Geophysical Research Abstracts, Vol. 8, 02184, 2006
SRef-ID: 1607-7962/gra/EGU06-A-02184

Effective Medium Modelling of Transversely Isotropic Rocks and Microstructural Data Recovery from Elastic Wave Velocity Measurements.

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Clay rocks, and shales in particular, represent approximately two-third of all sedimentary rocks on Earth's upper crust. In oil and gas drilling operations, shales constitute 80% of all the drilled sections, mainly because they overlie most hydrocarbon bearing reservoirs. Further, due to their low permeability, several countries are considering clay rocks as possible host lithologies for radioactive waste confinement, and therefore carrying out research programs to estimate feasibility of such solution. In this trend, the French agency for radioactive waste management, ANDRA, is evaluating the reliability of the Callovo-Oxfordian layer, Jurassic in age, located in the eastern part of France (near Bure), at a depth ranging from 400 m to 600 m.

This paper deals with the effective elastic properties of a porous transversely isotropic (T.I.) rock. The theoretical approach allows for the 3-D modelling of a T.I. solid with superimposed random distribution of ellipsoidal pores, possibly filled with fluid. It is restricted to ellipsoidal pores which axes are aligned with the symmetry axes of the T.I. solid. The main advantage in dealing with ellipsoidal pores is to yield a unified description of all important cavity geometries in geomechanics (thin cracks, spheroids). These results are derived in the non-interacting approximation, which implies no mechanical (stress) and no hydraulic (fluid pressure) interactions between pores of different shapes and orientations at all scales. This assumption may seem restrictive but it actually allows for a closed form modelling of the shale void space evolution under loading. Moreover, this non-interacting approximation acts as the basic building block for various approximate numerical schemes such as the self-consistent, differential or Mori-Tanaka effective stress schemes, devoted to take into account interactions

between pores.

Proper parameters are identified for quantitative macroscopic description of shale microstructure evolution under mechanical loading (strain). This approach is developed in order to be applied to actual experimental data obtained from shale preserved samples submitted to undrained triaxial conditions of loading. From the hydraulic point of view, it is well known that among all porosity geometries, equant pores are mostly responsible for rock fluid storage capacity, while anisotropic ones (crack-like pores) are mostly responsible for permeability (connectivity). Furthermore, from a mechanical point of view, static and dynamic elastic moduli are very sensitive to voids geometry and orientation. This fact allows anisotropy analysis to be used as a tool for microstructural data recovery in shales. In particular, elastic wave velocities (dynamic elastic moduli) are a powerful experimental tool in the quantification of these microstructural features. Therefore, we will extensively use this type of experimental data as input in the model.