

Formation conditions of labuntsovite group minerals from the Kovdor massif (Kola Peninsula, Russia)

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Minerals of the labuntsovite group were found in the Kovdor massif in various settings (Chukanov et al., 2003): labuntsovite-Mg is often present in younger hydrothermal associations related to veins of dolomite carbonatites that cut pyroxenites; labuntsovite-Fe and lemmleinite-Ba were found in a zeolite-calcite vein hosted in ijolites; nenadkevichite and korobitsynite (\pm labuntsovite-Mg) were identified in calcite-dominated veinlets in fenites.

Our samples contained various minerals of the labuntsovite group, which were identified by N.V. Chukanov. Two of the samples represented veins of younger Fe-dolomite carbonatites. One of the veins is hosted in a carbonatite-phoscorite stock at an apatite-magnetite deposit (sample I), and the other one cuts pyroxenites (sample IV). Both veins contain vugs and caverns whose walls are lined with rhombohedral dolomite-2 with higher iron and manganese concentrations (5.5 mass% FeO and 0.53 mass% MnO) than those of the rock-forming dolomite-1 (~3 and 0.35 mass%, respectively). Labuntsovite-Mg, ancylite, and catapleiite crystals occur as ingrowths in the outer zones of dolomite rhombohedras or overgrow them. The youngest dolomite-3, calcite, and strontianite crystallized at a later time.

Sample II was taken from the central part of a zonal natrolite-calcite vein in ijolites, whose caverns contained lemmleinite-Ba in association with major minerals and catapleiite.

Zeolite-calcite and anchimonomineralic calcite veins of analogous composition at the Kovdor massif cut across the silicate rocks (ijolites and fenites), phoscorites, and even the younger carbonatites and are thought to be products of the post-carbonatite stage. Calcites in these veins differ from this mineral in all older rocks in containing very low concentrations of typomorphic minor elements, such as Mg, Mn, Fe, Sr, Ba, and

REE. This exactly calcite occurs as veinlets and pockets in the fenites (sample V). Associated with it labuntsovite-Mg is found in the marginal zones of large calcite rhombohedrons (up to 5-7 mm) and also grows on them.

The mineralogy of the samples and the chemistry of the carbonates were examined under an optical microscope and by X-ray phase and quantitative spectral analyses. Inclusions were examined in transparent minerals (labuntsovite, calcite, dolomite, and natrolite). Thereby inclusions suitable for determining their homogenization temperatures (T_h) were found only in carbonates.

The rock-forming dolomite-1 from carbonatite veins (samples I and IV) contains primary melt inclusions (single inclusions or unzoned groups spatially separated from secondary inclusions) and accompanying fluid inclusions (FI) of various phase composition (Fig. 1a, 1b, 1c). The dolomite also contains abundant secondary gas-liquid inclusions

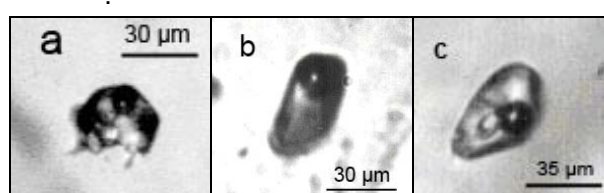


Fig. 1. Inclusions in dolomite-1: a. melt inclusion, b. two-phase fluid inclusion ($V + L$), c – multiphase fluid inclusion ($V + L + S_{is} + S_{an}$).

The melt inclusions (MI) consist of recrystallized aggregates of solid phases (partially isotropic) and two-phase fluid segregations, which homogenize ($LV \rightarrow L$) at 190-220 °C. This and the simultaneous occurrence of primary gas-liquid \pm solid inclusions in the host mineral suggest that the carbonatite melt was saturated with respect to a water-rich fluid.

We failed to homogenize these inclusions because of the intense decrepitation of the

secondary gas-liquid inclusions with low T_h (≤ 270 °C), which resulted in the destruction of both the MI and their host mineral at 320-460 °C.

The daughter solid phases of the primary FI in dolomite-1 (as in the other examined carbonates) are optically isotropic, with only a few exceptions, (sub)cubic or short-prismatic, and account for approximately 5 to 7 % of the inclusions by volume. The relatively high temperatures at which dissolution begins (120-130 °C) suggest that the solid phases are halite. The undisturbed inclusions homogenized into liquid at 290-360 °C.

Rhombohedral dolomite-2 from vugs and caverns contains primary FI ($V + L \pm S_{is}$) and rare crystal-fluid inclusions (CFI), which contain up to 35-45 vol% vapour and liquid (Fig. 2), and the inclusions eventually decrepitated from 290 to 410 °C.

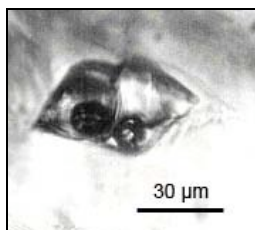


Fig. 2. Crystallofluid inclusions in dolomite-2.

Primary FI in dolomite-2 have a phase composition analogous to those of inclusions in dolomite-1. A few of these inclusions decrepitated at 185-270 °C, and the rest of them homogenized to liquid at 265-335 °C.

In calcites from samples II and V, primary gas-liquid inclusions dominate over FI with solid daughter phases (Figs. 3a, 3b). Almost all of inclusions did not leak in the heating stage and homogenized into liquid at similar $T_h = 180-210$ °C in sample II and 175-225 °C in sample V.

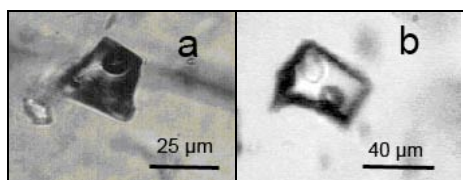


Fig. 3. Inclusions in calcite: a. gas-liquid inclusion, b. multiphase fluid inclusion ($V + L + S_{is}$).

The phase composition of the inclusions in the dolomites systematically evolved from fluidized

melt to hydrothermal solution. Dolomite-1 crystallized in the course of the magmatic process, and dolomite-2 started to crystallize in vugs from fluid with residual portions of the melt-brine, which was trapped by minerals in the form of CFI. Younger minerals (labuntsovite-Mg, ancylite, catapleiite, dolomite-3, calcite, and strontianite) precipitated from solution as the P-T parameters decreased.

The decrease in the fluid pressure (P_{fi}) during the development of the hydrothermal associations in vugs is indirectly confirmed by the fact that the dolomite contains progressively less primary FI, which decrepitated independently of the effect of secondary inclusions. This baric trend first induced an increase in the acidity of the solutions (Shcherbina, 1967), as follows from the increase in the concentrations of Fe and Mn (as more acidic components than Ca and Mg) in dolomite-2. However the replacement of the later dolomite by calcite testifies to an increase in the alkalinity that is agreement with manifestation of acidic wave in the carbonate-forming systems.

The virtual absence of the decrepitation of primary FI in calcites in samples II and V suggests that the calcite and zeolite-calcite veins were produced under P_{fi} no higher than 404 bar (Naumov et al., 1966) and hence the crystallization temperatures of these calcites (as well as the lemmleinite- Ba and labuntsovite-Mg) could not much higher than the T_h (175-225 °C). The formation of calcite (together with natrolite) in place of dolomite at these temperatures points to alkaline specialization of solutions. It cannot be ruled out that its source was the hydrothermas, the final evolutionary product of the carbonatite fluid.

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