AAPG HEDBERG CONFERENCE
"Paleozoic and Triassic Petroleum Systems in North Africa"
February 18-20, 2003, Algiers, Algeria

A Third-Order Sequence Stratigraphic Framework for the Devonian of Morocco: Its Implications for Enhanced Regional Correlation of the Devonian in North Africa

Stefan Lubeseder, Ian D. Carr & Jonathan Redfern
North Africa Research Group, Oxford Brookes University, Oxford, UK
slubeseder@brookes.ac.uk

Initial work by the North Africa Research Group identified a second-order sequence stratigraphic framework, which placed the Devonian sediments of North Africa within the defined NA3 sequence. This study aims to develop the third-order framework for the area, using integrated outcrop and subsurface data.

The Anti-Atlas of southern Morocco was selected for the initial research because it has an almost continuous exposure of Paleozoic rocks. Numerous biostratigraphic studies on the Devonian succession in this area provide a detailed time framework for a sequence stratigraphic analysis. Transgressive - regressive cycles are well developed in an Early Devonian mixed carbonate-siliciclastic ramp setting and on a Middle to Late Devonian slope of a pelagic cephalopod ridge.

The study is now being extended to include subsurface data from Algeria and Libya. Here biostratigraphic control is weak, but regressive / transgressive cycles can be identified and correlated with the third-order framework established in Morocco.

Early Devonian, Morocco

Two major facies types can be recognised in the Early Devonian of Morocco: a) a basinal to carbonate ramp system in the Eastern Anti-Atlas, and b) a mixed shallow marine siliciclastic-carbonate system in the southwest of Morocco (Dra Plain).

a) The carbonate ramp system is dominated by offshore muds (6 – 70 m thick) grading into an outer carbonate ramp facies made of nodular limestones with orthocone nautiloids, ammonoids, large bivalves, trilobites and small rugose corals as the main macrofauna (2 – 10 m thick). In a regressive hemicycle these are overlain by tentaculite-packstones, crinoid-packstones to grainstones or bioclast-grainstones (0.5 – 5 m thick). The latter show evidence of storm influence of a mid ramp setting.

b) In the mixed siliciclastic-carbonate system a regressive hemicycle consists of offshore muds (100 - 150 m thick), which grade into a siliciclastic sequence dominated by storm deposits (70 - 120 m thick). In the latter, stacked small scale shallowing cycles (5 - 15 m thick) consist of offshore muds, thin bedded sandstones and siltstones, thick bedded sandstones with hummocky cross stratification, bioturbated sandstones rich in brachiopods, and finally brachiopod-coquinas. The point of maximum regression is situated within the siliciclastic succession or just below a pronounced transgressive surface. The transgressive surface is marked at the very sharp boundary towards the overlying carbonate unit (10 m thick) showing a facies identical to the nodular wackestones of the outer carbonate ramp facies of the Eastern Anti-Atlas.

In the Early Devonian six transgressive / regressive cycles can be recognised (Fig. 1): ED1) early Lochkovian to late Lochkovian/early Pragian; ED2) late Lochkovian/early Pragian to late Pragian; ED3) late Pragian to early Lower Emsian; ED4) early Lower Emsian to late Lower Emsian (~Zlichovian/Dalejan boundary); ED5) late Lower Emsian (~Zlichovian/Dalejan boundary) to middle Upper Emsian; ED6) middle Upper Emsian to earliest Eifelian.

Middle and Late Devonian, Morocco

In the Eastern Anti-Atlas the disintegration of the Early Devonian carbonate ramp and the successive evolution of a ridge and basin topography started in the early Eifelian and continued until the late Famennian. A narrow condensed cephalopod ridge separated two subbasins, the Tafilalt and the Maider Basin. Strong sediment partitioning between the ridge, the slopes, and the basins resulted in large stratigraphic thickness and facies variations. These clearly reflect changes in accommodation space. Although synsedimentary tectonic movements are evident in this setting, it is believed that the primary control on sedimentation were regional rather than local relative sea-level changes for most of the studied cycles.

During relative sea-level lowstand grain-dominated calci- and siliciturbidites were shed on the lower slope and pinch out basinward, where calci-hemiturbidites dominate the succession. The lowstand deposits correlate with non-deposition or thin hardgrounds on the ridge, which was subject to submarine reworking. An onlapping marly basinal facies with a few mud-dominated calciturbidites is characteristic of the transgressive sequences that cover the ridge during maximum flooding. Cephalopod limestones from the ridge and nodular limestones on the slope indicate renewed carbonate production during the relative sea-level highstand. With lowering of the wave-base during the late regressive phase, high-order cycles become successively thinner on the ridge than on the slope.

The Middle to Late Devonian stratigraphic record can be assigned to six third-order transgressive / regressive cycles (Fig. 1): MD1) earliest Eifelian to middle Eifelian, MD2) middle Eifelian to middle Givetian, MD3) middle Givetian to upper Givetian, LD1) upper Givetian to ?late Frasnian/?early Famennian, LD2) ?late Frasnian/?early Famennian to middle Famennian, LD3) middle Famennian to ?upper Famennian/?earliest Tournaisian.

Extending the correlation into the Devonian of Algeria

The established Moroccan framework can be correlated to the Devonian outcrops in southern Algeria (Ougarta, Ahnet, Mouydir, Tassili) and to the subsurface of the Illizi and Ghadames Basin. Transgressive / regressive cycles from the subsurface can be identified using selected well-log data from published and unpublished sources, and correlate with the third-order cycles defined in Morocco.

The study aims to develop and extend this regional correlation of the Devonian strata of North Africa from Morocco across Algeria to Libya. Testing the sequence stratigraphic framework in various areas of North Africa will allow the distinction between eustatic controlled cycles and possible local tectonic influences. Once this has been tested, a sequence stratigraphic framework will be available for the correlation to areas with only weak biostratigraphic data.

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This study was funded by the North Africa Research Group, sponsored by Amerada Hess, Anadarko Algeria, BG International, Burlington Resources, Edison Gas, Philips Petroleum, Repsol YPF and Woodside Petroleum.

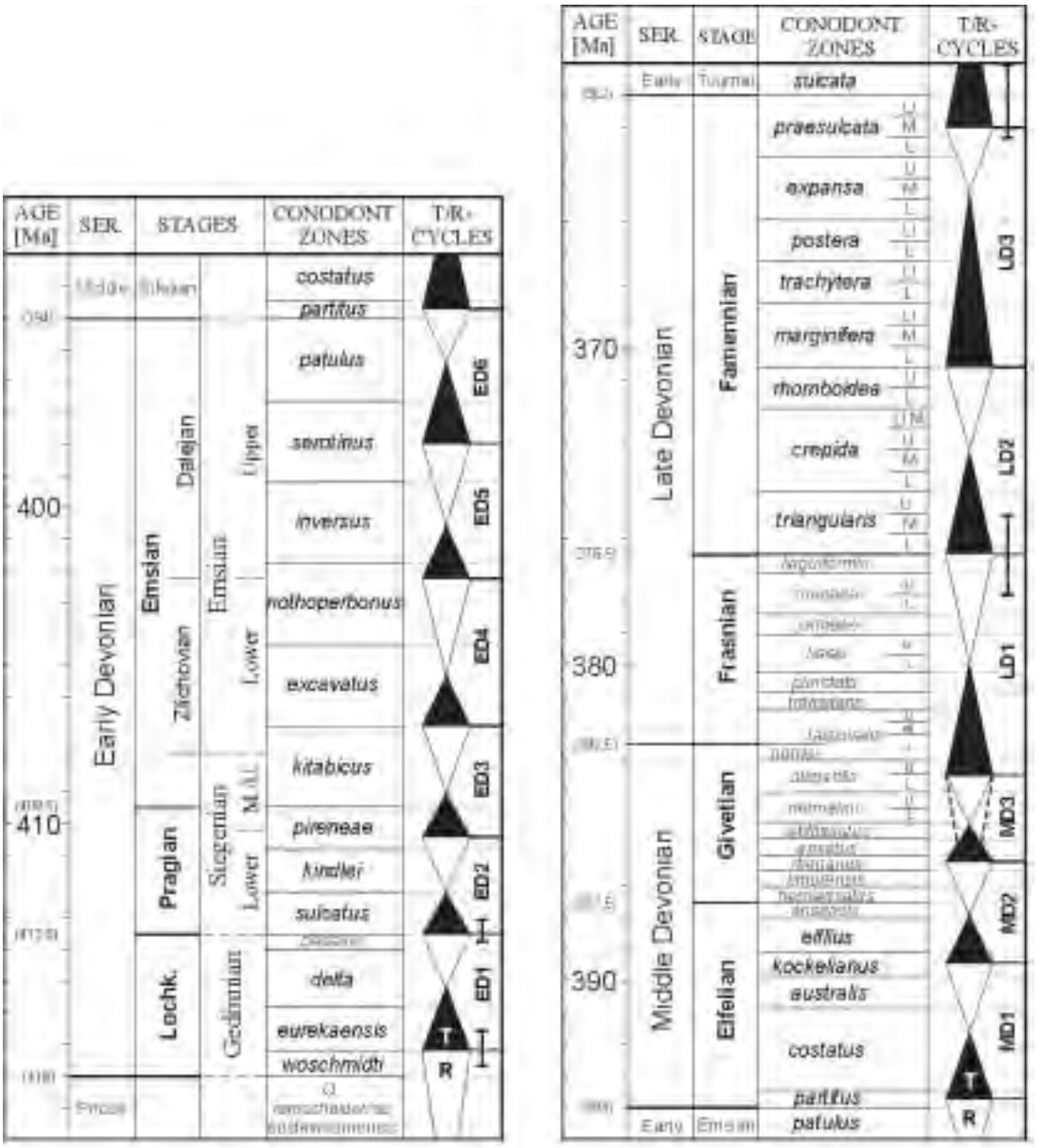

Fig. 1. Devonian T/R-Cycles from Morocco (Early Devonian: Eastern Anti-Atlas & Dra Plain; Middle and Late Devonian: Eastern Anti-Atlas). Vertical bars indicate possible range of turnaround points. MD3 could be the result of local tectonics. Time scale after Tucker et al. (1998). Devonian standard conodont zonation with relative lenght of biozones for the Lochkovian and Eifelian after Murphy & Berry 1983 and Bella et al. 1997.