THE SIGNIFICANCE OF REWORKING, FLUIDS AND PARTIAL MELTING IN GRANULITE METAMORPHISM, EAST PRYDZ BAY, ANTARCTICA

S. L. HARLEY, I. C. W. FITZSIMONS, I. S. BUICK and G. WATT

The Grant Institute, Department of Geology and Geophysics, University of Edinburgh, West Mains Road, Edinburgh EH9 3JW, Scotland

Abstract: The high-grade basement gneisses of the Rauer Group-Brattstrand Bluffs coastal region, Prydz Bay, exhibit a complexity of structural, metamorphic, and overprinting features. This reflects the presence of both monoclinal granulites, which only record a regionally extensive c. 1000 Ma event correlated with the Rayner metamorphism in Enderby and Kemp Lands, and interleaved polycyclic or reworked granulites which preserve initial metamorphic assemblages related to substantially earlier high-grade events. Within the Rauer Group a domain of partially reworked or polycyclic granulites, cross-cut by up to three generations of deformed metabasite dykes, includes sapphire-bearing metapelitic rocks describing an early metamorphic event at 1000°C and 10–13 kbar followed by high-temperature decompression to c. 8 kbar. The Archaean felsic orthogneissess hosting these rock-types include Y- and HREE-undepleted geochemical suites not found in the adjacent Westfolds block. The mid- to late Proterozoic metamorphic history at 1000 Ma is best defined from layered paragneiss successions which have Proterozoic model ages. In the Rauer Group these successions include garnet-sillimanite metapelites and wollastonite-scapolite calc-silicates which define peak conditions of 8–9 kbar and 850°C and later decompression to 5–6 kbar at greater than 750–800°C. Peak pressures were somewhat less in the Brattstrand Bluffs region (6 kbar), where garnet-cordierite metapelitic assemblages and cordierite migmatites are ubiquitous. The wollastonite-scapolite calc-silicates exhibit reaction textures and low-variance mineral assemblages which imply vapour-absent peak and post-peak metamorphic conditions. Similar inferences can be made from textural relationships consistent with vapour-absent melting, and the abundance of volatile-deficient cordierite, in the Brattstrand Bluffs granulites.

Key words: reworking, textures, fluids, melts, decompression, cordierite

Introduction
The definition of pressure-temperature-time paths (P-T-t) is a primary objective of most studies of high-grade terranes and provides important constraints upon the types of tectonic processes responsible for generation of granulites and the lower crust (Bohlen, 1987; Ellis, 1987; Harley, 1989; Sandiford, 1989). The interpretation of P-T data in terms of paths related to a particular tectonic episode must depend upon precise geochronology, and will not be at all straightforward in terranes where reworking has occurred and the effects of polymetamorphism must be considered. In this contribution we highlight some of the major features of and evidence for polymetamorphism and deformational complexity in the Rauer Group and Brattstrand Bluffs region of Prydz Bay, examine the pressure-temperature history and fluid regime of the regionally dominant 1000 Ma Proterozoic metamorphism, and contrast these conditions with those ascribed to the earlier events seen in local relics within the Rauer Group.

Polycyclic Granulites and Reworking in the Rauer Group
Domains of reworked Archaean basement containing polymetamorphic granulites can be recognised in the Rauer Group on the basis of distinctive lithological associations and geological relationships (Fig. 1) coupled with zircon U-Pb SHRIMP geochronology (Kinny and Black, 1990, 1992) which indicate Archaean ages of 3270 Ma and 2800 Ma for at least some of the dominant felsic orthogneissess.

Structural and geological features
An extensive array of deformed metabasite dykes dissect basement lithologies dominated by felsic orthogneisses and composite felsic-mafic layered gneisses in the reworked domains. The metabasite dykes include at least two compositional types, one characterised by bronzite + hornblende and the other by more typical two-pyroxene granulites with intermediate Mg/Fe. At any one locality up to three dyke orientations may be present, as shown by rose diagrams (Fig. 2), and cross-cutting relations may be preserved between the different dykes. At least two fold generations and deformed intrusive relations between felsic orthogneisses and enclosed lithologies pre-date the emplacement of these metabasite dykes. Events grouped as D4 (Harley, 1987) deform the dykes, which therefore serve as useful event markers and minimum age indicators but do not precisely constrain whether the earlier fold phases are of Archaean or Early to Mid-Proterozoic age. D4 has given rise to open to tight south-plunging upright folds in the southern Rauers and NS or EW trending upright ductile shear zones in the north and NW Rauers (Fig. 3a).

The relatively homogeneous to weakly banded felsic (granitic) to intermediate (tonalitic) orthogneisses show strong fabrics pre-dating the dykes, and host a distinctive suite of rafts which include forsterite marbles (Buick et al., 1992), andradite-plagioclase skarns, and rarer magnesian metapelites (association(3) of Harley and Fitzsimons, 1991; Fig. 1). Composite felsic-mafic gneisses may also host forsterite marble lenses (association(4), Harley and...
Fig. 1. Map of the Rauer Group showing the distribution of lithological associations described in the text and locations of forsterite marbles. The black shaded areas containing multiple dyke generations and early structures define the minimum extent of reworked old (Archaean) granulites. Gross layering orientations are a result of D4 and later deformations. Inset map: location of the Rauer Group in relation to Davis (D), Mawson (M), Napier Complex (N), Northern Prince Charles Mountains (NPCM) and the Rayner Complex (R). Rock associations are defined in the text.

Fig. 2. Map of the Rauer Group with rose diagrams showing the mean orientations of generally steeply-dipping deformed metabasite (mafic) dykes, uncorrected for the effects of gross D4 folding. Note several orientations of dykes from the N and NW islands. Also shown are the locations of wollastonite-scapolite calc-silicate gneisses (filled circles) which occur in paragneisses of association (2).
Fig. 3. Field and textural features of Rauer Group granulites. a) Deformed metabasite dykes cutting felsic orthogneiss, Lunar Island. There are three original dyke orientations and cross-cutting relations are preserved between some. All dykes are near-parallel in the steep D4 zone on the left side of the photo. Outcrop is 60 metres wide. b) Orthopyroxene-garnet bearing patch leucosome enclosed within hornblende-pyroxene granulite, Filla Island. The euhedral to subhedral orthopyroxene and garnet are interpreted as peritectic phases produced on local melting, so the patch leucosome as a whole does not correspond to a melt composition. c) Breakdown of $X_{Mg} = 0.65$ garnet to symplectic orthopyroxene and sapphire with cordierite (reaction (3)), Long Point magnesian metapelite. Note original garnet and orthopyroxene grain boundary and finger of relic garnet in right of photo. Field of view 1.5 mm. d) Symplectic wollastonite and scapolite intergrowth and coarser scapolite and clinopyroxene in a quartz-bearing calc-silicate granulite, Hop Island. This symplectite wholly replaces grossular-andradite garnet throughout most of this sample (reactions (An,V) or (An,Cc)). Field of view 2.5 mm.

Fitzsimons, 1991; Fig. 1). Rafts sometimes preserve internal folds and fabrics cut by those in the orthogneisses, and hence are considered to at least partially preserve a record of metamorphic events which pre-date the main 1000 Ma metamorphism and may even be Archaean in age.

**Chemical features of the older orthogneisses**

Homogeneous felsic orthogneisses cut by deformed dykes are generally 1-types and include at least two suites with geochemical signatures very similar to those of the Napier Complex depleted and undepleted orthogneisses (Sheraton et al., 1985). Depleted trondhjemite and tonalite to granitic orthogneisses ($SiO_2 = 60–72$ wt%; $Al_2O_3 >14.5$ wt%) show very low REE abundances and highly fractionated REE patterns ($Ce_N/Yb_N = 36$) with severe HREE depletions and positive Eu anomalies (Fig. 4b). They are characterised by high Ti/Y, low Nb, high Sr, low Rb/Sr (<1) and high K/Rb (up to 2550); features generally considered to reflect an origin through high-pressure hydrous melting of a garnet ± amphibole bearing mafic source (e.g. Sheraton and Collerson, 1984). These orthogneisses are geochemically similar to some of the Mossel gneisses in the nearby Vestfold Hills (Sheraton and Collerson, 1984).

Field observations (Fig. 3b) and geochemical studies (Tait and Harley, 1988) show that local partial melting of mafic granulite has played a role in the production of depleted tonalitic leucosomes prior to dyke emplacement and the late deformation phases. Patchy, agmatic, and schollon migmatitic structures featuring euhedral orthopyroxene (Opx) ± garnet, Grt, preserved in mafic granulites within low strain zones, are consistent with dehydration-melting of amphibole (Hbl) at $>950^\circ$C and $>8$ kbar via the generalised reaction:

$$Hbl + Plag = Cpx + Opix + Grt + L$$

A suite of undepleted granitic older orthogneisses ($SiO_2 = 67–74$ wt %) also occurs in the Rauer Group. These have much higher REE abundances and show either relatively unfractionated REE patterns with no Eu anomaly ($Ce_N/Yb_N = 5$; Fig. 4a), or fractionated REE with negative Eu anomalies ($Ce_N/Yb_N = 35$; Fig. 4b) and HREE abundances near ten times chondrite. Nb is variable and Rb/Sr relatively high (>1.0); but Sr, K/Rb and Ti/Y are low. The undepleted orthogneisses, which have no chemical equivalents in the Vestfold Block, may have formed through dry melting of

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Figs. 4. Chondrite-normalised REE plots for (a) relatively unFractionated (open circles) and (b) Fractionated orthogneisses defined as “old” on the basis of structural and overprinting relations. The highly depleted (filled circles) and undepleted suites (filled squares) in (b) both include granitic to tonalitic types (chlorite-schists and enderbites).

felsic to intermediate granulite crustal precursors, with plagioclase fractionation effective in causing intra-suite variations (e.g. Sheraton and Collerson, 1984; Sheraton et al., 1985).

Metamorphic conditions in the early (pre-1000 Ma) events

Unusual magnesian metapelite preserving assemblages and mineral compositions indicative of anomalously high pressure-temperature metamorphic conditions occur as rafts within the older felsic orthogneisses outcropping at Long Point (Fig. 1).

Quartz-bearing migmatitic metapelite contain highly magnesian garnet ($X_{Mg}^{Grt} = 0.57 - 0.59$) coexisting with sillimanite and feldspar, indicating minimum equilibration pressures of 10 kbar at 1000°C using garnet-aluminosilicate-plagioclase-quartz barometry (Essene, 1989). A quartz-deficient, migmatitic metapelite contains orthopyroxene-mesoperthite-anortioporite veins, with the highly aluminous orthopyroxene ($X_{Mg} = 0.80$; $Al_2O_3 = 8$ wt %) formed during high-temperature in-situ anatexis. The gneissosse garnet-orthopyroxene-sillimanite paleosome in this sample contains the most pyropic garnets yet found ($X_{Mg} = 0.69 - 0.72$) coexisting with orthopyroxene ($X_{Mg} = 0.80$; $Al_2O_3 = 9.5$ wt %) in granulites. Metamorphic $P$-$T$ conditions appropriate to this assemblage, calculated using garnet-orthopyroxene geothermobarometry (Harley, 1984a, b) are 10–13 kbar and 1000–1050°C (Harley and Fitzsimons, 1991).

A $P$-$T$ history involving post-peak near-isothermal decompression is deduced from symplectite and corona textures involving the formation of cordierite (Crd), sapphireine (Spr) and spinel (Spl) from garnet (Grt) with or without orthopyroxene (Opx) and sillimanite (Sil). Geothermobarometry using garnet-orthopyroxene assemblages with either plagioclase or sillimanite (Harley and Fitzsimons, 1991) indicates that this $P$-$T$ path traverses from c. 12–13 kbar to 8 kbar at temperatures in the range 900–1000°C (Fig. 5).

The Mg/Mg$^+$Fe ($X_{Mg}$) ratio of reactant garnet exerts a major control on the phase assemblages produced on garnet breakdown in these rocks, a feature which reflects the operation of different divariant $FeO-MgO-Al_2O_3-SiO_2$ (FMAS) reactions for different initial bulk compositions (Hensen, 1987). The most magnesian garnets ($X_{Mg} = 0.70$) in quartz-absent samples break down on decompression through c. 11 kbar (at c. 950°C) to form graphic to bladed intergrowths of orthopyroxene + sillimanite + sapphireine, via the FMAS divariant reaction:

$$\text{Grt}(0.70) = \text{Opx} + \text{Sil} + \text{Spr} \quad (1)$$

Fig. 5. $P$-$T$ estimates for the high-$T$ decompressional path (filled arrows) and later overprint (open arrow) on the Long Point metapelites. Estimates (dashed and barred lines) are based on a range of geothermobarometers, and define the shaded $P$-$T$ areas related to peak conditions (large dots), initial high-$T$ decompression (dashes) and later, 1000 Ma, overprints (small dots).
while sapphire-cordierite symplectites and overgrowths within orthopyroxene-sillimanite layers in the same samples were formed under similar conditions by the related garnet-absent reaction:

\[ \text{Opx} + \text{Sil} = \text{Spr} + \text{Crd} \]  

(2)

Garnets with lower \( X_{\text{Mg}} \) (0.65–0.58) are stable to lower pressures on the same decompression path, and breakdown to yield bladed, graphic, and leaf-like symplectites of orthopyroxene+sapphire and coarser areas of cordierite (Fig. 3c), explained by the divariant reaction:

\[ \text{Grt} (0.65–0.58) = \text{Opx} + \text{Spr} + \text{Crd} \]  

(3)

which occurs at progressively lower \( P \) for garnets of lower \( X_{\text{Mg}} \).

Decompressional reaction textures are also developed between garnet and sillimanite. Magnesian garnet (\( X_{\text{Mg}} = 0.55–0.60 \)) reacts with sillimanite and quartz to yield cordierite via the reaction:

\[ \text{Grt} + \text{Sil} + \text{Qtz} = \text{Crd} \]  

(4)

At similar or lower pressures (8–6 kbar) the breakdown of Fe-richer garnets (\( X_{\text{Mg}} = 0.48–0.38 \)) occurs instead through the reaction:

\[ \text{Grt} + \text{Sil} = \text{Spl} + \text{Crd} \]  

(5)

The textures summarised above are generated at different points or segments along a single decompressional \( P-T \) path because different reactions are involved. This can be seen in Fig. 6, where the \( P-T \) divariant fields appropriate to the reactions (1) to (5) are depicted. This high-\( T \) metamorphism and decompression is considered from the field relations to be unrelated to the c. 1000 Ma granulite metamorphism (Harley, 1988). The younger episode is manifested in these metapelites in the development of later biotite fabrics and subsequent formation of Crd + Opx symplectites on decompression from 7–8 kbar to 4–5 kbar at 700–800°C (Fig. 5).

The 1000 Ma Events: \( P-T \)-fluid Conditions in the Rauer Group

Two gneiss associations in the Rauer Group post-date the multiple metabasic dyke suites and preserve relatively simple deformational histories:

1. Felsic to intermediate (granitic to dioritic) I-type orthogneisses which commonly preserve relict igneous features, including K-feldspar megacrysts and rhythmic layering, overprinted by a simple foliation (association 1, Harley and Fitzsimons, 1991). These comagmatic rock-types are related by crystal fractionation at mid-crustal levels, are undepleted in terms of total REE and trace element contents, and show moderately to highly fractionated REE patterns (CeN/YbN = 4–30, Fig. 7) and high Ti/Y. A SHRIMP zircon U-Pb age of 1030 Ma has been obtained on one of these younger orthogneisses (Kinny and Black, 1990, 1992).

2. Layered paragneiss successions consisting of Fe-rich pelites and semipelites, quartzites, leucogneisses, impure calc-silicates, and rare mafic granulite (association 2),

![Fig. 6. Schreinemakers grid for the Long Point magnesian metapelites based on the grid of Hensen (1987) showing high-\( T \) reactions between the FMAS phases Grt, Opx, Spr, Crd, Qtz, Sil and Spl and the sense of \( P-T \) change indicated by the observed reactions (large arrowed path). Numbers in squares and adjacent to field ornaments correspond to the FMAS divariant reactions noted in the text.](image-url)
Harley and Fitzsimons, 1991). A SHRIMP zircon U-Pb age of 1000 Ma for one leucogneiss from Filla Island (Kinny and Black, 1990, 1992) provides a good estimate for the age of the main metamorphism affecting these younger lithological associations.

The Fe-rich metapelites are garnet (X_Mg = 0.25–0.37)-sillimanite gneisses with additional ilmenite (Ilm) and/or rutile (Rut), quartz (Qtz), feldspars (Plag, Kfs) and minor biotite (Bt). These record syn- to post-deformational decompression through 2 to 4 kbar from maximum P-T conditions of 7–9 kbar and 800–850°C (Harley and Fitzsimons, 1991). This decompression, manifested in such subtle textures as ilmenite overgrowths on rutile in Grt-Sil-Rut-Qtz assemblages and fine plagioclase moats between garnet and sillimanite, is consistent with that deduced from earlier studies of felsic granulites from association (1) (Harley, 1988).

The calc-silicates within the layered paragneiss association (2) contain grossular-wollastonite-scapolite-clinopyroxene initial assemblages, with either quartz or calcite. Symplectite and corona textures are developed in these rock-types, usually involving the growth of secondary wollastonite in various textural settings (e.g. Fig. 3d):

(1) wollastonite-scapolite-clinopyroxene symplectites replacing grossular;

(2) wollastonite-plagioclase symplectites replacing grossular or the earlier wollastonite-scapolite symplectites noted in (1);

(3) wollastonite-plagioclase rims and intergrowths between quartz and scapolite; and,

(4) wollastonite rims between quartz and calcite.

Only in domains lacking wollastonite and quartz is the breakdown of scapolite to symplectite plagioclase-calcite seen.

Calculated reactions between garnet (Grs), scapolite (Scp), wollastonite (Wo), calcite (Cc), quartz (Qtz), plagioclase (An) and vapour (V) in the CASHCO2 system show that these textures result from near-isothermal decompression (ITD) at 800–850°C, and in this case imply a decrease in P from 8 to 6 kbar, consistent with the c. 1000 Ma P-T paths deter-

mined for the Rauer Group (Harley and Buick, 1992).

Reaction grids have been calculated, after adjustment for activity-composition relations for Ca-end members in calc-silicate garnets (Grs) and scapolites, using the dataset of Holland and Powell (1990). An unusual result of this analysis is that important reactions limiting the stability of scap-lite + wollastonite involve carbonation with increasing temperature, rather than decarbonation. For example, texture (1) is inferred to result from the carbonation reaction (labelled using absent-phase notation):

\[ 3 \text{Grs} + 2 \text{Qtz} + \text{CO}_2 = \text{Sep} + 5 \text{Wo} \quad (\text{An,Cc}) \]

progressing with increasing \( T \), or on decompression, at 8–7 kbar, 820–850°C, and \( a_{\text{CO}_2} \) of 0.40–0.48. Texture (3) is consistent with the reaction:

\[ \text{Sep} + \text{Qtz} = \text{Wo} + 3 \text{An} + \text{CO}_2 \quad (\text{Cc,Grs}) \]

progressing from left to right with increasing \( T \), or decompression at slightly lower pressures (6.5 kbar). This can be visualised using the P-\( a_{\text{CO}_2} \) grid of Fig. 8, calculated for grossular and meionite activities relevant to many of the calc-silicates.

Systematic variations in modal proportions of product phases (e.g. wollastonite: clinopyroxene) occur in relation to the initial grossular garnet composition in these textures.
For example, grossular-poorer garnets yield clinopyroxene as well as wollastonite and plagioclase on breakdown (Fig. 3d). This feature is inconsistent with open system behaviour or the involvement of an external fluid phase in the generation of the textures. The vapour-absent reactions

\[ 3\text{Grs} + \text{Cc} + 3\text{Qtz} = 6\text{Wo} + \text{Scp} \quad (\text{An,V}) \]
\[ \text{Grs} + \text{Qtz} = 2\text{Wo} + \text{An} \quad (\text{Scp,Cc,V}) \]

are inferred to have produced textures (1) and (2) respectively, at c. 7.5 kbar 850°C and at low \( a_{\text{CO}_2} \) (0.4–0.5). The occurrence of orthopyroxene-K-feldspar-plagioclase assemblages within 2 cm of these calc-silicates also suggests a vapour-absent \( P-T \) evolution following peak metamorphism, as these generally imply low \( a_{\text{H}_2\text{O}} \).

The 1000 Ma Events: Partial Melting in Metapelites of the Brattstrand Bluffs Coastline

Two gneissic associations, one comprising interlayered felsic and mafic orthogneiss and the other dominated by metapelitic paragneisses, occur in the Brattstrand Bluffs region, 30–60 km south-west of the Rauer Group (Fitzsimons and Harley, 1991; for location map see Fitzsimons and Harley, 1992). A tectonically disrupted and transposed basement/cover relationship is inferred between these associations as the orthogneiss association (basement) preserves structural and migmatitic features not recorded in the paragneisses.

The metapelites of this area are not equivalent to those of association (2) in the Rauer Group. No wollastonite calc-silicates have been observed, many of the metapelites are cordierite-rich whereas cordierite is very rare in the typical Rauer metapelites, and graphite is a common accessory phase here. The well-layered to migmatitic pelites contain garnet-sillimanite-cordierite ( \( \text{Grt}: X_{\text{Mg}} = 0.13-0.30; \text{Crd}: X_{\text{Mg}} = 0.56-0.66 \) ) assemblages and often spilite (Splt: \( X_{\text{Mg}} = 0.11-0.22 \)). Peak granulite conditions of c. 6 kbar and 850°C are calculated from garnet-orthopyroxene assemblages in the semi-pelites (Harley, 1984a, b; Essene, 1989) and average pressure calculations on the metapelites (Powell and Holland, 1985).

There is abundant field evidence for the generation and extraction of leucocratic melts from the metapelitic gneisses during and immediately after peak metamorphism, leaving a residuum enriched in garnet and cordierite (Crd):

(a) Migmatitic textures are frequently developed. Pelitic schlieren and pods rich in Crd-Silt, Silt-Spl or Grt-Crd set in a leucocratic garnet- and cordierite-bearing matrix are interpreted as restite and recrystallized partial melt respectively.

(b) Leucogneiss sheets and lenses, often containing minor garnet, cordierite and graphite, cut across layered and migmatitic units and are interpreted as recrystallized bodies of extracted melt (designated by L).

The equilibria involved in this melting event are best preserved in the layered metapelites, where apparent melt production was low, and products and reactants are retained in close proximity. In such paragneisses, an early \( \text{Grt}(1)\)-Sil-Bt(1)-Qtz assemblage is preserved in garnet cores, but is replaced in the matrix by an assemblage characterized by absence of biotite and presence of cordierite and second generation garnet (Grt(2)-Crd(1)-Sil-Qtz-Kfs). Garnet(2) and cordierite(1) are interpreted as the solid products of incongruent vapour-absent melting of biotite by fluid-absent reactions such as:

\[ \text{Bt}(1) + \text{Sil} + \text{Qtz} = \text{Grt}(2) + \text{Kfs} + \text{L}, \text{and} \]
\[ \text{Bt}(1) + \text{Sil} + \text{Qtz} = \text{Grt}(2) + \text{Crd}(1) + \text{Kfs} + \text{L} \]

The proposal that cordierite is a peritectic phase has important implications for the interpretation of melting equilibria and migmatite morphology in this and other granulite terranes. This proposal has been tested through analysis of cordierites for channel volatile (\( \text{CO}_2 \) and \( \text{H}_2\text{O} \)) contents using newly-developed secondary ion mass spectrometry techniques (SIMS). Total volatile contents of Brattstrand Bluffs cordierites are considerably and uniformly less than the equilibrium values for fluid-saturated cordierites at 6 kbar and 800–850°C (Johannes and Schreyer, 1981; Vry et al., 1990) (Fig. 9). The proportion of \( \text{CO}_2 \) is also low (\( X_{\text{CO}_2} \) = 0.1 to 0.4), in contrast to many granulite-facies cordierites. These initial results are consistent with cordierite equilibration with a volatile-undersaturated melt rather than a free fluid phase, although other possible explanations such as post-metamorphic volatile leakage from the channels cannot be excluded until a thorough analysis of volatile zoning and variations in individual cordierite grains is undertaken. It is suggested that the peak metamorphism in this region occurred in the presence of melt but did not involve the pervasive influx of a fluid from reservoirs external to the metamorphic pile itself, a conclusion which is supported by the occurrence of graphite with relatively light \( \delta^{13}\text{C} \) (−15 to −24‰) in both metapelites and leucogneisses from the area.

The post-peak \( P-T \) evolution of the Brattstrand Bluffs granulites initially involved decompression at c. 17 bar/°C.

Fig. 9. Total volatile contents of Brattstrand cordierites (filled circles) in moles per formula unit compared with theoretical curves for the maximum channel occupancy of cordierites coexisting with \( \text{CO}_2\)-\( \text{H}_2\text{O} \) vapour at various pressures and at 800°C (Johannes and Schreyer, 1981; Vry et al., 1990). Filled triangles are channel-full cordierites from other terranes. All data obtained using SIMS analysis.
result in pervasive re-equilibration in earlier, presumably dry, basement gneisses despite the magmatism associated with the younger event in the Rauer Group and extensive partial melting in metapelites in the Brattstrand Bluffs.

We conclude that much of the metamorphic evolution associated with the 1000 Ma event occurred in the absence of a free vapour phase and that the presence of a coexisting melt was important in the evolution of the Brattstrand Bluffs area. This conclusion is based on results from a variety of methods, including phase equilibrium calculations on calc-silicates and metapelites, stable isotope analysis of graphite, and SIMS analysis of the volatile contents in cordierite. The regional occurrence in the Rauer Group of calc-silicates with mineral assemblages which buffer $a_{CO_2}$ to moderate and low values (0.4–0.5) and the prevalence of cordierites with low CO$_2$ contents (<0.6 wt %) precludes CO$_2$ “flushing” (e.g. Newton et al., 1980) as a cause of granulite formation in this terrane. Instead, the Rauer Group and Brattstrand Bluffs region can be regarded as an example where granulite metamorphism has largely occurred under fluid (vapour)-absent conditions (Lamb and Valley, 1984).

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