Tuesday, April 19, 2011

Crowne Plaza Hotel - Greenspoint (former Sofitel)
425 North Sam Houston Pkwy E

Social 11:15 AM, Luncheon 11:30 AM

Cost: $31 pre-registered members; $35 for non-members & walk-ups.

To guarantee a seat, you must pre-register on the HGS website and pre-pay with a credit card.
Pre-registration without payment will not be accepted.
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Application of Inorganic Whole-Rock Geochemistry to Shale Resource Plays: an Example from the Eagle Ford Shale, Texas

Introduction

Over the few past years, shale resource plays have become increasingly important hydrocarbon plays. In the USA, formations such as the Woodford Shale, the Marcellus Formation, the Haynesville Formation and the Eagle Ford Shale have become major hydrocarbon exploration and exploitation targets. However, understanding the controls on reservoir quality in these shale formations is still in its infancy, despite thousands of well penetrations.

Here, the Eagle Ford Shale is used to demonstrate how inorganic whole-rock geochemical data that are primarily obtained to provide stratigraphic correlations can be used to help understand mineralogy, organic content, and rock mechanics.

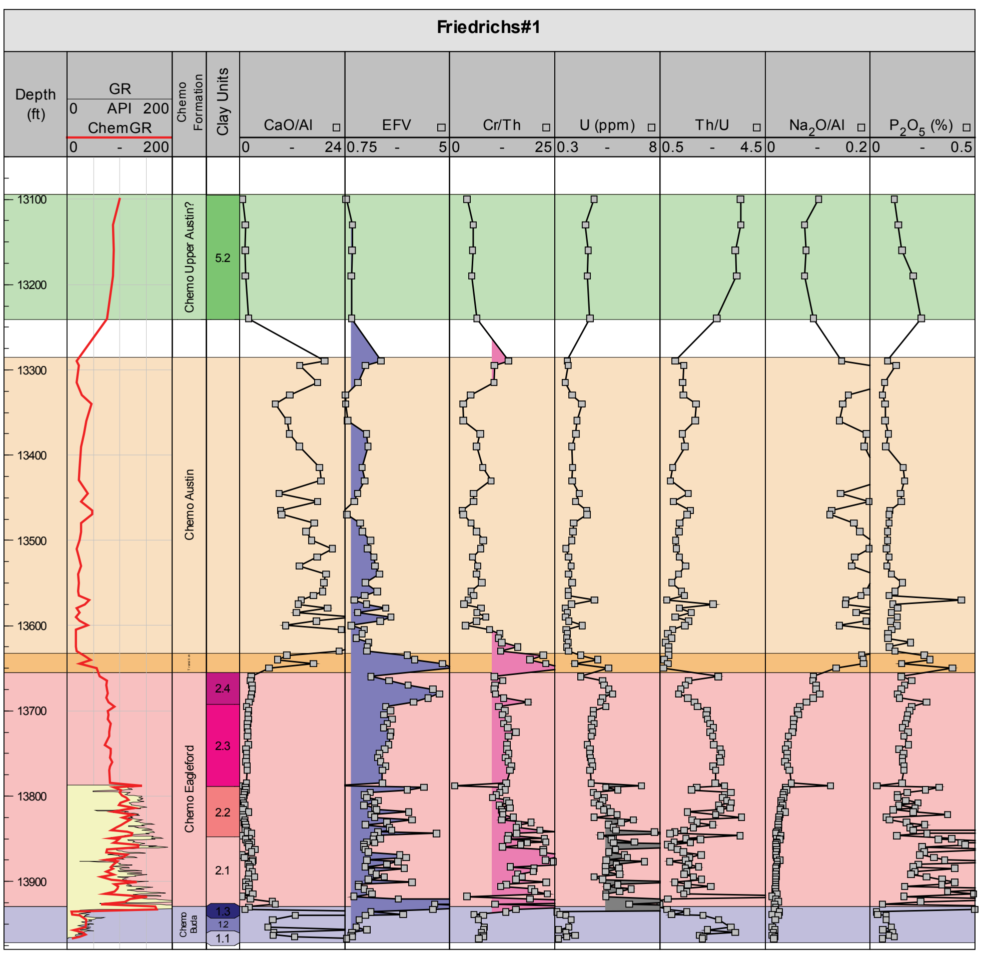

Figure 1. Chemical logs constructed for elements and element ratios used to define chemostratigraphic packages and geochemical units. Each square represents the location of an analysed sample.

The primary application of whole-rock geochemical data is to provide a chemostratigraphic correlation, which is of primary importance for temporally and geographically constraining other reservoir characteristics. The Eagle Ford Shale is divisible into two geochemical packages based on changing U values. Both packages can be further subdivided into three geochemical units, based on changing values of P, Th/U and Cr/Th. The top of the formation is readily geochemically defined by a decrease in the values of U, Cr/Th and V. Placing the top of the Eagle Ford Shale with confidence in itself is an important aspect for the drilling of horizontal wells, in addition to being able to chemically identify target zones within the formation itself.

Reservoir quality in shale resource

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plays is dependent on numerous factors, including mineralogy, terrigenous input, bottom water conditions during deposition and TOC values. Mineralogically, the Eagle Ford Shale is relatively simple, comprising quartz (av. 13%), calcite (av. 50%) and clay minerals (illite, illite/smectite, kaolinite and chlorite; av. 27%), with lesser amounts of pyrite, apatite and plagioclase feldspar. TOC values are typically between 1% and 7%. Each of these mineral phases and the TOC contents are readily modeled from the same elemental dataset used to define chemostratigraphic correlation framework. Furthermore, consideration of redox-sensitive elements, such as V, Ni, Th, U and Co provides a means to determine the degree of anoxia during deposition. The mineralogy plays an important role in how readily the formation can be fractured and because the inorganic geochemistry is directly linked to mineralogy, it is possible to calculate the relative brittleness of the mudstones.

The methodologies demonstrated here in the Eagle Ford Shale to define chemostratigraphic correlations, determine mineralogy, and better understand bottom water conditions are readily applicable to any shale-gas resource play around the world.

Methodology and Dataset

The Eagle Ford Shale is a dark grey, calcareous, locally organic-rich mudstone of Cenomanian – Turonian age that is sandwiched between the Cenomanian-age Buda Formation and the Coniacian – Santonian-age Austin Chalk. The study area, in south Texas, forms a narrow strip that extends from La Salle County in the SW to Lavaca County in the NE, a distance of >150 miles. Over this distance, the Eagle Ford Shale varies in thickness from approximately 75 to 300ft.

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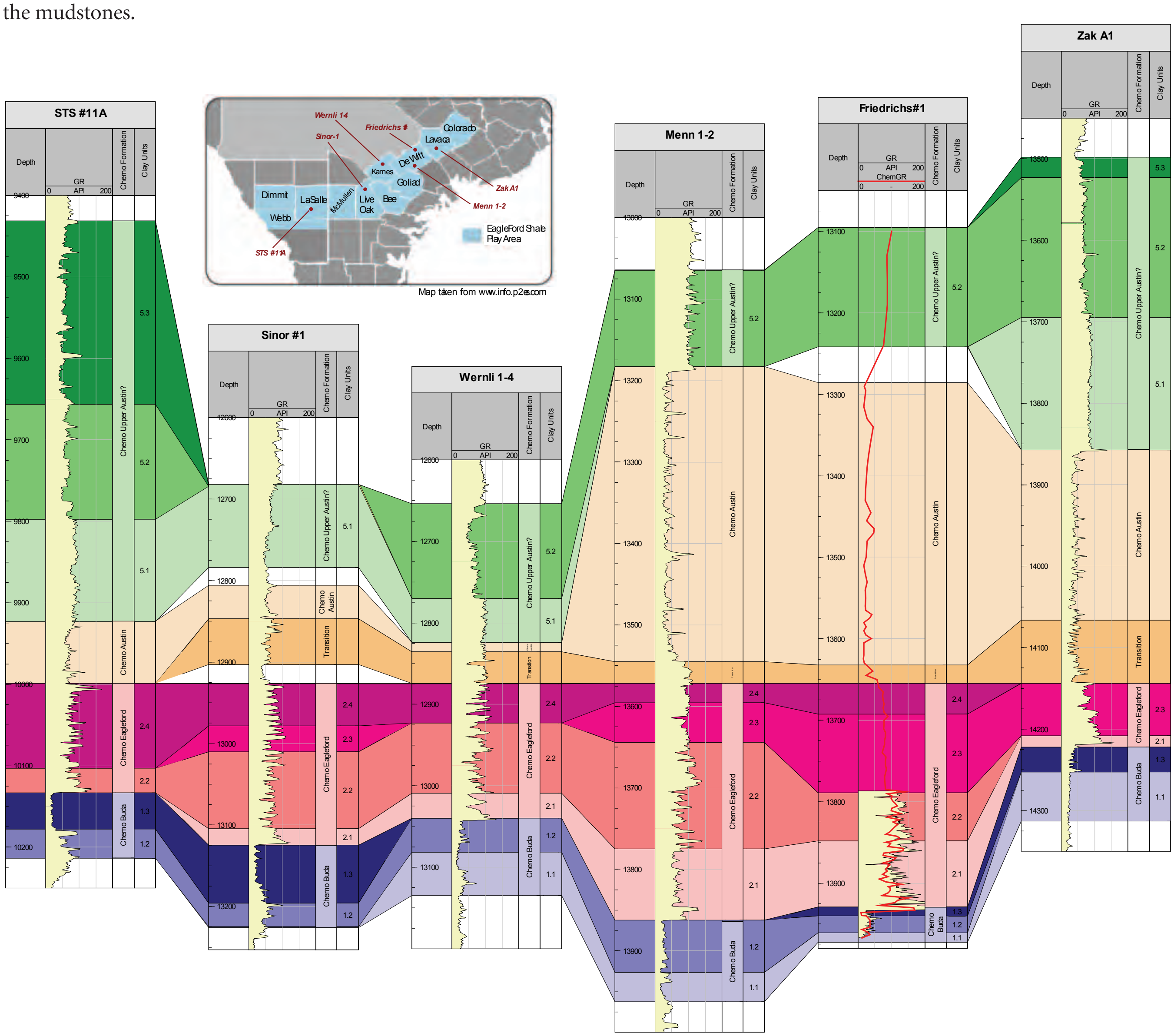

Figure 2. Chemostratigraphic correlation summary of the Eagle Ford Shale and the overlying Austin Chalk in selected wells.

Over 500 samples from 11 wells have been analysed using inductively coupled plasma optical emission (ICP-OES) and mass spectrometry (ICP-MS), following a Li-metaborate fusion procedure (Jarvis and Jarvis, 1995). These preparation and analytical methods provide data for 10 major elements, 25 trace elements and 14 rare earth elements. Precision error for the major element data is generally better than 2%, and is around 3% for the high abundance trace element data derived by ICP-OES (Ba, Cr, Sc, Sr, Zn and Zr). The remaining trace elements are determined from the ICP-MS and data are generally less precise, with precision error in the order of 5%.

Applications

Stratigraphic characterization and correlation

Developing stratigraphic frameworks is the key to the exploration for and exploitation of any hydrocarbon basin. In shale plays, the more traditional methods to stratigraphic correlations used by the petroleum industry are often limited. Commonly, the restricted basin nature of their accumulation can limit the use of biostratigraphy and palynomorphs are often thermally degraded. Electric log correlations are hampered by high, but erratic U values that reflect a mixture of detrital input and authigenic enrichment from sea water. Furthermore, the apparent macro-scale homogeneity of the mudrocks precludes the recognition of sedimentary facies that can be used for stratigraphic correlations, particularly when the only samples available are cuttings. Figure 1 displays the chemostratigraphic characterization of the Eagle Ford Shale in well Friedrichs #1 and Figure 2 the extension of that characterization into five of the 11 wells in the study.

Once a robust chemostratigraphic correlation is achieved, it can also be used as a basis for determining the well pathways in horizontal multilateral wells, pre- and post-drill or at well-site (Schmidt et al. 2010).

Mineral and TOC modeling

An important aspect to understanding shale reservoirs is determining their mineralogy and TOC contents. Typically, this is achieved using x-ray diffraction (XRD) and LECO analysis respectively. However, major element geochemistry can been used to provide semi-quantitative mineralogical data (Paktunc 2110, Rosen et al., 2004). Here, bulk mineralogy calculated from whole-rock geochemical data are compared against mineralogical data acquired from XRD to demonstrate the strengths and weaknesses of using calculated mineralogy. Similarly, semi-quantitative TOC values can be calculated from trace element geochemistry. This is achieved by determining a linear regression equation between selected trace elements and measured TOC. Provided the relationship between trace elements and TOC has a regression coefficient of over 0.8, it can be used to model TOC values where LECO determinations have not been made.

Paleoredox

Understanding paleoredox conditions is of paramount importance to shale-gas exploration, since high TOC values are only typically found in sediments deposited where bottom conditions were anoxic or euxinic. Oceanic anoxic events have long been recognized and studied (Schlanger and Jenkyns 1976) and in recent years, much has been written on the use of elemental geochemistry in sediments and water columns as a proxy for depositional redox conditions (e.g. Tribovillard et al., 2006, Turgen and Brumsack 2006, Tribovillard et al., 2008, Negri et al., 2009, Jenkyns, 2010). The key to using major and trace element changes to understand paleoredox conditions in ancient sequences is understanding the geological controls on each of the elements. Principal components analysis provides a quick and effective way to detangle the influences of terrigenous input, carbonate production and authigenic enrichment from sea water on major and trace elements. Vertical and lateral changes in elements associated with authigenic enrichment within the Eagle Ford Shale provide a means to understand temporal and geographic changes in paleoredox conditions, therefore providing important data regarding likely hydrocarbon productivity.

Relative Rock Brittleness

Another important feature of shale-gas production is the — fracability of the formations being drilled. This is controlled by the inorganic and organic composition of the sediments and the rock fabrics. Using the whole-rock geochemical data it is possible to define a relative brittleness value for any analysed sample. While this does not provide a quantitative value such as a Young's Modulus calculation, it does provide a rapid and visual indication of relative brittleness within the formation. This measure can be rapidly determined from core samples as well as from cuttings samples in horizontal wells.

Conclusions

Until relatively recently, the prime purpose of obtaining whole rock inorganic geochemical data for the petroleum industry has been for stratigraphic purposes. However, with increased exploration in shale resource plays, it is rapidly becoming apparent that the same dataset obtained to help refine stratigraphic correlations can be used to;

- Determine bulk mineralogy semi-quantitatively
- Determine TOC semi-quantitatively
- Understand temporal and lateral variation in paleoredox conditions
- Determine relative changes in rock brittleness

While the calculations of mineralogy, TOC, and brittleness are not as accurate as direct measurements using XRD, LECO or rock mechanics methodologies, the results described here can all be

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achieved rapidly and at no extra cost from the same ICP-derived data used for chemostratigraphy. Furthermore, the applications for the Eagle Ford Shale can readily be applied to any shale resource play. ■

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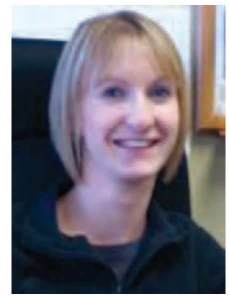
Biographical Sketch



Gemma Hildred graduated from the University of Birmingham with an M.Sci. Honours degree in geology in 2006. Gemma began her career at ChemoStrat International Ltd in 2006 and is now a senior geologist at ChemoStrat Inc in Houston, overseeing proprietary work throughout North America. Gemma also continues to research and publish work on the applications of inorganic wholerock geochemical data to geosciences and to the oil industry, specifically studying low accommodation fluvial sequences in Western Canada and the chemostratigraphic characteristics of the Eagle Ford Shale, West Texas.