3. Structure and Metamorphism

3.1. Structure

The structural geology of the Pine Creek Geosyncline is dominated by regional scale thrusts, upright to overturned folds (eg., the Howley Anticline and a series of anastomosing brittle-ductile shear zones and late faults with associated quartz veining eg., the Shoobridge Fault or Pine Creek Shear Zone), which deform the earlier fold structures. The shear zones contain a strong stretching lineation which plunges steeply, asymmetric structures, C-S structures, asymmetric pressure shadows and en echelon vein sets. These structures all suggest reverse movement whereas brittle kinematic indicators suggest the later faults had essentially conjugate dextral and sinistral strike-slip movements eg. the Giants Reef fault near Batchelor.

Structures from the first deformation event are preserved as rare small recumbent folds in the hinge area of the regional anticlines and a weak bedding parallel to fabric. The folds are isoclinal to tight asymmetric and are often confined to individual lithological horizons. These are associated with a bedding parallel spaced fabric and because these folds are folded around the hinge of the regional anticlines they have an opposite sense of vergence to parasitic folds associated with the regional folds. They are considered to have formed prior to the main fold event. This deformation event is considered to represent the early D2 deformation event of Johnson (1984).

The second event in the geosyncline is dominated by macroscopic anticlines (eg., the Howley Anticline) and a series of anastomosing brittle-ductile shear zones with associated quartz veining. An anastomosing series of north to north-west trending, sub-vertical, ductile-brittle shear zones deform the earlier fold structures, eg. the Pine Creek shear zone or the Shoobridge fault. The shear zones contain a strong stretching lineation which plunges steeply, asymmetric structures, C-S structures, asymmetric pressure shadows and en echelon vein sets. These structures all suggest that the movement along these zones was dominantly reverse, although a minor component of strike slip movement is recorded locally.

The folds associated with the second deformation event, D3 of Johnson (1984), are best described as tight, doubly plunging, upright to overturned, asymmetric, non cylindrical folds. Regionally the folds can be traced for over sixty kilometres. The non-cylindrical nature of this folding is well developed in the vicinity of the Cosmo Howley mine where the Howley Anticline plunges to the north and the fold axis strikes to the north-west, but plunges to the south with the fold axis striking to the north in the Bridge Creek area. A prominent axial planar cleavage is present in the finer grained sedimentary rock which can vary, due to a refolding of the fold axes by D3 and D4 folds, between 330° to 010°; eg, the Howley Anticline between Cosmo Howley and Bridge Creek. The folds are dominantly asymmetric in section with bedding on the eastern limb steep to overturned. There are numerous small scale M-folds and asymmetric parasitic folds in the limbs. These folds range in size from 3–5 centimetres to metres in wavelength and amplitude. The short limbs of these folds are commonly sheared and veined. In drill core, parasitic folds can be identified by bedding and cleavage relationships and by the presence of minor fold closures. The axial plane fabric is weakly developed with intensity of the fabric often lithology dependent. S2 is preserved in the more competent cherts and tuffs as a weak, spaced fracture cleavage while the phyllitic rocks preserve the fabric as a weak slaty cleavage.

These folds are also doubly plunging forming crests and troughs along the length of their fold axes. In some areas, eg, around Goodall, this has been accentuated by D4 cross folding related to the Maude Creek event of Stuart Smith et al. (1993). However troughs and crests appear to be related in general to the D2 event and appear to be related to the development of D2 duplex thrust zones.

In most areas of the Pine Creek Geosyncline the D2 folds have been obliterated by syn- to post-folding shearing.

These shear zones occur as an anastomosing set of moderate to high strain zones with a fabric (S3) that strikes parallel to the hinge zones of the D2 folds and dips between 30° (at Brocks Creek or the Western Arm) to 60° (at Cosmo Howley) when parallel to bedding, or steeply when parallel to the D2 axial planar cleavage. Two different fabrics are observed in the shear zones, which are interpreted to be C-S fabrics as defined by Berthe et al. (1985). The C-S fabrics are preserved in varying intensities, from weak alignment of fine muscovite, to the formation of a differentiated cleavage in the high strain domains. The shear zones can be mapped in the field by a penetrative S-fabric, up to 10 metres wide, which contains narrower high strain zones with C-fabrics up to 15 centimetres in width. The shear zones often contain thin quartz veins that are boudinaged and pulled apart. The shear zones also contain a well defined stretching lineation with an oblique to down dip plunge. Kinematic indicators in these zones all suggest that the movement along these zones was dominantly west block up. The D1 and D2 events both pre-date granitoid intrusion and can be assigned to the Nimbuwah Event as described by Stuart-Smith (1985).

A second generation of folds (D3), which are only locally developed (eg, south of Wolfram Hill, in the Ringwood Ranges where they refold the Ringwood Anticline and near Goodall where they form North East trending cross folds) occur in the Pine Creek Geosyncline. These folds are developed in the Tollis formation and refold the S2 cleavage locally. This deformation event has been assigned to the Maude Creek Event by Needham et al. (1988).

The D1 to D3 events all pre-date granitoid intrusion. D4 structures, however, appear to be associated with granitoid intrusion, forming open east-west trending folds (eg, the open folds that refold the Howley Anticline around the Burnside Pluton). This deformation event formed the broad dome and basin structures evident around the Burnside granite and the Burrundie Dome area and is probably part of the Shoobridge event as described by Stuart-Smith et al.