Journal of African Earth Sciences 116 (2016) 225–232

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Geological Society of Africa Presidential Review

A “chaos” of Phanerozoic eustatic curves

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ARTICLE INFO

Article history:
Received 31 October 2015
Received in revised form
17 December 2015
Accepted 4 January 2016
Available online 9 January 2016

Keywords:
Global sea-level changes
Eustatic curve
Geological time scale
Cambrian
Cretaceous
Paleocene
Phanerozoic

ABSTRACT

The knowledge of eustasy has changed during the past two decades. Although there is not any single global sea-level curve for the entire Phanerozoic, new curves have been proposed for all periods. For some geological time intervals, there are two and more alternative reconstructions, from which it is difficult to choose. A significant problem is the available eustatic curves are justified along different geological time scales (sometimes without proper explanations), which permits to correlate eustatic events with the possible error of 1–3 Ma. This degree of error permits to judge about only substage- or stage-order global sea-level changes. Close attention to two geological time slices, namely the late Cambrian (Epoch 3–Furongian) and the Late Cretaceous, implies that only a few eustatic events (6 events in the case of the late Cambrian and 9 events in the case of the Late Cretaceous) appear on all available alternative curves for these periods, and different (even opposite) trends of eustatic fluctuations are shown on these curves. This reveals significant uncertainty in our knowledge of eustasy that restricts our ability to decipher factors responsible for regional transgressions and regressions and relative sea-level changes. A big problem is also inadequate awareness of the geological research community of the new eustatic developments. Generally, the situation with the development and the use of the Phanerozoic eustatic reconstructions seems to be “chaotic”. The example of the shoreline shifts in Northern Africa during the Late Cretaceous demonstrates the far-going consequences of this situation. The practical recommendations to avoid this “chaos” are proposed. Particularly, these claim for good awareness of all eustatic developments, their critical discussion, and clear explanation of the employed geological time scale.

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1. Introduction

Much has changed in our understanding of the Phanerozoic global sea-level changes (=eustatic fluctuations) in the past two decades. The knowledge has become more precise and detailed.

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http://dx.doi.org/10.1016/j.jafrearsci.2016.01.009
1464-343X/

The productivity of this research has been remarkable. Twenty five years ago, there were only a few more or less trustable sea-level reconstructions, the best of which was proposed by Haq et al. (1987) for the Mesozoic–Cenozoic. Now, we have a series of curves permitting much deeper insight into the issue of the Phanerozoic eustasy. Specialists have used different methods of reconstruction (e.g., compilation of regional stratigraphical data and geodynamic modeling), different data (e.g., from different regions), and/or different "philosophical" frames (e.g., glacioeustasy, dynamic topography, etc.). As a result, another problem has appeared, namely the appearance of alternatives. If one needs a global reference, she/he faces with several eustatic curves, and it is unclear (if not to say "absolutely unclear") which of them to prefer.

The main objective of this article is to review of the current state of the knowledge of the Phanerozoic eustasy. To discuss advantages and disadvantages of each given reconstruction is beyond the scope because much research is yet to be done in order to test the validity of the available eustatic curves. The purpose of this article is different: if we have several alternative global sea-level reconstructions and do not know which of them is better, it is sensible to attempt their direct comparison. This permits 1) to outline common events and trends, which seem to be "real" (undisputable), and 2) to reveal the uncertainty in the modern understanding of the Phanerozoic eustatic fluctuations. The additional objective of this review is to list the available eustatic reconstructions in one work and, thus, to simply information search for specialists who are not experts in eustasy, but need any global reference and to provide some recommendations for further eustasy-related research. Although the entire Phanerozoic (except for the Quaternary) is considered in this article, alternative reconstructions for two lengthy geological time intervals (late Cambrian and Late Cretaceous) are used in order to provide representative examples. The noted intervals are chosen by different reasons. The late Cambrian is interesting because of the presence of two fully "independent" eustatic reconstructions and the absence of discussions of which of them is better. The Late Cretaceous attracts attention because of relatively big number of alternative global sea-level curves.

2. Conceptual remarks

The global sea level has changed throughout the geological history because of different, but interrelated causes (Fig. 1). Climatic and tectonic controls seem to be the most important. Two components can be distinguished in eustatic fluctuations. First, these are events that constitute the continuous succession of these fluctuations. These events are eustatic rises and eustatic falls. It is also possible to speak about eustatic minima (lowstands) and maxima (highstands). A pair of eustatic rise followed by fall (or vice versa) is an eustatic cycle. Second, there are trends that highlight the general direction of global sea-level changes for series of cycles. Such trends permit to delineate events of higher order (see below about the orders). Generally, each comparison of alternative eustatic reconstructions requires separate analysis of events and trends.

The Phanerozoic eustatic fluctuations were not simple, but multi-ordered. This means that events and trends can be established on several hierarchical levels. This is a very challenging task (Ruban, 2015). It has become very common in the modern geoscience literature to speak about the 1st-, 2nd-, 3rd-, and 4th-order sea-level changes. However, such a numbering is not sensible because the hierarchy of eustatic fluctuations itself changed through the geological time and it is difficult to understand what was the highest order until the Precambrian global sea-level changes will be deciphered (Ruban, 2015). To avoid this problem, it is possible to speak about the eon-order, era-order, period-order, epoch-order, stage-order, and substage-order fluctuations (Fig. 2). For instance, if there is a curve depicting global sea-level cycles with a length more or less comparable to that of a stage, these cycles are stage-order cycles.

When global sea-level changes are reconstructed, it is natural that the specialists attempt to be as accurate as possible. For this purpose, they follow the most precise geological time scale (at least, we hope they do so). However, the available reconstructions are based on different scales. On the one hand, different specialists make different choices of time standards. Some prefer absolute time scales, some aim at precise biozonations (e.g., ammonite-, foraminifer-, nannofossil-based zones) and/or magnetochrons, etc. Moreover, the geological time scale is under permanent maintenance, and the International Commission on Stratigraphy refines it each year (Gradstein et al., 2004, 2012; Ogg et al., 2008; see also stratigraphy.org). It is very possible that different specialists use different versions of this scale, and sometimes they are not able to follow the newest developments (the situation with geoscience books demonstrates this clearly – see Ruban (2011)). Finally, some

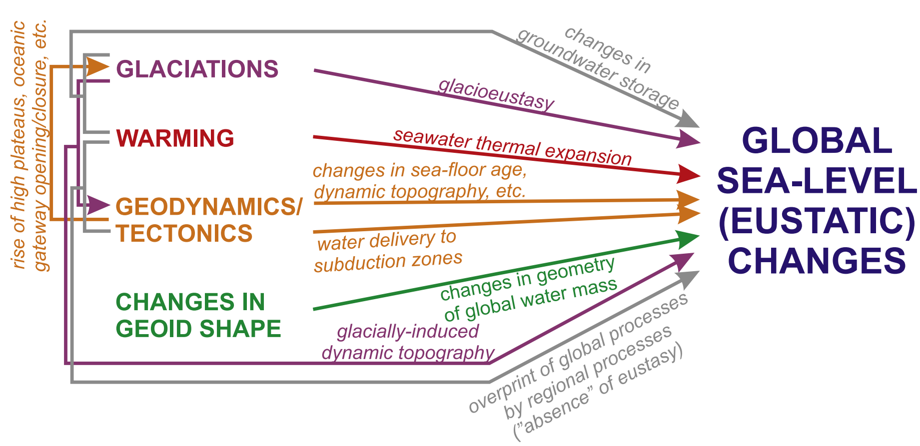

Fig. 1. A very tentative schema explaining the nature of global sea-level changes in the light of the modern knowledge (Jacobs and Sahagian, 1993, 1995; Abreu and Anderson, 1998; Eriksson et al., 2005; Miller et al., 2005; Cogné et al., 2006; Veeken, 2006; Archer, 2008; Cogné and Humler, 2008; Moucha et al., 2008; Müller et al., 2008; van der Lee et al., 2015; Conrad and Husson, 2009; Lovell, 2010; Ruban et al., 2010, 2012; Boulila et al., 2011; Gasson et al., 2012; Jones et al., 2012; Spasojevic and Gurnis, 2012; Conrad, 2013, 2014, 2015; Rowley et al., 2013; Zorina et al., 2013; Chen et al., 2014; Wagreich et al., 2014; Wendler et al., 2014; Cloetingh and Haq, 2015; Crowley et al., 2015; Sames et al., 2016; Wendler and Wendler, 2016). However, really much is yet to be known about 1) the full spectrum of factors and 2) the possible interconnections and direct/indirect influences of these factors. For instance, the role of global sedimentation should be considered.