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ABSTRACT

Previously published Rock-Eval 6/TOC pyrolysis data are used as a proxy to map the geographic distribution of hydrocarbons in the Canol Formation. Mainly from wells, S1 is interpolated with Kriging software. The contoured representation of both S1 and S1/TOC are overlain by a depth map of the Canol Formation, which was generated from interpretations of seismic data and well logs and is contained within a subsurface zero edge determined from both subsurface data and bedrock maps. The Norman Wells area shows relatively high S1 and S1/TOC values and areas structurally along strike also contain relatively high S1/TOC values.

INTRODUCTION

Rock-Eval 6/TOC pyrolysis data is a fairly standard technique for measuring source rock potential and S1 values in particular represent free hydrocarbons in the rock that either were generated from kerogen in the source rock itself since deposition or accumulated by migration. They are important indicators for the prospectivity of shale rocks as unconventional hydrocarbon plays. When considering unconventional shale oil plays, the presence of natural fractures can have a negative influence on oil production from stimulated hydraulic fractures (Gale et al., 2007). Pre-existing fractures will ultimately focus hydraulic fluids and decrease the effectiveness of hydraulic fracture treatments. In the case of the Canol Formation, it's lithology is unique in that it is very siliceous (see Pyle et al., 2011) compared to other Devonian mudstones in the region and could therefore behave in a more brittle manner than typical mudstone. Though no rheological analysis of the Canol Formation was performed we note the empirical observation that in the Norman Wells area that the Canol Formation contains natural fractures at reservoir depths of 500-350 m (Yose et al., 2001; see discussion in Hadlari, 2015). It stands to reason that the Canol Formation has better prospectivity for unconventional hydrocarbons at greater depths and the deeper it is the more likely that stimulated fractures will be oriented vertically (Hubbert and Willis, 1972). This report uses previously published Rock-Eval 6/TOC pyrolysis data of the Canol Formation as a proxy to interpolate a surface representing the geographic distribution of hydrocarbons in this unconventional shale oil play with superimposed depth contours to identify areas of prospectivity.

METHODOLOGY

The source of Rock-Eval 6/TOC pyrolysis data shown here for the Canol Formation is a compilation by Pyle et al. (2015). In the case of multiple samples for a given outcrop or well location, the results were averaged. Spatial S1 data were kriged in ArcGIS using the Geostatistical Analyst plug-in. Canol Formation depths were derived from an interpretation of seismic data and exploration wells that was developed in the manner described in MacLean (2012). The distribution of the Canol Formation in the subsurface is approximated by the distribution of the entire Horn River Group, of which the Canol Formation is the upper stratigraphic unit, and integrates both subsurface and bedrock maps (Aitken et al., 1969; Aitken and Cook, 1979a, b; Cook and Aitken, 1970, 1975a, 1975b, 1975c; Fallas, 2013; Fallas and MacLean, 2013; Fallas and MacNaughton 2013, 2014a, b; Fallas et al., 2013a,b,c; Norris, 1981a, b, c, d, 1982). Surface fault data is sourced from a 1:5 000 000 compilation by Wheeler et al. (1996) and 1:50 000 to 1:100 000 maps by Fallas (2013a, b, c, d), Fallas and MacLean (2013a, b), Fallas and MacNaughton (2013, 2014a, b, c) and Fallas et al. (2013a, b, c, d). Subsurface faults are sourced from MacLean (2012).

RESULTS

The contoured depth map of the Canol Formation with interpolated S1 contours in Figure 1 shows the geographic distribution of free hydrocarbons indicated by Rock-Eval pyrolysis. In general the central Mackenzie area has relatively high S1 values whereas free hydrocarbon contents decrease toward the northern and southern edges of the study area. Some of the highest S1 values are recorded near Norman Wells, consistent with early reports of oil production from the Canol Formation (see Irish and Kempthorne, 1987).

By normalizing the S1 values to bulk TOC, areas with anomalously high S1 are indicated by the S1/TOC map (Figure 2). The interpolated S1/TOC contours in Figure 2 are superimposed with a contoured depth map of the Canol Formation. In the central part of the study area where S1 is elevated, the S1/TOC map further delimits smaller regions with anomalously high S1 relative to TOC. Relatively high S1/TOC values at Norman Wells indicate that this method has potential to identify a Norman Wells-type play. It is tempting to suggest that the geographic trend of high S1/TOC follows along the strike of faults, in the region of elevated S1, but more work is required to explore this relationship.

It is intended that maps of free hydrocarbons in Canol Formation rocks as measured by Rock-Eval pyrolysis inform assessment of the unconventional resource potential in the Central Mackenzie region.

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This work benefited from discussions with Dr. Martin Fowler. It follows extensive subsurface work in the region by Bernie MacLean. The manuscript was reviewed by Dr. Zhuoheng Chen.

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Figure 1. Map showing contoured depth of the Canol Formation, faults and Rock-Eval S1 values. Depths are interpreted from seismic data and well logs (MacLean, 2012). Dark grey faults taken from Wheeler et al. (1996). Black Faults taken from Fallas (2013a, b, c, d), Fallas and MacLean (2013a, b), Fallas and MacNaughton (2013, 2014a, b, c) and Fallas et al. (2013a, b, c, d). Dark blue subsurface faults are interpreted from seismic data (MacLean, 2012 S1 values are from the compilation by Pyle et al. (2015).

Figure 2. Map showing contoured depth of the Canol Formation, faults and Rock-Eval S1/TOC ratios. Depths are interpreted from seismic data and well logs (MacLean, 2012). Dark grey faults taken from Wheeler et al. (1996). Black Faults taken from Fallas (2013a, b, c, d), Fallas and MacLean (2013a, b), Fallas and MacNaughton (2013, 2014a, b, c) and Fallas et al. (2013a, b, c, d). Dark blue subsurface faults are interpreted from seismic data (MacLean, 2012). S1 and TOC values are from the compilation by Pyle et al. (2015).

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Table 1. Tmax values from well and outcrop samples, modified by adding S1/TOC to the compilation by Pyle et al. (2015).