

The Application of Phytolith Stratigraphy to ‘Barren’ Red-beds

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Significant oil and gas reserves occur in so-called “barren red-beds” in several regions around the world. Although red-beds occur throughout the geological timescale, examples with an economic interest are the Late Carboniferous, Permian and Early Triassic of Europe (Barren Measures, Rotliegendes, Bunter; Doornenbal and Stevenson, 2010), the Triassic of the United States, and the Permian–Carboniferous of the Middle East. These sediments are generally deposited in non-marine environments under arid climate conditions. In terrestrial basins, biostratigraphic analysis of plant microfossils (pollen and spores) is often effective in constraining static geological models. Unfortunately, such organic-walled microfossils are not preserved in red-bed deposits due to oxidation, hampering stratigraphic correlation on both local (field) and regional scale.

In our research, a group of biogenic siliceous microfossils, termed phytoliths, has been applied as biostratigraphic tool in the Permian–Carboniferous red-bed sequences. Phytoliths, or biogenic silica particles (BSPs), originate in the cells of higher land plants. After organic matter decomposition, phytoliths can be preserved as siliceous bodies.

The first steps toward applicable fossil phytolith taxonomy have been established by Garming et al. (2010). The combination of BSP stratigraphy based on range tops and bottoms and on abundance change provides the possibility to improve existing regional geological correlations, position regional unconformities and refine reservoir architecture models. Encouraging results are obtained in the Permian Upper Rotliegend Formation in the Groningeng Gas Field, The Netherlands. While further studies are needed to evaluate the BSP-based correlations and explore the origin of the observed cycles, strong evidence suggests that BSPs have potential to provide the basis for better stratigraphic correlations in “barren” deposits.

BSPs have been also discovered in the subsurface sediments of the Permian–Carboniferous Unayzah Formation in Saudi Arabia. Also in these gas-bearing sandstones, BSPs are a potential tool for subdividing and correlating the reservoir units (Garming et al., 2010; Cantrell et al., 2011).

In the Upper Rotliegend in the Southern North Sea Basin, BSP stratigraphy has been applied with the aim of refining the basin infill model of the Upper Rotliegend and to detect the position of the Base Permian Unconformity (BPU), which are critical aspects for E&P activities in the Southern North Sea. Significant changes in the quantitative composition of the BSP assemblages are recorded in all wells, and provide the most direct biostratigraphic information. Traditionally, the infill for the Upper Rotliegend sediments in the Dutch sector of the Southern North Sea basin is modelled with a general southwards thinning towards the basin margin (van Ojik et al., in press). One of the discussions in the Rotliegend basin development is whether the basin infill reflects an onlap situation, where lithological units step onto and over the basin edge as the basin fills, or a wedge shaped model, where layer after layer is stacked on top of each other over the entire basin area.

The BSP results indicate that most BSPs have long stratigraphic ranges and that numerical methods are needed to interpret the data. The quantitative results show significant shifts in the BSP composition that readily allow the distinction of three Assemblage Zones. Further statistical analysis on the dataset using Principal Component Analysis reveals probable cyclicity. Spectral analyses on the PCA values indeed reveal cyclicity. In total, four to five cycles are recognized offering a still higher resolution to subdivide the aforementioned Assemblage Zones. The statistically significant trends and groupings are further supported by stable isotope analyses on the bulk samples. The oxidized rocks contain just enough organic matter to carry out $\delta^{13}\text{C}$ -organic carbon isotope measurements. The isotope trends are used to corroborate the correlations based on BSP analyses. The combined results enable a stratigraphic correlation in these wells that a clearly overstepping of the basin margin (Figure 1) and prove that is possible to do biostratigraphy on 'barren' red-bed deposits.

Conclusions

This new biostratigraphic tool is a powerful technique within the context of understanding reservoir architecture and the ongoing exploration for gas fields in barren red-bed deposits. Further challenges include the coupling of the BSPs to parent plants for palaeoenvironmental interpretation, increasing taxonomic and stratigraphic resolution, and enhancing quantitative data interpretation, all to establish a high-resolution regional standard stratigraphy. Furthermore, additional studies outside the North Sea basin have shown that the tool holds great potential in other Permian–Carboniferous red-bed sediments in the Middle East, and in the Oligocene deposits of South America. In principle, the application of BSPs can be extended to any other geological time period with “barren” deposits.

References

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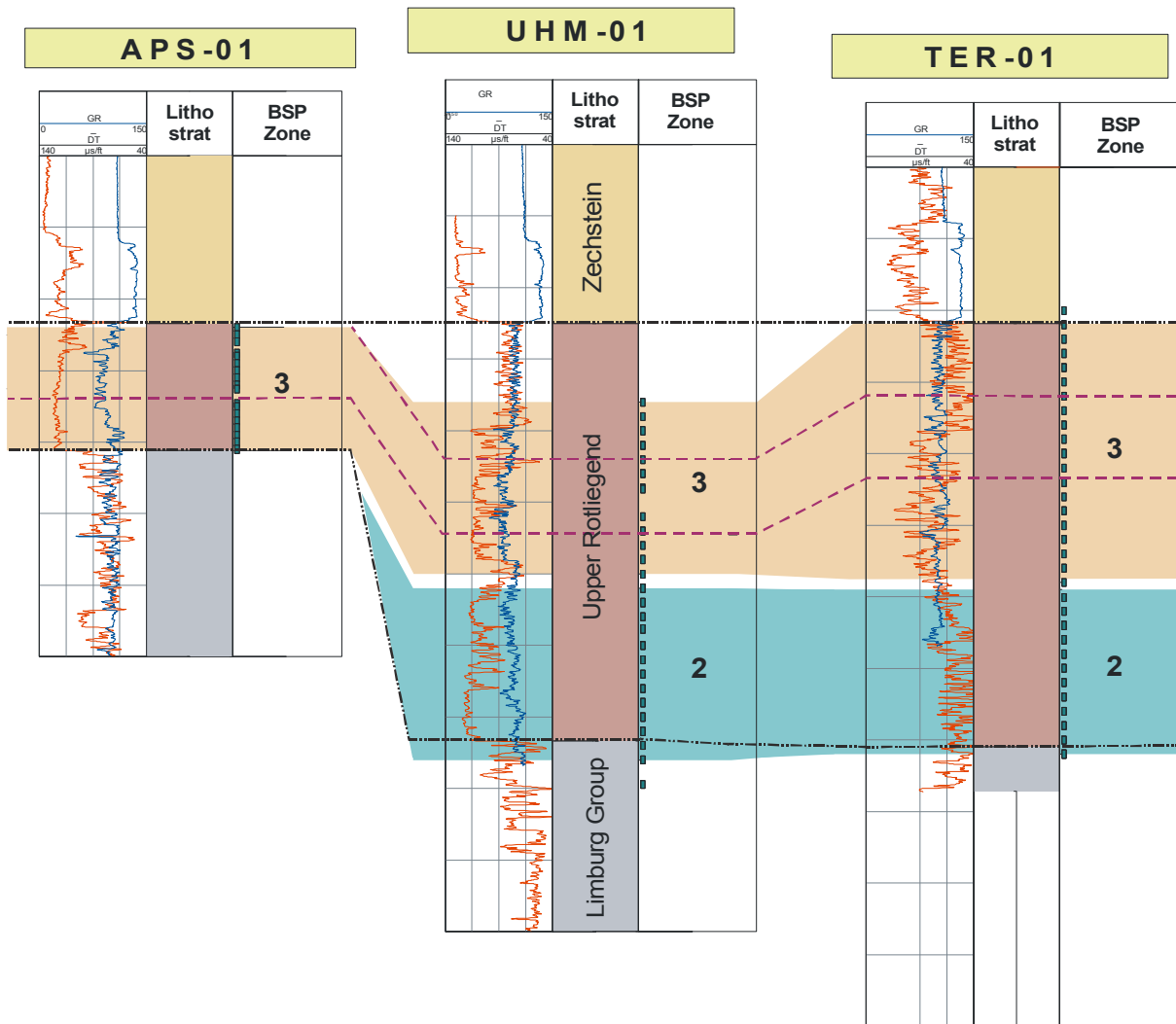


Figure 1: South-North BSP-based correlation panel in the Dutch Upper Rotliegend, showing onlap towards the south on the left, where the basin margin is located.