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Invited review

The assumed Aalenian stage-long eustatic lowstand did not exist: A review of the fresh evidence from Africa and other continents

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ABSTRACT

The views of the Jurassic eustatic fluctuations differ significantly: specialists either suggest multiple rises and falls ("Haq's view") or question the idea of global falls ("Hallam's view"). For instance, it is unclear whether there was a stage-long eustatic lowstand in the Aalenian. The presence of the noted alternatives is a serious problem complicating interpretation of events in the geological history. This paper summarizes the evidence of the Aalenian long-term shoreline shifts obtained in different regions of the world since 2000, i.e., after the noted views appeared. This evidence deals with the stratigraphical architecture of regions (interpreted in the present article), the established shoreline shifts (transgressions and regressions), and the knowledge of the regional tectonic activity. The compiled information characterizes "stable" regions located in the different parts of the world (Europe, Asia, Africa, North America, South America, and Australia). It is established that there were no regressions in some of these regions in the Aalenian, whereas regressions in the other regions can be explained by the influence of the tectonic activity. There was no coherence of the basin-scale eustatically-driven regressions (in contrast, the long-term Bajocian eustatic rise is proven by a coherence of regional transgressions). This finding contradicts the idea of the stage-long eustatic lowstand in the Aalenian and, thus, favours the "Hallam's view". This interpretation is in agreement with the present knowledge of the Earth's palaeoclimate and the past plate tectonics. This study demonstrates efficacy of interregional correlation of sea-level changes for resolution of the problem of the alternative views of the Jurassic eustasy.

Contents

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1. Introduction

Accurate reconstructions of eustatic (=global sea-level) fluctuations are not only interesting themselves, but also essential for the better understanding of the entire Earth's dynamics, the development of particular sedimentary basins, and the mechanisms of major events in the geological history. For instance, the sequence stratigraphic approach depends strongly on the knowledge of the global sea-level changes (e.g., Catuneanu, 2006). Unfortunately, this knowledge remains significantly imprecise and even controversial (Ruban, 2016). Particularly, there is not any single view of the Jurassic eustasy. The work of the famous Exxon Group culminated in the end-1980s when Haq et al. (1987) published their detailed eustatic curve. These specialists outlined a series of global sea-level rises and falls that occurred in the Jurassic. This development was critically considered by Hallam (1988) and Miall (1992). About 15 years later, Hallam (2001) revised the available knowledge and concluded that only the eustatic rises were of global extent in the Jurassic (with the global fall at the beginning of this period as exception). However, Haq and Al-Qahtani (2005) considered some new data (first of all, from Arabia) and updated the curve of Haq et al. (1987), which again would show a series of rises and falls. The "Hallam's view" ("no falls" – Hallam, 2001) and the "Haq's view" ("rises and falls" – Haq and Al-Qahtani, 2005) are mutually exclusive. The former was proven by the later developments by Zorina et al. (2008) for the entire period and Ruban and Sallam (2016) for the Bajocian–Bathonian interval. The modern international research community has not made an argued preference of the noted alternatives, and the problem of the different views of the Jurassic eustasy has persisted for more than 15 years. Unfortunately, many specialists (if not the majority of them) refer in their works to the older curve of Haq et al. (1987) simply ignoring the both updates of this curve made by Haq and Al-Qahtani (2005) and the arguments of Hallam (2001). Finally, there is a problem with the global sea-level change interpretations linked to the improvements in the geological time scale made regularly by the International Commission on Stratigraphy.

The Aalenian is the first stage of the Middle Jurassic that lasted 3.8 Ma (Gradstein et al., 2012). The chronostratigraphy of this interval was refined by many workers (Cariou and Hantzpergue, 1997; Pavia and Enay, 1997; Cresta et al., 2001; Gradstein et al., 2012). Consideration of this stage, i.e., the Aalenian, is crucial for finding out which eustatic curve is the best. According to Haq et al. (1987) and Haq and Al-Qahtani (2005), the Aalenian was marked by a significant global sea-level lowstand. On their short-term curve, there was a fall in the first half of the stage. On their long-term curve, the lowstand embraced the entire stage. Moreover, the global sea level reached its minimum level for the entire Middle–Late Jurassic in the Aalenian according to these authors. Hallam (2001) argued that the regional records of the Aalenian sea-level changes can be explained in the terms of the tectonic activity, and, thus, there was not any global fall. The data on the global distribution of hiatuses in sedimentary successions compiled by Zorina et al. (2008) indicate a number of them in the Aalenian, although not so significant to imply the eustatic lowstand. This is a true controversy: if the schemes of Haq et al. (1987) and Haq and Al-Qahtani (2005) are right, the Aalenian global sea-level lowstand was a really remarkable stage-long event in the Jurassic history of the Earth; if the scheme of Hallam (2001) is right, this event did not exist (Fig. 1). The main objective of the present article is to revise this persisting problem with the new evidence. This evidence has been accumulated since the beginning of the 21st century, i.e. after the time when the views of Haq and Hallam appeared.

2. Material and method

All the main reconstructions of the Jurassic and, particularly, Aalenian eustatic fluctuations (Haq et al., 1987; Hallam, 2001; Haq and Al-Qahtani, 2005) are based on the compilations of stratigraphical data from across the globe. Such an approach is judged efficient and even the only sensible by many specialists (e.g., Embry, 1997; Kominz et al., 2008; Miall, 2010; Ruban et al., 2012). In fact, regional evidence from different parts of the world permits to conclude about the presence (in the case of sufficient coherence of the evidence) or the absence (in the case when such a coherence does not exist) of the global sea-level rises and falls. Implementation of the "high-tech" approaches (e.g., the detailed studies of "ideal" records or modelling like those undertaken by Miller et al. (2005), Müller et al. (2008), and van der Meer et al. (2017)) is also important, but the results are probabilistic in somewhat, and it would be better to justify them by field geological observations.

The basic method of the present study is interregional correlation of the long-term Aalenian sea-level changes. Three questions should be answered for its successful application:

1) what are the sources of information to use?
2) what are the regions to be considered?
3) what is the evidence to be compared?

To abstain from repetition of the evidence already employed in the works of Haq et al. (1987), Hallam (2001), and Haq and Al-Qahtani (2005), only information that became available since the beginning of the 2000s should be employed. The available sources of information can be divided into two groups. Those of the first group are the already published reconstructions of shoreline trajectories. The sources of the second group contain stratigraphical information (accurate regional stratigraphical schemes) that is sufficient for judgments of the regional changes; in this case, the interpretations are not available and should be done in the course of the present study. The regions, which can potentially provide the most important eustatic evidence, should be tectonically "stable". Otherwise, the local tectonic activity could overprint signatures of the global events. In such a case, only cratons, passive continental margins, and some other regions of such kinds should be preferred, whereas the data from foredeeps, back-arc basins, orogenic belts, etc. will not help significantly.

The third question is about the essence of the new data from "stable" regions, which is necessary for the present study. When sea-level changes are considered, it should be understood that two patterns have to be distinguished, namely shoreline shifts (transgressions, which are landward shifts, and regressions, which are seaward shifts) and relative changes in the basin depth (shallowings and deepenings). Presumably, the former are better indicators of eustatic fluctuations because their appearance in any given open marine basin developed on a "flat" and "stable" margin depends less on the vertical motions of the bottom and the changes in the accommodation space linked to sedimentation. This is why the present article focuses on shoreline shifts. If Haq and Al-Qahtani (2005) outlined the stage-long eustatic lowstand in the Aalenian superposed by a short-term fall in the first half of this stage, we need evidence of long-term regional regressions. It should be kept in mind that such a regression could peak any time within the Aalenian depending on the interplay between the global and regional factors in each given basin. What is more important is that this regression should be significant enough to be judged a true signature of the global event, not just as the only smaller fluctuation complicating the long-term pattern. The stage-long duration of the analyzed event means that the evidence should come from the analysis of the longer (e.g., Toarcian–Bajocian) regional records,