Integrated Stratigraphy (Bio- and Sequence Stratigraphy) and Facies Analysis of the Upper Cenomanian–Turonian (Lower Upper Cretaceous) in the Eastern Desert, Egypt

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Abstract We have applied facies analysis and an integrated stratigraphic approach to make a detailed study of the Cenomanian–Turonian successions of the Eastern Desert of Egypt. A detailed ammonite biozonation is constructed that allows precise correlations. The predominantly shallow-marine successions include the Galala, Maghra El Hadida, and Umm Omeiyid formations, which represent a shallow-marine, mixed carbonate–siliciclastic open lagoonal to carbonate ramp setting. Six major sedimentary unconformities (Cenomanian sequence boundaries SB Ce 4 and 5, and Turonian sequence boundaries SB Tu 1–4) have been recognized and laterally tracked across the Eastern Desert. Their stratigraphic positions have been calibrated by means of ammonite biostratigraphy and they define five third-order depositional sequences (DS ED 1–5). The sequence-stratigraphic calibration of the study area with successions from other Cretaceous basins demonstrates the contemporaneity of the unconformities across different tectonic plates, strongly suggesting that the formation of these successions resulted from eustatic sea-level changes.

Keywords Mid-Cretaceous · Ammonite biostratigraphy · Sedimentary unconformities · Correlation · Depositional environments

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Introduction

We have studied in detail four upper Cenomanian–Turonian stratigraphic sections situated in the Eastern Desert of Egypt by applying facies analysis and an integrated stratigraphic approach (Nagm et al. 2010a, b; Nagm and Wilmsen 2012; Wilmsen and Nagm 2012, in press). The sections form a 130-km-long N–S transect from the Southern Galala Plateau in Wadi Araba to Wadi Qena in the south. During the mid-Cretaceous, the study area was located at the southern margin of the Neo-Tethys and the south–north arrangement of the sections follows a regional palaeogeographical onshore–offshore-directed gradient. Lithostratigraphically, the predominantly shallow-marine successions include the Galala, Maghra El Hadida, and Umm Omeiyid formations, which represent a shallow-marine, mixed carbonate–siliciclastic setting developing in response to the early Late Cretaceous transgression.

Results

Biostratigraphy

The upper Cenomanian–Turonian succession of the study area has been biostratigraphically dated using high-resolution ammonite biostratigraphy (Nagm et al. 2010a, b; Nagm and Wilmsen 2012). This approach assigns an early late Cenomanian age (*Neolobites vibrayeanus* Zone) to the Galala Formation and a mid-late Cenomanian to early late Turonian age for the Maghra El Hadida Formation in Wadi Araba, comprising the upper Cenomanian *Metoicoceras geslinianum* and *Vascoceras cauvini* zones, as well as the lower Turonian *Vascoceras proprium*, *Choffaticeras* spp., and *Wrightoceras munieri* zones. In the lower upper Turonian, the *Coilopoceras requienianum* Zone is recognized (Nagm et al. 2010b). Unfortunately, ammonites are absent from the middle Turonian, and the substage can be identified only due to its stratigraphic position between uppermost lower and lowermost upper Turonian strata. In Wadi Qena, a similar biozonation has been developed (Nagm and Wilmsen 2012). However, the *Metoicoceras geslinianum* Zone is absent in Wadi Qena due to a stratigraphic gap, and the upper lower Turonian *Pseudotissotia nigeriensis* Zone is equivalent to the *Wrightoceras munieri* Zone of Wadi Araba. The middle and lower upper Turonian for Wadi Qena is the same situation as found in Wadi Araba.

Facies Analysis

The Galala and Maghra el Hadida formations of Wadi Araba (northern Eastern Desert) document marine deposition at the southern margin of the Neo-Tethys in

tropical palaeolatitudes. A detailed facies analysis (Wilmsen and Nagm 2012) of these successions showed that the lower upper Cenomanian Galala Formation was deposited in a fully marine lagoonal environment. The rich suspension- and deposit-feeding macrobenthos indicate green water (i.e., meso- to eutrophic) conditions. Facies analysis of the uppermost Cenomanian–Turonian Maghra el Hadida Formation suggests deposition on a homoclinal carbonate ramp with subenvironments ranging from deep-subtidal basin via outer- and mid-ramp settings into the intertidal back-ramp. The facies analysis of the Wadi Qena sections essentially shows similar facies patterns but the more landward position resulted in a stronger siliciclastic input. Major facies shifts and sedimentary unconformities provide the basis for the sequence-stratigraphic analysis of the successions.

Sequence Stratigraphy

Six sedimentary unconformities (Cenomanian sequence boundaries SB Ce 4 and 5, and Turonian sequence boundaries SB Tu 1–4) have been recognized and laterally tracked across the Eastern Desert (Wilmsen and Nagm in press). Their stratigraphic positions have been calibrated by means of ammonite biostratigraphy and they define five third-order depositional sequences (DS ED 1–5), each consisting of transgressive and highstand systems tracts (TSTs and HSTs). Falling stage and lowstand systems tracts (FSSTs and LSTs) are generally missing due to the up-dip position of the study area (providing a lack of accommodation space). SB Ce 4 has been placed at the middle–upper Cenomanian boundary at the base of the Galala Formation. SB Ce 5 is of mid-late Cenomanian age (base *M. geslinianum* Zone) and it records a major sea-level drop. SB Tu 1 has been dated, placing it in the lower–middle Turonian boundary interval. SB Tu 2–4 are of mid-middle, early late, and mid-late Turonian ages, respectively. SB Tu 4 is a major unconformity at the base of the overlying Matulla and Taref formations (uppermost Turonian? to Coniacian–Santonian). The sequence-stratigraphic calibration of the Eastern Desert with successions from Sinai, Jordan, Tunisia, and Europe shows that the identified sequence boundaries match well with those from other Cretaceous basins. The contemporaneity of these surfaces across different tectonic plates strongly supports a eustatic origin of the unconformities, highlighting their chronostratigraphic significance.

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