

Applications of Inorganic Whole Rock Geochemistry to Shale Resource Plays: A Haynesville Shale Case Study

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Summary

The technique of chemostratigraphy is used here to show how the inorganic bulk geochemistry of the Upper Jurassic Haynesville Formation in Eastern Texas and Northwest Louisiana can be used to develop a robust basin-wide stratigraphic framework that allows for enhanced correlation as well as providing important insights into regional paleoenvironmental changes such as anoxia and terrigenous input.

Introduction

As the economic importance of shale resource plays continues to increase over the years, the need to fully understand and correlate the key reservoir intervals is a priority. The implementation of traditional approaches towards characterization and correlation of a reservoir is hampered by the fine grained, macro-scale homogeneity of most shale plays as well as the limited availability of biostratigraphic data. Consequently, additional techniques are needed to complement the traditional analytical methods.

Whole rock inorganic geochemical data has been successfully applied by the petroleum industry in the last two decades to define stratigraphic correlations, largely on fluvial successions where the common lack of regionally extensive marker beds and poor biostratigraphic control make stratigraphic correlation using traditional techniques problematic (Pearce et al., 2005, Ratcliffe et al., 2010, Wright et al., 2010a and Hildred et al., 2010). Beyond the stratigraphic applications, inorganic whole rock geochemical datasets have in fact routinely been acquired from organic-rich mudrocks to help elucidate paleoredox conditions during oceanic anoxic events (e.g. Tribovillard *et al.*, 2006, Turgen and Brumsack 2006, Tribovillard *et al.*, 2008, Negri *et al.*, 2009, Jenkyns, 2010).

In this study, the approaches of the chemostratigraphic workers and the oceanic anoxic event workers are integrated in order to provide a robust, repeatable, non-subjective stratigraphic correlation framework for the Haynesville Shale into which any well can be placed with high confidence. Then, within the broad stratigraphic framework, the internal stratigraphy of the Haynesville shale is refined using a traditional chemostratigraphic approach of defining geochemical units as well as an approach of identifying and correlating transgressive and regressive cycles. It can also be demonstrated that geochemical data can be used to recognize input points of terrigenous material, the distribution of anoxic areas, and potential relationships to TOC values.

Theory and/or Method

Whole rock geochemical data was obtained using ICP-OES/MS techniques from 1,421 core samples and 10 cuttings samples from a total of 10 study wells, with data for 50 major and trace elements acquired.

Variations in the inorganic geochemical dataset allow clear differentiation of the Haynesville shale from the underlying Smackover Formation, the Gilmer Limestone and the overlying Bossier Formation. More importantly, however, the data allow two chemostratigraphic packages and four geochemical units to be defined and correlated within the Haynesville shale. The lithostratigraphic units are differentiated using variations in SiO₂, Al₂O₃, MgO, Zr and Nb, whereas the units within the Haynesville shale are defined using changes in CaO, Al₂O₃, MgO, Fe₂O₃, Rb/K₂O and Th/U values and V enrichments. By integrating the geochemistry with XRD and TOC data, it becomes apparent that the main driving forces behind the changing geochemistry within the Haynesville shale are the amounts of anoxia in the lower portion of the Haynesville shale and of CaO input in the upper portion.

Furthermore, the correlation can be enhanced by the identification of transgressive – regressive cycles (T-R cycles) using repetitive fluctuations in the relative abundances of Zr and Nb. Combining the changes in Zr/Nb values with V enrichments, it is shown that greatest anoxia is associated with the transgressive portion of the oldest cycle. Importantly, this suggests that this stratigraphic horizon is where maximum TOC can be expected. By plotting lateral changes in geochemistry within the Haynesville shale, it is demonstrated that terrigenous input was highest in the northwest area of the basin, primarily in the Texas wells, and anoxia was greatest in the east of the basin, primarily in the Louisiana wells.

Acknowledgements

The authors would like to thank BP for allowing publication of the data pertaining to the study and to Chemostrat Inc. for allowing us the time and providing the support needed to prepare the presentation.

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