Geophysical Research Abstracts
Vol. 19, EGU2017-6086, 2017
EGU General Assembly 2017

Elastic and Viscoelastic Modeling of Stresses Induced by Hydraulic Fracturing in Shale Gas Reservoir

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Hydraulic fracturing is one of the most important engineering tasks in the development of an unconventional gas or oil play. Further exploitation of the reservoir is strongly influenced by the effectiveness of this process. Knowledge about the in situ stress state, and its changes is critical for successful fracturing of a reservoir. Hydraulic fracturing is usually carried out in several stages. The previous stages influence the later ones, because the induced and reactivated fractures, and the corresponding strain tend to increase the minimum horizontal stress (Shmin). This phenomena may lead to changes in the stress regime. The stress state, and fracture network changes result also in consecutive scattering of the microseismic events related to each of the stages.
The goal of the present work was to investigate what happens to the stress state after each of the hydraulic fracturing stages, and how it may affect the success of whole operation. Our investigation was divided in two major parts: first we characterized the rheological behavior of the shale rocks from prospective reservoir in northern Poland, and later we incorporated the constitutive models obtained in the laboratory into numerical models of the reservoir. Laboratory testing consisted of fourteen 72-hours-long triaxial creep tests, with ultrasonic acquisition (P, S1 and S2 waves) on cylindrical rock samples from different depths of one borehole. This procedure allowed us to construct a reliable vertical profile of rheological parameters. We did not only focus on the prospective intervals, but we also collected data for the interbedded marl or limestone layers.
Numerical modeling was performed with different rheological settings: we started with a simple one layer isotropic elastic material, and then we increased the complexity in steps. Finally we arrived at layered anisotropic viscoelastic material with several fracturing stages which were superimposed on each other.