse component of movement. This is distinct from thrusting; with reverse motion along steeply dipping shear zones, transport of the hanging wall is limited by the thickness of the crust. Thrust movement, which by definition occurs within zones which dip 45° or less, allows transport of major allochthons for significant distances. No evidence for thrusting has been found. In addition, rocks of the Gander Group adjacent to the boundary, with the exception of those located within the high-strain zone in Ragged Harbour and those within the thermal aureoles of granites south of Gander Lake, have experienced greenschist-facies metamorphism, which is not what would be expected of rocks in the footwall of the major thrust sheet suggested by previous workers. Evidence from this study does support the conclusion of Uzuakpunwa (1973) and Piasecki (1988) that the Gander and Davidsville groups are in tectonic contact.

As noted by O'Neill and Knight (1988), aeromagnetic anomalies within the Gander Lake Subzone (e.g., the Ocean Pond Anomaly Belt of Miller, 1988) are oblique to the main trend of the Gander Lake—Exploits subzone boundary. The Ocean Pond Anomaly Belt appears to end at the Exploits—Gander Lake subzone boundary. This anomaly belt is spatially associated with a number of features at the surface, including the regional structural grain, the leucocratic Ocean Pond Granite and a small ultramafic body. Linear features within the anomaly belt (see Kilfoil, *this volume*) are spatially coincident with a strong physiographic lineament in which steeply dipping, highly strained rocks are locally exposed. These structural relationships and the consistently linear expression of the anomalies are more compatible with strike-slip and oblique-slip motion along steep shear zones than with thrusting. These observations suggest that the north-trending anomalies are associated with structures that developed during a different, perhaps earlier, deformation episode than that which formed the northeast-trending subzone boundary. In the eastern Gander Lake Subzone, the Wing Pond Shear Zone (See O'Neill, *this volume*) exhibits evidence of strike-slip motion and is coincident with an aeromagnetic anomaly and felsic, mafic and ultramafic bodies.

Shear zones partitioned into strike-slip and oblique-slip domains would transport rocks along strike and also bring material from depth toward the surface. The GRC clearly contains a basement component of ultramafic, gabbroic and trondhjemitic rocks. Some or all of the GRC could have been exhumed through oblique-slip motion. If portions of the GRC, and of the Weir's Pond Formation, were already at the surface when these shear zones initiated, then these rocks could have been placed in their present position through strike-slip motion. These shear zones may also explain the development of the aeromagnetic anomalies observed in the Gander Group. Zones of oblique-slip and strike-slip motion, localized along the present anomalies, could bring rocks up from depth within the Gander Lake Subzone in the same way as along the Exploits—Gander Lake subzone boundary. The presence of a few small ultramafic bodies along the anomalies suggests the possibility that the Gander Lake Subzone is floored by oceanic basement; however, few basement rocks were brought to the surface within these high-strain zones. This may reflect either a greater component of strike-slip movement within high-strain zones along the anomalies, or a smaller net displacement relative to the Exploits—Gander Lake subzone boundary.

Structural relationships in the area record coincident strike-slip and oblique-slip motions. Evidence in the Ragged Harbour area suggests that some strike-slip and oblique-slip motion was contemporaneous with Siluro-Devonian plutonism. Oblique-slip and strike-slip motion may have initiated prior to the Silurian, but the geochronologic data is limited and does not allow us to date the onset of this deformation.

CONCLUSIONS

The northern Exploits—Gander Lake subzone boundary records a complex deformation history. The boundary in its present form is largely the result of at least two episodes of strike-slip and oblique-slip motion; evidence of any previous structural event(s) has been obliterated. Siluro-Devonian granites and zones of high-grade metamorphic rocks are locally associated with high-strain zones (strike-slip and oblique-slip shear zones), indicating that intrusion and deformation were intimately related. This is further substantiated by the spatial association of the majority of Siluro-Devonian granites with the western and eastern boundaries of the Gander Lake Subzone, (see also Hanmer, 1981). Kyanite appears to be spatially restricted to these high-strain zones, suggesting significant dip-slip displacement in areas of oblique-slip motion. Low-angle normal motion, which postdates these two events, may have occurred during isostatic adjustment to a crust thickened by oblique-slip movement, or may be associated with Atlantic opening. Later high-angle faulting also influenced the pattern of isograds, spatial distribution of rock types, and orientation of structures. These faults may be associated with Atlantic opening.

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