DISCUSSION OF "STRUCTURAL STUDY OF HIGHLY DEFORMED MEGUMA PHYLLITE AND GRANITE, VICINITY OF WHITE HEAD VILLAGE, S.E. NOVA SCOTIA" BY C.K. MAWER AND P.F. WILLIAMS

J.D. Hill
Geological Survey of Canada
601 Booth Street, Ottawa, Ontario K1A 0E8

R.P. Raeside
Department of Geology, Acadia University
Wolfville, Nova Scotia B0P 1X0

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INTRODUCTION

Mawer and Williams (1986) recently described a series of structures in the Whitehead area, Nova Scotia, which they related to dextral transcurrent shear on the Cobequid-Chedabucto fault system (Fig. 1). They inferred a sequence of overlapping events involving isoclinal folding, development of an associated steady state transposition foliation, late syntectonic granite intrusion, asymmetric refolding and quartz vein formation. Their work was primarily based on detailed study of several isolated outcrops. Although we agree with most of their conclusions, mapping of the whole area (Hill, 1986) has revealed additional information that is pertinent to the story. An expanded version of the structural history of the Whitehead-Canso area is presented in the following section. Specific comments on Mawer and Williams' (1986) paper are made where necessary. The reader should note that structural correlation is very difficult due to the similar orientations and styles of structures of different generations. In this regard, we have correlated structures mainly relative to porphyroblast growth and granite intrusion, two events that appear to be <u>approximately</u> coeval.

STRUCTURAL HISTORY

For simplicity in discussion, structures are assigned to two main events - D_1 and D_2. All of the structures described by Mawer and Williams (1986) are related to D_2. Post-D_2 kink bands, north-trending crenulation cleavages of more than one generation and associated open warps of bedding are developed sporadically in less competent rocks. These structures appear to be of minor importance and are omitted from the discussion that follows.

D_1

Four separate features point to one or more deformation events that predate D_2. Although correlation between these features is virtually impossible, they could all be related to a single period of deformation. With this in mind, they are tentatively assigned to D_1.

a) Kilometre-scale stratigraphic repetition within the Meguma Group indicates the presence of symmetrical, upright to steeply inclined, gently-plunging synclines and anticlines. Axial traces trend ENE in the southwest and east in the northeast. Similar macrofolds are recognized in the Meguma terrane southwest of the Canso-Whitehead area where D_2-related deformation is less intense or absent. The schistosity associated with these folds southwest of the Canso-Whitehead area has been dated at 400-415 Ma by Reynolds and Muecke (1978).

b) A transposition foliation (S_{2a}) oriented subparallel bedding is the dominant fabric in the southwestern part of the area. At Spears Head (location 1, Fig. 1), the transposition foliation is represented by a crenulation cleavage and remnants of an older mica foliation (S_1) are clearly visible between the spaced S_{2a} septae (Fig. 2, inset A). At Whitehead (location 3, Fig. 1), the transposition foliation postdates an earlier planar fabric, represented by parallel bands of garnet (S_1) extending across coticule nodules, preserving a stage 5 texture of Bell and Rubenach's (1983) model of schistosity development (Fig. 3).

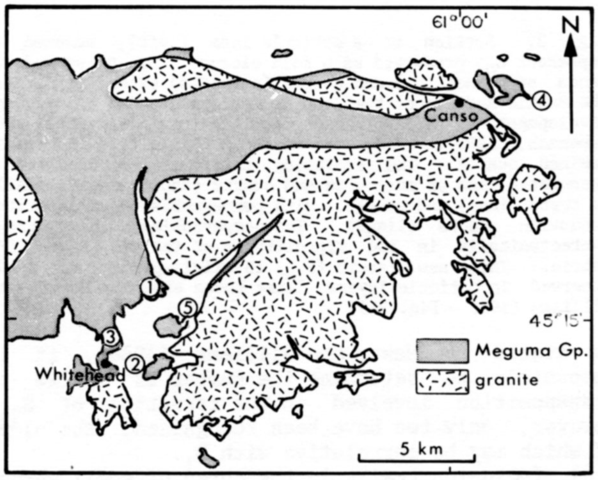

Fig. 1. Location map showing the distribution of the Cambro-Ordovician Meguma Group and Devonian granite. Circled numbers refer to locations cited in subsequent figures.

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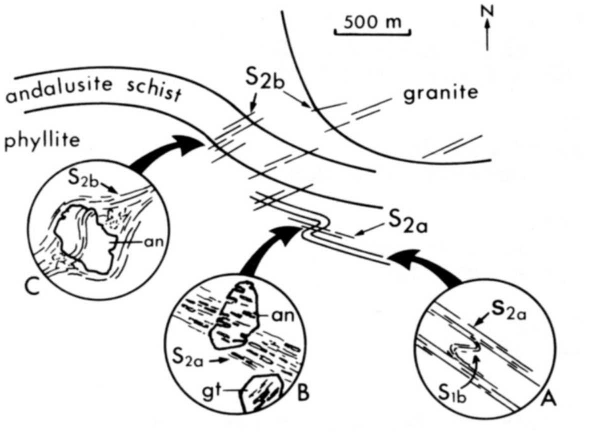

Fig. 2. Structural relationships in the Spears Head area (location 1, Fig. 1). S_{2a} transposition foliation, locally preserving crenulated relics of S_1 (inset A), is axial planar to isoclinal asymmetric F_{2a} folds. Andalusite (an) and cordierite porphyroblasts overprint S_{2a} and garnet (gt) typically contains inclusion trails oriented at large angles to S_{2a} (inset B). S_{2b} crenulation cleavage deforms porphyroblasts (inset C), is axial planar to an open F_{2b} fold and is concordant with a flattening foliation in adjacent granite.

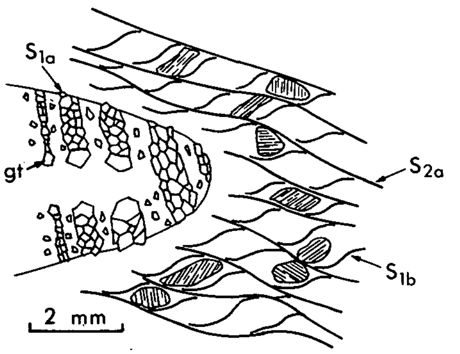

Fig. 3. Portion of a coticule lens (left), assumed to represent S_0, preserved as a fold closure. S_1, preserved as bands of garnet (gt) and quartz (unshaded) extending across the mantle and rim of the lens, displays stage 5 of cleavage development in a deformation partitioning model (Bell and Rubenach, 1983). The core of the coticule fold is coarse grained quartz. The enclosing fabric is composed of a crenulated mass of muscovite and quartz (shown schematically by trend lines) and garnet, with porphyroblasts of chlorite-muscovite stacks (lined). The porphyroblasts have grown syntectonically in the microlithons of the new stage 3/4 fabric. This new fabric (S_{2b}) is axial planar to folds observed in coticule layers, like those shown by Mawer and Williams (1986 - Fig. 2b).

As stated by Mawer and Williams (1986), it is impossible to determine the number of cycles of transposition involved in the formation of S_{2a}. However, only two have been recognized, the older of which may be correlative with D_1.

c) Inclusion trails in the cores of small garnet porphyroblasts are typically oriented at large angles to the enclosing S_{2a} transposition foliation at Spears Head (Fig. 2, inset B). This suggests that the garnet cores overgrew an older fabric (S_1?) that may have been tectonic in origin.

d) Isoclinal, ENE-trending, gently-plunging folds at scales up to tens of metres are preserved in Halifax Formation hornfels at location 5 (Fig. 1). A single schistosity, which is barely visible on weathered surfaces because of the overprinting effects of contact metamorphism, is axial planar to these folds. This relationship suggests that the folds could be related to either D_1 or D_{2a}, both of which predate granite emplacement. However, the symmetrical style of the folds indicates they are more likely related to D_1.

D_2

The D_2 event is divided into a series of phases that appear to overlap and which are tightly constrained in time based on isotopic age data (see below). Three generations of structures are recognized (D_{2a}, D_{2b}, D_{2c}), each of which produced Z-shaped folds (looking down plunge) that plunge gently to moderately to the east and west. Deformation both preceded and followed granite intrusion, and tectonic fabrics in the granite are only obvious in the northern 10 km of the area and in a narrow east-trending shear zone south of Whitehead (location 2, Fig. 1).

The oldest phase of D_2 deformation is represented by the S_{2a} transposition foliation, which was described in detail by Mawer and Williams (1986). It is axial planar to cm to tens-of-metres-scale asymmetric, isoclinal folds in the Spears Head area that plunge gently eastward (Fig. 2). S_{2a} is assigned to D_2 on the basis of fold asymmetry, its spatial association with other D_2 structures, its postdating of one or more planar fabrics, and because its formation appears to have partly overlapped porphyroblast growth (see next paragraph). Its age relative to other D_2 structures is based on the fact that it is overprinted by the porphyroblasts and does not occur in granite.

Cordierite, staurolite, biotite and andalusite porphyroblasts overprint S_{2a} (Fig. 2, inset B). One km southwest of Whitehead where evidence for post-F_{2a} deformation is absent, biotite porphyroblasts that truncate S_{2a} are locally kinked, with kinkband boundaries oriented parallel to S_{2a}. This suggests that their growth partly overlapped F_{2a}. Elsewhere, cordierite and andalusite contain inclusion trails that are concordant with S_{2a}. In random section, some of these porphyroblasts appear to preserve sigmoidal inclusion trails, but in sections cut parallel to lineation and perpendicular to foliation, a number of "millipede structures" (Bell and Rubenach, 1980) can be identified. These indicate that the porphyroblasts grew in zones of inhomogeneous progressive shortening of a deformation partitioned rock rather than as rotated syntectonic porphyroblasts. Fig. 2d of Mawer and Williams (1986) shows a cordierite porphyroblast which appears to display such a structure (Fig. 4), which we would interpret as synchronous with S_{2a}. Nevertheless, this particular millipede structure has an asymmetry indicative of dextral shear, which we ascribe to deformation postdating formation of the millipede microstructure. Thus, at least locally, domains existed that sustained increments of more or less coaxial strain during D_2. Other examples of millipede structures occur at location 5 (Fig. 1) where an enclave of phyllite has been preserved almost surrounded by undeformed granite. There, both andalusite and cordierite porphyroblasts display distinct millipede

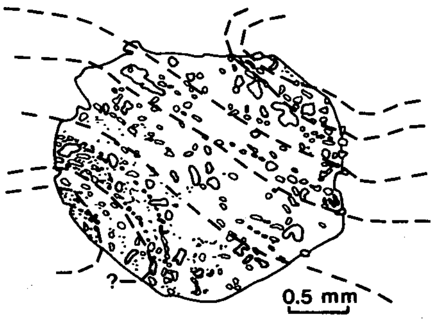

Fig. 4. Sketch of Fig. 2d of Mawer and Williams (1986), showing an alternative interpretation for the development of the internal fabric of a cordierite porphyroblast involving a millipede structure and deformation partitioning model. The U-shaped trend of the inclusions is represented by dashed lines.

structures in spite of sillimanite grade contact metamorphism. Elsewhere, andalusite contains inclusion trails that are weakly crenulated, with crenulation axial planes oriented parallel to S_{2b}. This suggests that porphyroblast growth also overlapped the initial stages of F_{2b}. Biotite porphyroblasts southwest of the Whitehead-Canso area have been dated at 362-365±7 Ma (Dallmeyer and Keppie, 1984). Isograds defined by porphyroblasts appear to be truncated by the 369±2 Ma Sherbrooke pluton (Keppie, 1983). Mawer and Williams (1986) have interpreted the cordierite porphyroblasts north of Whitehead to be due to contact metamorphism. Although this conclusion may be valid for pink (in hand specimen) acicular andalusite which is restricted to pelitic rocks within 500 m of granite, the origin of other porphyroblasts is much less certain. For example, cordierite and staurolite occur sporadically at irregular distances up to 2 km from the closest granite. Grey blocky andalusite is confined to a specific stratigraphic horizon (depicted in Fig. 2) that lies as much as 2.5 km from the granite, the maximum distance possible in the Whitehead-Canso area. This distribution of porphyroblasts cannot be attributed to the subsurface presence of granite since a preliminary gravity model (unpublished) suggests that no large granite bodies lie beneath the Meguma Group exposures. Thus, the porphyroblasts (possibly excluding the pink andalusite) could be related to either contact or regional metamorphism.

The next phase involved granite emplacement. Unpublished U-Pb monazite dates of three granite plutons in the area fall in the range 370-372 Ma (Krogh, personal communication, 1986). The fact that both the porphyroblasts (described above) and the granite plutons are coeval with or postdate S_{2a} and are deformed by S_{2b} (Fig. 2) indicates that intrusion and porphyroblast growth were approximately synchronous. This implies a close causal relationship between granite intrusion and low pressure regional(?) metamorphism. Since the andalusite schist horizon is truncated by granite east of Spears Head (location 1, Fig. 1), granite emplacement cannot have preceded porphyroblast growth. Rather, plutonism must have been either coeval with or slightly later than the period of porphyroblast crystallization. Post-granite deformation is not concentrated at pluton margins, contrary to the interpretation of Mawer and Williams (1986). The deformation they describe in the granite at Whitehead is related to an east-trending D_{2b} shear zone that completely ignores pluton boundaries (Fig. 5).

An ENE-trending crenulation cleavage (S_{2b}) that is axial planar to asymmetrical, open to isoclinal folds (F_{2b}) that plunge gently to moderately both east and west defines the next phase of deformation. S_{2b} deforms the porphyroblasts (Fig. 6, inset A) and is concordant with a "flattening" foliation in granite (Fig. 2). In the Canso area where strain is more intense, older fabrics are completely transposed into S_{2b} and a mylonitic S-C fabric (also developed in the D_{2b} shear zone shown in Fig. 5) is present in granite. S_{2b} has been dated by Dallmeyer and Keppie (1984) at 365-373±7 Ma.

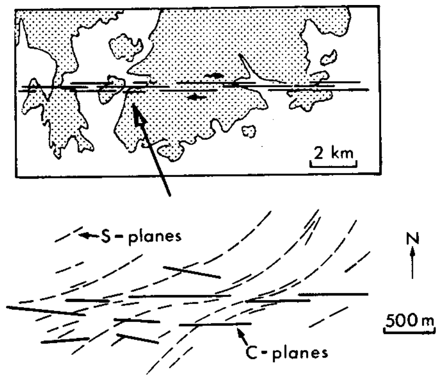

Fig. 5. S-C fabric relationships in a D_{2b} dextral shear zone (location 2, Fig. 1). The shear zone ignores pluton boundaries and extends along strike for at least 12 km.

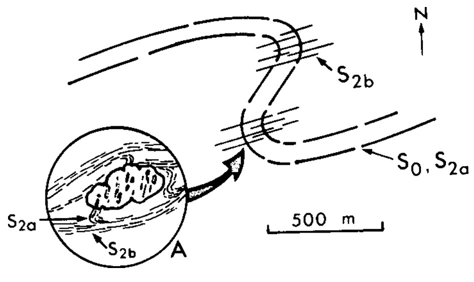

Fig. 6. Structural relationships in an isoclinal F_{2b} macrofold at Whitehead (location 3, Fig. 1). S_{2b} crenulates an older mica foliation (composite S_1-S_{2a}?) and deforms biotite and andalusite porphyroblasts (inset A).

The last phase of ductile deformation associated with D_2 was only recognized in the Canso area where gently-plunging asymmetric folds deform boudinaged granite sheets in migmatitic metawacke (Fig. 7). Although some of the folds are correlated with D_{2b} because the foliation in the granite has an axial planar relationship, others have S_{2b} folded with the granite and must be F_{2c} in age. A new crenulation cleavage (S_{2c}) is locally developed in some F_{2c} closures.

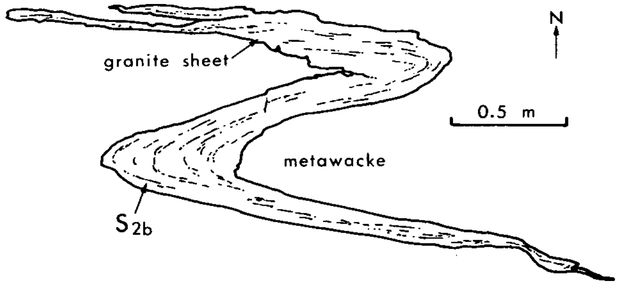

Fig. 7. Isoclinal F_{2c} fold defined by a boudinaged granite sheet in migmatitic metawacke (location 4, Fig. 1). S_{2b} is folded with the granite and an axial planar S_{2c} crenulation cleavage is developed locally in some F_{2c} closures.

CONCLUSIONS

Regional mapping in the Whitehead-Canso area has substantiated and amplified the structural history presented by Mawer and Williams (1986). Various features point to a poorly-defined early phase of deformation (D_1) that is tentatively correlated with the 400-415 Ma event recognized farther southwest in the Meguma terrane. All of the dominant structures in the area define a multiphase D_2 event that appears to be related to transcurrent movements along the Cobequid-Chedabucto fault system (Keppie, 1983; Mawer and Williams, 1986). Isotopic age data suggest D_2 was tightly constrained within the period 370±5-10 Ma. Granite plutons were emplaced relatively early in D_2, not late as suggested by Mawer and Williams (1986).

ACKNOWLEDGEMENTS

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