Bubble nucleation as trigger for dike initiation in the mantle

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Many xenoliths show evidence that they originate at depths of tens to hundreds of kilometers in the Earth's mantle. Limited reaction between xenoliths and the surrounding magma suggests short transport time, of the order of hours to days. The fast transport rates, as well as the physical size of the xenoliths indicates rapid magma ascent in dikes. This raises two difficulties: 1. How to initiate a dike in hot, ductile rocks? 2. How can the dike propagate fast enough?

We suggest that the mechanism for dike initiation involves the nucleation of bubbles in volatile-bearing magmas. At depth, the magma can segregate into channels that may coalesce into diapirs. However, initiation of cracks is surpressed by the high strength of the rocks (which increases with pressure) and the release of stresses by ductile flow of the hot rocks. Bubble nucleation from volatile supersaturated magmas may provide a mechanism for rapid pressure build-up and initiation of cracks.

We measured the supersaturation needed for nucleation of CO_2 bubbles in basanitic melt. The basanite was saturated with 1.5 wt% CO_2 at 1.5 GPa and 1350 C. CO_2 bubbles were observed only after decompression by 0.2 GPa, or more. No new bubbles were observed after decompression by 0.1 GPa in four experiments.

Following segregation a volatile-bearing magma ascends slowly by viscously deforming the mantle rocks. As pressure falls it becomes saturated and finally reaches the critical supersaturation of 0.1-0.2 GPa. The newly nucleated bubbles are in equilibrium with the melt, and the excess gas pressure in the critical nuclei is compensated by surface tension. However, as bubbles expand the internal pressure overcomes the surface tension and the bubbles grow rapidly. Diffusion is very efficient while the bubbles are small and high gas pressure is maintained during the initial stages of expansion. When the bubbles grow to size of a few critical radii, surface tension becomes negligible and the gas pressure is exerted on the melt and the surrounding rock. The process is very rapid and the sudden pressure increase is sufficient to overcome the strength of the rock and initiate a crack. Once formed, the crack can propagate and a dike is born.

The exsolved volatile is also important for the propagation of the leading crack. As suggested in the past, volatile transport from the bubbles into the tip of the crack helps in maintaining pressure at the tip and ensures fast propagation of the dike.

Origin and biologic significance of graphite and apatite in early Archean supracrustal rocks from Isua belt and Akilia association

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The oldest known supracrustal rocks on the Earth from the Isua belt (ISB) and Akilia association in Greenland have gathered wide publicity as the hosts of the earliest traces of life. Tracking of life in these highly metamorphosed rocks is possible only with the aid of geochemical and mineralogical data. Isotopically light graphitic carbon, suggestive of a bioorganic origin has been reported from both Isua and Akilia formations. The occurrences of such graphite as inclusions in apatite crystals in some of these rocks have suggested the use of the apatite-graphite association as a biomarker.

If life on Earth emerged and evolved in liquid water, the metasedimentary units of supracrustal rocks would be the most likely locations to contain traces of biologic activity. Therefore, confident recognition of sedimentary rocks is an essential geological distinction to be made before drawing conclusions from carbon isotopic signals as indicators of early life - geological evidence may help to evaluate the significance of _^{13}C values of graphite, but the reverse is not necessarily true. The sedimentary origin of the Akilia quartz rich rock that is reported to contain isotopically light graphite has recently been questioned. It is argued that this rock may represent a biologically irrelevant metasomatic quartzite vein. Such reservations are even more directly borne out in the Isua where the carbonate rich rocks that did provide basis for biogenic interpretations have shown to have metasomatic origin but not sedimentary as previously believed.

This paper aims at clarifying the origin of graphite and apatite-graphite association and their applicability as biomarkers in rocks of the ISB and Akilia association. Our petrographic data show that the graphite in ISB occurs predominantly in carbonate-rich metasomatic rocks (metacarbonates) whereas sedimentary BIFs and metacherts are exceedingly poor in graphite. The association of graphite with siderite and magnetite is consistent with thermal siderite disproportionation as the graphite producing mechanism. Such graphite-siderite-magnetite association is also found in rocks of Akilia association from Innersuartuut Island.

Apatite crystals in Isua BIFs and metacherts do not have graphite inclusions or coatings. Graphite inclusions and coatings on the other hand characterize apatite in metacarbonate rocks where graphite is produced by thermal-metamorphic reduction of siderite. In view of the non-sedimentary, metasomatic origin of Isua metacarbonates and the abiogenic source of graphite, the apatite-graphite assemblage can not be considered as a biomarker in the ISB.