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Relation between creep compliance and elastic modulus in organic-rich shales observed through laboratory experiments.

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We studied the ductile creep behavior of organic-rich shales from shale gas reservoirs in North America through laboratory triaxial experiments to better understand controls on the physical behavior of these rocks over time and the effect of creep on other rock properties. Laboratory experiments conducted at room-temperature conditions show that creep deformation observed at in-situ differential stress conditions is approximately linear with the applied differential pressure. The creep behavior is also anisotropic such that creep occurs more in the bedding-perpendicular direction than in the bedding-parallel direction. The reduction in sample volume during creep suggests that the creep is accommodated by a small amount of pore compaction occurring in the clay-aggregates and/or the relatively porous kerogen in the rock. Thus, the tendency to creep (creep compliance) is generally observed to increases with clay and kerogen volume. However, the strongest correlation is found between creep compliance and Young's modulus. A strong negative correlation between creep compliance and elastic Young's modulus exists regardless of the sample orientation and despite the wide range of sample mineralogy (5-50% clay, 5-60% quartz-feldspar-pyrite, 0-80% carbonates). This correlation is quite interesting as inelastic creep and elastic stiffness depend on somewhat different physical attributes.

We attempt to quantitatively explain the correlation between creep behavior and elastic stiffness by appealing to a stress-partitioning that occurs between the soft components (clay and kerogen) and stiff components (quartz, feldspar, pyrite, carbonates) of the shale rock. First, the stress-partitioning occurring within the soft and stiff components is quantified based on the rock composition, elastic properties of the individual components, and the overall average Young's modulus of the rock. By combining the stress-partitioning behavior with knowledge that the creep behavior is linear against the applied stress, we forward calculate the creep compliance of the whole rock. Results show that when creep is linear against stress, a unique relation between creep compliance and elastic modulus can be established for rocks with similar mineral assemblages, consistent with our laboratory results. Thus, our results provide insights into how creep behaviors of poly-mineralic rocks can be re-constructed from the creep properties of the individual phases composing the rock.