Integrated Wellsite Biostratigraphy and Chemostratigraphy: A multi-disciplinary approach for drilling the Wilcox.

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Summary

This study proposes an integrated multidisciplinary workflow for the correlation of wells within the Gulf of Mexico. Integrating wellsite biostratigraphy and chemostratigraphy. Wells previously analysed for biostratigraphy have been subjected to elemental analysis by Inductively Coupled Plasma - Optical Emission Spectrometer (ICP-OES) and Inductively Coupled Plasma - Mass Spectrometer (ICP-MS) analysis, as well as x-ray fluorescence (XRF) in a simulated wellsite situation. The newly implemented workflow in this study exhibits a robust correlation between biostratigraphy and chemostratigraphy, leading to a more confident identification of major intra Wilcox surfaces.

Introduction

The Wilcox Group is a prolific reservoir and numerous discoveries have been made in this sequence across the Gulf of Mexico. However, despite the extensive drilling the understanding of the basic stratigraphy of the Wilcox Group remains contentious and renewed drilling has brought this issue back into focus. Despite many years of research, the stratigraphy of the lower Paleogene remains relatively poorly resolved, most especially within the Early Eocene & Paleocene Wilcox Group where calcareous fossil recoveries are much more limited and some biostratigraphic techniques cannot be used. Palynology has in recent years proven a more effective stratigraphic tool. Cornick et al. (2023) outlines a new palynostratigraphic framework for the Wilcox Group, established from quantitative analytical studies of 70+ deep water wells and 30+ onshore wells and outcrops. This workflow and palynostratigraphic framework are now routinely used at wellsite (using non-acid palynology) to refine the stratigraphy, help facilitate improved correlation, reduce exploration uncertainty and to support drilling engineering. Despite the improvement in stratigraphic definition, problems can be encountered at wellsite especially in thick rapidly deposited sand prone sections where biostratigraphic resolution may remain less well defined. Chemostratigraphy, a stratigraphic technique which allows interpretation of inorganic geochemical data, has been deployed extensively in Wilcox succession (Pearce et al. (2023a). This work demonstrates that although more forensic chemostratigraphy data can be acquired from Inductively Coupled Plasma - Optical Emission Spectrometer (ICP-OES) and Inductively Coupled Plasma - Mass Spectrometer (ICP-MS) analysis (which is commonly used for detailed desktop studies), reliable data for a subset of elements can be acquired using portable Energy Dispersive X-ray Fluorescence (ED-XRF) technology, which can be deployed at wellsite. This study also highlights the adverse impact of drilling additives on XRF data and how data can be corrected for compensate for low sample quality. This consideration of contaminants, how they can affect analytical methodology/data quality and how best they can be removed or corrected for proves that XRF based wellsite chemostratigraphy is viable in the Wilcox Group.

This paper discusses a new multidisciplinary wellsite workflow (Navistrat®) that combines the biostratigraphic capability of PetroStrat with chemostratigraphy from Chemostrat via their Joint Venture Company Future Geoscience (FGL). Both parent companies have many years of experience in the Gulf of Mexico and have analyzed many Wilcox wells. The wellsite workflow is also supported by access to a large legacy biostratigraphy and chemostratigraphy dataset, and many years of experiences working in the Gulf of Mexico. This approach has been routinely deployed in the North Sea and a refined deployment workflow for analysis and reporting have been established (O'Neill et al. 2022; Pearce et al. 2022). This service is staffed by experienced biostratigraphers and chemostratigraphers offshore and supported by additional supervision onshore that can provide real time interpretation.

Methodology

This paper summarizes a lab-based simulation of the trial analysis for wellsite services on two wells from the Wilcox Group. Both wells have been subjected to quantitative biostratigraphy and high resolution ICP analysis. ICP cannot be deployed at wellsite, and as portable ED-XRF analysis is less sensitive and accurate it is important to test the capability of ED-XRF versus the ICP to establish whether aspects the laboratory based chemostratigraphy can be determined at wellsite sufficient to influence operational decisions. Therefore, all ICP samples were re-analysed using the wellsite ED-XRF equipment to cross check the capabilities, accuracy and overcome the analysis constraints of drilling contaminants. The results of biostratigraphy and chemostratigraphy have been integrated into a new standard joint reporting template, suitable for real-time drilling and required by operation geologists.

Sample Selection and Preparation

- Selected two wells from the Wilcox Group as the focus of the study.
- Gathered representative cutting samples from each well, considering the lithological variations and potential biostratigraphic and chemostratigraphic markers.
- Prepared the samples for quantitative biostratigraphy, high-resolution ICP analysis, and ED-XRF

Biostratigraphy Methods

Quantitative palynology was undertaken on >500 samples from Wells A and B. Detailed sample preparation, analytical techniques and the stratigraphic framework are summarized in (Cornick et al. (2023). However, the key to the improved resolution is the integration of the temporal variations observed within the allochthonous (terrestrially derived) spore & pollen assemblages with changes in the composition of the autochthonous marine dinoflagellate assemblages Cornick et al. (2023).

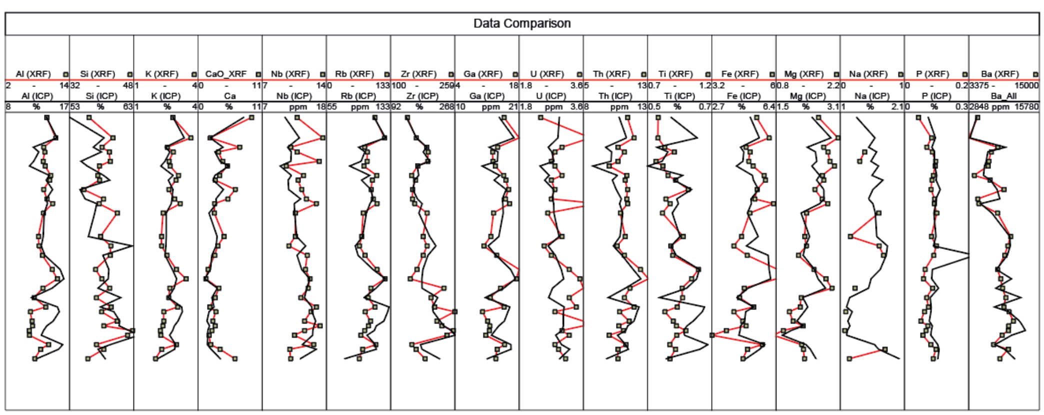

Figure 1: Comparative plot for selected elements determined by ICP and ED-XRF.

Chemostratigraphy Methods

High-resolution Inductively Coupled Plasma (ICP) analysis was utilized to determine the elemental composition of the rock samples, measuring the concentrations of major and trace elements, and aiding in the understanding of geochemical variations vertically in both wells. In addition to it, the wellsite chemostratigraphy technique using Energy Dispersive X-ray Fluorescence (ED-XRF) for rapid elemental analysis was implemented on all samples. This XRF analysis on the same set of rock samples with the portable XRF instrument at the wellsite to allow a direct data comparison and a means verify the real-time capabilities and upscaling the operation effectively.

To complete this chemostratigraphy evaluation, over 500 samples from Well A and B were selected for analysis. And were analysed using the ICP as described by Pearce et al (2023a).

These samples have also been analysed by ED-XRF to provide a data comparison. For ED-XRF analysis, 4 grams of samples is ground to a fine powder and placed in a sample cup with a mylar film base. Spectro Scout ED-XRF provides data for c.30 elements. The precision of the geochemical data acquired by the XRF is determined using the replication of standard reference material (SRM) and drift is monitored using an inhouse standard (similar protocol for wellsite deployment).

ICP provides the largest elemental dataset (c.50 elements) and has superior limits of determination and an ability to quantify data contaminated samples. ED-XRF typically acquires data for c.30 elements, but certain key elements are often below levels of determination or affected by matrix interferences or drilling additive contamination. Drilling challenges in the Wilcox are common and the introduction of additives is common. Although, onshore cleaning can reduce the impact of additives on the XRF spectra, time pressures at site limit sample preparation and as result certain key elements (Ti, Na, Cr, Sc, Cs V and U) cannot be detected consistently by ED-XRF in Wilcox samples.

However, Figure 1 plots comparative data for ICP and ED-XRF and highlights that ED-XRF matches closely the ICP readings, though is sporadically determined and U XRF values are somewhat erratic. In conclusion, ICP data is far more reliable and informative if samples are being analyzed in the laboratory. Notably, in the laboratory there are no significant speed or cost differentials between ICP and XRF analysis. Figure 1 highlights which elements can be used reliably at wellsite. The comparative dataset also enables alternative wellsite ready ratios to be emphasized for ED-XRF deployment that mimic ICP mineralogical trends. Furthermore, the ICP data can be used as a reliable training set for machine learning tools to assist in the correction of elemental data effected by contamination obtained from ED-XRF whilst drilling or ML can be used to re-evaluate legacy XRF data obtained from ED-XRF and from different laboratories; either because they occur at levels below determination or are contaminated. It is also important to recognize that the chemostratigraphic zonation developed from ICP / XRF data has been cross verified with QXRD and Raman heavy mineral data can be tied to the biostratigraphic and chronostratigraphic scheme.

Results

Biostratigraphy

The construction of any biostratigraphic zonation requires regional knowledge and understanding. Based on the regional biostratigraphy a palynological scheme of 8 regionally correlative assemblage zones can be defined within the Wilcox, with up to 21 subzones identifiable given sufficient sample density and the existence of a complete stratigraphic succession. Overall, these zones/subzones rely upon quantitative abundance changes rather than species inception and extinction events, making for a more statistically valid approach to correlation. Although not all of these zones and subzones will be preserved in any single (inboard or deep-water wells will preserve differentiate successions), the scheme can be ready deployed at wellsite and tied to a chronostratigraphic framework. Figure 2 illustrates a summary of the PetroStrat palynostratigraphy and how it related to the existing stratigraphic schemes.

Chemostratigraphy Results

The results of the ICP and ED-XRF analyses are discussed in detail by Pearce et al. (2023a). Following analysis an assessment of the samples' representation is key; samples that are representative of the depths they are taken can have a higher level of confidence attached to the interpretation. The raw data is then tested against the wireline to assess the representivity of the samples analysed using the real-time Chem Gamma, and machine learning (using the ICP chemostratigraphic dataset as a training set) is used to compensate for zones of drilling additive contamination.

A series of key element ratios (Pearce *et al*. 2023a) have been selected to best characterize these well penetrations. The elements used within these key ratios are associated with changes in climate, provenance, and geological processes. Figure 2 also illustrates how the chemostratigraphic zonation matches closely with the palynostratigraphic zonation and in some sections enhances the stratigraphic resolution with a finer stratigraphic zonation. Critically, some of the key ICP based chemostratigraphic ratios can be determined by wellsite ED-XRF (Figure 3). This confirms that wellsite chemostratigraphy is a viable tool for deployment for stratigraphic monitoring through the Wilcox. However, once combined with palynology the cumulative benefit provides

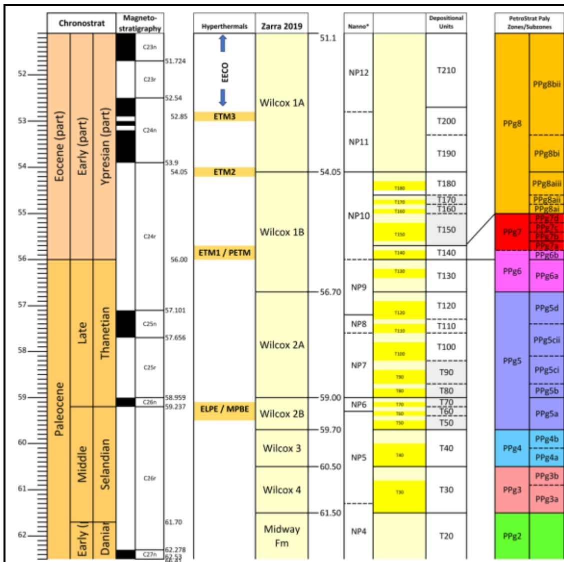

Figure 2. An integration of palynostratigraphic summary (Cornick et al. 2023) with the published scheme of Zar(2019)

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Wellsite chemostratigraphy of the Wilcox Group

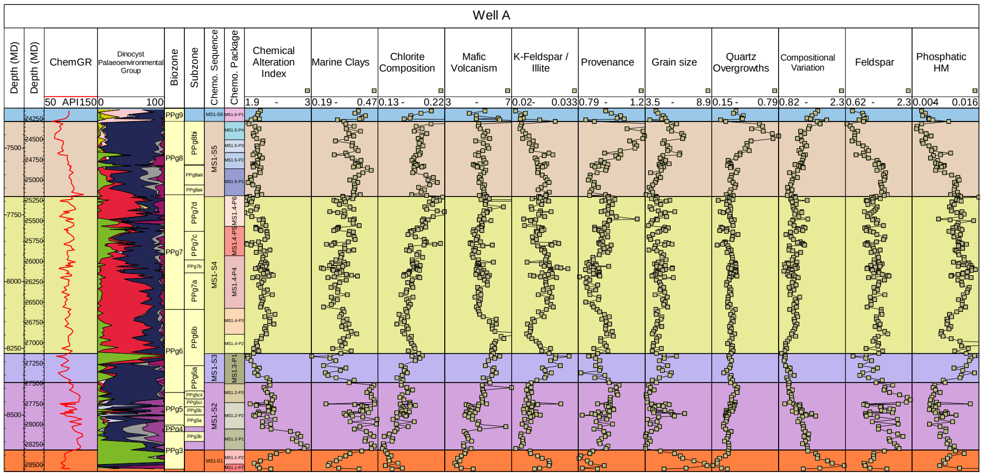

Figure 3: ED-XRF Chemostrat ratios plotted in conjuction with palynostratigraphic data for well A

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Conclusions

The acquisition of real-time reservoir characterization data speeds up the completions program and limits the need for time consuming post well laboratory analysis. All biostratigraphic and chemostratigraphic data acquired at wellsite are combined into a Spotfire® data dashboard along with MWD data to provide real-time updates at wellsite.

The newly implemented workflow in this study exhibits a robust correlation between biostratigraphy and chemostratigraphy, leading to a more confident identification of major intra Wilcox surfaces. By integrating Spotfire® and machine learning (ML) techniques, the data modeling process is further enhanced, enabling a comprehensive analysis of the combined biostratigraphic and chemostratigraphic data. The results obtained from this integrated approach offers valuable insights into the geological history of the Wilcox formation. Key markers are identified from palynology and chemostratigraphy, for example the presence of volcanic tuffs at the top of the Wilcox Group, indicating periods of starved sedimentation in association with carbonates and siliceous ooze. Additionally, evidence of increased marine influences is discernible in the Upper Wilcox Group from palynological data and is further supported by elemental signals linked to elevated marine clay content. Furthermore, the study identifies distinct occurrences of strong influxes of freshwater algae and fresh mineralogical immature detrital mineralogy at multiple points within the Upper Wilcox. These findings contribute to a better understanding of environmental conditions and sedimentation processes during the formation's deposition. The data also reveal climatic cyclicity and evidence of the Paleocene-Eocene Thermal Maximum (PETM) just above the Paleocene boundary, as detected from both palynological data and changes in major and trace element geochemistry. These findings shed light on past climatic fluctuations and their potential impact on the depositional environment. Overall, our study demonstrates that the integration of chemostratigraphy and biostratigraphy at the wellsite is a powerful tool for enhancing stratigraphic analysis, minimizing uncertainties, and optimizing drilling operations. The successful implementation of this approach holds great promise for advancing hydrocarbon exploration and production efforts in the studied formation and beyond. As the energy industry continues to evolve, this integrated methodology presents an essential resource for maximizing efficiency, accuracy, and economic success in future drilling campaigns.

This new technical approach to wellsite deployments in the Wilcox Group represents a major step up in the ability to bring laboratory science to the wellsite and combines high quality data acquisition with high quality scientific interpretation to aid decision making in a fast moving, decision making environment.

Acknowledgments

The authors would like to thank the directors of Chemostrat Ltd, PetroStrat Ltd and Future Geoscience Ltd for permission to present their work. To the laboratory staff of Chemostrat and PetroStrat for the analysis of samples.

The authors acknowledge C. Tansell (Chemostrat) for comments and reviews of the manuscript.