

## Fluid regimes in Precambrian granulites

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A reconstruction of fluid regimes is based on the study of individual fluid inclusions in quartz and certain other minerals (e.g. garnet, sillimanite, plagioclase and sapphirine) by the cryometry technique and Raman spectroscopy (RS).

Bulk composition of inclusions is determined from carefully selected monomineral garnet or, more rarely, quartz fractions, by degassing, followed by gas chromatography (GC). This permits simultaneous analysis of CO<sub>2</sub>, H<sub>2</sub>O, CO, H<sub>2</sub>, N<sub>2</sub>, H<sub>2</sub>S and hydrocarbons from C<sub>1</sub> (CH<sub>4</sub>) to C<sub>5</sub> from one sample (50-300 mg). Compositions of cordierite structural channel gases were also studied by GC.

Our data represents different areas of the Aldan and Anabar Shields, the Boothia uplift (northern Canadian Shield), the Kamsky Complex of the Enisey Ridge Belomorsky Belt of the Baltic Shield, and the Chogar Block of the Stanovik Belt.

Cryometry results revealed that for all minerals of studied granulites, one-phase inclusions of dense liquid CO<sub>2</sub> are typical. The presence of film water is also possible, as is proved by formation of gas-hydrates CO<sub>2</sub> in some cases. The following lowest homogenization temperatures ( $T_{\text{hom}}$ ) and the highest densities ( $\rho$ ) of metamorphic fluid established for the higher pressure granulites are as follows: the Chogar Block ( $T_{\text{hom}} = -42^{\circ}\text{C}$ ,  $\rho = 1.12 \text{ g/cm}^3$ ), the Belomorsky Belt ( $T_{\text{hom}} = -33^{\circ}\text{C}$ ,  $\rho = 1.09 \text{ g/cm}^3$ ), the Daldyn Complex from central part of Anabar Shield ( $T_{\text{hom}} = -29^{\circ}\text{C}$ ,  $\rho = 1.08 \text{ g/cm}^3$ ); the Sutam block from southern part of Aldan Shield ( $T_{\text{hom}} = -27^{\circ}\text{C}$ ,  $\rho = 1.06 \text{ g/cm}^3$ ), and the Kamsky Complex ( $T_{\text{hom}} = 2^{\circ}\text{C}$ ,  $\rho = 1.05 \text{ g/cm}^3$ ). Much higher  $T_{\text{hom}}$  and lower densities are characteristic of moderate and lower pressure granulites from the Nimnyrsky Block of Aldan Shield ( $T_{\text{hom}} = -3^{\circ}\text{C}$ ,  $\rho = 0.94 \text{ g/cm}^3$ ) and the Boothia Uplift ( $T_{\text{hom}} = -8^{\circ}\text{C}$ ,  $\rho = 0.97 \text{ g/cm}^3$ ).

The RS of inclusions confirmed that metamorphic fluid in granulites consisted basically (above water) of  $\text{CO}_2 = 91.8-99.2$  mol %. Nitrogen is also present everywhere but its content varies in a relatively narrow range from 0.1 to 8.2 mol%. Methane occurs in the same inclusions but, more rarely than nitrogen, and its concentration does not exceed 1.6 mol%.

A sharp increase in nitrogen and methane concentrations (up to 43.4 and 9.1 mol% respectively) is fixed in ancient tectonic zones (Idjek-Nuyam for Aldan Shield and Kharap and Kotuikan-Monkholin for Anabar Shield).

Fluid pressures during metamorphism, calculated on the basis of inclusions data (at  $900^\circ\text{C}$ ), reaches 8.0-8.5 kb and more for higher pressure granulites, and less than 6.0 kb for moderate pressure and lower pressure ones. These values do not contradict the estimate obtained by other methods. The  $\text{CO}_2/(\text{CO}_2 + \text{H}_2\text{O})$  ( $K_{\text{CO}_2}$ ) ratio by GC data of bulk compositions of inclusions varies, due to P-T conditions of metamorphism, from 0.14-0.24 for lower pressure granulites to 0.75-0.81 for higher pressure granulites.

A similar dependence takes place for gas composition of cordierite channels. This varies from mainly water (typical of lower pressure granulites and transitional to upper amphibolite facies,  $K_{\text{CO}_2} = 0.17-0.22$ ) to those enriched in  $\text{CO}_2$  (for higher pressure granulites,  $K_{\text{CO}_2} = 0.79-0.83$ ). Cordierites from tectonic zones of ancient shields often contain some amount of nitrogen (up to 0.1 wt.% and more). There is a statistically significant positive correlation between a sum of reduced gases and nitrogen. Nitrogen and methane were fixed in individual fluid inclusions in garnets and quartzes by GC and RS for the same zones. It seems to be reasonable to suggest that tectonic activity of ancient structures tends to bring about fluid enrichment in nitrogen and methane.

The comparison of results on fluid inclusions from different granulites and on gases from cordierites proves the existence of correlation between their compositions and conditions of metamorphism. Therefore, this study provides reliable evidence for peculiarities of fluid regimes during granulite metamorphism in Precambrian shields and in the basements of mobile zones.