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Structural Study of Highly Deformed Meguma Phyllite and Granite Vicinity of White Head Village, S.E. Nova Scotia

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A long history of dextral transcurrent shear on the Cobequid-Chedabucto Fault System is indicated by structures in Meguma Zone phyllite and granite, and late veins, which outcrop close to the present Chedabucto Fault trace. The phyllite deformed first upon collision of Meguma with Avalonia during the Acadian Orogeny, and progressively since that time by ductile deformation mechanisms for almost the total deformational history of the rocks. Its foliation is due to transposition and dynamic recrystallization. Granite was intruded syntectonically, as shown by contact metamorphic formation of syntectonic porphyroblasts in the phyllite which are rotated, and progressive development of an inhomogeneous shear zone foliation towards the phyllite-granite contact. This foliation is approximately parallel to that developed in the phyllite. Quartz veins, which overprint all earlier structures, were deformed and accomodated by ductile mechanisms while being rotated in the continued progressive dextral shear regime.

Une longue histoire de cisaillent transversale dextrale, sur les systemes de failles Cobequid-chedabucto, est indiqué par des structures dans les phylites et les granites Meguma et les jeunes veines qui affleurent pres de la trace de la faille Chedabucto actuelle. La phylite s'est d'abord deformé a la suite de la collision entre Meguma et Avalonia pendant l'orogenese Acadienne, et depuis, par des mécanismes progressifs de déformation ductile pendant presque toute la durée de l'histoire déformationelle des roches. Sa foliation est attribuée a la transposition et a la recristalisation dynamique. Le granite a été pénétré syntectoniquement, comme le demontre la formation de porphyroblastes syntectoniques par moyen de metamorphisme de contact, dans les phylites retournées, et par le développement progressif d'une foliation de zone de cisaillement inhomogene vers le contact phylite-granite. Cette foliation est plus ou moins paralelle a celle qui est développée dans la phylite. Des veines de quartz, qui surimpose toutes les structures précédentes, ont été déformées et accomodées par des mécanismes ductile, pendant qu'elles étaient retournées par le régime progressif de cisaillement déxtral.

INTRODUCTION

Meso- and microstructures of strongly deformed phyllite and granite, which outcrop close to the CHEDABUCTO fault in south-eastern Nova Scotia (Figure 1a), include a variety of features which place constraints on:

a) the style, and style variation with time, of progressive deformation of the rocks;

b) the sense of displacement of the Meguma Zone with respect to the Avalon Zone along the Cobequid-Chedabucto Fault System; and

c) the relative timing of deformation and granite emplacement in this area.

The rocks described were examined and sampled at several localities in south-eastern Nova Scotia, close to White Head Village (the granite - see Figure 1b) and approximately 4 km north of White Head (phyllites). The phyllites are thus found some 10 km south of the present surface trace of the Chedabucto Fault. In addition, outcrops of phyllites and highly deformed quartzofeldspathic rocks were studied

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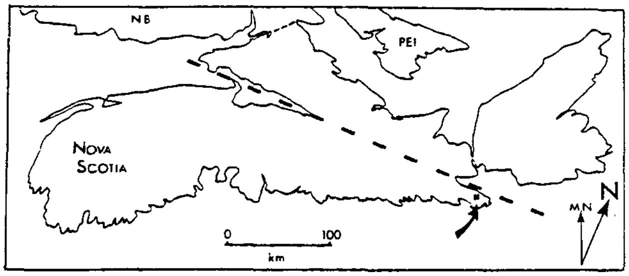

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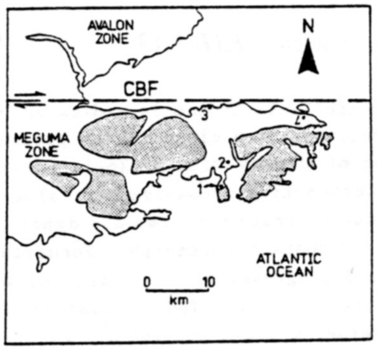


Figure 1: Location maps. 1a - Nova Scotia, showing approximate surface trace of Cobequid-Chedabucto Fault System (dashed line), and study area (arrowed square). 1b - eastern tip of Nova Scotia, showing approximate surface trace of Chedabucto Fault (dashed line). Numbers show locations of: 1 - White Head Village; 2 - transposed phyllite outcrops; 3 - Half Island Cove; 4 - Canso. Main granite bodies are stippled.

in a reconnaissance fashion at Half Island Cove, approximately 500 metres south of the present Chedabucto Fault surface trace, and at several localities between this cove and Canso to the east (Figure 1b).

With the exception of the coastal exposures, the phyllite and granite outcrops are glaciated and of limited areal extent, though sufficiently three-dimensional to allow structural analysis. After field study, oriented samples were collected and petrographic thin sections prepared, finely-ground to thicknesses of ca.25 μm for granite, and ca.10 μm for phyllites. Such very thin sections permit analysis of the microstructures of these fine-grained rocks, which are relatively uninformative and misleading in normal (30μm) thin sections. The sections were cut parallel to lineation and perpendicular to foliation (the monoclinic symmetry plane of deformation, essentially horizontal), and perpendicular to both lineation and foliation (essentially vertical).

GENERAL GEOLOGY

The Meguma Zone is a distinct lithological and tectonic entity within the Appalachian Orogen of North America, and is interpreted as African in origin, accreted to the North American craton prior to the opening of the present Atlantic Ocean (Schenk 1971, 1978). It is separated from the Avalon Zone to the north by a major steep-dipping to vertical dextral transcurrent zone of shearing, the Cobequid-Chedabucto Fault System (hereafter CCFS; Webb 1969). The Meguma Zone was first deformed during the Devonian Acadian Orogeny, as it was accreted. This was the time of formation of the CCFS and also the time of emplacement of numerous pre- to post-tectonic granitic intrusions, and regional metamorphism of generally low grade (Fyson 1966, Eisbacher 1970, Reynolds et al. 1973). Deformation due to the Carboniferous Hercynian Orogeny is considered important only along the Avalon-Meguma boundary (for example, Williams and Hatcher 1982). The present area lies within this belt, and suffered effects of both Acadian and Hercynian movements. Later movements of the CCFS during the Mesozoic led to the opening of the Bay of Fundy (for example, Keppie 1982). Thus the CCFS, as other major shear zones, has a complex and long-lived geological history.

Rocks occur along and both north and south of the CCFS trace which preserve evidence of this long deformational and metamorphic history. For example, mylonites occuring north of the Cobequid Fault trace formed solely by ductile deformation mechanisms. These mylonites were overprinted by transitional brittle fracturing and faulting (Eisbacher 1970). The rocks described in this paper, which are found south of and close to the present trace of the Chedabucto Fault (the major eastern member of the CCFS - Figure 1b), show a similar complex developmental history.

The Meguma Zone is largely composed of rocks of the Meguma Group, a thick Cambrian - Lower Ordovician turbidite succession. This group is subdivided into two formations, the greywacke-rich, supposedly basal Goldenville Formation, and the slate/phyllite-rich, supposedly upper Halifax Formation, though these two formations may be complexly intercalated (Schenk 1976, 1978). The present study is concerned with phyllites, of various compositions, of the Halifax Formation, and their associated Acadian syntectonic granitic intrusions. The area covering the outcrops we have examined has been mapped at a scale of 1" to 1 mile by Stevenson (1964). In the area examined, the dominant foliation in both phyllites and granite is oriented approximately 078° and vertical, and the mineral elongation lineation on this foliation plunges shallowly east to horizontal. This is in accord with the data of Eisbacher (1970) gathered in the Cobequid Mountains along the CCFS to the west, and work of J.C. White (pers. commun., 1984) at Greville Bay even further west along the CCFS. These two studies plus the present work therefore sample almost the total lateral extent of exposed rocks affected by movement on the CCFS.

Major folds in the Meguma Terrane are upright or steeply inclined, and have esentially horizontal hinges at the macroscopic scale. At a finer scale the fold hinges are seen to be doubly plunging. Traces of the major fold hinges lie at a high angle to the CCFS trend in the southwestern part of the terrane, and curve smoothly towards coincidence with the CCFS trend in the north and east parts of the terrane (for example, Keppie 1979). This pattern has been explained as due to ductile reorientation of the major folds during the history of deformation which followed accretion of the terrane (Mawer 1984).

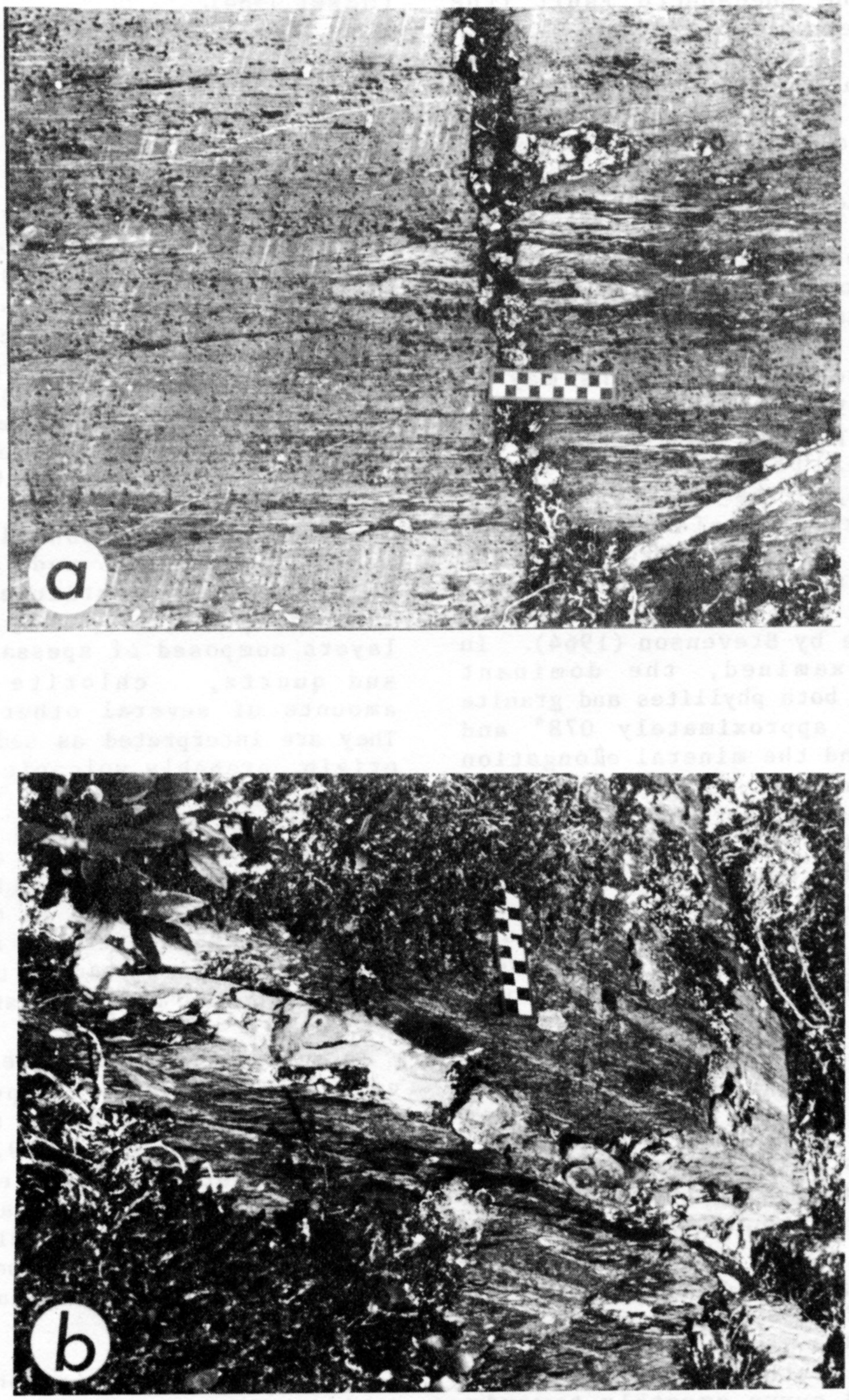
THE PHYLLITES

Mesostructural aspects

As mentioned above, phyllites were examined at several closely-spaced outcrops approximately 10 km south of the Chedabucto Fault. Several varieties of phyllite occur in these outcrops, mainly a fine-grained and occasionally porphyroblastic pelitic phyllite and a coarser-grained psammitic phyllite/schist. Intercalated with the pelitic phyllite are several very thin layers of coticule. Here we consider only the pelitic phyllite and associated coticule layers (coticules are thin, extensive, and laterally continuous layers composed of spessartine garnet and quartz, chlorite and minor amounts of several other minerals). They are interpreted as sedimentary in origin, probably volcaniclastic tuffs (Kramm 1976), and to have been deposited on oceanic crust or continental margin (Kennan and Kennedy, 1983). They are an excellent marker horizon in rocks such as the present phyllite, which often do not possess any indicators of bedding that survive deformation and metamorphism.

In outcrop, the phyllite exhibits a very well developed penetrative foliation. This is a transposed foliation (Hobbs et al. 1976, pp. 252-264); ellipsoidal pods of less deformed phyllite are occasionally found isolated within and intrafolial to this foliation. Internally, these included pods of phyllite are intricately folded (Figure 2a).

The transposed foliation is itself folded by open to tight metre-scale folds, and field evidence (fold vergence reversals and lithological patterns) indicates the existence of tens-of-metres-scale folds of bedding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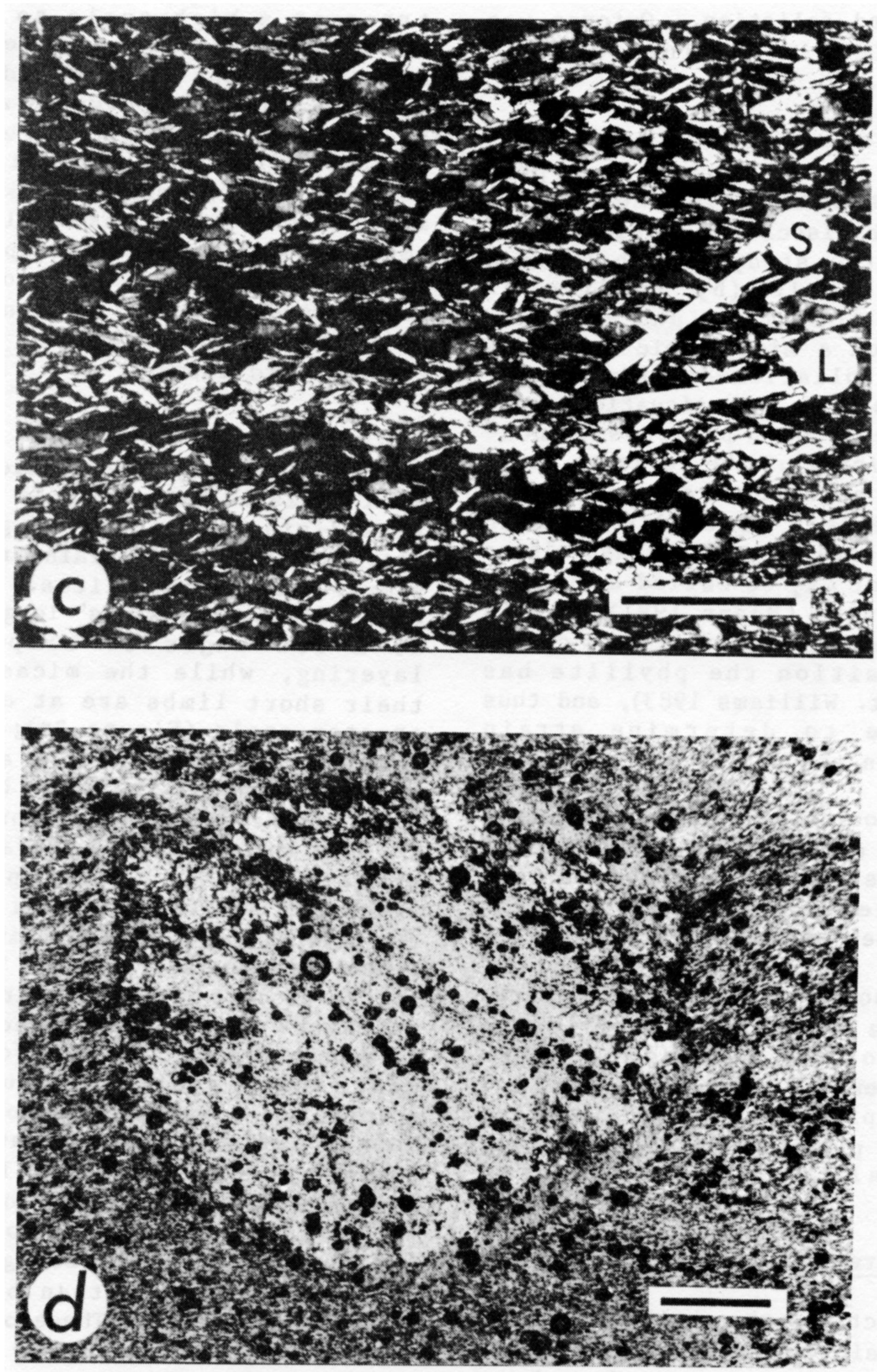


Figure 2: The transposed phyllite (Figure 1, location 2). North to top in all photographs. 2a - pod of strongly folded phyllite intrafolial to transposed foliation. Scale 10 cm long. 2b - folds of coticule layer in transposed phyllite. Scale 10 cm long. 2c - photomicrograph of kinked, transposed foliation, two dominant white mica orientations marked (L - long limb orientation, S - short limb orientation). Scale bar 200 um, NX. 2d - photomicrograph of rotated syntectonic cordierite porphyroblast. Scale bar 0.5 mm, PPL.

and transposed foliation. Outcrop was not sufficient to delineate these larger folds.

The transposition process is essentially one of rotation of pre-existing structural elements into parallelism by isoclinal folding. This is seen in the study area both on a mesoscopic scale (by folding of transposed foliation and coticule layers) and on a microscopic scale (by kinking of foliation-defining white mica - see below). In situations such as the present, with progressive non-coaxial straining of the rocks to large but unknown magnitudes of strain, and the added effect of cyclic dynamic recrystallization, this transposition produces what may be called a steady-state foliation (Means 1981). It is impossible to determine how many cycles of transposition the phyllite has undergone (cf. Williams 1983), and thus impossible to determine strain magnitudes in the phyllite.

Included coticule layers are strongly folded, and except on short limbs of larger folds, these minor folds have dextral vergence (Figure 2b). Prominent open metre-scale folds of the transposed foliation in a central outcrop also have dextral vergence. The coticule folds show a progressive sequence of development, with increasing dextral shear, from open and vertically plunging to isoclinal and horizontally plunging while remaining intrafolial to the transposed foliation.

Microstructure

In thin section, the phyllite is seen to consist mainly of well-aligned white mica and inequant quartz grains whose shapes are controlled by the mica. A subsidiary amount of equant albite is present, as is a few percent of opaques of two varieties (a very small, elongate type and a larger, equant type which often has quartz or quartz-chlorite pressure shadows). Chlorite-white mica stacks are common, and almost always have their basal plane trace at a high angle to the mica foliation. Most samples contain several percent of small idioblastic garnets, which are usually zoned with an inclusion-rich core and an inclusion-free rim. A small amount of fine grained, elongate, poikiloblastic andalusite occurs, as well as minor amounts of tourmaline and apatite. In layers of appropriate bulk composition, large pseudohexagonal or rounded highly poikiloblastic syntectonic cordierite crystals are found.

Close inspection of the mica foliation in very thin sections reveals that it is in fact defined by tightly kinked single white mica grains and aggregates of a few grains rather than simply well-aligned micas. The micas which define the kinks' long limbs are at a low angle to compositional layering, while the micas defining their short limbs are at a somewhat greater angle (Figure 2c); the kinks have dextral vergence. At an advanced state of kinking, the kinks become very tight and new white mica grows parallel to the kinks' axial surfaces. All stages of kink development are preserved in different small volumes of the phyllite, and early kinks can be redeformed at later times. This is due to the process of transposition, which nucleates at different places, and at different times, in the deforming rock mass, and is cyclic. Because of this spatial and temporal heterogeneity of development, and cyclic nature of the process, it is usual to get overprinting relationships in a progressively transposing body of rock, but they are formed during continued deformation rather than by discrete deformation events. These overprinting relationships can be on any scale, and can be very complex.

The cordierite porphyroblasts mentioned above overgrow the latest transposed foliation, preserving traces of the foliation internally. They are also rotated, again in a dextral sense, with respect to the foliation and hence are late syntectonic (Figure 2d). They are due to contact metamorphism associated with granite intrusion, and as such offer proof that the granite was intruded syntectonically. W.K. Fyson (written commun., 1984) notes that cordierite and andalusite porphyroblasts occurring in numerous outcrops marginal to granites in this area show a consistent dextral sense of rotation.

THE GRANITE

Mesostructural aspects

Distant from its contact with the Halifax Formation phyllites, the granite appears to be undeformed (but see section (ii) below). It is pink and equigranular, and grain sizes of quartz, feldspars and micas average 0.5 cm or so. No evidence of primary structures, such as flow foliations, has been observed.

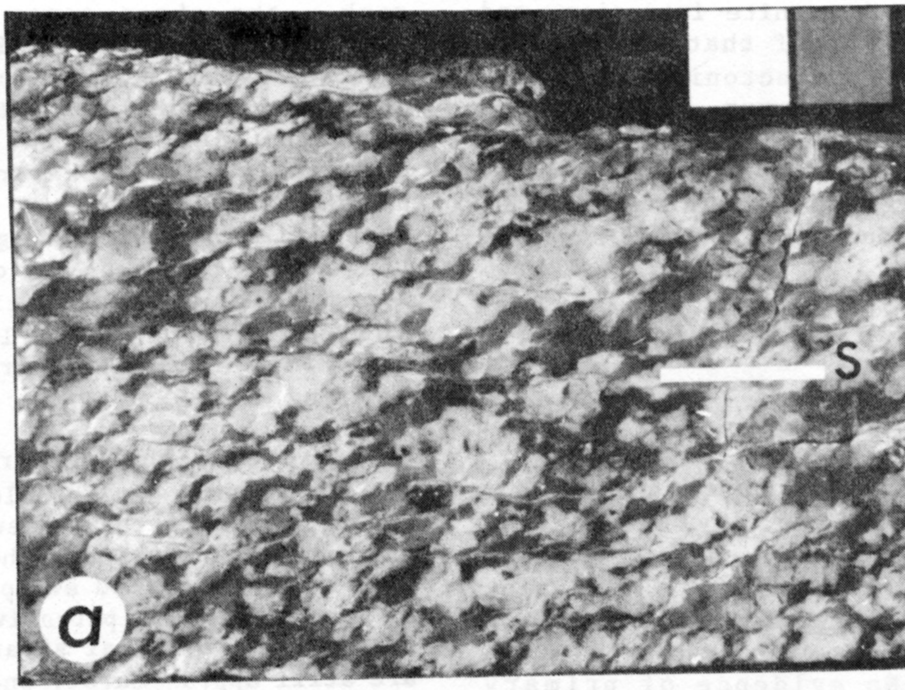
Approaching the phyllite contact, a very inhomogeneous style of deformation becomes evident. Its first manifestation is as rare, short, isolated, narrow (one to several mm) slightly curved shear zones. Towards the contact these narrow shear zones rapidly increase in number, length and planarity (though not in width), and become more closely spaced and quite periodic. They appear similar to the C surfaces (Berthe et al. 1979) often developed in mylonites at low strains, or the second transecting foliation sometimes developed in highly strained rocks with a pre-existing foliation (Vernon et al. 1983). It can be seen in the field and by optical microscopy (see section (ii) below) that in the present case the small shear zones develop progressively in unfoliated parent material, and that the apparently earlier gneissic foliation developed synchronously with them (Figure 3a). As deformation becomes more intense towards the phyllite contact, the angle between the two foliations decreases. This is an example of deformation partitioning (Lister and Williams 1983, Figure 5a), whereby alternating narrow layers of rock - the shear zones - deform by essentially progressive simple shearing (thereby effectively acting as surfaces of sliding), while the intra-shear-zone material deforms by essentially progressive pure shearing (shortening perpendicular to the shear zone boundaries and extending along their length). At the scale of the whole outcrop, though, the deformation of this granite mantle perhaps approximates to bulk progressive simple shearing.

The actural phyllite-granite contact is not exposed. At the closest granite outcrop, no more than a few metres from the contact, the narrow shear zones are very closely spaced and periodic (0.5 cm intervals) and pervasive throughout the rock. Individual shear zone widths are still approximately one mm.

Microstructure

The progressive microstructural development of the granite, from 'undeformed' parent material in the centre of the body to very inhomogeneously deformed material at the bodies' margin, considered together with the late syntectonic rotated cordierite porphyroblasts described above and the fact that the phyllite foliation is approximately parallel to the spaced shear zone foliation in the granite carapace and is not deflected by or wrapped around the granite body, indicates that the granite was emplaced syntectonically, and probably late, in the ductile deformation history of the host phyllites.

The 'undeformed' granite in thin section exhibits a wide range of ductile deformation microstructures. All minerals show moderate to strong undulose extinction, with quartz and both plagioclase and K-feldspar possessing well-developed subgrains. Plagioclase grains almost always have pervasive, fine, irregular, lenticular, mechanical polysynthetic twinning (Figure 3b). Both these deformation twins and the ubiquitous growth twins are often bent through a small angle.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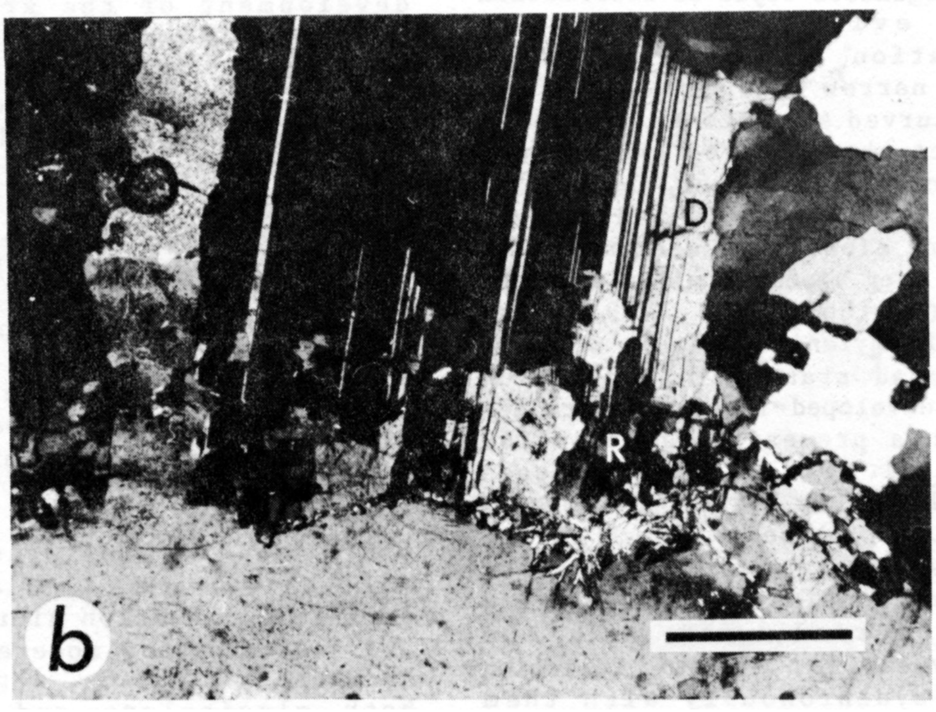
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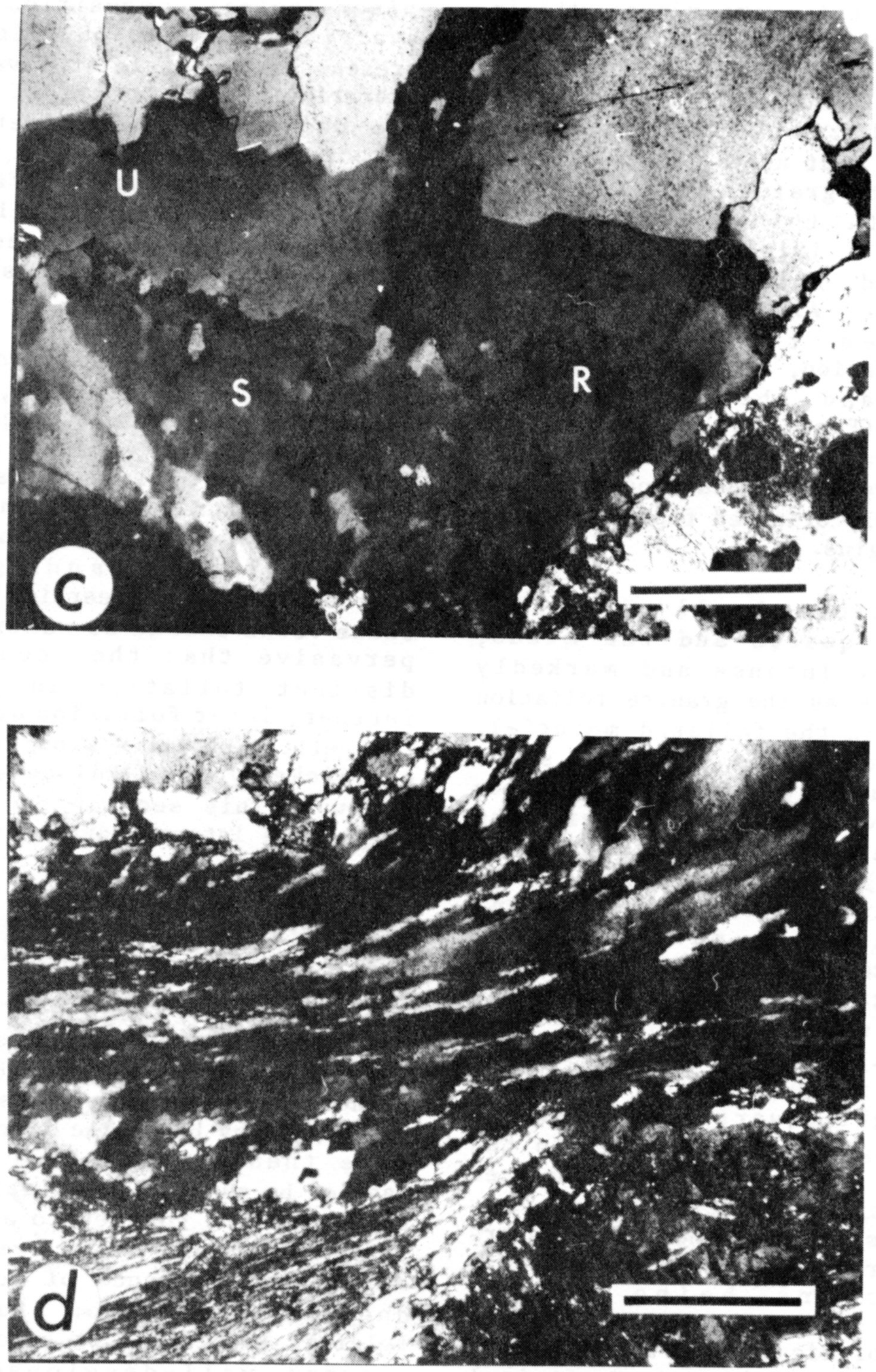

Figure 3: The granite (Figure 1, location 1). North to top in all photographs. 3a - slabbed specimen of foliated granite, shear zone foliation orientation marked S. Scale bar 2 cm. 3b - photomicrograph of plagioclase in 'undeformed' granite. Note irregular deformation twinning (D), subgrains and recrystallization along grain boundary (R). Scale bar 300 um, NX. 3c - photomicrograph of quartz in 'undeformed' granite. Note undulose extinction (U), subgrains (S), finer recrystallization along strongly sutured grain boundaries (R). Scale bar 300 um, NX. 3d - photomicrograph of quartz in shear zone foliation, same specimen as 3a. Scale bar 300 um, NX.

K-feldspar grains are microperthitic, and have pronounced but inhomogeneously developed microcline tartan twinning. K-feldspar also occasionally has minor recrystallization along grain boundaries. What appear to be original single quartz grains in hand specimen are seen in thin section to be aggregates of irregular grains with lobate and interlocking grain boundaries. Along many of these boundaries there is finer recrystallization, the new grains being inequant and showing undulose extinction (Figure 3c). Biotite and muscovite grains are generally slightly bent and have a shredded appearance due to irregularly oriented finer grains at crystal margins.

Deformation of all minerals, especially quartz and the micas, becomes more intense and markedly inhomogeneous as the granite foliation develops. In the foliated material, the foliation planes (the small shear zones) are usually defined by elongate aggregates of ribbon quartz which has often dynamically recrystallized (Figure 3d), and fine dynamically recrystallized layers of quartz and mica. That the minerals have recrystallized dynamically is shown by their fine grain size and weak undulose extinction when compared to the non-recrystallized grains, their weakly serrated or irregular grain boundaries, their slight (quartz) to moderate (mica) elongation subparallel to the small shear zones, and their pronounced crystallographic preferred orientation. All minerals in intra-shear-zone layers are very strongly deformed, both sorts of feldspars being partly recrystallized around grain margins, both types of micas being strongly bent and occasionally kinked, and original quartz grains now completely recrystallized and elongate.

All microstructural features indicate a dextral sense of shear.

LATE QUARTZ VEINS

Veins of different ages and differing mineralogical composition are found everywhere in the phyllites of the present area. At least five distinct, overprinting generations of vein types are observed; their mineralogy and structural development is the subject of a separate study. Briefly, the geological history of all types is consistent with the argument of long-lived dextral transcurrent shear in the region.

Ubiquitous in the pelitic phyllites is a family of quartz veins, of various (closely spaced) relative ages, various thicknesses and various mesoscopic structural styles. These are the latest structure, apart from joints, in the study area and as such overprint all phyllite (and granite) microstructures and earlier vein types. These veins become so numerous and so pervasive that they constitute a distinct foliation in places (a further, later foliation developed in the pelitic phyllite along the margins of thicker veins is discussed briefly below). This section will consider only these latest quartz veins.

The approximate mean trend of these latest veins is 052°, whereas that of the transposed foliation is 078° (the Chedabucto Fault trends E-W). The veins formed in tensile fractures oriented in the usual way - approximately parallel to the bulk principal compressive stress direction - probably by hydraulic fracturing, and were then rotated in a clockwise fashion by continued dextral shearing. All veins are rotated to a greater or lesser extent. All veins show mesoscopic evidence of considerable ductile deformation (for example folding, boudinage, et cetera) and all possess well-developed ductile deformation microstructures, such as subgrains, dynamically recrystallized grains, and so on. These latest quartz veins are of several different but closely-spaced ages, as some have been rotated slightly more, others slightly less, than the mean trend; those that have been rotated more than this mean trend are cut by those rotated less, and hence are earlier.

Many of the mesoscopic structures in these veins appear to indicate a sinistral shear sense on cursory examination. In fact, all structures can be demonstrated to be formed during progressive dextral shear, and accommodated by ductile mechanisms. We will illustrate and discuss several of these structures below.

Extensional structures

All veins except those with a small length-to-width ratio show evidence of extension parallel to their length. Thick veins (5-10 cm) are boudinaged or have well-developed low amplitude pinch-and-swell, with a wavelength similar to that of boudin length - about five times vein thickness. Veins of moderate thickness (1-3 cm) have low amplitude pinch-and-swell, the wavelength of which is variable but generally about seven to ten times vein thickness. Thin veins (3-5 mm) show very low amplitude pinch-and-swell with wavelengths of about ten or several tens of centimetres which is about twenty to sixty times vein thickness. Also, small shear zones (similar geometry to 'shear bands', White et al. 1980) occasionally transect veins or vein boudins, and have a dextral sense of shear offset.

These extensional structures originated as the veins rotated into and through the extensional segment of the incremental strain ellipsoid for progressive simple shearing (Hobbs et al. 1976, p. 48), following an initial period of shortening. During this earlier period of shortening, the veins may have thickened or folded somewhat, and unfolded as they rotated into and through the extensional segment. W.K. Fyson (written commun., 1984) notes that in other places in the Meguma Terrane, quartz veins are found which lie axial planar to dextral kinks, and which are sometimes boudinaged. He suggests that veins such as are illustrated in Figures 4b and 5a could have formed in this

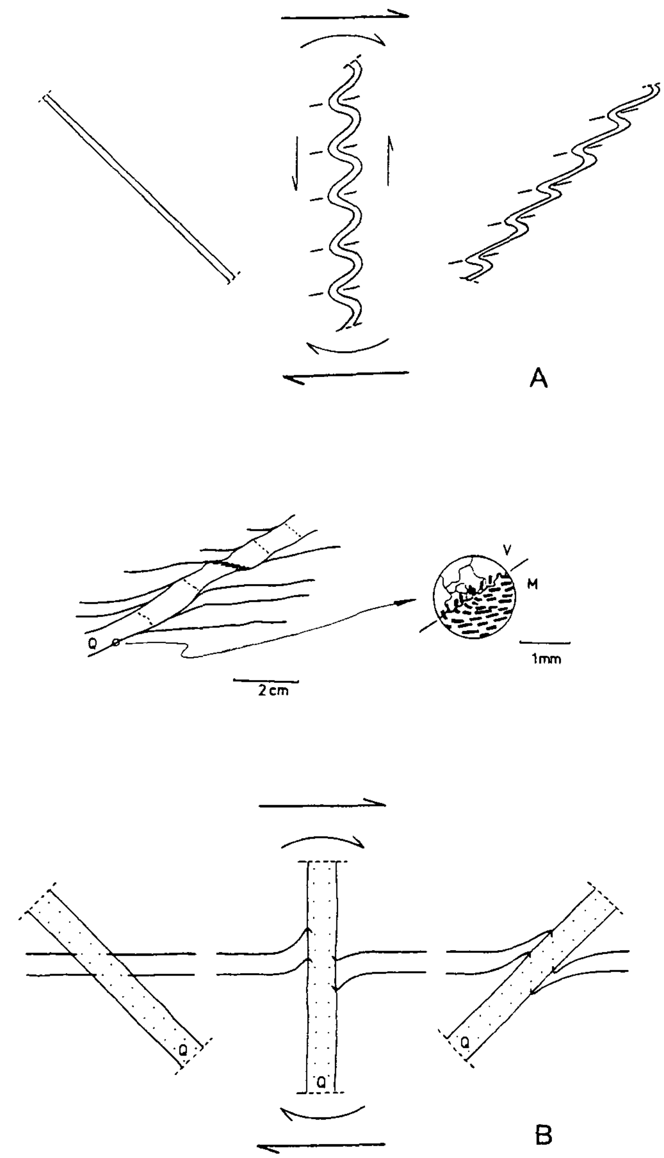

Figure 4: Diagrams of structures in latest quartz veins. 4a - model of forming sinistral-verging folds in a dextral progressive simple shear environment. 4b - top part shows sketch of slabbed specimen and part of thin section of same specimen. Note deflection of transposed foliation at vein margins. In sketch of slabbed specimen, a small shear zone is shown by the oblique ruling, and several joints by the dashed lines which traverse the vein. In sketch of thin section, note folding of transposed foliation at vein margin; V indicates vein, M indicates phyllite matrix. Individual mica grains are shown by the black bars. Lower part of figure shows the model for forming deflected foliation by dextral progressive simple shearing.

manner, mostly obscuring the kink short limb. Some of the veins we have examined may have formed in this way; as we see no remnants of kink short limbs associated with these veins, this would require that the veins consistently obliterate the entire short limb of each kink, or that the short limb remnants are destroyed by further ductile deformation.

Folds

A number of veins are folded, and the small folds possess sinistral vergence. These can be explained by antithetic shearing across the vein during rotation; the process is illustrated in Figure 4a. Some of these folded veins show pinch-and-swell, indicating extension along their length, superimposed on the earlier folds.

Deflection of foliation

Along the margins of most veins, the transposed foliation is deflected in a fashion expected from sinistral shearing across the vein (Figure 4b). Furthermore, in thin section, mica grains of the transposed foliation are observed to be overgrown in places by the quartz of the vein - see top right of Figure 4b - so that the foliation trace is folded through a large angle at the vein margin. Both features are due to rotation of the veins during progessive dextral shearing (lower part of Figure 4b).

One further important feature is the new foliation developed along the margins of some veins, especially those with small length-to-width ratios. This foliation is due to crenulation of the transposed foliation, and is in fact a differentiated crenulation cleavage (see feature 6, Figure 5a). It is a product of antithetic shearing which occurred along the quartz vein margins as they were rotated during the progressive dextral shearing history (Figure 4). As shown in Figure 5a, it is in essentially conjugate relationship to small shear zones developed in the quartz veins. Thus,

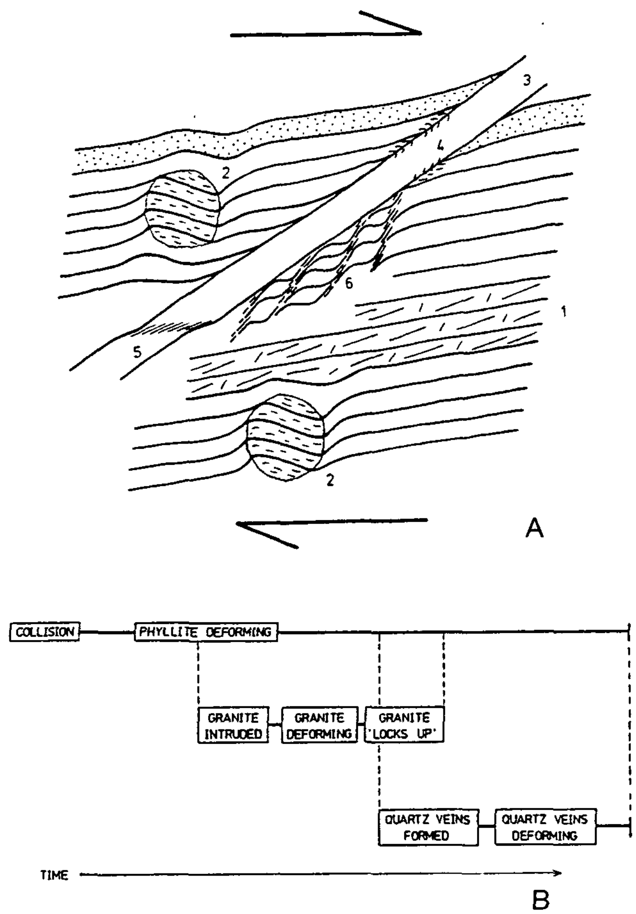

Figure 5: Summary. 5a - composite diagram of microstructural shear asymmetry indicators in transposed phyllite. Numbers are: 1 - dominant orientations of limbs of asymmetric kinks of white mica (see Figure 2c); 2 - rotated syntectonic cordierite porphyroblasts; 3 - quartz vein; 4 - deflected and partly overgrown transposed foliation at quartz vein margin; 5 - small shear zone in quartz vein; 6 - differentiated crenulation cleavage at vein margin. 5b - deformation history of study area. Time axis is non-linear.

in summary, all structural features associated with these latest quartz veins indicate a continuation of the progressive dextral shearing deformation history, and all features are accommodated by ductile mechanisms.

DISCUSSION AND CONCLUSIONS

The various microstructural features of the transposed pelitic phyllite which indicate a deformation history of progressive, long-lasting dextral transcurrent shear over the study area are summarized in Figure 5a. Together with the mesostructural indicators discussed previously (folds in coticule layers, shear zones developed in syntectonic granite, various structures defined by quartz veins), they offer evidence of movement sense along the CCFS covering much of its history. Furthermore, latest brittle structures such as faults and joints which overprint all earlier structures, from almost the total exposed length of rocks affected by movement on the CCFS (Eisbacher 1970, J.C. White, pers. commun., 1984, unpublished results of the present authors from along the SE coast of Chedabucto Bay), also indicate a continued dextral sense of displacement.

It has been shown that the various mesoscopic and microscopic structures which are found in the granite, the pelitic phyllite and the latest quartz veins, have been formed by (or in the case of vein rotation, accommodated by) ductile deformation mechanisms. Evidence for dislocation mechanisms exists in the form of dynamic recovery (which causes subgrain development) and dynamic recrystallization in quartz, K-feldspar and plagioclase feldspar, deformation-induced twinning in K-feldspar and plagioclase feldspar, bending and kinking of the crystal lattice in biotite and muscovite micas, and ubiquitous undulose extinction of all minerals. Evidence for diffusion mechanisms occurs in the form of quartz and quartz-chlorite pressure shadows on opaque mineral grains and the formation of a differentiated crenulation cleavage at vein margins following their rotation through large angles. Therefore, ductile deformation mechanisms were operative throughout and up until the latest stages of the history of the rocks.

The granite body within the study area was emplaced syntectonically, probably fairly late in the history of the host phyllites. This is shown by the formation, due to contact metamorphic effects, of cordierite porphyroblasts in the surrounding phyllite, which overgrow the latest transposed foliation and are themselves rotated; by the fact that the phyllite foliation is approximately parallel to that developed in the granite mantle and is not deflected by the granite body; and by the progressively increasing intensity of deformation from slightly deformed core to strongly and inhomogeneously deformed mantle of the body.

The proposed structural history of the present area is summarized in Figure 5b. The time axis is non-linear. The bulk deformation of the studied area can be divided into that occurring in three subsystems, those of the phyllite, the granite and the quartz veins. Figure 5b shows this subdivision, and emphasises that the deformation effects in each subsystem develop together through time, as each subsystem is interrelated with the others. Thus, the phyllite began deforming upon accretion of the Meguma Terrane, and continued deforming until the latest stages of ductile deformation. Early-formed foliations were transposed and their component grains recrystallised, and folds were generated, rotated, tightened and refolded. During this ductile deformation history (and, it is argued previously, late in this history) the granite intruded the phyllites and was deformed with deformation concentrated at the margin of the cooling body. Subsequent to granite intrusion and some deformation, quartz veins were formed. These cut all earlier structures in the phyllite and the granite, and are themselves deformed by ductile mechanisms. Significant ductile deformation in the granite ceased (the box "granite 'locks up'" on Figure 5b), though deformation in the phyllite and its quartz veins continued. Finally, ductile deformation in the whole system ceased. It does not seem useful to attempt to separate 'Acadian' deformation from 'Hercynian' deformation (cf. Williams and Hatcher 1982) in this area, as structural evidence is compatible with a single progressive deformation history rather than one which is episodic.

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