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Simple shear deformation of partially molten aplite

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The tectonic processes which are important for melt distribution and transport in the intermediate and lower crust and which can result in crustal weakening are not yet well understood. Natural migmatites are usually overprinted by annealing and retrogression during uplift and exhumation, largely obliterating the deformation structures and microstructures of their partially molten history. Deformation experiments on partially molten crustal rocks have so far been conducted in pure shear geometry and mostly under low confining pressures in the brittle deformation field, both of which are not representative of nature. We carried out deformation experiments in simple shear that predominates in the crust and especially crustal shear zones. Undrained experiments were carried out on Enfield aplite at ~1.5 GPa, 900°-1000°C, and $\leq 5*10^{-6}$ s^{-1}, conditions which favor crystal plastic deformation of quartz and feldspar (Dell'Angelo and Tullis, 1988). Sample slices 1.0-1.5 mm thick were placed between the shear pistons with the shear plane at a 45°-angle to the compression direction. Maximum shear strain in the experiments is $\gamma \approx 2.8$. Despite difficulties in controlling the melt content by varying the amount of added water, we were able to achieve the full range of brittle to crystal plastic deformation mechanisms. With decreasing melt content Enfield aplite displays a transition from discrete fracturing at a high angle (~70-90°) to the shear plane (>20 vol.% melt), to cataclastic shearing (10-20 vol.% melt) and to crystal plastic deformation (<10 vol.% melt) with shear bands at a lower angle (~10-50°). Stress-strain records of the cataclastically and plastically sheared samples display significant weakening after yielding, while some of the fractured samples with high melt content were weak from the beginning of shearing. The strong dependence of deformation mechanism on melt content is primarily due to the undrained experimental conditions; drained conditions were technically not feasible in our high pressure/high temperature set-up. Similar transitions in deformation mechanisms have been observed with increasing temperature or decreasing strain rate (decreasing differential stress). Plastic deformation of the aplite is indicated by dynamic recrystallization microstructures of quartz and initially also of albitic plagioclase. Fine-grained polyphase shear band layers of plagioclase, quartz, K-feldspar and some mica and other minor mineral phases are suggestive of diffusion creep and grain boundary sliding. Melt is usually distributed but locally also concentrated along shear bands. In the samples with dominantly cataclastic and brittle deformation, the segregation of the melt and the transport inside the fractures appears to be more effective as most of the melt occurs in the fractures and at the sample-piston interface. Melt concentration during plastic deformation causes weakening (e. g., Holtzman et al., 2003) that adds to the likely weakening by grain size reduction and by shear zone/shear band-formation in these samples. The combination of these processes might result in local weakening of the intermediate and lower crust.

References

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