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Application of profile (probe) permeability and mechanical (rebound) hardness tests for characterization of fluid transport and geomechanical properties of selected formations in western Canada

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Summary

The results from an ongoing laboratory study investigating fluid transport and geomechanical characteristics of selected formations in western Canada are presented. The primary objectives are to 1) characterize profile (probe) permeability and mechanical (rebound) hardness in areas with limited datasets and 2) investigate the possible interrelationship between profile permeability and mechanical hardness data for the analyzed formations.

Two slabbed core intervals obtained from shallow depths of the Upper Cretaceous section in Newell County (Alberta) were analyzed in this study. Profile permeability and mechanical hardness measurements were conducted on the surfaces of slabbed core at the same spots. For the analyzed intervals, the profile permeability values range between 0.002 and 430 mD while the mechanical hardness values range between 120 and 610 HLD. The profile permeability and mechanical hardness data are weakly correlated in most intervals; permeability decreases with increasing mechanical hardness. There are, however, some anomalies. The correlation between profile permeability and mechanical hardness data appears to be more significant for those intervals with lower permeability and higher mechanical hardness values (harder rocks typically). These intervals are commonly the target of reservoir stimulation during fracking.

Introduction

Characterization of fluid transport and geomechanical properties is a critical step in the evaluation of both unconventional reservoirs and potential geological sites for subsurface CO_2 sequestration. In particular, combined with the "in-situ" stress regimes, the geomechanical properties play a key role in drilling, completion and hydraulic fracturing of tight oil/gas reservoirs as well as assessment of cap rock integrity.

The profile (probe) permeability technique is a fast ''screening'' tool that can be useful for developing a permeability profile, which in turn can be used to characterize small-scale (<2.5 cm) heterogeneities (e.g., laminations), along slabbed cores. Application of this technique for petrophysical characterization of sedimentary rocks has been previously examined (Clarkson et al., 2012; Solano et al., 2012; Ghanizadeh et al, 2015b). This technique is particularly useful when only slabbed cores are available as sample material other than core plugs and/or cuttings. The lower range of profile permeability tests is, however, limited (down to 0.001 mD).

Standard laboratory techniques for determination of geomechanical properties are commonly destructive, time-consuming and expensive. Therefore, indirect mechanical tests have been alternatively used to provide an indication of rock mechanical strength. The Equotip Piccolo hardness test is one of the fastest and least-destructive techniques to differentiate and quantify the mechanical properties of cm-scale heterogeneities in slabbed cores. Application of this technique for mechanical characterization of tight sedimentary rocks has been previously examined (Solano et al., 2012; Ghanizadeh et al, 2015a). Application of both profile permeability and mechanical (rebound) hardness techniques is of particular interest for the present work, where the formations exhibit abundant vertical cm-scale heterogeneities.

This work presents results from an ongoing laboratory study investigating fluid transport and geomechanical characteristics of selected formations within Upper Cretaceous section in western Canada (Alberta). The profile and mechanical hardness data are collected in support of a field-based project to develop and calibrate different surface and subsurface monitoring technologies with a focus on CO_2 detection and discrimination at relatively shallow depths (Osadetz et al., 2015).

Samples & Experimental Methods

Two intervals of a 1/3 slabbed core drilled in Newell County (Alberta) were analyzed in this study. The drilled core encounters the Basal Belly River Sandstone, the Foremost Formation, MacKay coal zone, Pakowki Formation, Medicine Hat Formation, and 1st White speckled Shale in the Colorado Group (Osadetz et al., 2015). Profile (probe) permeability were conducted on the surfaces of slabbed core (1 inch intervals; 2.5 cm) with a PDPK-400™ (CoreLab®) probe permeameter using a mean gas (N_2) pressure of 170.3 kPa (24.7 psia). Mechanical hardness measurements were conducted with an Equotip Piccolo 2 (Proceq SA®) at the same spots as profile permeability tests.

Selected Results

More than 2500 profile permeability and 25000 mechanical hardness values were collected in this study. Following the approach proposed by Ghanizadeh et al. (2015a), only the lithological “units” with comparatively homogeneous profile permeability and mechanical hardness data were considered to establish the correlation between the two datasets. The profile permeability and mechanical hardness data are weakly correlated in some intervals; permeability decreases with increasing mechanical hardness (**Fig. 1**). The collected data are further compared to those previously gathered by Solano et al. (2012) and Ghanizadeh et al. (2015a) for Cardium, Bakken and Montney formations.

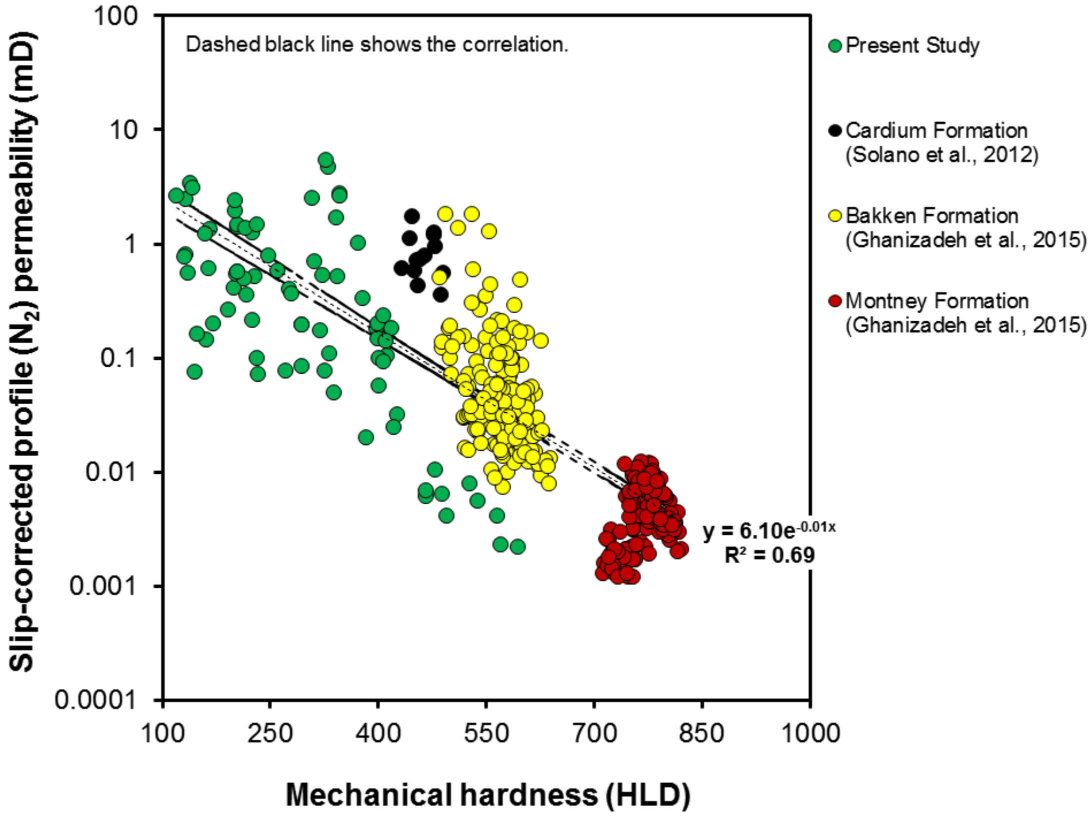

Fig. 1: The interrelationship between mechanical hardness and profile permeability values. The black solid lines indicate the non-simultaneous 'functional' 90% confidence envelope for the proposed correlation.

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