Tectonostratigraphy, Biostratigraphy, and Magnetostratigraphy of Late Triassic-Early Jurassic Red beds in Morocco: An Overview.

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Late Triassic–Early Jurassic predominately continental red beds formed during the Triassic/Jurassic rifting of Pangea crop out over large portions of northern Morocco, comprising several sedimentary basins now partly dismembered by the subsequent Alpine orogeny. The palaeolatitude of these basins in earliest Jurassic coordinates was centered in arid climes around 23°N. These basins have facies broadly similar to the Fundy basin (Nova Scotia, Canada) but also show some similarities to the Triassic age sequences of the Newark basin (New Jersey, USA).

In the Central and Western High Atlas stratigraphic sections are divided into four tectonostratigraphic sequences (TSI – TS IV) that are at least locally separated by synrift unconformities corresponding to presumed extensional pulses. Elsewhere in Morocco, maybe with the exception of the Essaouira basin, the basins appear to consist nearly entirely of TS III and TSIV.

The oldest tectonostratigraphic sequence (TSI) (F1-F2 of Biron, 1982; T1-T2 of Tixeront, 1973), Permian in age (Tatarian?), comprises alluvial fan conglomerates that grade into fluvial sandstones and mudstones.

TSII (F3-F4 of Biron, 1982; T3-T5 of Tixeront, 1973), Ladinian?-Carnian in age, overlies TSI unconformably in both Central and Western High Atlas. It consists of fluvial and lacustrine clastic rocks with an especially well developed cyclical lacustrine sequence in the Argana basin.

In the Central and Western High Atlas, an angular unconformity at least locally separates TSII and TSIII (F5-F6 of Biron, 1982; T6-T8 of Tixeront, 1973). In the other basins, TSIII (séries argileuse et salifère inférieures of BRPM, 1955) rest unconformably on the Paleozoic basement. It is Norian?-Rheatian in age and consists in its basal unit of fluvial conglomerate and sandstone and prominent eolian sandstones. The latter grade vertically into massive gypsiferous mudstones and sandstones arranged into distinctive sand patch cycles overlain conformably by CAMP flows. The uppermost few meters of the pre-basalt sediments has a well developed cyclicity with very thin black and gray shales. This sequence, present throughout Morocco, contains, at least in the Argana basin, the Triassic-Jurassic boundary based on palynology. It represents the lower part of succeeding tectonostratigraphic sequence TSIV, although there is no known physical evidence for an unconformity in the exposed strata.

The Central High Atlas outcrops show the thickest CAMP sequence in all of Morocco that comprises four multiple flow formations, which termed from the bottom up, the lower unit, the intermediate unit, the upper unit, and the recurrent flow (Bertrand, 1991). The later is of high-Fe high-Ti quartz-normative composition (HFTQ) as are the Hook Mountain and Hampden basalts (Newark basin and Hartford basins respectively). The other units are high-Ti quartz-normative tholeiites (HTQ) as are the Mt. Zion Church, Aspers, Orange Mountain, Talcott, East Hill, and North Mountain basalts (Culpeper, Gettysburg, Newark, Pomeraug, Hartford, and

Fundy basins, respectively). The 40Ar/39Ar ages of the High Atlas basalt flows are indistinguishable from their North American counterparts (Marzoli et al., 2004), although no high-Fe quartz-normative (HFQ) or low-Ti quartz-normative (LTQ) flows, present in the Newark basin, have been identified in the Central High Atlas. In the other Moroccan basins, there are only one or two basaltic units of HTQ composition. Throughout, the basaltic units are interbedded or overlain by limestone-rich cyclical sequences. These preserve a gradient from fully continental facies in western Morocco, comparable to those in the Fundy basin outcrops, to fully marine facies with newly discovered well-preserved echinoderms in easternmost Morocco, thereby documenting a marine connection from western-most Tethyan basins during at least part of the rift sequence. The carbonate-dominated thin units are succeeded by predominately red clastic rocks which are unconformably overlain by post-rift Early Jurassic conglomerates and marine strata.

In the subsurface of several Moroccan basins, the cyclical red beds of TSIII and TSIV give way to thick salt sequences (série salifère inférieure et série salifère supérieure of BRPM, 1955), with an order of magnitude higher accumulation rates. In these settings the Triassic-Jurassic boundary is entirely within bedded halite and potash salts (e.g. Khémisset basin).

The paleomagnetic polarity stratigraphy of outcropping Bigoudine Formation in the Argana basin (TSIII and lower TSIV) allows correlation with the Newark GPTS. This correlation: (1) indicates that the deposition of the Bigoudine began at about 218 Ma and ended at about 201 Ma, with the conformable outpouring of the Argana Basalt and (2) demonstrate that the major cyclical wet climatic intervals in the Newark basin sequence can be recognized in the Argana basin and therefore the synchrony of major climate changes caused by the very long term celestial mechanical cycles of a very large part of central Pangea. The polarity stratigraphy also affords tight correlation to the Newark basin extending to individual 20 ky cycles, especially in the lower half of the Bigoudine Formation.

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