



Calcite Decarbonation and its Influence on the Mechanical Behaviour of Carbonate-bearing Faults

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Calcite decarbonation has been identified as one of the important, thermally-activated physicochemical processes that are triggered by temperature rise during fast fault motion. This process has been observed in the laboratory during high-velocity friction experiments where the dynamic weakening that occurs for carbonate-rich gouges is strictly controlled by the thermal decomposition of calcite. Furthermore, this process has also been identified along ancient, exhumed faults and is an important indicator of seismic slip.

The thermally-induced decarbonation ($\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$) and microcracking (due to thermal expansion) of calcite are likely to be primary mechanisms in controlling the mechanical and hydrologic properties of carbonate rocks. In addition, the process and products of decarbonation will likely exert significant influence on the behaviour of faults at both geologic and earthquake time scales by causing changes in (1) the effective normal stress on the fault and (2) the frictional behaviour of material within it.

Due to the paucity of scientific information on the effects of decarbonation and thermal microcracking on the mechanical properties of carbonate fault rocks, we present results from experiments performed on portlandite (>90 wt.%), a hydrous mineral formed by the recombination of CaO and water, and stable product of the decarbonation reaction. We produced portlandite by thermally-treating powdered Carrara Marble (calcite >98 wt.%) in the laboratory at 1100 °C under air buffering conditions. We then sheared gouge layers of this water-reacted, decarbonation product under saturated conditions at room temperature. These tests were designed to evaluate the frictional strength, stability, and healing behaviour of portlandite-bearing rocks to better understand how its presence affects fault mechanics.

Our data indicate that the conversion of calcite to portlandite, results in a distinct change in the mechanical behaviour of the fault gouge. The difference in frictional strength, between marble and portlandite, increases from 0μ to 0.4μ as the normal stress is increased from 1 to 50 MPa. Additionally, at the low shearing rates of 0.1 and 0.3 $\mu\text{m/s}$, portlandite fails through stick-slip motion whereas calcite slides stably. Furthermore, we observe power-law type healing in portlandite that results in a dramatic increase in static frictional strength of $\sim 0.2\mu$ over a relatively short hold time of 3000s.

We suggest that decarbonated fault patches are (1) frictionally weaker, (2) more frictionally unstable, and (3) likely to regain their frictional strength more quickly, than patches in pure carbonate rocks. Under water-saturated conditions, the occurrence of portlandite and other hydrous minerals is undoubtedly the key for interpreting changes in the mechanical behaviour, both transient and long-term, of decarbonated faults.