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Chemically induced fracturing in alkali feldspar

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Gem quality sanidine from the Eifel with an initial composition of X_{Or} = 0.85 was reacted with a NaCl-KCl salt melt with $X_{KCl} < 0.67$ at close to ambient pressure and 850 ˚C for one week. Due to cation exchange, zones of more albitic feldspar start to develop from the grain surfaces and propagate into the grain interiors by Na^+/K^+ interdiffusion. Na^+/K^+ interdiffusion only takes place in the cation sub-lattice of the feldspar; the Si-Al framework, however, remains unaffected. If the chemical shift towards more albitic composition exceeds about 10 mole%, cracks develop. The fracturing produces a regular pattern of subparallel cracks with a (h0l) direction and a characteristic spacing. The characteristic spacing of this first hierarchical set of cracks depends on the extent of chemical shift of the feldspar; it increases with decreasing chemical shift. Locally a second set of fractures corresponding to a second hierarchical level forms, which follows the (010) or (001) feldspar cleavage planes. Fracturing is due to the fact that the lattice parameters of alkali feldspars are strongly composition-dependent. When the sanidine is shifted towards more albite-rich compositions this causes a lattice contraction, where the composition strain is highly anisotropic. Shortening in the a-direction is larger by a factor of 5 than in the b- and c-directions. As a consequence, chemical heterogeneities such as the different composition of the exchanged zones and the unexchanged cores of the grains lead to coherence stress. When a critical stress is overstepped, fracturing is initiate.

To determine the critical stress the composition of the NaCl-KCl melt was varied in 1 mole% steps. Fracturing occurs only when the composition of the original sanidine is decreased to X_{Or} = 0.78 corresponding to a 7 mole% shift.

From a continuum mechanical analysis it is inferred that the cracks are orientated perpendicular to the direction of the maximum tensile stress. The critical stress needed to initiate fracturing in this general (h0l) direction is estimated at $\leq$ 0.15 GPa. The increase of the fracture spacing with decreasing composition shift of the feldspar suggests that the crack spacing is controlled by a shielding effect. In this case a simple relation exists between stress intensity factor K_I, tensile stress σ, and cracks spacing h (Tada, 2000).

$$K_I = \sigma * h^{1/2}$$

On the basis of the observed fracture spacing of 50 μm at a tensile stress of 0.2 GPa we estimate the stress intensity factor in feldspar to be 40 $MPamm^{1/2}$.

References

Tada, H., Paris, P. C., Irwin, G.R. (2000): The Stress Analysis of Cracks Handbook - American Society of Mechanical Engineers.