Lower Silurian Black Shales of North Africa: The Role of Glaciation on the Distribution of Source-Rock Quality Facies*

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Abstract

A key exploration risk in the Lower Paleozoic of North Africa is the local absence of source rock facies in the lower Silurian shale. Following the Late Ordovician glaciation, decaying ice sheets left a residual topography that included a series of “underfilled” glacial incisions, carved by ice and/or meltwater. Some models explain the patchy distribution of high TOC shales as deposition in anoxic pools within this topography during Silurian post-glacial transgression. In some parts of North Africa, however, a high TOC shale “blanket” occurs, whereas in other parts a clear connection with fault activity is observed. We present data from Al Kufrah Basin in southern Libya, which includes a continuous section straddling the Mamuniyat (Late Ordovician) and Tanezzuft (Late Ordovician-Silurian) formations respectively. The topmost Mamuniyat Formation comprises glaciogenic sandstones, which pass upward into mixed facies of the Tanezzuft Formation. At its base, the Tanezzuft Formation includes a basal carbonate facies association, comprising bioturbated peloidal micrites and wackestones, bearing fragmented crinoids, bryozoa and orthocones (interpreted as reworked coolwater carbonates deposited under oxygenating conditions). Above, the remainder of the Tanezzuft Formation comprises hummocky cross-bedded and graded sandstone intervals intercalated with shale and siltstone (interpreted as storm influx onto a muddy shelf). These latter deposits, however, are interrupted by several lonestone-bearing intervals (interpreted as ice-rafted debris), a striated pavement (interpreted as glacial in origin), manganese crusts and concretions. The putative glacial deposits occur at the same stratigraphic level as high TOC shales elsewhere in North Africa. Deposition of the manganese concretions is interpreted as the result
of a drop in sea level, a result of glaciation, which was accompanied by a fresh water influx, flushing out the potential for anoxia to develop and hence high TOC shales to accumulate.

Reference

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³Goettingen University, Germany
⁴Libyan Petroleum Institute, Libya
North Africa and the Saharan basins

- Late Ordovician sediments at outcrop
- Late Ordovician sediments in subcrop (sedimentary basins)

Exposures are excellent but widely scattered!
Late Ordovician (Hirnantian, ~443 Ma)
Glacial valley at Iherir, Tassili N’Ajjer, Algeria

- Unconformity >150 m relief
- Glacially-related incision
- Coarser grained, sometimes chaotic deposits above: major reservoir interval, intensely studied
## Early Palaeozoic of North Africa

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<thead>
<tr>
<th>Chrono-stratigraphy</th>
<th>MOROCCO</th>
<th>ALGERIA</th>
<th>LIBYA</th>
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<tr>
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<tr>
<td>Llandoverian</td>
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*Note: The diagram provides a detailed stratigraphic overview of the Early Palaeozoic of North Africa, including the distribution of various formations and events across different regions.*
Typical section of Silurian “hot shale”

Public access data: http://www.es.ucl.ac.uk/research/mprg/research/Pubs/Craig2008-2/Picture%2028.html
Model for high TOC shale, Early Silurian

A. Hirnantian: LST modulated by glacial-interglacial high frequency cycles. Deposition of glaciogenic reservoirs.

- Glacially sculpted topography (palaeo-ice stream fairways, underfilled tunnel valleys, glaciotectonic features, +/- isostatic rebound relief)
- Palaeo-ice stream fairway (~60 km wide x 300 km long; hundreds m deep)
- Tunnel valley fairway (~4-8 km wide x 90 km long; 100 m deep)
- Push moraines (several km along strike, max ~50 m high)
- ice sheet

B. Rhuddanian: Early TST, deposition of hot shales

- North Gondwanan upwelling
- Initial transgression
- Restricted circulation
- Hot, shales with underfilled glacial palaeo-valleys

C. Post-Rhuddanian: TST, deposition of organically leaner shales

- Continuing sea level rise leads to deposition of shales with lower organic content

Modified from Lüning et al. (2000)
Distribution of Silurian “hot shale” (source rock)

Public access data: http://www.es.ucl.ac.uk/research/mprg/research/Pubs/Craig2008-2/Picture%2029.html
Map showing the location of Jabal Eghei-Nuqay in the Murzuq Basin of Libya.
Stratigraphy

Post-glacial shale
(source rock and seal)

Glacial deposits
(major reservoir interval)

Late Ordovician (Hirnantian)
Glaciation: regional incision

Fluvial to shallow marine deposition
Sedimentary log and gamma ray results

First known occurrence of intra-Tannezuft glacial deposits in North Africa
Soft-sediment striated surface
Calcareous lonestones
MnO$_2$ concretions
Graptolites

New species:

*Normalograptus kufraensis* nov. sp.

Age: Rhuddanian-Hirnantian

MnO₂ concretions

Hummocky cross-stratification
Conclusions

• Previous model: diachronous flooding of glacial topography in Early Silurian explains patchy organic enrichment in the Tanezzuft (Lüning et al., 2000)

• New model: glacial re-advance “flushed out” potential for anoxia in some areas. Oxidative processes confirmed by MnO2 concretions

• New data does not overturn interpretations of Lüning et al but adds another layer of complexity
Thankyou

- To our field team (I hope you are still safe)
- To sponsors of the CASP Southern Libyan Basins Project
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