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Magnetic susceptibility in experimentally compacted Rochester Shale powder

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Anisotropy of physical and hydraulic properties of rocks is often coupled with textural development, most notably in phyllosilicate bearing rocks. Mechanical and chemical processes progressively transform argillaceous sediments into strongly foliated pelites with well-developed texture and as such have important implications for example in modelling crustal processes and interpreting seismic data. In well-studied shallow basins (depth < 2-3 km, T <100 °C), mechanical processes dominate clay/mud compaction and associated clay alignment. In deeper domains, higher pressure and temperature increase the role of chemical processes. Yet, few studies have investigated such pelite compaction and corresponding texture development. Rock texture is essentially a product of deformation; strong correlations between strain and texture strength have been reported for numerous rock types and deformation conditions. Additionally, some attempts have been made to couple magnetic texture with strain or in the case of argillaceous sediments and pelites, compaction.

A set of hydrostatic tests at elevated temperature and confining pressure on Rochester Shale powder followed by uniaxial compression or continued hydrostatic deformation has been performed to simulate high temperature compaction of pelites. Here, we report magnetic susceptibility development in those compaction tests, expressed as anisotropy of magnetic susceptibility (AMS) and bulk susceptibility (Km). Both properties were measured at room temperature with an AGICO KLY-2 kappabridge using a 15-measurement orientation scheme.

Sample material was obtained by crushing and sieving (<150 μm) Silurian Rochester Shale from Western New York (USA). Isostatic cold pressing at 200 MPa prepared the powder for the first hydrostatic compaction test (HIP1), performed in a hot isostatic press (HIP) apparatus for 24 hours at 160 MPa confining pressure and 590 °C. Further compaction was achieved inside a Paterson-type gas medium HPT testing machine in either uniaxial compression or hydrostatic compaction tests (PAT1). A separate batch of sieved powder experienced two hydrostatic compaction events in HIP mode; of which the second event was performed at slightly lower experimental conditions (480°C and 130 MPa) (HIP2).

The different methods used to compact the Rochester shale powder, resulted in grouped bulk susceptibility readings. Starting material powder recorded values between 40 and 80 μSi. HIP1 and PAT1 samples grouped between 360 and 540 μSi, whereas HIP2 samples recorded much higher bulk susceptibility values (920-1120 μSi). The degree of AMS is expressed by Pj values, which is effectively the ratio between maximum and minimum principal susceptibilities. HIP1, HIP2 and PAT1 samples have comparable average Pj values, 1.09, 1.12 and 1.10 respectively, regardless of their degree of compaction or porosity.

We believe that the elevated bulk susceptibility values can be attributed to crystallization of ultrafine ferromagnetic minerals or paramagnetic iron-bearing minerals, whose crystal alignment is expressed by the recorded Pj values. Their AMS is both strain and compaction independent, despite strain values of 14% and noticeable phyllosilicate foliation development, which indicates either fast recrystallization cycles or lack of rotation for the ultrafine ferromagnetic minerals.