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# How global are the Jurassic–Cretaceous unconformities?

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## ABSTRACT

**The reality of the global-scale sedimentation breaks remains controversial. A compilation of data on the Jurassic–Cretaceous unconformities in a number of regions with different tectonic settings and character of sedimentation, where new or updated stratigraphic frameworks are established, permits their correlation. Unconformities from three large reference regions, including North America, the Gulf of Mexico, and Western Europe, were also considered. The unconformities, which encompass the Jurassic-Cretaceous, the Lower–Upper Cretaceous and the Cretaceous–Palaeogene transitions are of global extent. Other remarkable unconformities traced within many regions at the base of the Jurassic and at the Santonian–Campanian transition are not known from reference regions. A correlation of the Jurassic–Cretaceous global-scale sedimentation breaks and eustatic curves is quite uncertain. Therefore, definition of global sequences will not be possible until eustatic changes are clarified. Activity of mantle plumes is among the likely causes of the documented unconformities.**

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## Introduction

Phanerozoic unconformity-bounded sequences defined in North America by Sloss (1963) have led to the development of global cycle charts and a possible eustatic curve (Vail *et al.*, 1977; Haq *et al.*, 1987). An updated curve for the entire Phanerozoic has been recently proposed by Haq and Al-Qahtani (2005). However, any eustatic constraints should always be tested to avoid errors and inconsistencies (Miall, 1992; Hallam, 2001; Catuneanu, 2006). Thus, it is sensible to return to the original concept of Sloss (1963) and to attempt broad correlation of the unconformities across the world. Interregional correlations like those previously performed by Soares *et al.* (1978), Petters (1979), Ross and Ross (1985), Embry (1997) and Hallam (2001) suggest the efficacy of such an approach.

During the past decade, new stratigraphic frameworks have been established for the Jurassic and Cretaceous successions of a number of important sedimentary basins of Eurasia, Africa, and America. These provide enough data to substantiate global-scale sedimentation breaks during this time interval.

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## Geological setting

To be global, an unconformity should be present not only in many regions in the world, but it should also be traceable in far-located regions with various tectonic settings and sedimentation types. A number of regions worldwide with the newly-established Jurassic–Cretaceous stratigraphic frameworks have been selected in order to correlate the Jurassic–Cretaceous unconformities (Fig. 1). Their tectonic settings differed strongly, which helps to avoid recognition of unconformities that result from specific tectonic events. Most of the above-mentioned basins were dominated by marine sedimentation, except the non-marine basins of Africa. In the Neuquén Basin, continental sedimentation since the Late Cretaceous has been established (Howell *et al.*, 2005). This permits us to outline the nearly-global unconformities traceable within a broad spectrum of depositional settings. Good correspondence in stratigraphic architecture between marine and non-marine strata is not so unusual (Catuneanu, 2006; Ruban *et al.*, in press). In all the studied regions, the lithological composition of the Jurassic–Cretaceous strata is quite diverse and the total thickness exceeds several hundreds of metres.

Available stratigraphic frameworks for the studied regions allow delineation of the hiatuses, which are established within at least the main part of each region. These hiatuses mark regional unconformities. An interregional correlation then becomes possible. We do not omit regional unconformities with probable tectonic origin, because an interregional correlation is itself important for understanding the nature of hiatuses.

## Correlation of unconformities

Numerous unconformities are recognized, but not one unconformity is identified within all studied regions (Fig. 2). However, five nearly-global unconformities are common for at least 2/3 of the studied regions. They characterize the base of the Jurassic (T–J), the Tithonian–lower Valangianian interval (J–K), the Albian–Cenomanian (K1–K2), the Santonian–Campanian (S–C), and the Maastrichtian–Danian (K–T) transitions.

A striking feature of all the above-mentioned unconformities is their strong diachroneity. This is especially significant for the T–J and the J–K transitional intervals. They cannot be recognized by any unique surface, but only by a concentration of regional hiatuses. Three Cretaceous unconformities seem to be less diachronous. This diachroneity may have at least two possible causes, namely (1) errors in the dating of the unconformity in given regions, (2) tectonic influence. In the first case, a diachrony can be proclaimed as an artefact of the

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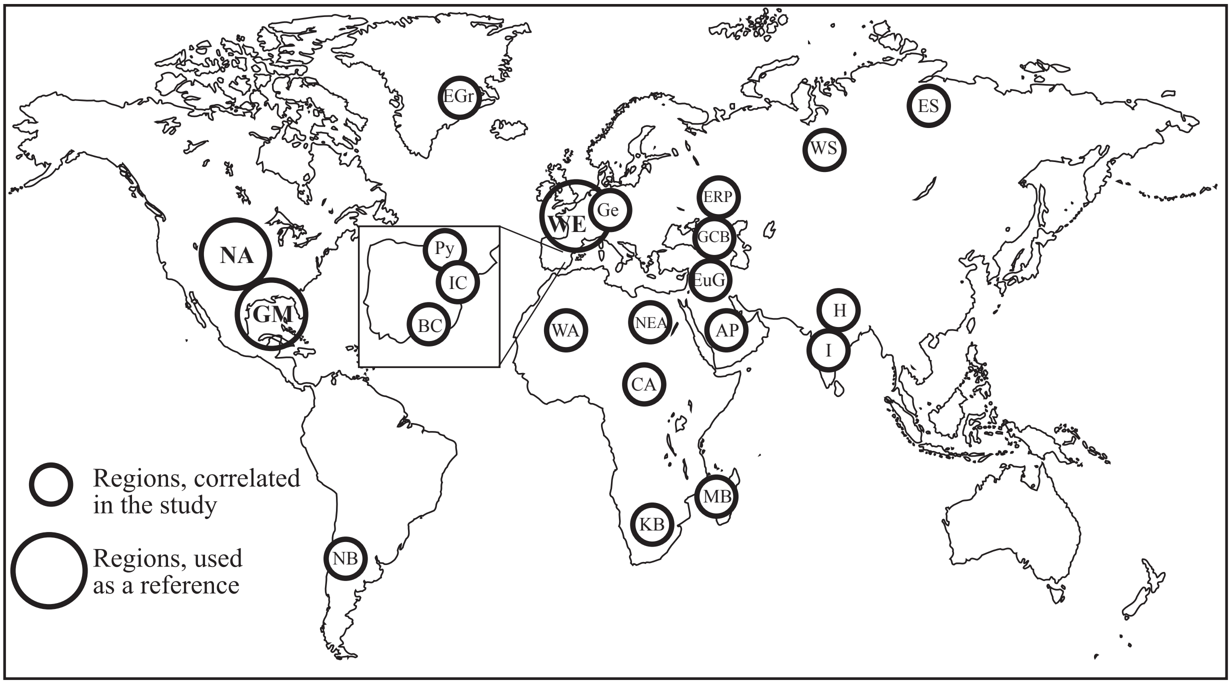


**Fig. 1** Location of regions, considered in this study. ERP – eastern Russian Platform, Ge – Germany, Py – Pyrenees-Basque-Cantabrian domain, IC – Iberian Cordillera, BC – Betic Cordillera, EGr – East Greenland, WS – West Siberia, ES – East Siberia, EuG – Euphrates Graben, AP – Arabian Plate, WA – Western Africa, NEA – Northeastern Africa, CA – Central Africa, KB – Karoo basins, MB – Morondava Basin, GCB – Greater Caucasus Basin, NB – Neuquén Basin, H - Himalayas and adjacent blocks, I – India, WE – Western Europe, GM – Gulf of Mexico, NA – North America.

stratigraphic analysis. In contrast, tectonic influences are able to create a true diachroneity. It is possible to hypothesize two kinds of tectonic influences. Any given unconformity may have resulted from the global-scale tectonic pulse. If so, diachroneity of such an activity resulted in diachroneity of the unconformities. Alternatively, an unconformity is resulted from a global eustatic fall. But the age of the unconformity corresponds to the time of such a fall only in those regions that were tectonically stable. Tectonic uplift causes the unconformity to occur earlier, whereas subsidence causes a later unconformity.

It is sensible to correlate the identified unconformities with those established earlier for other regions. We concentrated our attention to three such regions. They are Western Europe, where the principal unconformities have been used to outline the major cycles of sedimentation (Jacquin and de Graciansky, 1998), North America, where some key unconformities were used as major sequence boundaries (Sloss, 1963, 1988) and the Gulf of Mexico, where Salvador (1991) identified a number of extensive unconformities. We observe that the J–K, the K1–K2, and the K–T unconformities are identified in these reference regions (Fig. 3). However, only the oldest is established in all three regions. Note that two unconformities relevant to the latter in the Gulf of Mexico, are not considered by Salvador (1991) among major. Intriguing are the T–J and the S–C unconformities. Their global extent is evident from our correlation (Fig. 2), but it is difficult to identify them in three reference regions (Fig. 3). However, one should take into consideration the absence of pre-Late Jurassic record in the review of data from the Gulf of Mexico by Salvador (1991) and the presence of the Early Cimmerian unconformity at the Norian/Rhaetian boundary.

## Sedimentation breaks and eustatic curves

As the five above-mentioned sedimentation breaks are known from many regions and can be labelled as *potentially*-global, they might have been caused by eustatic drops. We use the present Phanerozoic curve of Haq and Al-Qahtani (2005), the curve of Hallam (1988) and Hallam (2001) for the Jurassic, and the curve by Miller *et al.* (2005) for the Late Cretaceous to test this hypothesis (Fig. 3). The first two curves are based on the global compilation of data. However, Hallam (2001) pointed out that the earlier constraints by Haq *et al.* (1987) were based on information from the North Sea and some European sections. The curve reconstructed by Miller *et al.* (2005) is based on data from the New Jersey margin, although compared with those from other regions.

The T–J, the J–K and the K–T sedimentation breaks corresponded to the eustatic lowstands depicted by the curve of Haq and Al-Qahtani (2005). In contrast, the K1–K2 break coincided with a remarkable global sea-level rise. The situation at the S–C transition is unclear, although some eustatic drops are known from there. The other curve (Miller *et al.*, 2005)

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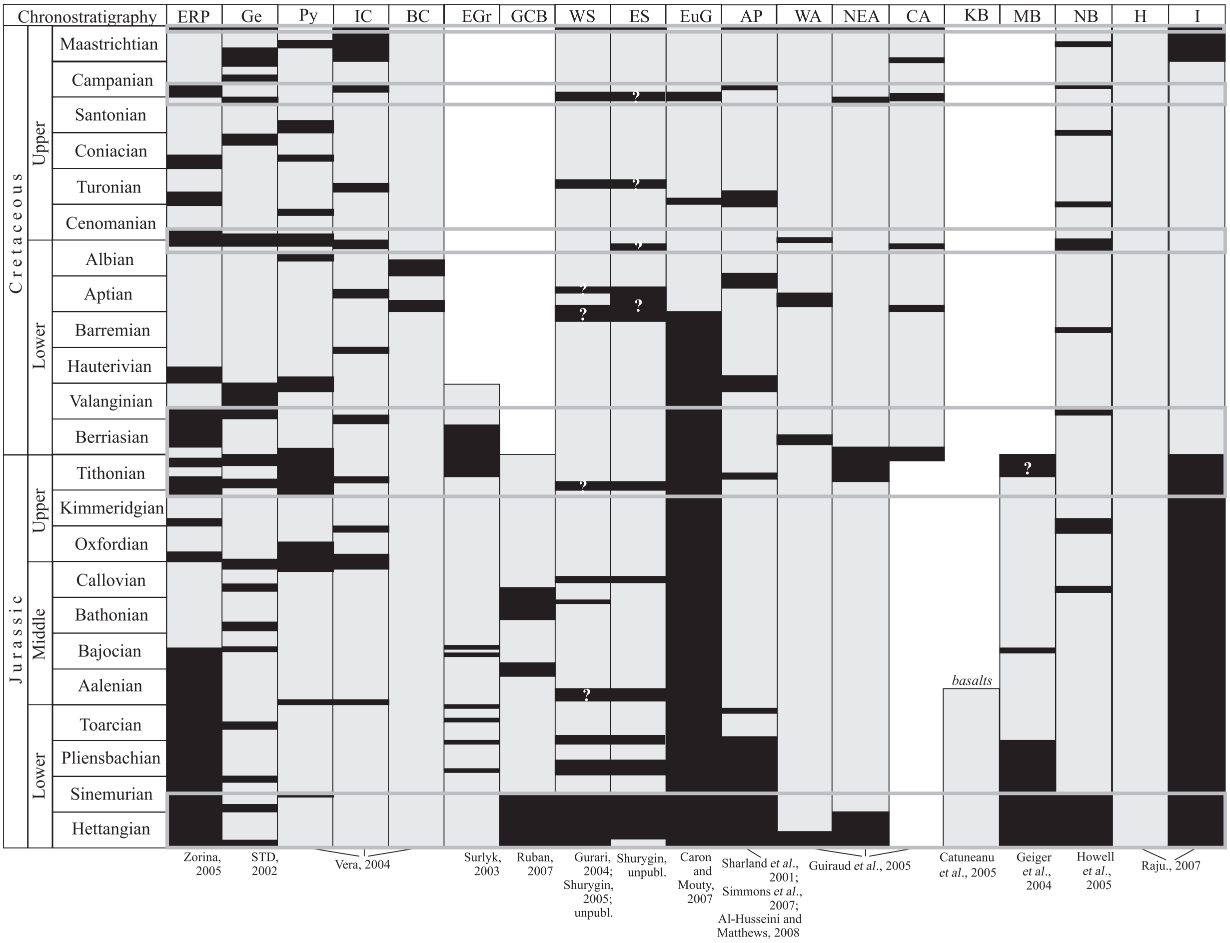


**Fig. 2** The Jurassic–Cretaceous hiatuses in the studied regions. The considered intervals are highlighted as grey. No sufficient data are available for the rest intervals of some regions, which are shown by white. Bold dark-grey rectangles outline the common sedimentary breaks. See Fig. 1 for abbreviations.

establishes that both the K1–K2 and the S–C sedimentary breaks corresponded to the prominent global sea-level falls. However, why are there no global sedimentation breaks associated with some other remarkable eustatic drops, such as those in the Bathonian (Haq and Al-Qahtani, 2005) or Turonian (Haq and Al-Qahtani, 2005; Miller *et al.*, 2005)? In some regions, we may easily recognize the unconformities, which correspond to these eustatic falls (Fig. 2). But in some other regions, these unconformities do not exist. This may be explained by the above-mentioned tectonic influences. Rapid tectonic subsidence in some regions did not allow the unconformities to be formed during a time of eustatic fall. Moreover, in deep-marine environments, we do not necessarily see unconformities caused by the sea-level falls. Alternatively, those global falls, not reflected by the presence of wide-spread sedimentation breaks, are artefacts. According to Hallam (2001), regressions were mostly regional events, whereas transgressions are better traced across the world. If so, one should be careful interpreting the eustatic falls. The results of our unconformity correlations agree with Hallam (2001), suggesting the presence of many drops on the global sea-level curves not reflected by wide-spread unconformities, but also question the reliability of proposed eustatic curves.

If potentially global unconformities exist, they may be used to outline the global sequences similar to those proposed by Haq *et al.* (1987). However, it is necessary to remember that a sequence is bounded by both unconformities and correlative conformities (Van Wagoner *et al.*, 1988; Catuneanu, 2006). If so, sequence boundaries may exist at those levels, where unconformities are not so common across the globe. Thus, a more precise reconstruction of global sea-level changes will permit us to outline the global sequence boundaries.

## Discussion

Although correspondence between documented sedimentation breaks and eustatic curves remains controversial, one may emphasize that only eustasy could cause them. If so, the next question is what factors would

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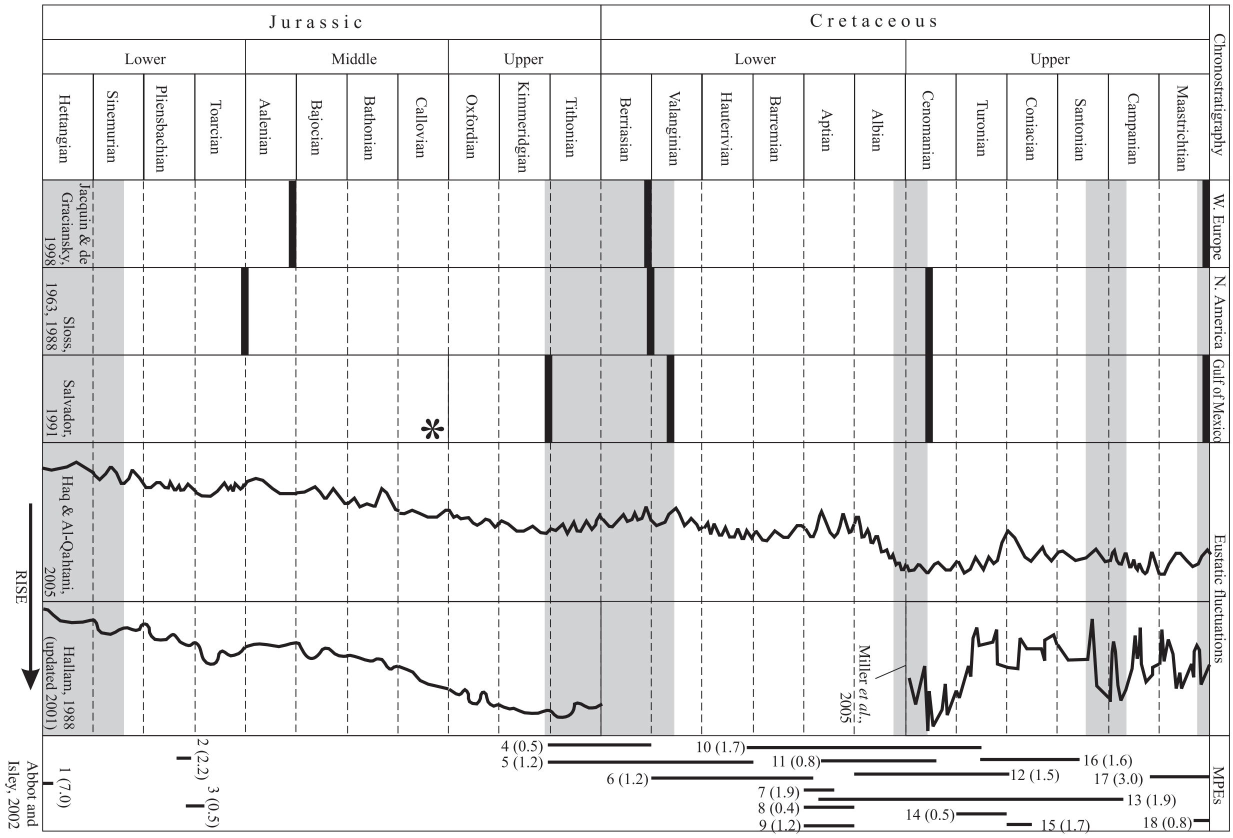


**Fig. 3** Unconformities of reference regions, common sedimentary breaks for the studied regions (grey lines), eustatic fluctuations and MPEs. The horizontal scales of the eustatic curves are not identical. Each MPE is shown as a range accounting the dating errors. 1 – Central Atlantic, 2 – Karoo Province, 3 – Ferrar Dolerite, 4 – Magellan Rise, 5 – Shatsky Rise, 6 – Parana–Serra Gelal, 7 – Ontong Java Plateau, 8 – Wallaby Plateau, 9 – Manihiki Palteau, 10 – Alpha Ridge Plateau, 11 – Hess Rise, 12 – Kerguelen Plateau, 13 – Venezuelan–Colombian, 14 – Broken Ridge, 15 – Rio Grande, 16 – Madagascar, 17 – Peary Land, 18 – Deccan. Number in brackets means a size of volvanic province ($\times 10^6$ km$^2$). *Salvador (1994) constrained sedimentary cyclicity since the Late Jurassic.

control the T–J, the J–K, the K1–K2, the S–C and the K–T eustatic drops? Two best candidates are changes in the ice-volume and tectonics. Data from Gondwana establish that the climate was generally warm during the most of the Cretaceous with a noted exception at the Jurassic/Cretaceous boundary, when temperatures dropped by about 10 °C (Scotese, 1998; Anderson *et al.*, 1999; Scotese *et al.*, 1999). A recognizable cooling took place near the end of the Cretaceous (Keller, 2001; Nordt *et al.*, 2003). Miller *et al.* (2005) suggested episodic occurrences of ephemeral glaciations during the Late Cretaceous. Undoubtedly, these cooling phases were able to cause some eustatic drops. However, glaciation episodes are also known from the Pliensbachian (Morard *et al.*, 2003), the Callovian (Dromart *et al.*, 2003), the Early Cretaceous (Alley and Frakes, 2003) and the Turonian (Frakes and Francis, 1988; Frakes and Krassay, 1992; Frakes *et al.*, 1992), but none of them is associated with large unconformities. Several regional hiatuses can be brought into correspondence with these climatic episodes (Fig. 2). But why were other minor cooling phases more important in producing global-scale sedimentation breaks? Moreover, relative to the J–K transition, the present evidence relies on controversial climatic interpretations for this time (Husinec and Read, 2007; Zorina and Ruban, 2007).

Tectonic events such as supercontinent amalgamations and break-ups caused long-term influences on the global sea level (Miller *et al.*, 2005). But to explain relatively short-term sedimentary breaks like those documented by our study within the Jurassic–Cretaceous interval, only abrupt and intense tectonic processes are likely. The clue is given by Hallam (2001) who underlined an importance of the large-scale plume tectonics for sea-level changes at the Triassic–Jurassic transition. The available record of episodes of mantle plume activity (MPE) (Abbott and Isley, 2002) permits us to relate the T–J unconformity with the Central Atlantic MPE, the J–K unconformity with the Magellan Rise MPE and the Shatsky Rise MPE, the K1–K2 unconformity with the Alpha Ridge Plateau MPE, the Hess Rise MPE, the Kerguelen Plateau MPE, and the Venezuelan–Columbian MPE, and the K–T unconformity with the Peary Land MPE and the Deccan MPE


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(Fig. 3). No plume activity is known around the Santonian/Campanian boundary (Abbott and Isley, 2002). But taking into consideration the uncertainty in the age of the Venezuelan–Colombian MPE, one may suggest its coincidence with the S–C sedimentation break. Many other MPEs took place at times, when no sedimentation breaks occurred (Abbott and Isley, 2002).

Neither climatic nor tectonic origin of the Jurassic–Cretaceous sedimentation breaks should be excluded, but our knowledge of them remains incomplete. Moreover, local tectonic subsidence could have countered their influences on regional sedimentation. The above-mentioned considerations suggest that MPE is a more likely cause of the potentially global sedimentation breaks.

## Conclusions

An attempted correlation of the Jurassic–Cretaceous unconformities established in a number of regions with new or updated stratigraphic frameworks allows recognition of three potentially global sedimentation breaks, which occurred at the Jurassic–Cretaceous, the Lower–Upper Cretaceous and the Cretaceous–Palaeogene transitions. The unconformities established at the base of the Jurassic and at the Santonian–Campanian transition are not recognized in the reference regions of Western Europe, North America and the Gulf of Mexico, but they are common within those regions considered herein. Moreover, there are no unconformities existing within all considered regions. Five unconformities mentioned above are diachronous and their relationships with the eustatic falls are uncertain, because of the differences in the global sea-level constraints. The Jurassic–Cretaceous potentially global unconformities might have been caused by glaciations or MPE, among which the latter appears to be a more likely cause.

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