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The transformation of magnetite to hematite and its influence on the rheology of iron oxide rock

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Phase transformation is an important process for strain localization after the initiation of ductile shear zones. In polyphase aggregates one important aspect to consider is likely to be the interconnectivity of weak phase after the transformation of the load-bearing framework grains. However the physical processes involved in that transition is not well understood, partially because the microstructures of the initial weakening are generally obliterated by subsequent deformation. Iron oxide-quartz rocks from paleoproterozoic Iron Formations in southern Brazil preserve microstructures that allow a good insight into the evolution of the deformation mechanisms and fabrics during the transition from a load-bearing framework (magnetite) to an interconnected weak phase (hematite).

We conducted microstructural and textural analyses of aggregates of magnetite and hematite combining observations in an optical microscope and measurements in the electron back-scatter diffraction (EBSD). The samples were cut parallel to the mineral lineation (the X-axis) and perpendicular to the foliation. Our goal was to understand the evolution of fabric and texture of the iron oxide aggregates caused by the change in deformation behavior resulting from the phase transformation.

The studied samples consist mainly of aggregates of magnetite and hematite in a varied proportions. Samples that preserve the early microstructures consist in aggregate of magnetite grains of varied sizes. The grains are partially transformed to hematite along {111} planes but no foliation is observed in the samples. Basically the samples consist of grains of irregular shapes and a weak or absent crystallographic preferred orientation. The newly transformed hematite crystals share the (0001) planes and directions <11-20> with planes {111} and directions <110> of magnetite grains. Other samples present relicts of initial magnetite grains surrounded by a matrix of tabular to platy hematite crystals. The matrix show a preferred orientation of hematite grains. Close to the magnetite, hematite crystals show crystallographic relationship similar to those observed inside the magnetite crystals showing a good match in crystallographic planes and directions. However away from the magnetite crystals hematite of the matrix tend to show a more independent crystallographic orientation with respect to the magnetite grains. The poles to the basal planes of hematite distributed in a small circle centered around the Z-axis and the crystallographic directions <11-20> spread in a wide angle along the foliation plane. In samples where no crystal of magnetite grains is observed only platy hematite with a strong shape preferred orientation occur. Their basal planes show a strong concentration around the foliation pole contrasting to the more dispersed distribution around the Z-axis found in the samples with magnetite relicts.The directions <11-20> also distributed along the foliation planes in platy hematite samples but with a narrower angles than those of samples with magnetite relicts.

The progressive transformation of magnetite to hematite led to a change in the iron formation rock fabrics from an isotropic distribution of a load-supporting magnetite to an interconnected weak platy hematite forming a strongly anisotropic fabric. The hard magnetite behaves in a brittle manner with a very limited operation of slip along the main crystallographic planes. The microfracturing creates an easy path for oxidation and transformation of magnetite. The newly formed hematite grains behave in a ductile manner and form a matrix of strongly oriented crystals. The deformation mechanisms change from the microfracturing of the harder magnetite phase to a crystal plastic deformation of the softer hematite platy grains through slip along their basal planes.