Pressure solution and mica in quartzose sandstone: Observations and experiments

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Observations and experiments show that quartz pressure solution is greatly accelerated in the presence of micaceous clays. Quartz grains typically flatten against detrital muscovite but enhanced dissolution is not a general effect with all clays (cf., kaolinite, chlorite). In a North Sea oil reservoir, quartz dissolution causes micaceous organic lamina to deform into irregular stylolites in which the wavelength and amplitude is several times the magnitude of the mean grain diameter. No stylolites develop in lamina free sandstones. Modeling of the formation of these stylolites shows that they develop by a more complicated process than simple random differences in solubility of grains. Thus, stylolites must provide feedback to the dissolving grains. Furthermore, the tips of some stylolites have dissolution fronts or spaces that advance ahead of the stylolite, precluding a simple pressure solution mechanism for their development. Rocks from 10^2 to 10^3 m.y. show well developed pressure solution compared with younger rocks. However, incipient pressure solution occurs in marine sedimentary rocks as young as 6 m.y at burial conditions as low as 40-50°C and lithostatic pressures of <22 M Pa (<1 km burial depth).

Using a Surface Forces Apparatus (SFA) we have measured the repulsive ‘hydration’ forces and water and ionic diffusion rates in nm-thin water films confined between mica surfaces in various electrolyte solutions. We observe (1) strong short-range repulsive hydration forces, determined by the bound solution ions to the clay surfaces, with Na^+ and Ca^{2+} having antagonistic effects, and (2) rapid ion transport rates. We have also performed SFA experiments with ‘asymmetric’ systems of mica sheets pressed against quartz crystal and silica surfaces. Unlike the symmetric systems, with the asymmetric systems we observe ‘pressure solution,’ i.e., quartz (but not mica) dissolution. Given the angstrom resolution of the optical interference technique used in the SFA, we can monitor typical geologic dissolution rates in hours and *in situ*, rather than over months or years.

The evolution of grain contacts undergoing pressure solution – Unique insights from a confocal viewpoint

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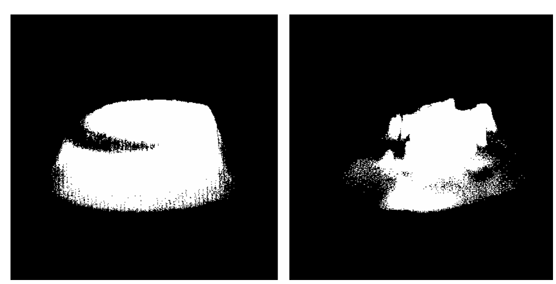
We used a confocal microscope to follow the evolution of a contact between a fluid saturated cone-shaped halite indenter undergoing pressure solution and a flat silicate plate. The top of the indenter initially undergoes axi-symmetric inward dissolution along its perimeter at rates that are highest at the contact plane and decrease at more elevated surfaces. During this initial phase, which generally lasts tens of hours, the surfaces of the indenter remain relatively smooth. As the contact approaches a critical size, plastic flow ensues, the contact becomes larger and its geometry becomes more complex. We observe a mesa-like structure at the contact, standing tens of microns above relatively smooth planes, that is incised by steep interconnecting channels. The location of this structure and its internal geometry constantly change, a feature we attribute to the competition between plastic flow that drives material from above downward and outwards, and strain-energy driven dissolution, which consumes the contact region along its perimeter.



3D projections of the top of the indenter immediately after brine was added to the system (left) and 120 hours later. During this period the indenter accrued 60um of vertical displacement. Field of view ~500um