A quartzite inclusion in the Rønne Granite – the first Danish sediment?

HENRIK FRIIS

Friis, H.: A quartzite inclusion in the Rønne Granite – the first Danish sediment. *Bulletin of the Geological Society of Denmark*, Vol. 43, pp. 4–8. Copenhagen, 1996–07–14. https://doi.org/10.37570/bgsd–1996–43–01

The original thin sections from a quartzite inclusion in the Rønne Granite described by Karen Callisen in 1934 have been reexamined. They appear to represent a sandstone, which has been strongly recrystallized in the granite, but which has retained some evidence of the original fabric. It is concluded that the sandstone was either still porous or was carbonate cemented when it was included in the granitic magma. Part of the intergranular space has been filled by granitic minerals, mainly microcline, but carbonate minerals are important. Some of the recrystallized quartz grains contain many mineral inclusions as well as liquid/gas inclusions. It is suggested that future studies of sedimentary rocks included in the basement rocks of Bornholm may give important knowledge on intrusion depth and temperature of the granites.

Henrik Friis, Department of Earth Sciences, Aarhus University. C.F. Møllers Alle 120, DK–8000 Aarhus C, Denmark. 15h April 1996.

Introduction

In her thorough description of the basement rocks of Bornholm, Karen Callisen (1934) also described an inclusion of quartzite in the Rønne Granite, which she at that time believed to be of magmatic origin. Later, she described the inclusion again (1956) and concluded that the quartzite was probably of sedimentary origin. The quartzite was found in a small quarry to the southwest of Knudsker Kirke (Fig. 1), probably in the 1920's. It was part of a loose block, and cannot be recovered. It was approximate 0.5 m in diameter and had a sharp contact with the granite. According to the description of Callisen (1934) there was no zoning or mineral differentiation in the granite towards the boundary. Small cracks penetrated into the margin of the quartzite inclusion, and these cracks were filled by granite or granitic minerals, mainly microcline, plagioclase and hornblende. The composition of these minerals was estimated to be identical to the composition of those in the host granite. There are two thin sections from the quartzite preserved in the Geological Museum in Copenhagen (C210 and C211). They have probably been cut from samples (or a single sample) taken at the margin of the inclusion in order to obtain information on the relationship between granitic magma and the quartzite, rather than to represent relatively unaltered quartzite from the interior of the inclusion. Unfortunately, the original samples of the quartzite were not found in the Geological Museum.

Description of the quartzite

The following description of the 'Callisen Inclusion' is a modification of the original descriptions from Callisen (1934, 1956). It is limited by the unfortunate lack of original samples and points to fields of further investigations which should be carried out when similar inclusions are found in the Rønne Granite or other basement rocks from Bornholm.

In all parts of the available thin sections the quartzite has a granular texture, since quartz appears to constitute a framework of grains with an intergranular fill of other minerals: microcline, plagioclase, hornblende and carbonate (Figs 2 and 3).

The quartzgrains are of uniform size (0.1–0.2 mm) within specific areas and would be characterized as well sorted fine sand. There is a field with smaller grainsize (0.05–0.1 mm), still well sorted, appearing much like varying lamellae of well sorted sand and coarse silt (Fig. 4). Seen in thin section, the grains generally have linear contacts which join at approximately 120° to give triangular or no intergranular space (Fig. 2), or they may appear rounded and almost floating in

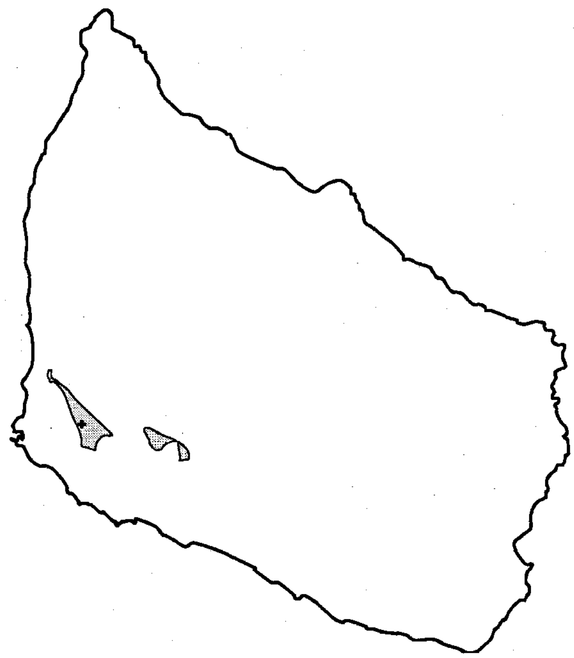

Fig. 1. Bornholm with location of sample site according to Callisen (1934). Dotted area shows the distribution of Rønne granite after Jørgart (1969).

the "cement" (Fig. 3). Each grain unit consists of a single crystal with uniform extinction. Callisen (1934) mentioned that the quartz was rich in inclusions, which she concluded to be diopside and cordierite. These identifications are accepted in the following, but the small size of the inclusions make an identification difficult. The inclusions occur mainly in separate areas of the quartzite, but again the limited sample does not allow proper evaluation of their spatial distribution. The mineral inclusions appear to be more common close to the cracks and to the margin of the quartzite. Some quartz grains contain only diopside, others only cordierite, and others only trails of minute needle-like inclusions, crossing each other at approximate 60° angles (Fig. 5). Some of the diopside inclusions are prismatic crystals measuring up to 30 microns (Fig. 6). Some of them have a satellite crystal, usually much smaller (a few to several microns), more or less spherical and most typical at one end of the host crystal. This satellite phase has not been identified but is probably a separate mineral. It is suggested, that the diopside and the satellite mineral crystallized from a melt inclusion in the quartz, indicating, that the quartzite has been totally recrystallized. The cordierite inclusions range in size up to 5-10 microns.

The quartz also contains numerous fluid inclusions. They are typically very small, ranging up to about 5 microns. In a few cases they form planar trends corresponding to fracture zones through several grains, but in most cases they are irregularly distributed in the quartz grains and apparently are primary inclusions related to the recrystallization of the quartz. They are two-phase inclusions with one liquid and one gas phase. The gas bubble is small compared to the total volume of the inclusion. This could probably best be explained if this is a CO_2-inclusion. A H_2O–inclusion, formed at high temperatures as indicated by the presence of the two-phase diopside inclusions, would probably have resulted in a much lager vapour bubble than is actually seen. Callisen (1934) noted that fluid inclusions did occur in quartz in the Rønne Granite, but were uncommon. Fluid inclusions are apparently much more common in the quartzite.

The volume and composition of intergranular fill vary within the two thin sections. Close to the margin and along thin cracks, hornblende is a common mineral, but it does not occur in what seems to be more isolated parts of the inclusion. Such distinctions are, of course, rather uncertain because of the limited information about the position of samples. Callisen (1934) considered the hornblende to be identical to that in the host granite. Many hornblende grains have been partly replaced by carbonate. In some parts of the sections, microcline is the sole constituent in the intergranular space. According to Callisen (1934), perthite lamellae in the microcline consist of albite. Plagioclase occurs sporadically together with microcline. Callisen (1934) referred to an "acid oligoclase", sometimes with a distinctly more albitic margin. In her original description Callisen (1934) considered sphene to be an important intergranular fill. Later (1956) she identified the supposed sphene to be a carbonate, dissolvable in warm hydrocloric acid. This carbonate is locally an important constituent (Fig. 5). It is always placed direcly on quartz grains and may share the intergranular space with microcline. In a few places it occurs as mm–sized polycrystalline aggregates, which could resemble recrystallized limestone clasts (Fig. 7). Refractive index determination indicate that the carbonate is not a dolomite, but has a high content of iron.

At the margin of the inclusion, the composition is quite different. There are large garnet crystals (up to 2 mm), microcrystalline chlorite and some apatite. The quartz grains are large and some with highly ondulating extinction. There are many fluid inclusions in long trails though the grains. Chlorite or other minerals may mark former grain boundaries indicating that the larger grains may have grown by the recrystallization and coalescence of several smaller ones.

Discussion

Many authors have noted the occurrence of various sedimentary rocks included in the basement rocks of Bornholm (Callisen, 1934, 1956; Micheelsen, 1961; Platou, 1970; Jørgart, 1973), and the occurrence of sedimentary inclusions – as such – in the Rønne Granite is not necessarily of special interest. What makes

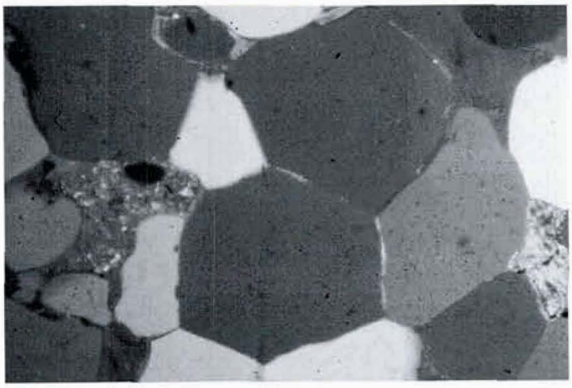

Fig. 2. Recrystallized quartz with small intergranular volume, filled by microcline and carbonate. Width of photo: 0.7 mm. Analyzer: 70°.

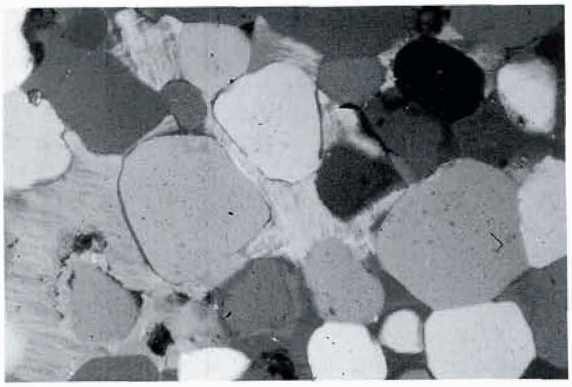

Fig. 3. Recrystallized quartz with large intergranular volume, filled by microcline and carbonate. Width of photo: 0.7 mm. Analyzer: 70°.

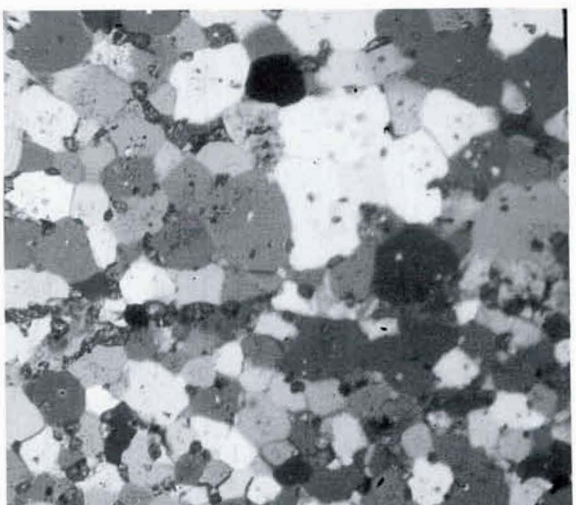

Fig. 4. Grain size variation between well sorted sand and well sorted silt. Width of photo: 1.6 mm. Analyzer: 70°.

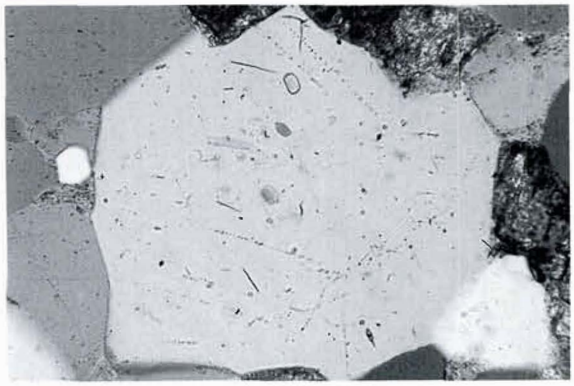

Fig. 5. Recrystallized quartz grain with numerous needle like inclusions in planar trends crossing at approximate 60°. Width of photo: 0.2 mm. Analyzer: 70°.

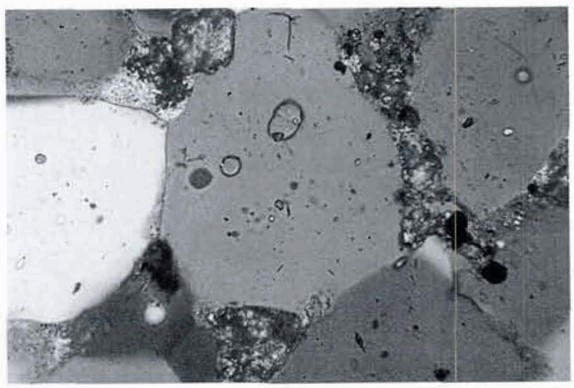

Fig. 6. Recryallized quartz, rich in mineral inclusions. According to Callisen (1934) the inclusions are supposed to be diopside. Largest inclusion with distinct mineral satellite at one end. Width of photo: 0.5 mm. Analyzer: 70°.

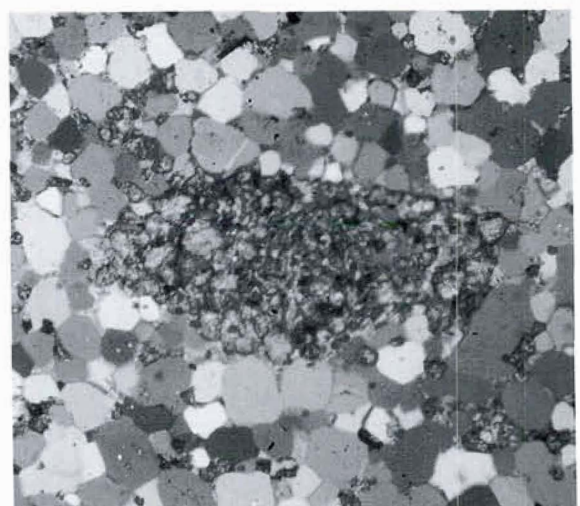

Fig. 7. Polycrystalline aggregate of carbonate, probably a former lime clast. Width of photo: 1.7 mm. Analyzer: 70°.

the Callisen Inclusion particularly interesting is the apparent porosity of the quartzite prior to inclusion in the granitic magma. According to the original description of Callisen (1934), the quartzite is strongly recrystallized and has an intergranular matrix of microcline perthite. If it is assumed that the volume of the sediment remained essentially constant, and that quartz was not removed – although strongly recrystal-lized – then the intergranular space might have been open porosity, which was eliminated by the crystallization of microcline; water filling the pore spaces might have been partly trapped in the recrystallized quartz as fluid inclusions. Alternatively the intergranular space might have been filled by another mineral, which was destroyed and replaced by the microcline. Such a mineral might well have been a carbonate, dolomite or ankerite, and while Ca^{2+}, Mg^{2+}, and Fe^{2+} would be retained in silicate minerals included in the quartz crystals, part of the CO_3^{2-} must have decomposed to form CO_2 which became trapped in the recrystallized quartz as fluid inclusions.

The importance of the quartzite inclusion is the potential information about the trapping depth and temperature of the sedimentary rock. Sandstones generally loose their porosity with increasing burial depth, either by strong compaction and pressure solution, or by cementation. At depths of more than 4000 m most of the porosity is usually lost (Schmidt & McDonald, 1979). If the quartzite was a porous sandstone at the time of its inclusion in the granitic magma – and judging from the large volume of intergranular space the porosity would then still be large – then it was probably not trapped in the magma at a very great depth. A modest guess would be less than 4000 m, a more daring guess less than 2500 m. Such evidence might be very useful in discussion of the formation of the Rønne Granite, rather than giving an interesting picture of the pre-basement sediments of the area. Also if a carbonate mineral originally filled the intergranular space in a cemented sandstone, study of the sedimentary rock(s) in the granites may provide more information on the processes that formed the granites than hitherto has been recognized.

Implications for the formation of the Rønne Granite?

It is important to note that the quartzite has been thoroughly recrystallized, at least in its marginal part. This is demonstrated by the fabric and the large amount of mineral inclusions in the quartz, which are systematically ordered and not the result of random deposition. The mineral assemblage in the inclusion might give an indication of the intrusion temperature, and it should be expected that the fluid inclusions in the quartzite might give evidence as to the transformation temperature and pressure. Another important aspect of the formation of the granite is the intrusion depth. The Rønne Granite is generally believed to have crystallized at large depth. Berthelsen (1989) suggests that the basement has been raised at least 10 km. Evaluation of the original texture of the quartzite may yield important evidence on this point. The quartzite appears to have been a well sorted sandstone with a large volume of intergranular space – either porosity or cement, probably a carbonate (dolomite). From the existing thin sections and without available intact samples it difficult to evaluate this point further. The formation of diopside and cordierite inclusions in quartz could be mediated by the breakdown of an original dolomite cement in the sandstone. This would also produce CO_2, which might be trapped as inclusions in quartz, or might react to form siderite or another iron-rich carbonate to replace hornblende or to fill intergranular space. But is it realistic to produce new intergranular space? or should it rather be expected, that "carbonate cement" is a preserved, or slightly reduced original cement, modified by the loss of some Ca and Mg to form diopside and cordierite. Again, knowledge on the texture and composition in central parts of the quartzite would be most welcome. Whatever doubt might exist concerning an original porosity or the presence of a carbonate cement, it is highly unlikely that the sandstone was originally tightly cemented by quartz. In relation to evaluation of the intrusion depth of the granite, it is obvious that the quartzite inclusion cannot give evidence unless its relation to the intrusive body is well known. Was it caught close to the margin or the roof of the intrusion (i.e. sinking) or was it carried upwards from deeper parts of the crust. However, it may give an impression of possible depths. If it is presumed that the quartzite was a porous sandstone when it was included in the granite, it is not likely that is was buried to great depth. According to its texture, the sandstone would have retained a large porosity which would not have survived burial to depths greater than 4000 m, and probably not greater than 2500 m. Such an assumption would give a strong constraint for evaluation of a possible depth of the intrusive body. However, it is more probable that the porosity, or a large part of it was filled by dolomite. This situation would expand the probable depth interval for the intrusion. A study of the fluid inclusions might suggest a range of possible formation temperatures and pressures. These may be close to the intrusion conditions, since there appears to have been little reaction at the margin of the quartzite, probably indicating that its transformation took place rapidly after enclosure in the granitic magma.

The above observations are meant to increase the interest of studying the sedimentary rocks included in the basement of Bornholm, mainly to obtain new knowledge on the formation of the basement, but also to shed light on the pre-basement rocks of Bornholm.

Acknowledgements

Thanks are due to Niels Hald, Geological Museum, Copenhagen, for supplying the thin sections, and to Richard Wilson, Aarhus University, for inspiring comments and liguistic assistance. The journal referee Tommy Jørgart, Roskilde University, is thanked for constructive suggestions.

Dansk Sammendrag

Karen Callisen beskrev i sin disputats fra 1934 en kvartsitindeslutning i Rønne Graniten (Fig. 1). Denne indeslutning, som hun i 1956 genbeskrev som en sedimentær bjergart, er blevet undersøgt igen ud fra det begrænsede materiale, der findes af den. Der er bevaret de to oprindelige tyndslib i Mineralogisk Museum, men håndstykker synes at være gået tabt. Kvartsiten har givetvis været en sandsten, og at dømme efter dens nuværende udseende, har den enten været stærkt porøs eller den har været cementeret med sandsynligvis karbonat på det tidspunkt, da den blev indesluttet i den granitiske magma. Kvartsiten synes at have været en velsorteret, finkornet sandsten (Fig. 4), bestående næsten udelukkende af kvarts, men den har ikke været kvartscementeret. Der kan have været en mindre mængde karbonatklaster (Fig. 7). Det intergranulære rum er nu optaget af granitiske mineraler, især mikroklin (Fig. 2 og 3), men også af karbonat. Dette intergranulære rum kan have været porøsitet, eller sandstenen kan have været tæt karbonat–cementeret. En karbonatcement kan være blevet delvis omdannet til Ca- og Mg-holdige mineraler (antagelig diopsid og cordierit), der stedvis findes som hyppige indeslutninger i kvartsen (Fig. 5). CO_2 fra den nedbrudte karbonat findes måske som væske/gas inclusioner, der ligeledes er hyppige i kvartsen. Den tilbageblevne karbonat synes at være meget jernrig. Det foreslås, at der gøres en fornyet indsat med under-søgelser af andre sedimentindeslutninger i de bornholmske grundfjeldsbjerggarter for at belyse temperatur- og trykforhold på indeslutningstidspunktet.

References

Berthelsen, A. 1989: Bornholms Grundfjeld. Varv, 1989, 1, 3–39.

Callisen, K. 1934: Das Grundgebirge von Bornholm. Danmarks Geologiske Undersøgelse, række 2, 50, 266 pp.

Callisen, K. 1956: Fragmenter og spor af bjergarter ældre end granitten på Bornholm. Meddelelser fra dansk geologisk Forening 13, 158–173.

Jørgart, T. 1969: Prækambrium. I M. Hansen (Ed): Geologi på Bornholm, Varv Ekskursionsfører nr. 1, 3–22.

Jørgart, T. 1973: Metasomatisk dannelse af de bornholmske graniter – en test. Dansk geologisk Forening, Årsskrift for 1972, 77–84.

Michelsen, H. 1961: Bornholms grundfjæld. Meddelelser fra dansk geologisk Forening 14, 308–349.

Platou, S.W. 1970: The Svaneke granite complex and the gneisses on East Bornholm. Bulletin of the Geological Society of Denmark 20, 93–133.

Schmidt, V. & McDonald, D.A. 1979: The role of secondary porosity in the course of sandstone diagenesis. In Scholle, P.A. &. Schluger, P.R. (Eds): Aspects of Diagenesis. Society of Economic Paleontologists and Mineralogists Special Publication 26, 175–207.