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THE LATE TREMADOCIAN–EARLY ARENIG 2ND ORDER SEQUENCE OF THE CADENAS IBÉRICAS (NE SPAIN) AND ITS COMPARISON WITH BALTICA

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INTRODUCTION

Lately, the authors of this study had subdivided the Late Vendian–Early Ordovician succession of the Cadenas Ibéricas (Fig. 1) into 2nd order sequences (Schmitz, 2006; Gámez Vintaned et al., 2009), with the aim to place the succession into the regional and/or global context and to correlate the sequences – subject to verification – with those of adjoining areas, particularly of Northwestern Gondwana.

At about the same time, global sea-level charts covering the entire Palaeozoic succession, were published (Haq and Schutter, 2008; Snedden and Liu, 2010). The basis of these global charts are analyses of successions predominantly from cratonic and peri-cratonic areas. Reference districts of the Ordovician interval under study are those of North America and Australasia, complemented in certain parts by Estonian sections (identified on Fig. 2). Presented are 3rd order sequences ("short-term") and their "long-term" envelope (see Fig. 2). They are controlled by absolute age dating and specific biozones. At Ordovician level, index fossils of the biozones are conodonts and graptolites.

Obviously, the data base in the Cadenas Ibéricas differs from that available for the global curve. The fact that (1) in the Cadenas Ibéricas the sedimentary pattern of the investigated levels reflects fast subsidence under sag phase conditions (Gámez Vintaned et al., 2009), that (2) only 2nd order sequences have been established, and that (3) fundamentally only trace fossils, brachiopods and rarely trilobites are at hand for age determination, makes correlation with the 3rd order sequences established by Haq and Schutter (2008) difficult. Upon applying, however, the results from the analyses of Nielsen (2003) – who, for Baltica, at the levels of interest had established not only 2nd order sequences but had also underpinned those by 3rd order drowning events – it seems possible to recognize the pattern of the studied Cadenas Ibéricas succession in the equivalent succession of Baltica, and as a consequence to critically review earlier suggested allocations.

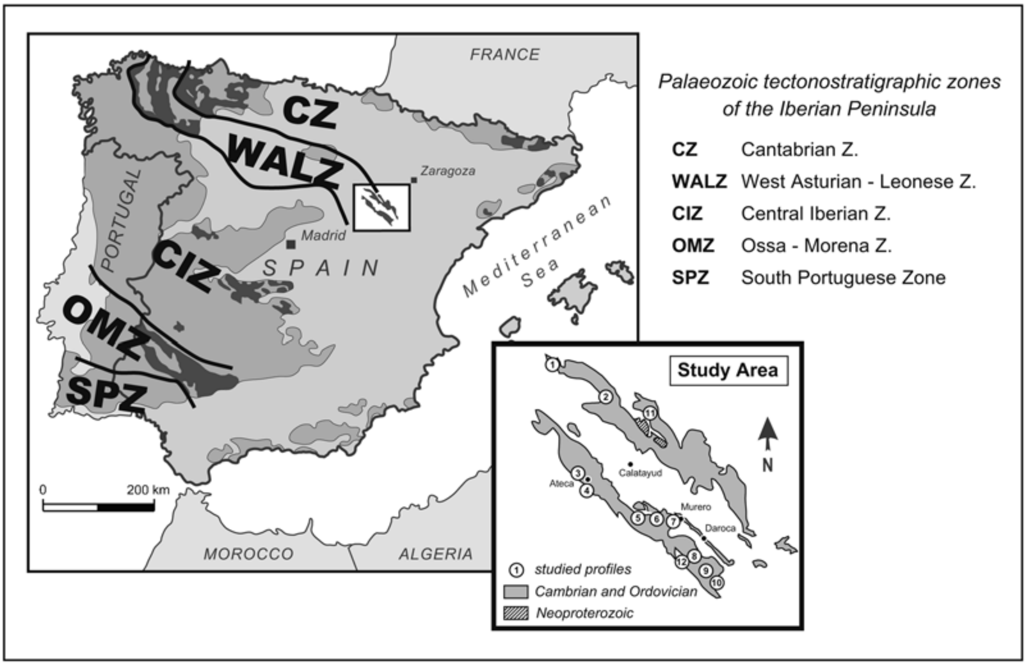

Figure 1. Geological setting of the Cadenas Ibéricas in the context of the Iberian Massif. General map: slightly modified from von Raumer et al. (2006). Inset map: from Schmitz (2006).

THE 2ND ORDER SEQUENCES OF THE BALTIC CRATON

The Baltic (Russian) Craton had been covered at early Palaeozoic times by an epicontinental sea (Nielsen, 2003). The Ordovivician deposits reflect differentiated shelf conditions (Kanev et al., 2001), they are dominated by shales and limestones, with coarser clastics only in their basal part. The sedimentary succession of the Ordovician is being summarized by Nielsen (2003) as comprising three highstand intervals and three lowstand intervals. Subject subdivision is being accompanied by a detailed sea level curve (see Fig. 2).

According to Nielsen (2003), the Tremadocian–Arenig succession is covered by two high and low stand intervals each. The Ordovician starts with the early–mid Tremadocian High Stand interval which follows on the *Acerocare* Regression. Obviously that represents the younger part of a full 2nd order sequence, which in turn starts within the Furongian (not having been dealt with by Nielsen, 2003). Follow the intervals of primary interest in the context of this study, which are the Late Tremadocian–earliest Arenig Lowstand interval and the early Arenig Highstand interval. They form the Late Tremadocian–Early Arenig 2nd order sequence. It is bound by the *Ceratopyge* Regression at its base and by the Komstad Regression at its top, whilst the sequence's lowstand and highstand intervals are separated by the Billingen Transgression. The sequence, as a whole, is adequately controlled by index fossils and shows a good fit with the global curve (see Fig. 2). To facilitate comparison with the suggested sea level curve derived from the Cadenas Ibéricas, on Figure 2 a trend line is being superimposed on the detailed sea level curve (and duplicated on the

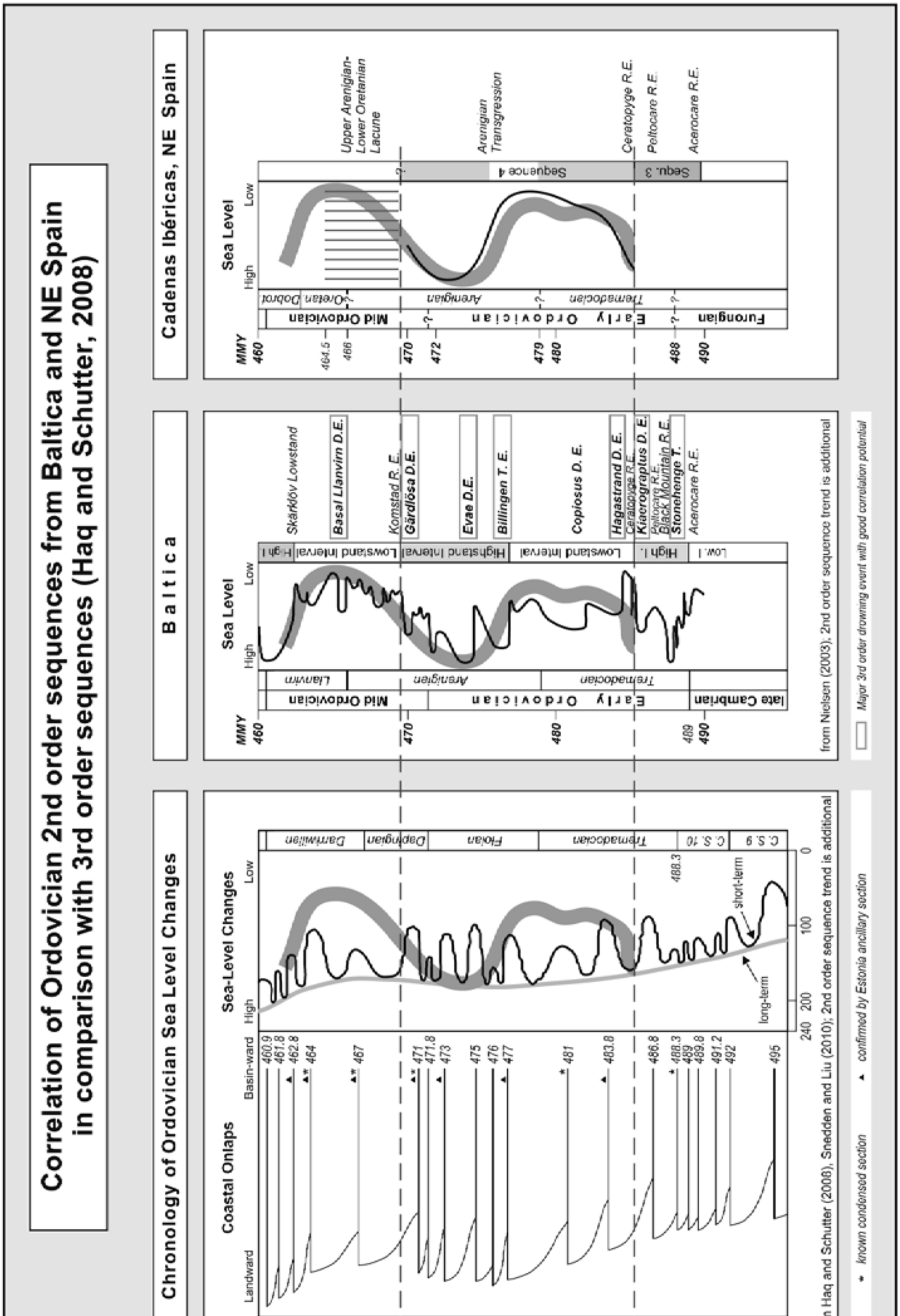

Figure 2. C. S. 9, Cambrian Stage 9. C. S. 10, Cambrian Stage 10. D. E., drowning event. Dobrot., Dobrotivian. Oretan., Oretanian. R. E., Regression event. T. E., Transgression event. (As for Spain, regional stages are used.)

respective sections of the global and Cadenas Ibéricas curves). Comparing the Nielsen (2003) curve with the global one, it is noted that the lowstand intervals show similarities to a lesser degree than the highstand intervals. Upwards, the sequence passes into a conspicuous lowstand interval trend which in its lower part is of late Arenig age. That trend is used in the comparison with the sedimentary pattern interpreted from the Cadenas Ibéricas succession (see below).

THE LATE TREMADOCIAN–EARLY (?) ARENIG SEQUENCE OF THE CADENAS IBÉRICAS

This 2nd order sequence likely represents the closing succession of the Middle Cambrian–Early Ordovician sag phase, which had been preceded by a rift phase (Gámez Vintaned et al., 2009). Age identification within the sequence is poor (see Gutiérrez-Marco et al., 2002), in particular some uncertainty exists as to the exact position of the Tremadocian–Arenig boundary. The base of the sequence has been placed by Schmitz (2006) at the *Ceratopyge* Regression level, on the basis of circumstantial evidence. The sequence top is the top of the "Armorican Quartzite", with no biozone control of its age allocation. (Middle Arenigian graptolites were recovered from Armorican facies of the Cantabrian Zone, N Spain, while the oldest graptolites found elsewhere in shaly levels above the Armorican formation are middle to late Arenigian in age; Gutiérrez-Alonso et al., 2007, and references therein.) With reference to fossil assemblages in the Castillejo Formation (the unit overlying the "Armorican Quartzite" in the Cadenas Ibéricas), a late Oretanian age was evidenced (Gutiérrez-Marco et al., 2002). From the biostratigraphic data mentioned, it is concluded that we face a gap between the "Armorican Quartzite" and the Castillejo Formation, referred to as "upper Arenigian-lower Oretanian lacune".

The sequence (see Fig. 3) consists of a lower part, the Santed Formation, which is dominated by shales, with sandstone intercalations at various levels, and of an upper part, the "Armorican Quartzite". The latter comprises sandstones and quartzites as well as shale intercalations and shale intervals. The lower parts of the Santed Formation represent a lowstand phase, with turbidites characterizing the slope phase and the coarsening upward trend characterizing the progradational wedge phase. Somewhat generalized, the succession in the Santed Formation below the "Armorican Quartzite" and in the lower part of the "Armorican Quartzite" is suggested to represent the transgressive systems tract, whilst highstand deposits seem to dominate its upper parts, as indicated by the listing of sedimentological and ichnological features (Schmitz, 2006).

The suggested sea level curve related with the sequence is shown on Figure 3. It is a generalized curve, to be modified as additional information becomes available. Likewise, the conversion of that Figure 3-curve into a time-controlled sea level curve involves uncertainties, mirroring the little age control along the 2nd order sequence. One way to assess the reliability of the conversion, under the given circumstances, is the comparison with an established, time-controlled curve. In the case of the Cadenas Ibéricas sequence, as will be noted on Figure 2, correlation with the Nielsen (2003) curve only fits if its highstand phase is being moved, ending at intra-late Arenigian times. Consequently, the match for the entire curve fits only if the belief is being abandoned that the top of the "Armorican Quartzite" equals the top of the Arenig (which is also supported by biostratigraphic data mentioned above; cf. Gutiérrez-Alonso et al., 2007).

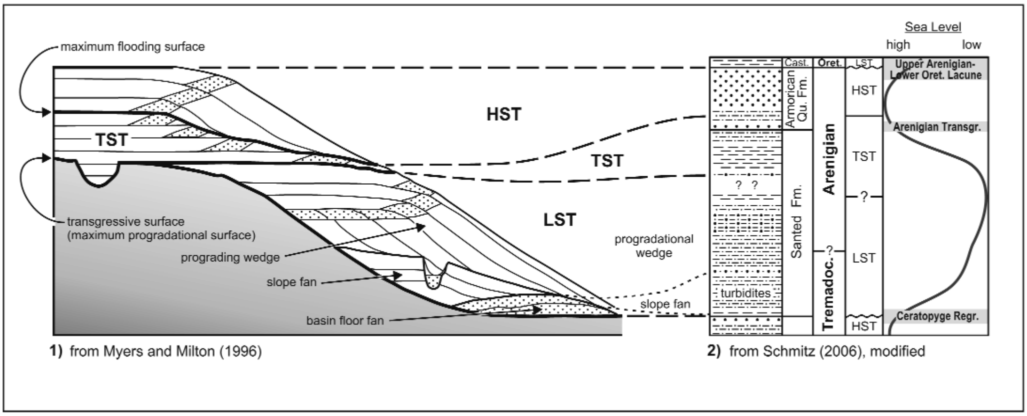

Figure 3. Suggested systems tracts and sea level curve of the Tremadocian–Arenig 2nd Order Sequence in the Cadenas Ibéricas. Cast., Castillejo Formation. Fm., Formation. HST, highstand systems tract. LST, lowstand systems tract. Oret., Oretanian. Qu., Quartzite. TST, transgressive systems tract.

SUMMARY AND CONCLUSIONS

It is suggested that the depositional history of the Tremadocian–Arenig clastic succession in the Cadenas Ibéricas was dominated by a 2nd order sequence. The exact stratigraphic positions of the sequence phases cannot be verified, owing to poor age-dating. To still enable correlation with globally established sequences, the succession is being compared with the equivalent succession of Baltica. That succession had been analyzed for 2nd order sequence subdivision, it is reliably controlled through age-dating and 3rd order sequence events (Nielsen, 2003). The comparison suggests that the correlation proves an effective tool in as much as it shows good agreement for the major part of the succession and that it points to a discrepancy which ought to be addressed, relative to the top part of the section: there, the conventional belief that top "Armorican Quartzite" and top Arenig are identical is incorrect and needs to be critically reviewed.

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