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

Luning, S., D.K. Lydell, O. Sutcliffe, A. Ait Salem, E. Zanella, J. Craig, and D.A.T. Harpel, 2000, Silurian-Lower Devonian black shales in Morocco: Which are the organically richest horizons?: Journal of Petroleum Geology, v. 23/3, p. 293-311.

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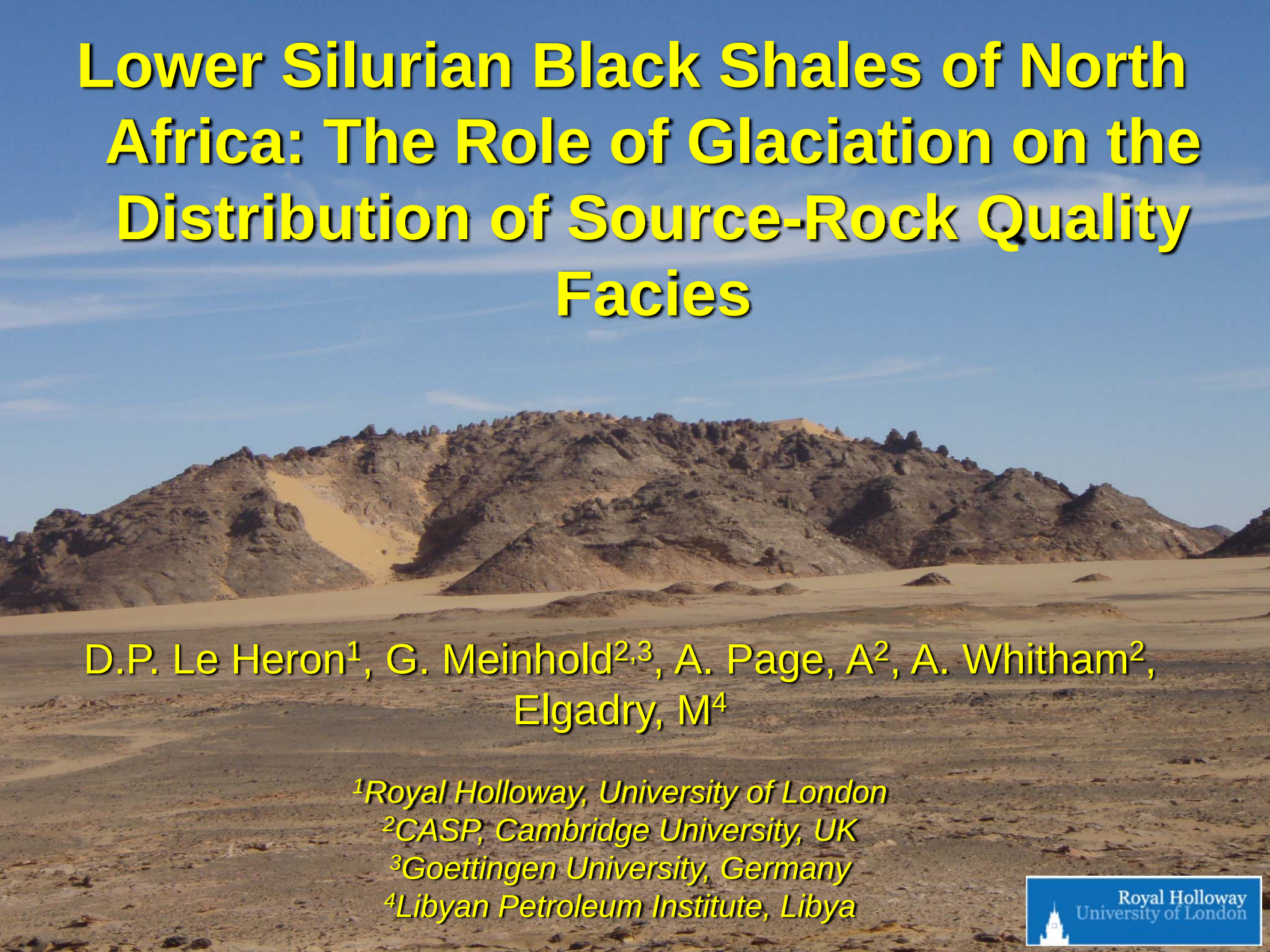

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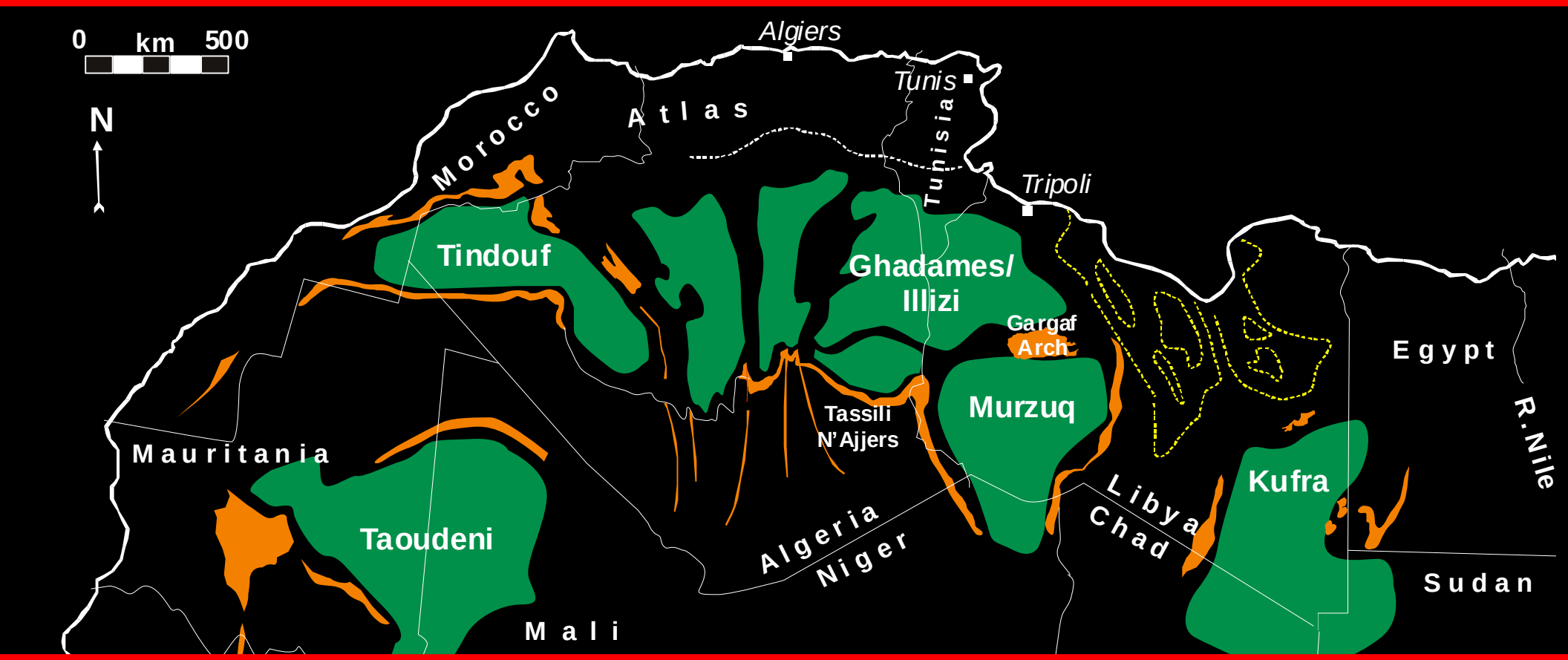
North Africa and the Saharan basins



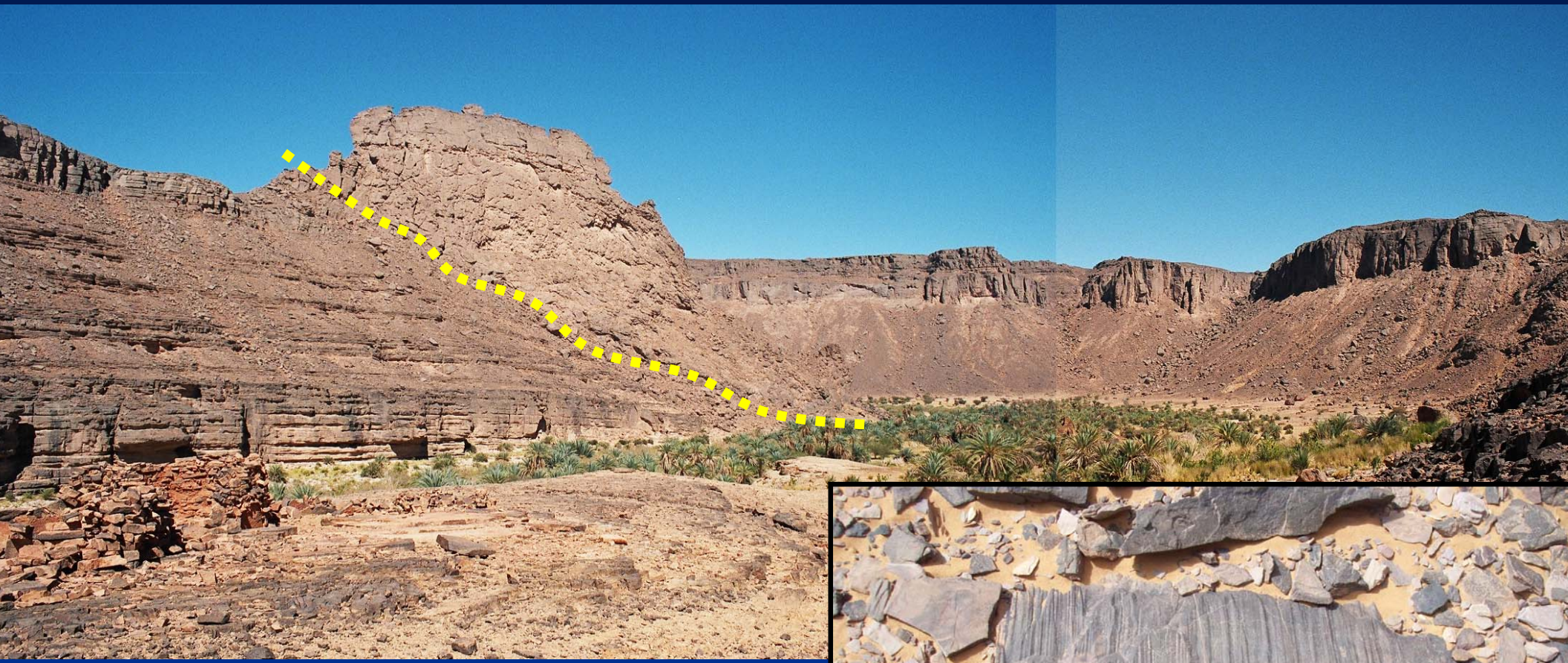
Orange **Late Ordovician sediments at outcrop**

Green **Late Ordovician sediments in subcrop (sedimentary basins)**

Exposures are excellent but widely scattered!

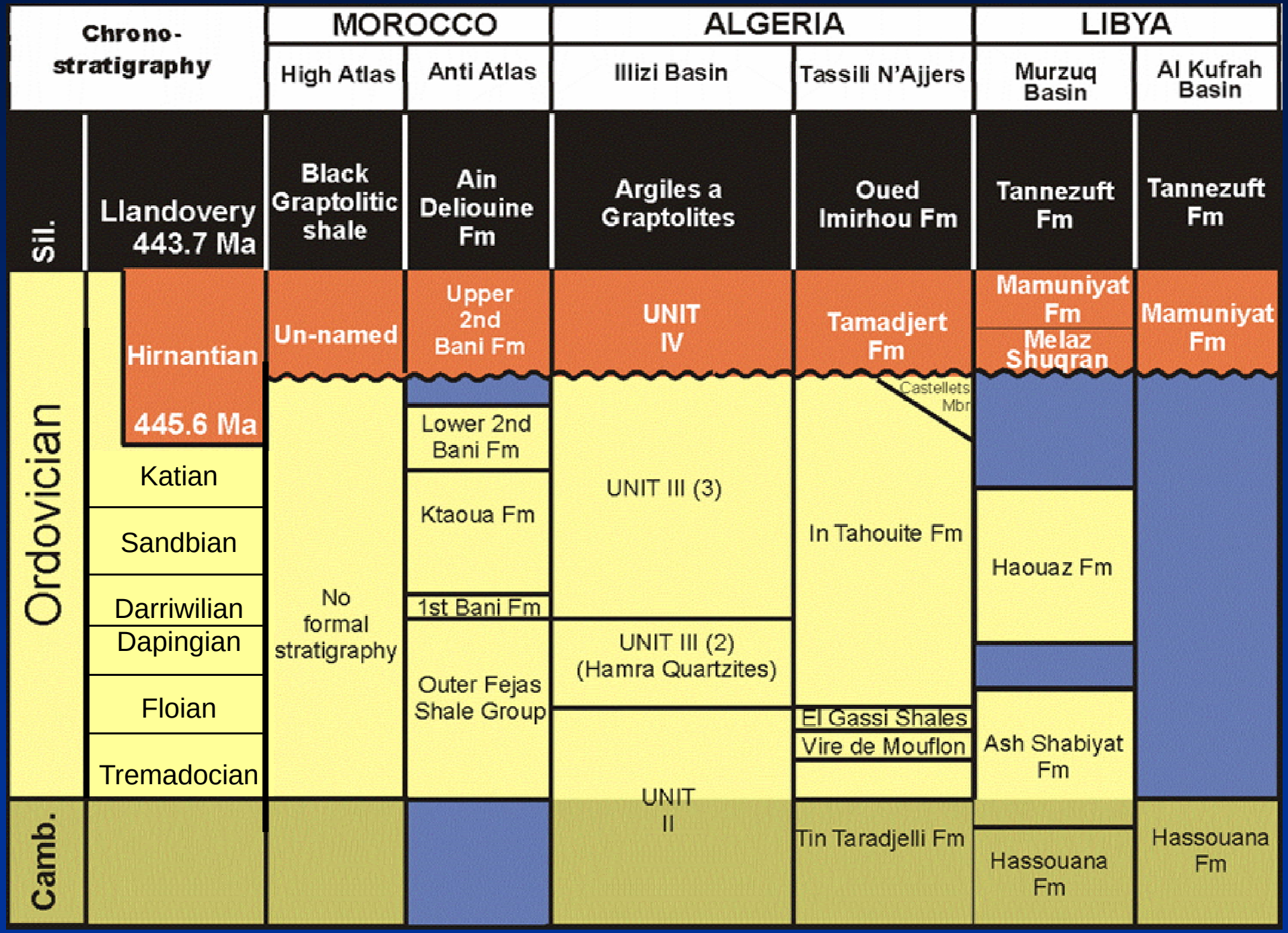
Late Ordovician (Hirnantian, ~443 Ma)

Glacial valley at Iherir, Tassili N'Ajjer, Algeria

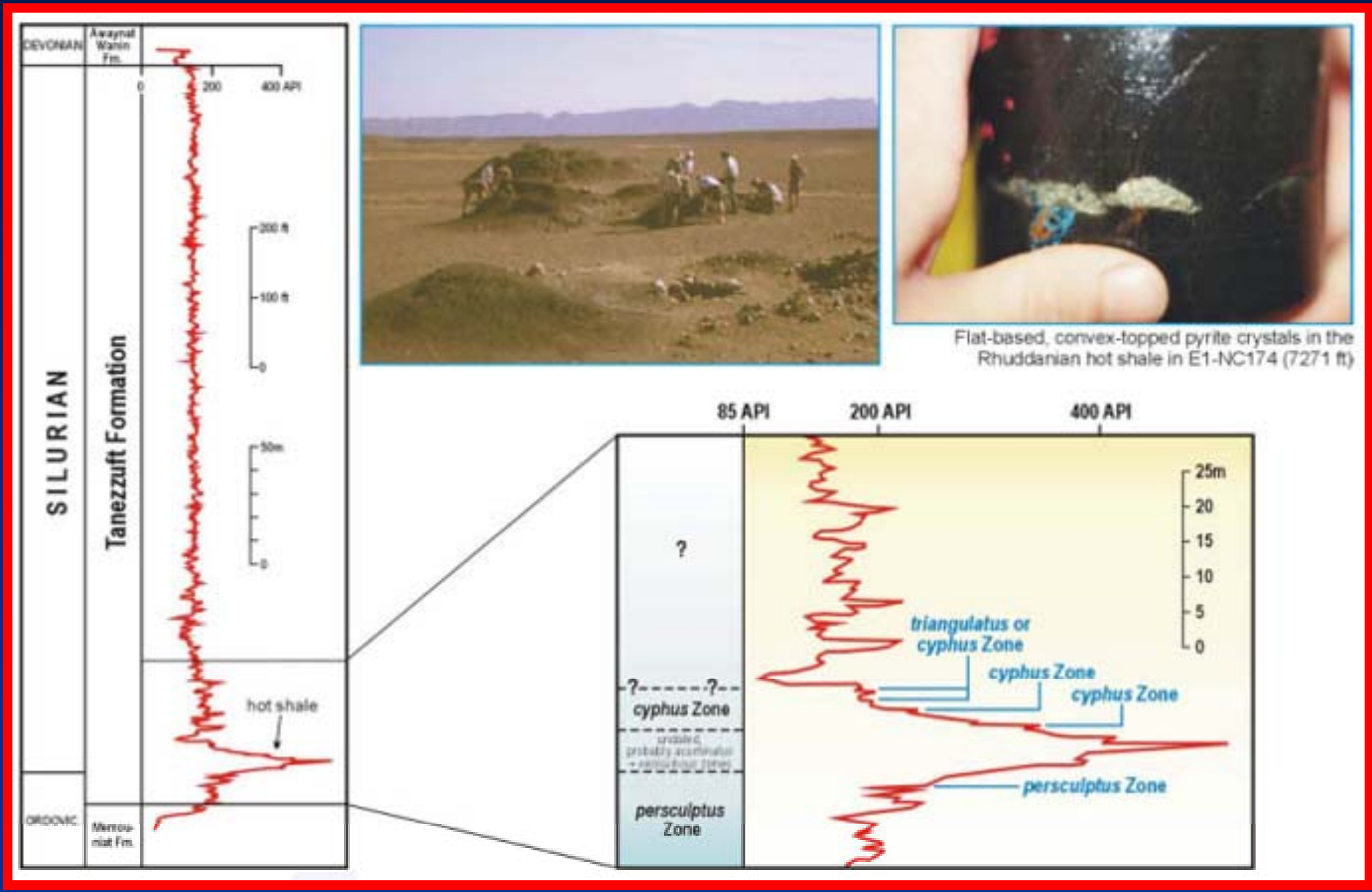


- Unconformity >150 m relief
- Glacially-related incision
- Coarser grained, sometimes chaotic deposits above: major reservoir interval, intensely studied

Early Palaeozoic of North Africa



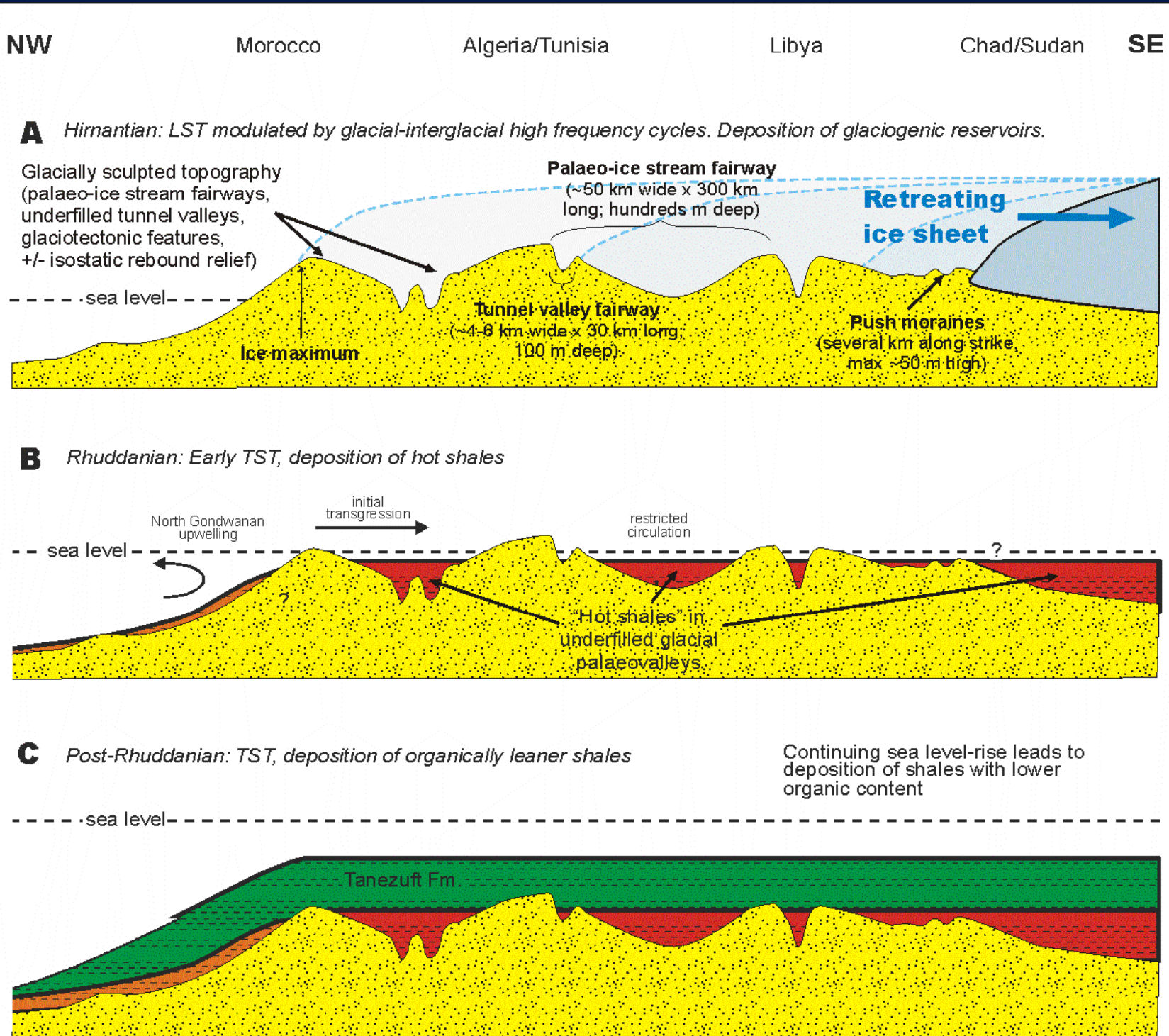
Typical section of Silurian “hot shale”



Flat-based, convex-topped pyrite crystals in the Rhuddanian hot shale in E1-NC174 (7271 ft)

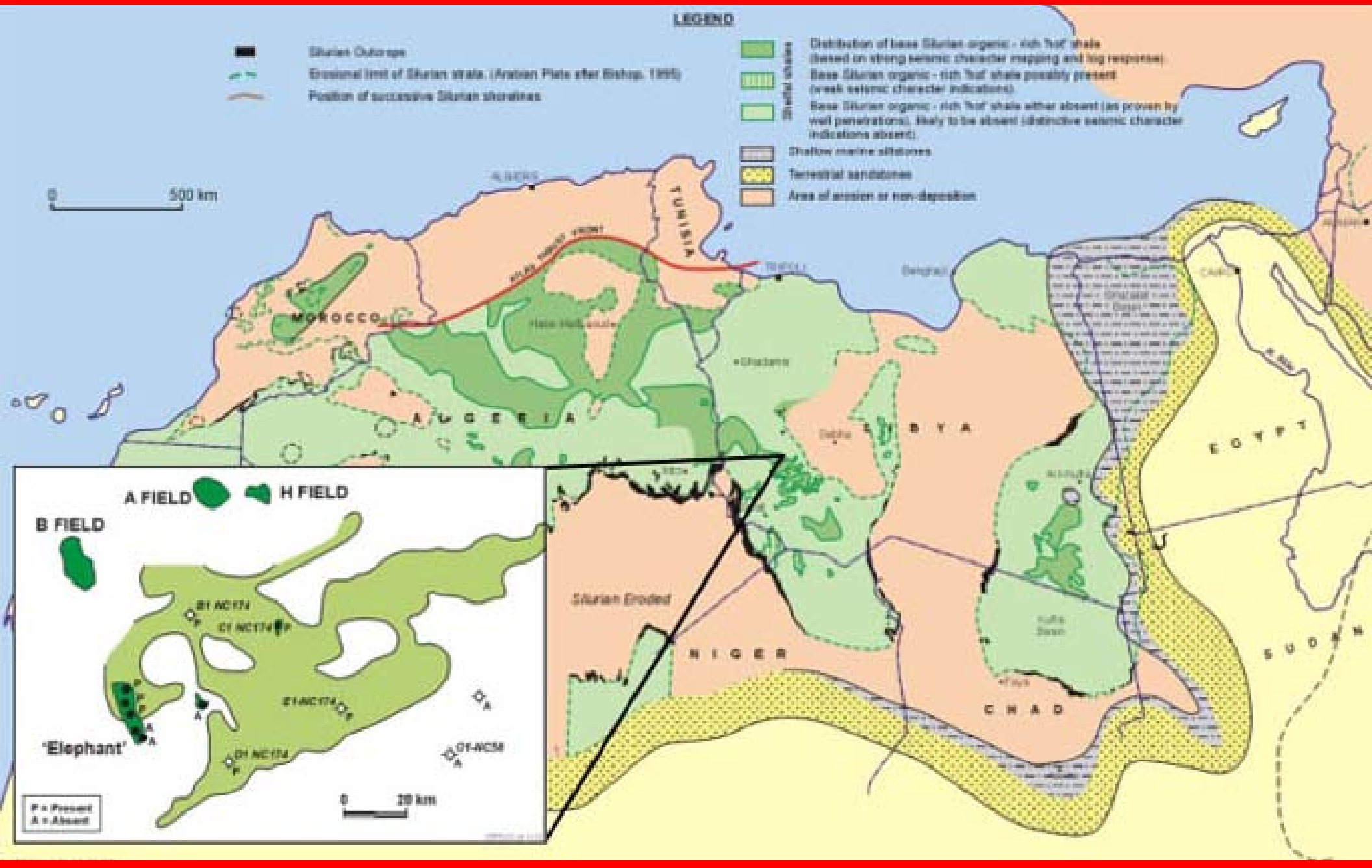
Public access data: http://www.es.ucl.ac.uk/research/mprg/research/Pubs/Craig2008-2/Picture%2028.html

Model for high TOC shale, Early Silurian

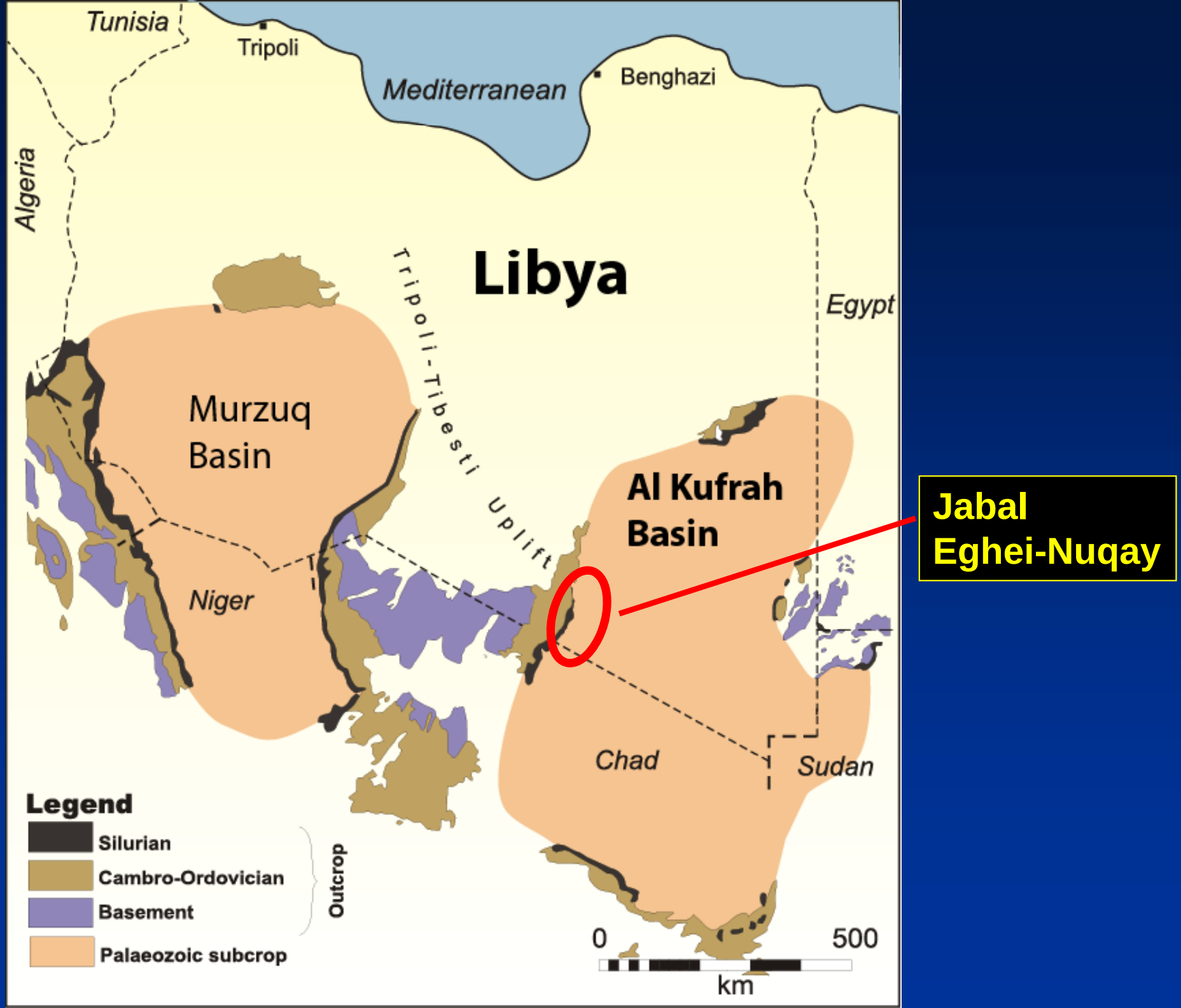


Modified from Lüning et al. (2000)

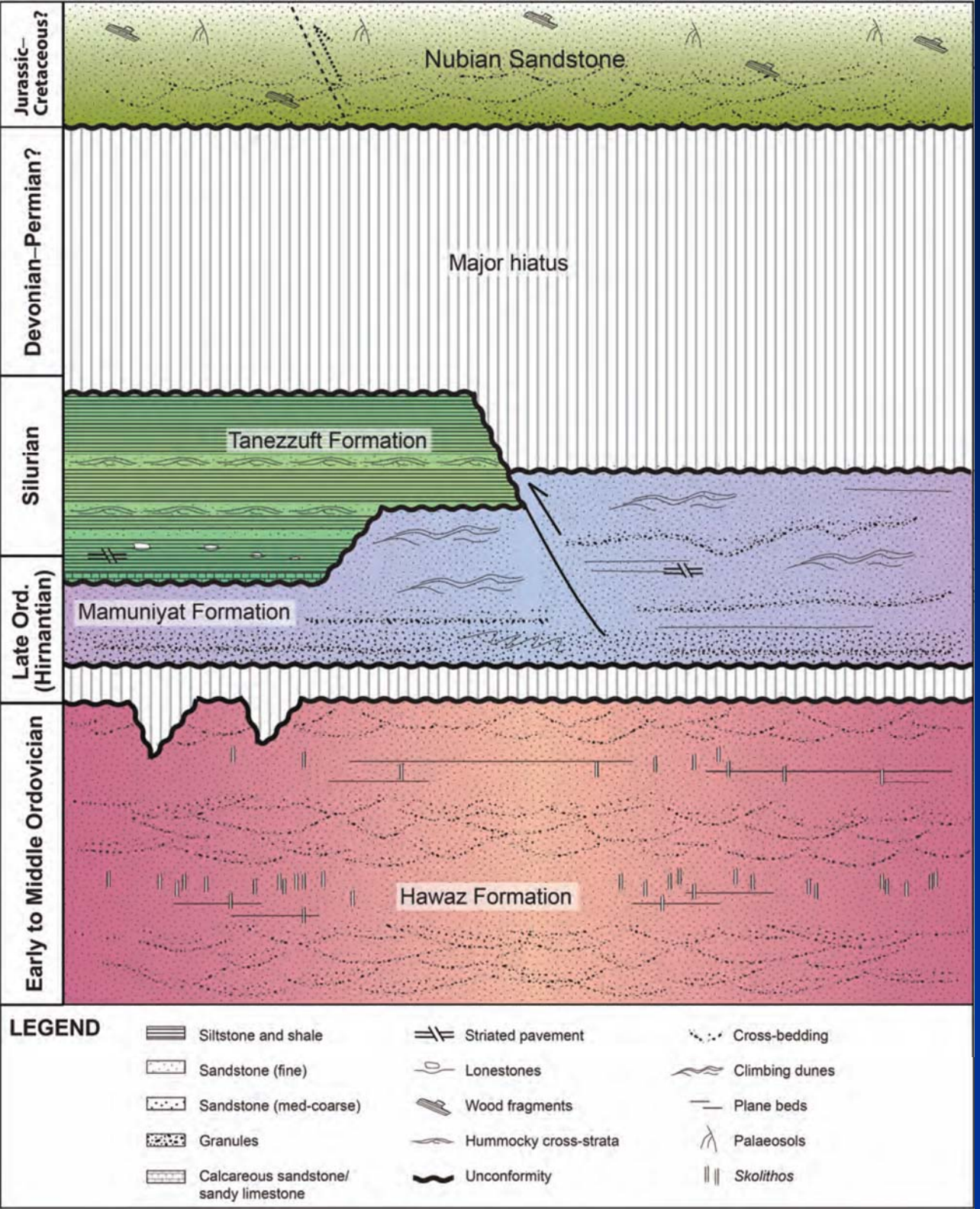
Distribution of Silurian “hot shale” (source rock)



Public access data: http://www.es.ucl.ac.uk/research/mprg/research/Pubs/Craig2008-2/Picture%2029.html


Tunisia
Tripoli
Mediterranean
Benghazi
Algeria
Libya
Egypt
Murzuq Basin
Tripoli-Tibesti Uplift
Al Kufrah Basin
Jabal Eghei-Nuqay
Niger
Chad
Sudan
Legend
Silurian
Cambro-Ordovician
Basement
Palaeozoic subcrop
Outcrop
0
500
km

Stratigraphy

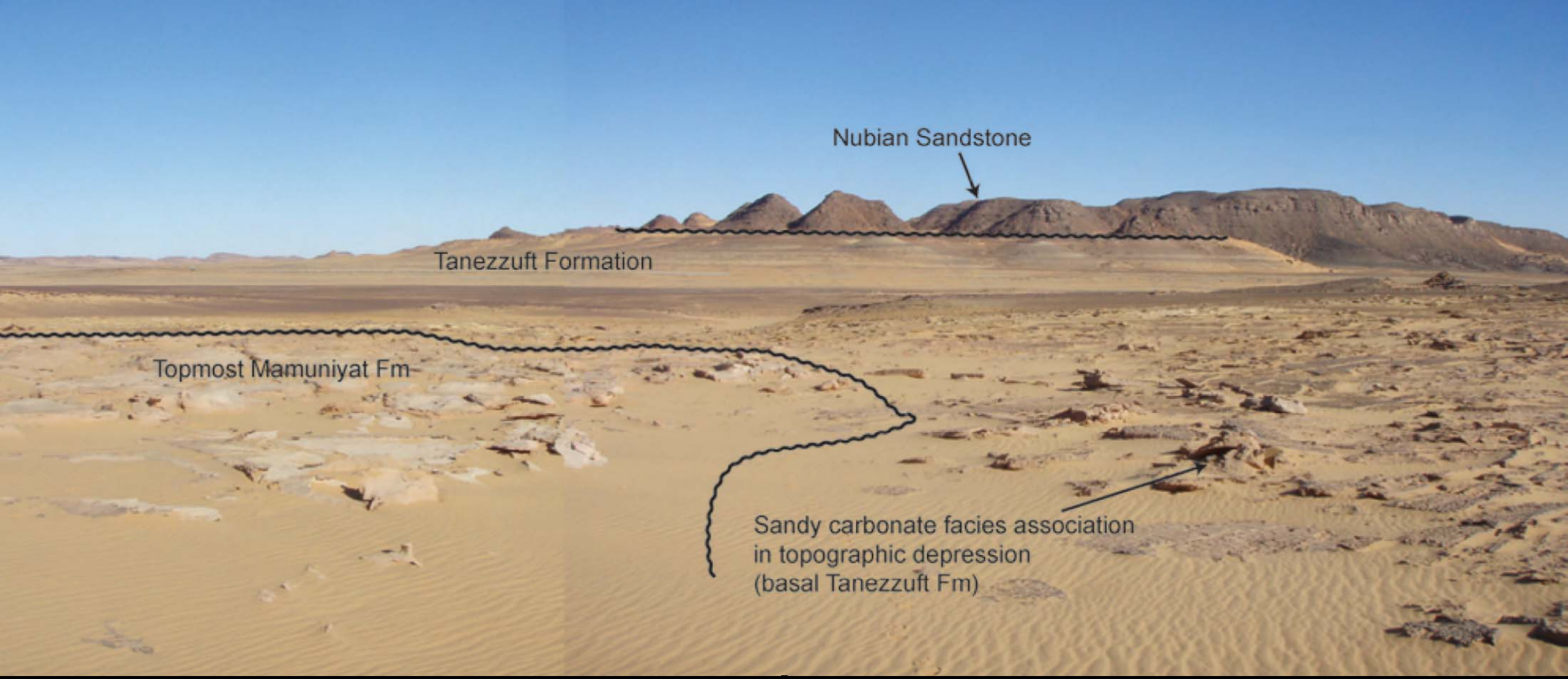


Post-glacial shale (source rock and seal)

Glacial deposits (major reservoir interval)

Late Ordovician (Hirnantian) Glaciation: regional incision

Fluvial to shallow marine deposition

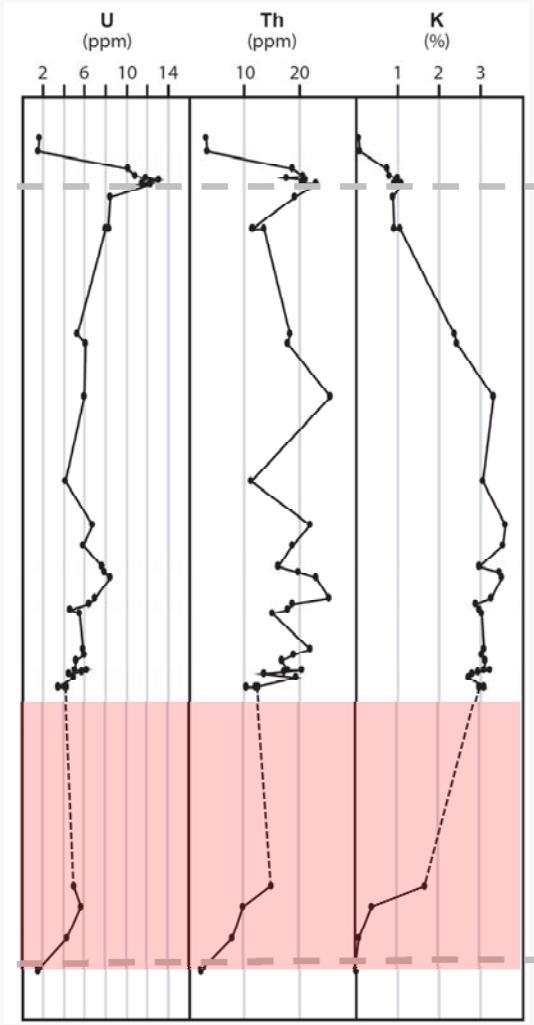


Planolites trails

Crinoid ossicles

Sedimentary log and gamma ray results

Spectral γ

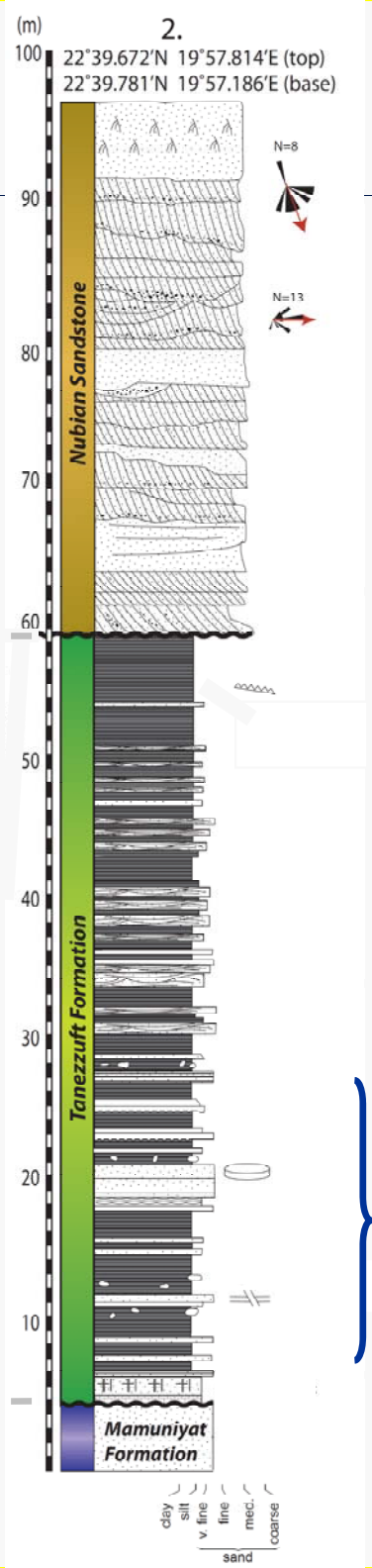


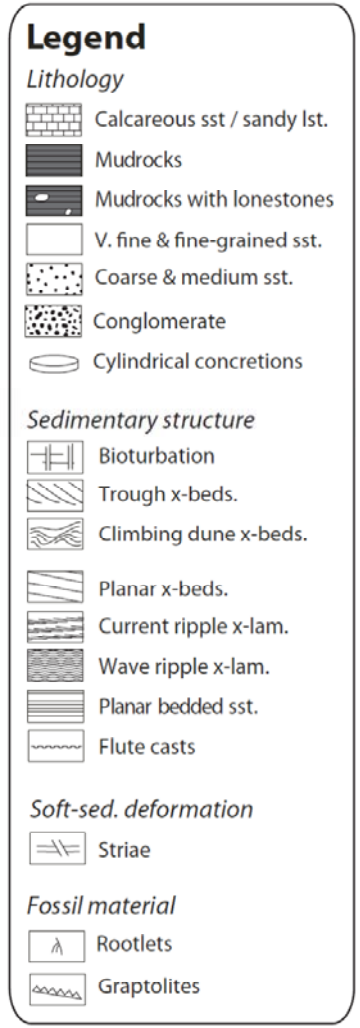
Base Mesozoic U/C

Tannezuft Fm.
(Early Silurian)

Expected
"hot shale"
interval

Mamuniyat Fm.
(Late Ordovician)



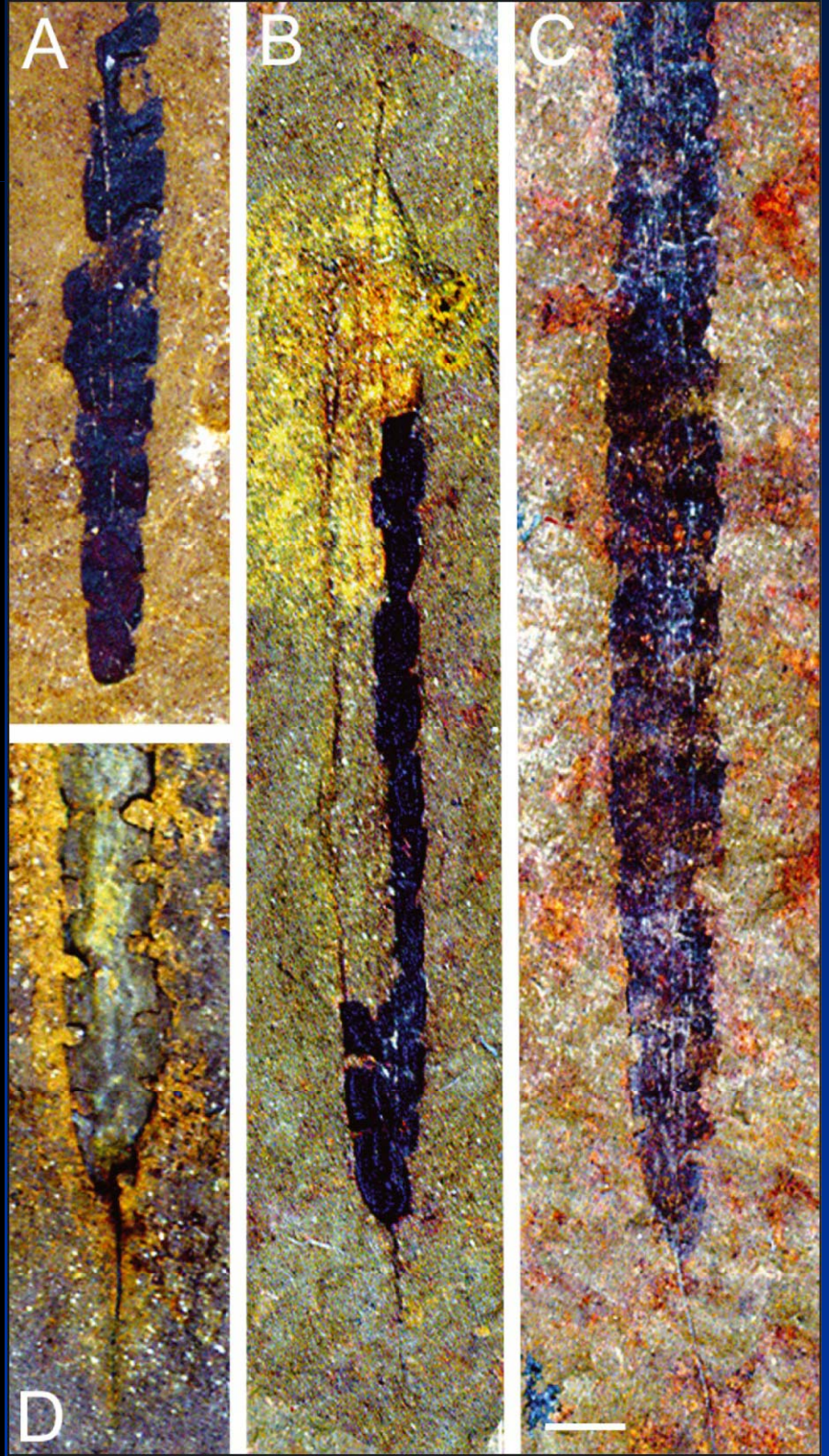


First known occurrence of intra-Tannezuft glacial deposits in North Africa

Soft-sediment striated surface

Calcareous lonestones

MnO_2 concretions



Graptolites

New species:-
Normalograptus kufraensis nov. sp.

Age: Rhuddanian-Hirnantian

Page, A., Meinhold, G., Le Heron, D.P., Elgadry, M. (in review). A new species of graptolite from the western margin of the Kufra Basin, Libya. *Geological Magazine*.

MnO_2 concretions

MnO_2 concretions

Hummocky cross-stratification

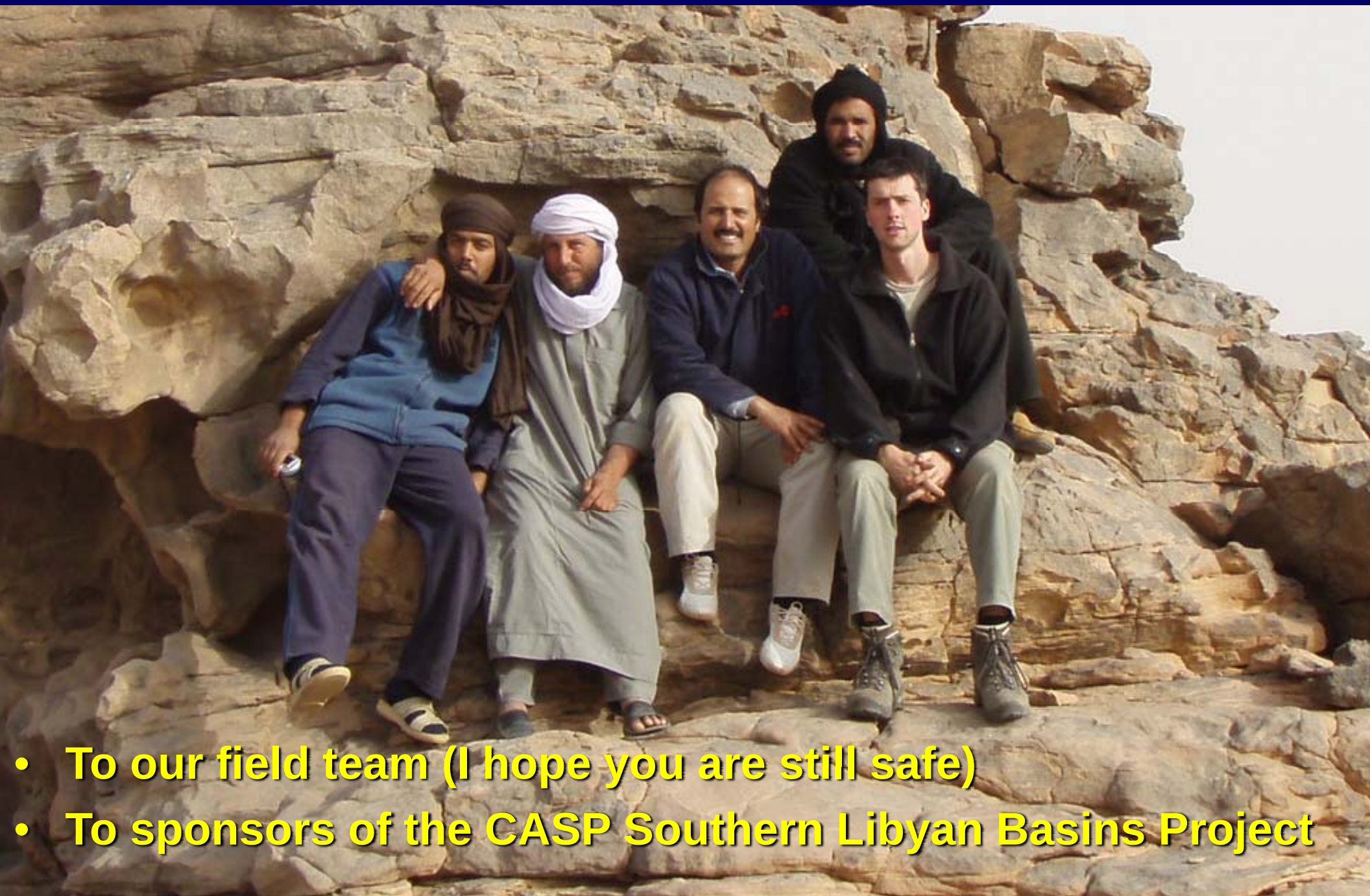
Conclusions

- *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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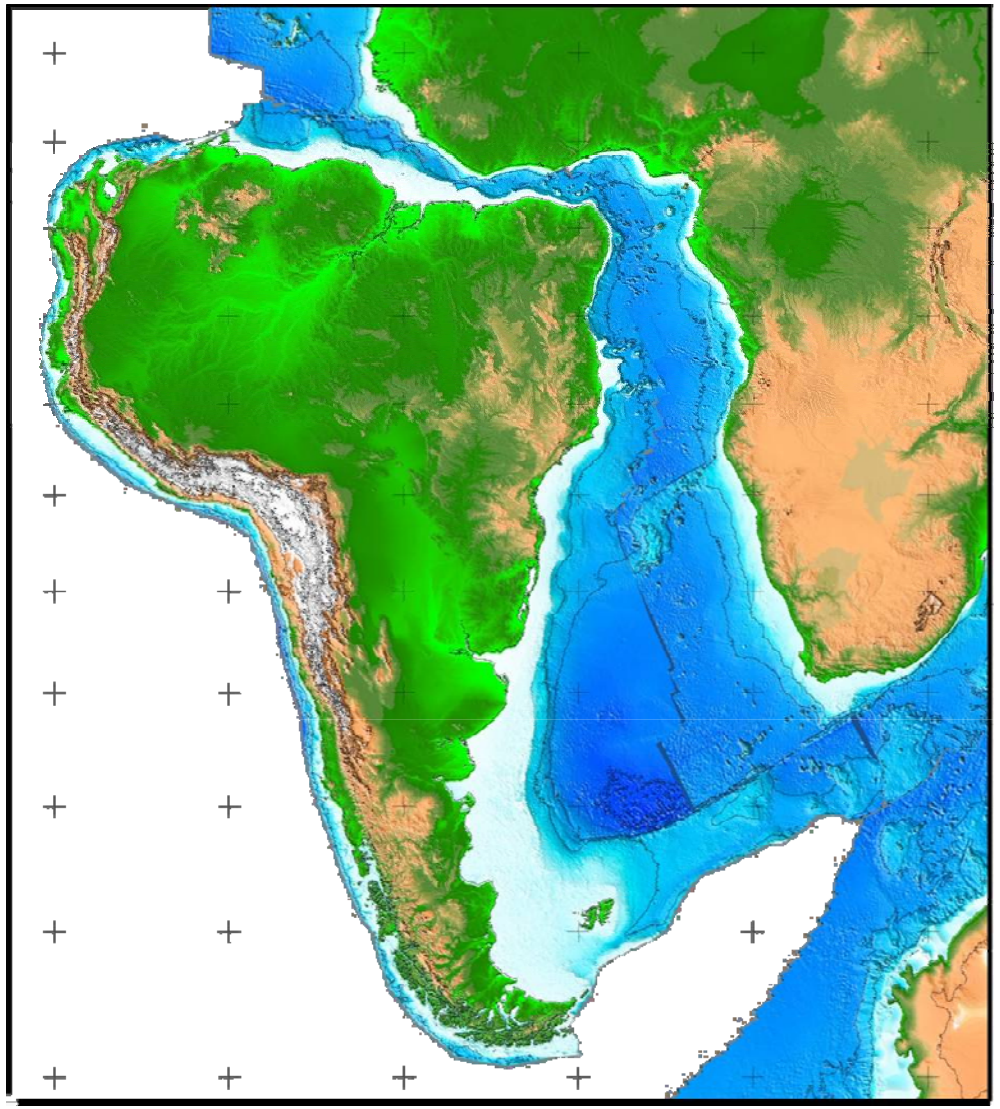

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