Magnetite microexsolutions in plagioclase in granites and their significance for magnetic fabric and paleomagnetism

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The generation and emplacement of granitoids are fundamental processes in the continuing evolution of continental crust. The magmatic flow pattern of granitoids constrains the generation and emplacement of granitoid. Anisotropy of magnetic susceptibility (AMS) has been widely used to infer magmatic flow patterns of granitoids. It is commonly assumed that AMS foliation and lineation are parallel to the mean penetrative planar and linear petrofabrics. However, AMS in granitoid combines petrofabric contributions dominantly from magnetite (mainly large multidomain) as well as mafic silicates, but negligibly from framework-forming silicates of plagioclase, pyroxene, and feldspar because of their low magnetic susceptibilities. We verify the magmatic flow fabric in Cretaceous granitic plutons from northeastern Japan using an analysis of anisotropy of partial anhysteretic remanent magnetization (ApARM) which further isolates the magnetite subfabrics according to magnetite grain-size. Image analysis of microphotographs reveals that the preferred orientation of polysynthetic twins in plagioclase laths and clinopyroxene is discordant with the bulk AMS fabric along outer marginal zones of the granitoid. Scanning electron microscopy (SEM) reveals that submicroscopic, needle-shaped magnetite inclusions exsolved in euhedral plagioclase and clinopyroxene may resolve such anomalous exceptions to the validity of AMS fabrics. Our ApARM measurements show that the ApARM alignment of relatively high-coercive (15-60 mT), fine-grained magnetite is concordant to the linear orientation of plagioclase and clinopyroxene. This suggests that the magnetite microexsolutions are the chief contributors to high-coercive ApARM and that ApARM in our granitoid is a direct reflection of magnetically less detectable plagioclase fabric, which is formed early in the crystallization history and best defines flow. We conclude that the combination of AMS, image analysis, SEM and ApARM is required to confirm the flow pattern of our granite and is generally preferable to the use of AMS alone. In this fabric study, magnetite microexsolutions represented the high coercivity and embedded within host silicate matrix, which protects the microexsolutions from terrestrial alteration. This makes them as good candidates for paleomagnetic studies in plutonic rocks. Plutonic rocks have potential to reveal the history of geodynamo in long timescale to gigayears because of their relatively common occurrence in ancient terranes and slow cooling rate to average out the secular variation. However, slow cooling rate gives enough time for igneous magnetites to grow large, resulting in undesirable multidomain signals. One way to overcome this difficulty is measuring single silicate crystal. Therefore, we collect plagioclase crystals with magnetite microexsolutions by hand picking and subject them to stepwise AF and thermal demagnetization. The plagioclase crystals show high (25 mT) mean destructive field (MDF) of NRM, confirming the high coercivity of magnetite microexsolutions. Together with the high and narrow-range unblocking temperature of NRM (570-590 ^oC), the magnetite microexsolutions in granite can be a good carrier of paleomagnetic record.