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Siliciclastic Sedimentary Rocks of the Phanerozoic of the Arabian Plate: An Interplay of Tectonics and Climate

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Abstract

The Arabian Plate, a tectonic entity encompassing much of the Arabian Peninsula and adjacent regions, has experienced a complex interplay of tectonic, climatic, eustatic, and provenance-related controls throughout the Phanerozoic Eon (approximately the last 541 million years). These controls have governed the deposition, distribution, and characteristics of siliciclastic sedimentary rocks—those derived from the mechanical weathering of pre-existing rocks—across the region. Understanding these controls is not only of academic interest but is also crucial for petroleum exploration, as many of the world's largest hydrocarbon reservoirs are hosted within siliciclastic systems of the Arabian Plate. This presentation analyses some of the main controls on siliciclastic sedimentation in the Arabian region through the Palaeozoic, Mesozoic and Cenozoic, focusing on some new techniques that may provide predictive value. It also looks at research gaps and opportunities and new uses for siliciclastic sedimentary rocks through the energy transition.

Main events

During the early Palaeozoic, the Arabia was part of the northern margin of Gondwana, characterized by a stable, subsiding platform overlying the Neoproterozoic Arabian–Nubian Shield. The Cambrian to Devonian periods saw the deposition of thick quartz-rich sandstones, with tectonic stability and low subsidence rates resulting in a layer cake stratigraphy. However, the Carboniferous Hercynian Orogeny introduced significant tectonic complexity causing block faulting, uplift, and erosion, particularly in central Arabia, and large hiatuses that cut out important source and reservoir rocks (Fig. 1.; Stephenson et al. 2024).

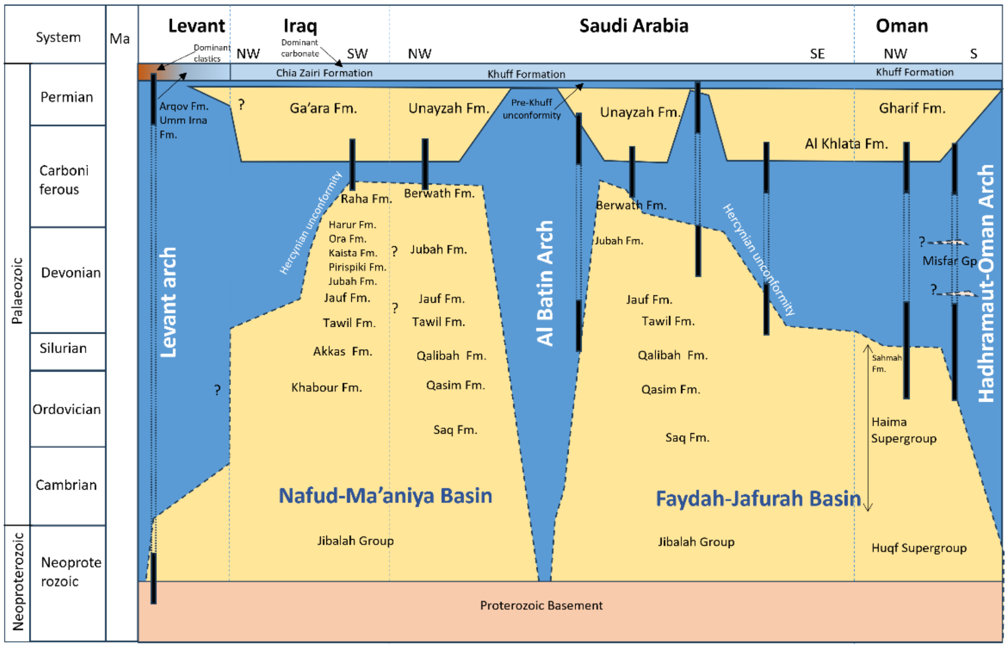

Fig. 1. Time-stratigraphy diagram for the Hercynian unconformity

In much of Arabia, glacigene rocks overlie the Hercynian unconformity. In the Mesozoic, the Permian–Triassic transition was marked by the rifting and opening of the Neo-Tethys Ocean along the northeastern margin, transforming the Arabian area into a passive margin that accumulated thick carbonate and siliciclastic sequences. The Triassic and Jurassic periods saw further rifting events, the development of horst and graben systems, and the formation of intrashelf basins, which localized siliciclastic input and created new sediment pathways. During the Late Cretaceous, the convergence of the Arabian and Eurasian plates led to the obduction of ophiolites (slices of oceanic crust) onto the northeastern margin, the formation of the proto-Zagros foreland basin, and the onset of compressional tectonics that would culminate in the Zagros Orogeny. The Cenozoic was dominated by the collision of the Arabian and Eurasian plates, and the opening of the Red Sea further modifying sediment supply and accommodation space.

New techniques, new models

The presentation will emphasize new modeling and visualization that allows the influence of climate on facies to be more precisely analyzed. In broad terms the influence of climate can be regarded as very simple with colder temperatures (higher latitudes) tending to encourage siliciclastic sediments, whereas warmer temperatures (lower latitudes) encourage carbonate rocks (Fig. 2)

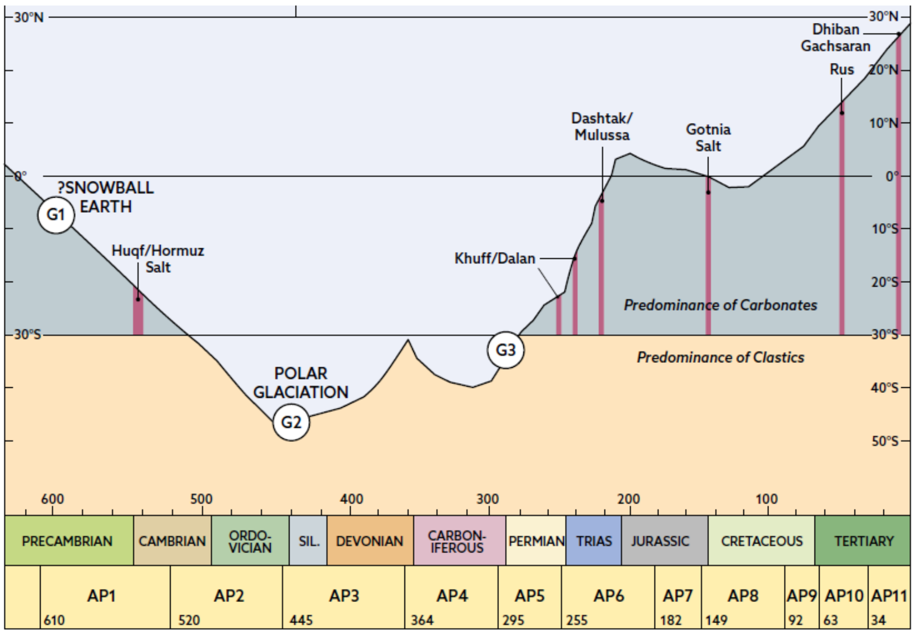

Fig. 2. The influence of latitude (broadly temperature) on the occurrence of siliciclastic and carbonate sedimentary rocks across the Arabian region (adapted from Sharland et al 2001).

However new models and tools allow this generalization to be tested. An example is palaeotemperature modelling by Li et al. (2022) visualized in the DDE Earth Explorer tool which allows the 0°C palaeoisotherm to be traced across northern Gondwana for 10 Ma time intervals allowing the theoretical limits of glaciation to be mapped on modern palaeogeographical reconstructions such as those of Scotese and Wright (2018; Fig. 3). Similarly palaeotemperature modelling can allow the progress of deglaciation to be tracked in detail even for small regional areas (Stephenson et al. in review).

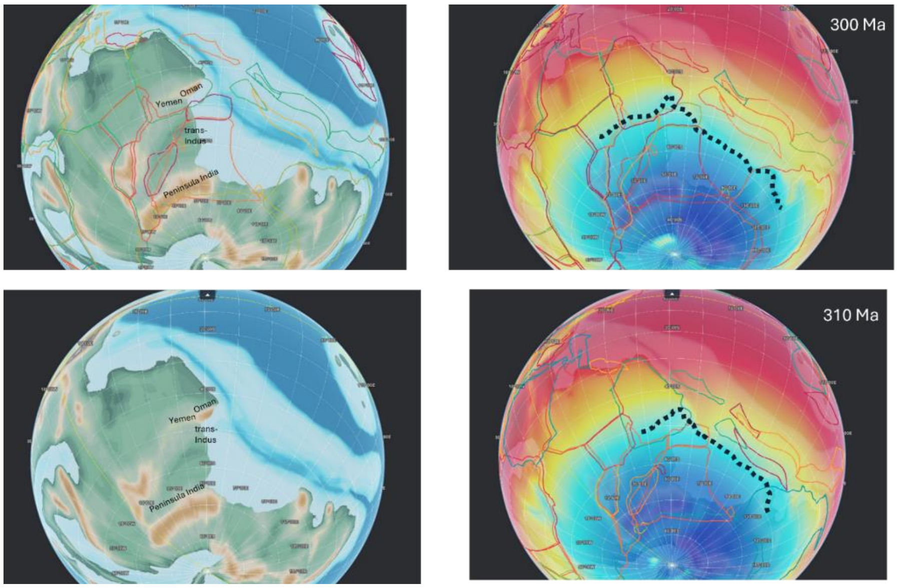

Fig. 3. The 0°C palaeoisotherm traced approximately across northern Gondwana for two time slices allowing the theoretical limits of glaciation to be mapped on modern palaeogeographical reconstructions at 300 and 310 Ma

New techniques in palynology piloted in the Arabian region have shown that they can help to understand reservoir heterogeneity in complex alluvial siliciclastic reservoirs (Stephenson et al. 2025). Future work could involve high-resolution stratigraphic correlation using machine learning, advanced petrophysical characterization, and geochemical fingerprinting for provenance analysis.

New uses

Finally, the potential for other uses of siliciclastic sedimentary rocks for energy transition and groundwater are considered. A recent study (Ye et al. 2023) found that carbon capture and storage technologies are vital for net-zero goals. The study looked at storage capacity of 17 basins and sub-basins throughout Saudi Arabia and found the most suitable basins in the eastern part of the country, and the estimated total effective storage capacities in deep saline aquifers, future depleted oil reservoirs, and non-associated gas reservoirs to be ~432, ~5, and ~ 9 gigatons, respectively.

Conclusions

Siliciclastic sedimentary rocks are influenced by tectonic, climatic, eustatic, and provenance-related controls. In this presentation I will look at how new modelling and visualization in a few pilot studies can allow a more precise understanding of how palaeoclimate might have affected facies and thus allow some predictive capability. Similarly, I show how new techniques may allow a better understanding of heterogeneity in

siliciclastic reservoirs. Some of the world's largest hydrocarbon reservoirs are hosted within siliciclastic systems of the Arabian Plate, but looking forward it is likely that these reservoirs will find other uses in a more hydrocarbon-constrained world aiming at net zero, for example through CCS.

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