THE CORMACKS LAKE COMPLEX, DASHWOODS SUBZONE: A WINDOW INTO THE DEEPER LEVELS OF THE NOTRE DAME ARC

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ABSTRACT

The Cormacks Lake complex, long thought to be a distinct Precambrian retrograde granulite complex within the Dashwoods Subzone, comprises Tremadocian metaplutonic rocks of the Notre Dame Arc that intruded a broadly coeval arc volcano-sedimentary sequence, represented by mafic, siliciclastic and cordierite–gedrite paragneisses. Early polyphase deformation and burial of the arc and related sedimentary rocks predated, or was contemporaneous with, intrusion of the syn-tectonic mid-Ordovician Southwest Brook complex tonalites. Thickening and high-pressure metamorphism likely occurred in response to hard collision between the Dashwoods microcontinent and the Laurentian margin.

The restricted occurrence of high-pressure, uppermost amphibolite- to granulite-facies rocks in the typically high-temperature but more moderate pressure Dashwoods Subzone is most simply explained by exposure of the Cormacks Lake complex in a structural window, in part, formed by interference between two phases of deformation. Associated retrograde, lower pressure events may have commenced during the waning stages of arc-magmatism, but continued into the late Early Silurian (ca. 430 Ma). The latest event involved rapid exhumation that preserved both high- and low-temperature decompression reactions. The exhumation was concurrent with bimodal Silurian magmatism and local basin formation, potentially linked to slab break-off and uplift of the Dashwoods Subzone relative to the adjacent Annieopsquotch Accretionary Tract.

INTRODUCTION AND BACKGROUND

The Notre Dame and Dashwoods subzones (Figure 1) of the Newfoundland Appalachians (part of the Dunnage Zone situated west of Red Indian Line; Williams, 1995), preserve a record of Late Cambrian-Early Ordovician obduction of the Baie Verte Oceanic Tract (BVOT) onto the Peri-Laurentian Dashwoods microcontinent (Waldron and van Staal, 2001) and the subsequent injection by syntectonic Early Ordovician to Early Silurian plutons of the Notre Dame Arc (van Staal et al., 1996, 1998; Whalen et al., 1997a). The Dashwoods Subzone, situated in southern Newfoundland (Figure 1), generally represents a deeper, more intensely metamorphosed and deformed structural level, than the dominantly low-grade rocks of the Notre Dame Subzone, which occurs in north-central Newfoundland. The Dashwoods Subzone comprises ophiolitic remnants, mélange (Fox and van Berkel, 1988; Hall and van Staal, 1999) and a variety of mafic through felsic paragneisses, all intruded by a large volume of mainly tonalitic to granodioritic metaplutonic rocks (informally referred to as the 'sea of tonalite' in Newfoundland).

The highest grade rocks occur in the Cormacks Lake complex (CLC), an upper amphibolite to granulite-facies gneiss complex (Owen and Greenough, 2000) that was thought to be Precambrian (Riley, 1957, 1962; Herd, 1978; Kean, 1983; van Berkel, 1987). Quartzofeldspathic gneisses that volumetrically dominate the complex have been interpreted as both metaplutonic rocks (Herd, 1978; Herd and Dunning, 1979; van Berkel et al., 1986) and siliciclastic paragneisses of a deformed basement-cover sequence (van Berkel and Currie, 1988). Northwesterly trending foliations present in part of the CLC deviated markedly from the characteristic northeasterly structural grain of the Dunnage Zone in central Newfoundland, and hence were interpreted together with the high-grade metamorphism, as pre-Appalachian, Precambrian features. However, a distinctive, high-K charnockite (Whalen et al., 1997a) that intrudes the gneisses yielded an age of 460 ± 10 Ma, establishing a Middle Ordovician age for peak metamorphism and deformation (Currie et al., 1991). Coeval ca. 455 Ma K-Ar hornblende and biotite ages from rocks adjacent to the CLC (Stevens et al., 1982), were suggested to reflect rapid Ordovician cooling (Currie et al., 1991). Regional deformation and metamorphism was thought to have ended by the Silurian because late gabbros of the, ca. 431 Ma Main Gut suite (Dunning et al., 1990), are generally unmetamorphosed and undeformed (Currie and van Berkel, 1992) and the rocks are unconformably overlain by unmetamorphosed Silurian redbeds (Chandler and Dunning, 1983).



Figure 1. Lithotectonic domains of the Newfoundland Appalachians (modified after Williams et al., 1988).

Thematic mapping of the CLC and adjacent rocks was undertaken in the summers of 2001-2002 with the aim of establishing its tectonothermal history and relationship to the adjacent Humber Zone and Annieopscquotch Accretionary Tract (AAT, Lissenberg and van Staal, 2002). This context is critical to evaluating the tectonic evolution of the Notre Dame Arc and Dunnage Zone, as the deeper structural level represented by the Dashwoods Subzone provides a window on some processes only incompletely recorded in the upper levels. In this contribution a preliminary description of the geology, structure and metamorphism of the CLC and its environs is presented. These data are compared and integrated with those from other parts of the Dashwooods Subzone (e.g., southern Long Range, Hall and van Staal, 1999) and a testable hypothesis is presented of the tectonic evolution of the entire subzone as a whole.

GENERAL GEOLOGY

THE CORMACKS LAKE COMPLEX (CLC)

The CLC comprises amphibolite- to granulite-facies gneisses and schists that occupy a large (Figure 2), mushroom-shaped culmination straddling the Puddle Pond (NTS map area 12A/5), Main Gut (NTS map area 12B/8) and Dashwoods Pond (NTS map area 12B/1) areas. The oldest units of the CLC are supracrustal rocks that were transformed into paragneiss and layered amphibolite. These rocks occur as narrow mappable units, and also as smaller scale inclusions, within younger metaplutonic rocks (Figure 2). The paragneiss includes rusty-weathered gedritecordierite or gedrite-biotite±hornblende quartzofeldspathic rocks, biotite+sillimanite±garnet bearing psammite and semipelite, and minor calc-silicate rock and marble. These rocks are interlayered on a decimetre- to tens of metre-scale (Plate 1a), and locally have preserved breccia horizons and internal compositional grading, suggesting that compositional layering, at least locally, represents transposed bedding. The micaceous paragneiss is commonly migmatitic, dominantly nebulitic to stromatic, but locally also diatexitic. Volumetrically, the gedrite-biotite quartzofeldspathic gneisses represent the largest component of the paragneiss but the scale of interlayering of the other rock types makes more detailed subdivision impractical on 1: 50 000 scale.

The amphibolites are interlayered with the paragneiss, both at the metre-scale and as separate narrow units (Figure 2). They are locally characterized by a strong centimetre- to



Figure 2. Simplified geology of the Cormacks Lake complex and environs.



Plate 1. Selected units of the Cormacks Lake complex. a) Interbedded gedrite–garnet–cordierite–gneiss (dark grey) and garnet–sillimanite psammite (light grey). b) Clinopyroxene–hornblende– \pm garnet layered amphibolite . Note the discontinuity and convergence of individual compositional layers (white arrows), suggestive of deformed pillows and pillow selvages. c) Garnet–hornblende granodiorite orthogneiss with biotite paragneiss inclusions, demonstrating the metaplutonic character of the Cormacks Lake orthogneiss. A sample from this site has yielded an age of ca. 483 Ma. d) Migmatitic mélange of the Midway Lake area. White arrows denote clinopyroxene–hornblende \pm garnet mafic blocks in a migmatitic, sillimanite–K-feldspar–cordierite matrix.

decimetre-scale lenticular, discontinuous layering reminiscent of highly elongated and smeared-out pillow basalts (Plate 1b). Associated calc-silicate lenses are suggestive of original interpillow or interflow carbonate. More massive, homogeneous mafic layers in the amphibolites may represent syn-volcanic gabbroic-diabasic intrusions.

Considering the overall make-up of the supracrustal sequence, the gedrite–cordierite paragneiss has been interpreted as the metamorphic product of hydrothermally altered intermediate to felsic volcanic rocks. A sample south of Cormacks Lake has a preliminary U–Pb crystallization age of ca. 489 Ma (V. McNicoll and S. Pehrsson, unpublished data, 2002), suggesting that the Cormacks Lake paragneiss and interlayered amphibolite are of Late Cambrian–Early Ordovician age.

The predominant map unit of the CLC is a buff-weathering, hornblende-biotite-magnetite±garnet, ±clinopyroxene granodioritic orthogneiss. Preservation of intrusive contacts with the paragneiss (Plate 1c), feldspar phenocrysts and blue quartz eyes confirm a plutonic origin. The orthogneiss is well-foliated, locally migmatitic and contains abundant schlieren of paragneiss. An increase in the proportion of paragneiss inclusions toward its contacts with the supracrustal rocks and the presence locally of an intervening hybrid, strongly foliated unit consisting of equal proportions of paragneiss and orthogneiss, suggest that the paragneiss formed pendants within the granodioritic orthogneiss. A preliminary Tremadoc U-Pb crystallization age of ca. 483 Ma (V. McNicoll and S. Pehrsson, unpublished data, 2002) has been obtained from a quartz-phenocrystic sample on the east side of Cormacks Lake.

The granodioritic orthogneiss locally contains map- to outcrop-scale, coarse-grained, clinopyroxene-plagioclasehornblende metagabbroic bodies. Locally cumulate-textured, the metagabbro was tentatively correlated by van Berkel (1987) with ophiolitic remnants occurring elsewhere in the Dashwoods Subzone. Pending geochemical analysis, these metagabbros could also represent subvolcanic intrusions related to the layered amphibolites in the paragneiss.

The aforementioned Middle Ordovician, Cormacks Lake charnockite, a pink- to buff-weathering, weakly foliated, alkaline felsic rock, underlies the prominent hills immediately north of Cormacks Lake. The charnockite is variably retrograded and ranges from a perthitic K-feldspar megacrystic, two-pyroxene syenogranite to a hornblende– garnet–clinopyroxene, K-feldspar megacrystic granite. It apparently forms a sill-like body exposed in the core of the complex. Based on its texture and mineralogy, it most likely represents a Middle Ordovician felsic pluton emplaced under high-grade conditions.

INTRUSIVE AND SURROUNDING COUNTRY ROCKS

The CLC is bounded to the southwest by the sinistraloblique Lloyds River fault (Lissenberg and van Staal, 2002) that separates it from the Annieopsquotch Accretionary Tract (van Staal et al., 1998). To the east, west and north, the CLC is surrounded by migmatite and metatonalite to granodiorite plutons (Southwest Brook complex of Dunning et al., 1996) that characterize much of the remaining Dashwoods Subzone (Figure 2). The oldest units in this domain are ophiolitic remnants represented by small mafic-ultramafic complexes such as that immediately west of Blue Hill Pond (Figure 2; Currie and van Berkel, 1992; C. Lissenberg and C. van Staal, unpublished data, 2002), and migmatitic, metamorphosed mélange, such as is found in the southern Dashwoods Subzone associated with the ophiolitic Long Range complex (Hall and van Staal, 1999). The mélange is characterized by blocks of medium- to coarse-grained diorite, pyroxenite and cumulate-textured gabbro in a matrix of > 50 percent biotite-magnetite-quartz-plagioclase leucosome and chaotic schlieren of garnet-sillimanite-biotitecordierite-K-feldspar-muscovite paragneiss, i.e., metamorphic assemblages similar to those occurring in the CLC (Plate 1d). Mafic inclusions in the mélange also contain hornblende together with garnet. Hence, there is presently no evidence that the CLC and surrounding rocks of the Dashwoods Subzone experienced significantly different metamorphic histories.

The migmatitic mélange, ophiolitic remnants and the CLC were intruded by a voluminous suite of syntectonic granitoid plutons of the ca. 463 to 456 Ma Southwest Brook

complex (Dunning et al., 1996; V. McNicoll and C. van Staal, unpublished data, 2002) of the Notre Dame Arc (Whalen et al., 1997a). This arc -granitoid suite consists predominantly of white- to grey-weathering, plagioclaseand/or quartz-phyric biotite-magnetite-hornblende tonalite to granodiorite. It is weakly to strongly foliated and recrystallized, and locally contains numerous, commonly partially brecciated amphibolite to hornblende diorite inclusions, that are thought to represent remnants of comingled intermediate composition magmas (J.B. Whalen, personal communication, 2002). Intrusive relationships between the CLC and the southwest Brook complex have been preserved along the northwestern margin (Plate 2a). The northeastern flank of the CLC, along Barachois Brook, is inferred to be a fault (Barachois Brook fault) on the basis of an apparent truncation of structures and units (Figure 2) and magnetic lineaments. This fault has been tentatively interpreted as a Silurian, northeast-dipping normal fault, consistent with preliminary age data that suggest the CLC experienced a younger cooling history than rocks north of the fault.

A variety of variably deformed and metamorphosed mafic dykes cut the CLC. They include an early, plagioclase-phyric set that experienced at least upper-amphibolitefacies conditions, and a likely younger set that is either unmetamorphosed or partially altered to greenschist-facies conditions. The latter set of dykes also intrude the Southwest Brook complex. The upper-amphibolite-facies dykes show comingling textures (Plate 2b) with a pink, leucocratic, biotite±muscovite granite-granodiorite that forms kilometre-scale, sill-like intrusive bodies and abundant late aplitic dykes within the CLC. It is tentatively correlated with a distinctive biotite±muscovite granite suite that intrudes the Southwest Brook tonalites and forms a large complex in the Midway Lake area, where it is intimately associated with Lower Silurian gabbros of the Main Gut suite (Dunning et al., 1990; V. McNicoll and C. Lissenberg, unpublished data, 2002). A late leucogranite dyke in this area has yielded a preliminary Early Silurian age (ca. 430 Ma, V. McNicoll and C. van Staal, unpublished data, 2002).

STRUCTURAL AND METAMORPHIC HISTORY

The main fabric in the CLC rocks is a transposition foliation that is folded by the large fold interference structure that dominates the map pattern (Figure 2). Intrafolial hinges of older foliations in the para- and orthogneiss, suggest that this transposition foliation is at least an F₂ structure, and hence is referred to as S₂. F₂ folds themselves are at least locally accompanied by a new crenulation cleavage, indicating that S₂ is a composite structure. Pre-S₂ foliations and lineations are best preserved in F₂ intrafolial hinges. Here earlier fabric(s) are defined by aligned biotite, gedrite, and sillimanite, staurolite-biotite-quartz-plagioclase inclusion



Plate 2. Structural and metamorphic relationships. a) Screen of Cormacks Lake orthogneiss cut by hornblende quartz diorite, northwest shore of Cross Pond. The quartz diorite cuts a strong S₂ transposition layering with intrafolial F₂ folds in the orthogneiss but is itself folded by F₃ and carries a weak S₃. b) Magma commingling texture between leucocratic granite and an amphibolite dyke. Mafic dykes of this suite and folded by F₃ and contain hornblende +/- clinopyroxene +/- orthopyroxene but not garnet, suggesting that they experienced high temperatures but not peak pressure conditions.

trails in garnet porphyroblasts and migmatitic leucosome veins in the paragneiss, and folded gneissic layering in the orthogneiss. These pre-F₂ structures are grouped in D, although at present the possibility that D₁ comprises more than one generation of structures cannot be overruled. D₁ was accompanied by at least amphibolite-facies conditions.

F2 folds are typically moderately plunging (30 to 60°), generally having steeply inclined axial surfaces and attenuated or dismembered limbs. Partial alignment of peak metamorphic minerals in S₂ (Plate 3a), syn-D₂ poikiloblasts and garnet-hornblende-plagioclase-quartz or clinopyroxene-hornblende-plagioclase-quartz assemblages in syn-D₂ migmatitic leucosome suggest that M2 metamorphism took place at transitional upper amphibolite to granulite conditions. Peak metamorphic assemblages are represented by gedrite-garnet-sillimanite±hornblende in gedrite gneiss, sillimanite-garnet-cordierite-K-feldspar or orthopyroxene-garnet-biotite in psammite, and clinopyroxene-garnet-hornblende in mafic rocks and the CLC orthogneiss.

The minimum age of D_2 and peak M_2 amphibolite–granulite conditions is constrained by a ca. 460 Ma hornblende tonalite– quartz diorite of the Southwest Brook complex that cuts a strong S_2 in the CLC orthogneiss (Plate 2a; V. McNicoll and S. Pehrsson, unpublished data, 2002). The local presence of a weak S_2 in the tonalite suggests that the latter intruded late kinematically, consistent with the weak character of S_2 in the coeval Cormacks Lake



Plate 3. Structural and metamorphic relationships. a) Polished slab showing the regional S_2 foliation defined by aligned gedrite and wrapping large garnet and tiny orthopyroxene porphyroblasts (not visible) in gedrite gneiss. b) Metamorphosed, but unfoliated clinopyroxene–hornblende dyke cuts the regional S_2 foliation (white arrow) but with apophyses deformed in S_2 (black arrow), suggesting a phase of mafic magmatism contemporaneous with D_2 deformation. c) Fold pattern in outcrop of doubly plunging F_3 folds of S_2 , north of Esker Lake. d) Garnet-bearing leucosome vienlets crosscut S_2 in sillimanite–gedrite paragneiss and are parallel to the axial surfaces of open F_3 warps of S_2 .

charnockite. Peak garnet–clinopyroxene assemblages are best preserved near Cross Pond (Figure 2). Lower Silurian metamorphosed mafic dykes (V. McNicoll and S. Pehrsson, unpublished data, 2002) that cut S₂ and are folded by F (Plates 3b and 4b) in this area contain amphibolite-facies assemblages, suggesting that high temperatures were maintained in the CLC for a considerable time period following peak M₂ conditions.

A weakly to strongly developed S₃ foliation is axial planar to upright, close to tight F₃ folds of S₂ at all scales (Plate 3c). The F₃ fold axes vary in plunge from 20 to 80° and are generally (sub)parallel to a strong mineral or stretching lineation. Whether the mineral/stretching lineation formed during F₃, earlier or a combination of both is at present not well understood. The northwest foliation trends discussed by previous authors and used as evidence for the presence of Precambrian basement are an artifact of a regional-scale F₃ to F₄ mushroom-like, fold interference structure that defines the shape of the CLC (Figure 2). This mushroom was produced by refolding of a tight, doubly plunging regional-scale F₃ antiform (major hinges centred on the Cross Pond and Blue Hill Pond areas) by an easterly trending F₄ fold.

D₃ deformation appears to have taken place under waning pressure but elevated temperature conditions. This is indicated by several lines of evidence: 1) the recrystallization of M₂ mineral phases folded and crystalplastically deformed by F₃; 2) nucleation of garnet–quartz–plagioclase leucosomes parallel to S₃ and folded by F₄ (Plate 3d); and 3) reaction rims and corona structures on elongated M₂ aggregates such as orthopyroxene–cordierite rims on gedrite–garnet, and hornblende-plagioclase rims on garnet-clinopyroxene (Plate 4a).

The latest phase of deformation, F4, is represented by east- to east-southeast-trending, upright F4 folds at all scales that fold S₂, S₃ and L₃. F₄ folds are commonly accompanied by a widely spaced, generally weakly developed crenulation cleavage (S₄). A distinctive phase of cordierite-bearing leucosome has nucleated (sub)parallel to S₄ in several places (Plates 5a and b), while intergrown cordierite and gedrite locally also shows a preferred dimensional orientation parallel to S₄. These small-scale structures suggest that F₄ was accompanied by relatively low pressure and moderate tem perature metamorphic conditions. The small-scale F4 folds, the predominant D4 structures in outcrop, are congruent with the east-west-trending regional-scale structure that generally controls the mushroom geometry of the CLC (Figure 2), hence, the latter is also interpreted as a F4 fold. The F4 fold plunge varies with the dip of the S₂, especially where they cross F₃ axial surfaces, but is predominantly moderately to steeply east plunging (ca. 60°).

The region surrounding Cormacks Lake and south to the Lloyds River fault is characterized by more penetrative D₄ retrogression and only very local preservation of upper amphibolite–granulite-facies assemblages. Preliminary metamorphic zircon, monazite, and rutile U–Pb ages from a sample with D₄ cordierite–gedrite are all ca. 430 Ma, suggesting very rapid decompression and cooling during the early Silurian (V. McNicoll and S. Pehrsson, unpublished data, 2002).

DISCUSSION

Field observations and preliminary U–Pb dating have resolved a long-standing controversy surrounding the CLC, namely that it does not consist mostly of metasedimentary siliciclastic rocks, but instead is dominated by a Tremadoc granodioritic orthogneiss. The less voluminous paragneiss and layered amphibolite intruded by the orthogneiss, appear to be nearly coeval in age and both probably represent the remnants of a volcano-sedimentary sequence and associated subvolcanic plutons related to the earliest phase of the continental Notre Dame Arc in western Newfoundland. Similar age arc plutons occur also in the Southern Long Range (Dubé *et al.*, 1997; Whalen *et al.*, 1997a, 1998) and demonstrate that the Tremadoc was an important stage of arc magmatism in the western part of the Dunnage Zone.

The Tremadoc arc sequence was subsequently deeply buried and intensely deformed (F_1 and F_2) prior to, and during the, Middle Ordovician (ca. 463 to 457 Ma) tonalite flare-up represented by the plutons of the Southwest Brook complex, and related syn-tectonic plutons in the neighbour-



Plate 4. Structural and metamorphic relationships. a) Decompression reaction rims in metagabbro, Soldier Hill, north Cross Pond. Cores of clinopyroxene-garnet are isolated from matrix garnet-hornblende by plagioclase rims (white), consistent with decompression from high to moderate pressure while temperatures remained elevated. b) Dyke of the late leucogranite crosscuts S₂ in deformed Cormacks Lake gneisses but is itself folded by F₃ folds, south Cross Pond. Note the F₂/F₃ overprinting in adjacent gneiss.

ing Annieopsquotch Accretionary Tract that intrude during early shearing along the Lloyds River fault (Lissenberg and van Staal, 2002). The Cormacks Lake charnockite also intruded during this phase of arc magmatism, close in time to attainment of peak M, upper amphibolite–granulitefacies conditions in the CLC paragneisses. F₃ and F₄ related metamorphic assemblages and decompression textures from rocks in the CLC and surrounding areas west of the Lloyds River fault, combined with preliminary U–Pb ages of minerals having a variety of closure temperatures, all indicate that elevated metamorphic temperatures and at least moderate pressures of this part of the Dashwoods Subzone were maintained into the Early Silurian. This is in contrast to similar rocks in the southern part of the Dashwoods Sub-

zone, which are unconformably overlain by a Late Ordovician–Silurian volcano-sedimentary sequence (Dubé *et al.*, 1997). The CLC and surrounding parts of the Dashwoods subzone are most simply explained as a structural window into the deepest buried part of the Ordovician Notre Dame Arc, exhumed in the Lower Silurian.

Large inclusions of ophiolite and mélange of the BVOT in both the Tremadoc and Middle Ordovician Notre Dame Arc plutons (Hall and van Staal, 1999, this work) indicate that early Notre Dame Arc magmatism and the subsequent deep burial of the CLC took place after obduction of the BVOT onto the Dashwoods microcontinent (Waldron and van Staal, 2001). This poses an interesting problem concerning the tectonic setting of D₂ shortening and M₁₋₂ upper amphibolite-granulite-facies metamorphism, because intrusion of the Southwest Brook complex arc plutons into the CLC requires that the Dashwoods occupied an upper plate setting. One possible explanation is that burial of the CLC and surrounding Dashwoods microcontinent is due to thickening and struc-

tural burial (possibly aided by emplacement of sill-like plutons) resulting from an Arenig-Llanvirn (ca. 470 Ma), hard collision between the Dashwoods microcontinent and the Laurentian margin following closure of the intervening Humber seaway (Waldron and van Staal, 2001; *see also* Brem *et al.*, *this volume*). Subsequent tonalites–granodiorites could then represent magmatism related to east-dipping slab-breakoff and/or initiation of west-directed subduction and convergence of the AAT with the Dashwoods (van Staal *et al.*, 1998).

The post- D_2 , pre- F_4 high-temperature decompression reactions of the CLC suggest that it experienced partial exhumation prior to the late Early Silurian (ca. 430 Ma)



Plate 5. D_4 structural relationships. a) Vertical slab of folded cordierite–gedrite gneisses sectioned perpendicular to the F_4 axial surface showing an upright F_4 fold of S₂. The cordierite-bearing leucosome phase cuts S₂ but is parallel to the F_4 axial surface. b) Coarse, ijolite cordierite in leucosome developed subparallel to F_4 fold axial surfaces, demonstrating the association between D_4 deformation and low pressure conditions. Note the F_4 - F_2 overprinting.

when rapid exhumation quenched lower temperature F4related assemblages. This early decompression event is as yet not well understood, but may explain the moderate-pressure, high-temperature conditions discussed above. It is constrained to have occurred between ca. 457 Ma (the age of the Cormacks Lake charnockite) and 430 Ma, raising the possibility that elevated temperatures may be related to waning 450 to 435 Ma arc magmatism.

The rapid exhumation during the late Early Silurian is likely dynamically linked to ca. 430 Ma reactivation of the Lloyds River fault (V. McNicoll and C. Lissenberg, unpublished data, 2002) and is coeval with both bimodal magmatism of the Main Gut gabbro suite and red bed deposition in restricted subaerial basins (Chandler and Dunning, 1983). Exhumation, magmatism and basin formation is related to an Early Silurian break-off of the west-dipping slab (Whalen *et al.*, 1996, 1997b; van Staal *et al.*, 1998). Forthcoming detailed quantitative geothermobarometry, U–Pb and Ar–Ar geochronology, and geochemical studies will test these hypotheses and their application to the Dashwoods Subzone as a whole.

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