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Using Viscoplastic Stress Relaxation Theory on Core Measurements to Determine the Least Horizontal Principal Stress

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Abstract

Over roughly the past ten years, a concept called viscoplastic stress relaxation theory has been developed with direct implications for measuring the in situ stresses regarding the long-term deformation of clay and organic rich rocks. The theory was advanced by using laboratory measurements of shales that are subjected to a constant axial stress over the course of months. The result of this constant load is that the rock slowly strains. In the earth, it is the strain that is relatively constant, and over geologic time, the stresses acting on these rocks relax. By making the assumption of a nearly isotropic stress state at the time of diagenesis, we can mathematically model the viscoplastic relaxation and hence the modern-day stresses. A method has previously been developed a method for normal faulting regimes that incorporates direct measurements of the least horizontal principal stress at depth and an anisotropic velocity model to characterize that stress in the Denver-Julesburg Basin in Colorado, although the location only matters insofar as the faulting regime present. An anisotropic velocity model is rare, and typically only corresponds to sites where microseismic monitoring has taken place. The novelty of the present work is that I have determined certain values of the least horizontal principal stress by using geomechanical laboratory measurements of the horizontal Young's modulus, which allows me to circumvent the need for the anisotropic velocity model. The stress profile that is generated by this method is valid only for depths at which core was taken and the geomechanical measurements were performed such that there are discrete points along the depth profile rather than a continuous model. Nonetheless, this innovative approach has elucidated the state of stress in the recently drilled State 16-2 research well and subsequent lateral (State 16-2LN-CC) in the Paradox Basin. A hydraulic fracturing stimulation was performed in the lateral at a TVD of 9,701 feet and there were six valid measurement points for the least horizontal principal stress – three above the stimulation and three below. The least principal stress appears to be higher around the depth of the stimulation and lower both above in the same Cane Creek formation and below in a different clastic formation. This implies that the stimulation likely generated large hydraulic fractures because the injection pressure would have had to be high relative to the rock above and below. This is a desired effect for stimulation, although the operators had little data that could inform the state of stress prior to stimulation. In the future, this new method has the potential to inform the state of stress for any project that has access to clay and organic-rich core from the interval of interest.

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