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Widespread CO_2-rich cordierite in the UHT Bakhuis Granulite Belt, Suriname

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The Bakhuis Granulite Belt, approx. 30 x 100 km, transects the large Paleoproterozoic greenstone belt along the north-eastern coast of South America. Part of the Granulite belt witnessed typical Ultrahigh-Temperature Metamorphism (UHTM). A metapelite area in the NE of the belt shows assemblages characteristic of UHTM: aluminous (up to 10 wt.%) orthopyroxene + sillimanite +/- sapphirine. Leucosomes commonly show mesoperthite or K-rich antiperthite. Ternary feldspar thermometry indicates a peak temperature of 1000-1050°C and pressure is estimated to have been around 9 kbar. Metapelites elsewhere in the belt lack mineral assemblages characteristic of UHTM. However, feldspar thermometry for these metapelites as well as for mesoperthite granulites indicates that peak temperatures were 900°C or higher throughout the belt and locally reached 1000-1050°C. It is, therefore, concluded that the other parts of the belt also witnessed UHTM, despite their lack of typical UHTM assemblages.

Study of peak assemblages in metapelites in these parts is hampered by varying, but usually considerable retrograde metamorphism. The main mafic mineral in metapelites is coarse Mg-rich cordierite, accompanied by coarse sillimanite. Widespread occurrence of cordierite + sillimanite in metapelites is unusual for UHTM, the more so as UHTM assemblages are commonly formed at the expense of cordierite-bearing assemblages. In a small part of the metapelites cordierite is accompanied by coarse aluminous (up to 9 wt.%) orthopyroxene. Associated cordierite and orthopyroxene appear to have formed in equilibrium with each other. Only the presence of aluminous orthopyroxene (as well as the presence of mesoperthite) is typical for UHTM, but is limited to a small part of the metapelites. Peak P-T conditions for the cordierite-bearing part of the belt are estimated to have been similar to those in the NE area with its characteristic UHTM assemblages. Primary and secondary fluid inclusions in UHT quartz blebs in orthopyroxene consist of pure CO_2 and have a high density. Raman spectroscopy indicated a considerable CO_2 content in cordierite. Estimated from their birefringence, the CO_2 content of most cordierites is in the range of 1-2 wt.% CO_2. This corresponds to a substantial filling of the cordierite channels with CO_2 and for the higher levels possibly near-saturation with CO_2 according to the model of Harley and Thompson for the maximum level of CO_2 in cordierite. Thermodynamic data for CO_2-rich cordierite are poorly known. However, a high level of CO_2 in cordierite has been considered to lead to a substantial expansion of its stability field, also into the field of UHTM, at T > 900°C. This is, therefore, assumed to be the explanation for the unusual, widespread occurrence of cordierite in the UHTM belt.

A small part of the metapelite samples shows cordierite of a high birefringence, twice that of quartz. SIMS analysis of such cordierite showed 3.0 wt.% CO_2, the highest level known from nature. The level is far too high to have formed at UHTM conditions according to the model of Harley and Thompson and would be possible only at conditions such as 700°C and 10 kbar. It is assumed that locally the CO_2 level of cordierite changed after UHTM, by taking up additional CO_2. Secondary fluid CO_2 inclusions in UHT quartz have a higher density than the primary inclusions, indicating a near-isobaric cooling path down to 700-750°C. In these conditions cordierite probably could steadily re-equilibrate at decreasing temperature while taking up more and more CO_2, up to 3 wt.% around 700°C.

The heat source for the UHTM in the Bakhuis Granulite belt is considered to be asthenospheric upwelling or mafic underplating, but mafic magmatism of identical age to the UHTM has not yet been found. One mafic intrusion was found to be around 20 Ma older than the UHTM, whereas in the SW of the belt numerous mafic intrusions formed around 70 Ma after UHTM.