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Sources of remanent and induced magnetization in the Bjerkreim-Sokndal Layered Intrusion

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Significant natural resources of titanium (hemo-ilmenite) and magnetite are associated with the 7000m- thick, 930 Ma, Bjerkreim-Sokndal Layered (BKS) Intrusion, and associated anorthosites. Recently the Geological Survey of Norway acquired high-resolution aeromagnetic surveys and we have complemented these by ground-magnetic surveys. The BKS, with an area of 250 km2, lies in a tight, doubly plunging syncline produced during high-temperature solid-state deformation. It contains six magmatic megacyclic units, each beginning with intrusion of a noritic magma that gradually became more reduced and more mafic. Each megacycle began with intrusion of new magma that mixed with more evolved magma already in the chamber, temporarily producing plagioclase- and hemo-ilmenite-rich cumulates. Later the magma returned to normal fractional crystallization, leading to evolved compositions, and precipitation of Fe- richer silicates, Ti-richer ilmenite, and magnetite. Generally the dominant oxides in the layers result in negative remanent magnetic anomalies over hemo-ilmenite–rich cumulates and positive induced anomalies over cumulates dominated by magnetite and Ti- rich ilmenite. Magnetic contrasts are most striking over the top megacyclic Unit IV, where a negative remanent anomaly traces for >15 km in the northern Bjerkreim Lobe of the intrusion. Here magnetic intensity in the trough of the ground anomaly varies, depending on position in the south plunging syncline. At the northern hinge, where layering and foliation dip south, the trough is at 3000 nT below background where as on the east limb at Heskestad, 15km away, where the distal edge of Unit IV of the layered series abuts against the gneissic basement below the intrusion, layering and foliation are vertical, parallel to the reversed early Neoproterozoic magnetizing field. Here the anomaly is approximately 12 000 nT below background in the high-resolution helicopter survey and the ground anomaly locally is 30 000 nT below background. In this unit the mean values for NRM and for induced magnetism are NRM 23 A/m and 4.5 A/m, respectively with a Q=5. Strong lattice-preferred orientations hemo-ilmenite (001) planes and orthopyroxene c-axes lie quasi-parallel to the Neoproterozoic magnetizing field. Such orientations could lead to enhanced remanence related to hematite exsolution in ilmenite and also to exsolved rods and blades of hemo-ilmenite oriented parallel to c-axes in orthopyroxene. The role of multi-domain magnetite remains enigmatic. Combined thin-section-scale electron probe element mapping and mapping by magnetic scanning microscope is a new approach to map individual grains for NRM and induced magnetization and to locate the sources of the remanent magnetization.