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Transgressive Surface as Sequence Boundary

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Abstract Analysis of the four cases of the sequence boundary (SB)-transgressive surface (TS) relation in nature shows that applying transgressive surfaces as sequence boundaries has the following merits: it improves the methodology of stratigraphic subdivision; the position of transgressive surface in a sea level curve is relatively fixed; the transgressive surface is a transforming surface of the stratal structure; in platforms or ramps, the transgressive surface is the only choice for determining the sequence boundary; the transgressive surface is a readily recognized physical surface reflected by seismic records in seismostratigraphy. The paper reaches a conclusion that to delineate a SB in terms of the TS is theoretically and practically better than to delineate it between highstand and lowstand sediments as has been done traditionally.

Keywords: transgressive surface, sequence boundary, improvement of stratigraphic subdivision

1 Introduction

In the late of the 90's, Chinese geologists studied sequence stratigraphy in China quite a lot (Shi et al., 1996; Zhang et al., 1996; Guo et al., 1996; Mei, 1996; Xiao and Zhao, 1997; Yan et al., 1997; Ji and Zhang, 1997; Peng et al., 1998; Wang et al., 1999; Zhang et al., 1999). Most of them, following Haq (1987, 1988), divided the sequences by the boundary below a lowstand system tract. The authors consider that it is better to delineate a sequence boundary in terms of the transgressive surface.

2 Cases of SB-TS Relations in Nature

(1) In landward areas around coastal lines, there are no deposits of lowstand system tract or shelf margin system tract, and the sequence stratigraphical boundary coincides with the transgressive surface. In such a case the sequence stratigraphical boundary agrees with the biostratigraphical and chronostratigraphical boundaries (Fig. 1a).

(2) On the shelf covered by shallow water, there are some very thin lowstand remnant sediments or sediments of shelf margin system tract, in which fossil groups are the same as those from the underlying sequence but very impoverished. An new biota, symbolizing a new stage, occurs only at the overlying transgressive surface, so this surface is the chronostratigraphical boundary (CB). Between the traditional SB and CB is a thin interval (SMST). Such a case usually appears in the second-type sequence, or in the first-type sequence of ramp or of platform above the (with remnant sediments) (Fig. 1b). The second-type sequence around the Permo-Triassic boundary of South China is just such a case.

(3) On the slope below the shelf turn and the slope foot, there are well developed and very thick sediments of lowstand system tract, in which organisms are survivors from the underlying sequence. Transgression brings about new organisms and thus the transgressive surface represents the chronostratigraphical boundary, which is clearly higher than the sequence surface by one lowstand system tract (Fig. 1c).

(4) At the basinal depth, the poorly-developed lowstand system tract is in general represented only by a thin condensed bed. The transgressive surface above is usually a condensed surface. Here the sequence boundary and the chronostratigraphical boundary are essentially identical. Detailed examination may distinguish the lower biotas from the upper sequences within a very thin condensed bed and then identify the transgressive surface. However the traditional se-

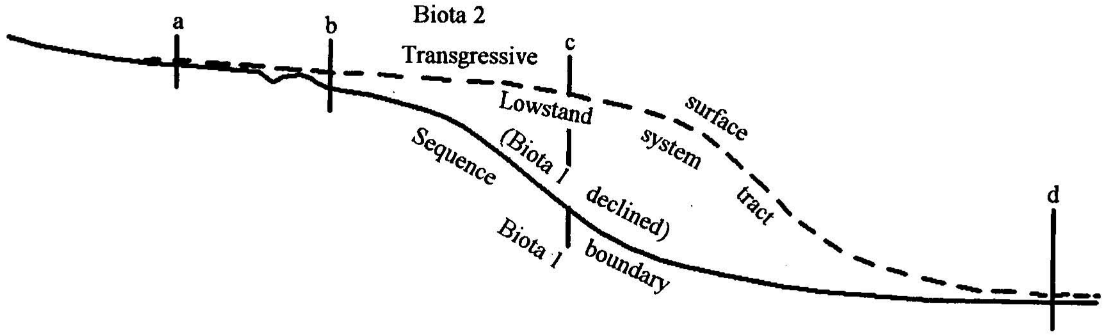

Fig. 1. General relationship between sequence boundary and chronostratigraphical boundary (transgressive surface) (stratigraphical section).

quence boundary immediately below the transgressive surface is theoretically very difficult to be distinguished unless there are lithological markers indicating upward shallowing of the series (Fig. 1d).

3 Merits of Applying TS as SB

Analysis of the above cases shows that applying transgressive surface as sequence boundary has the following merits.

3.1 It incorporates sequence boundary with bio- and chrono-stratigraphic boundaries, thus improving stratigraphic subdivision

The existent studies of sequence stratigraphy show that the traditional sequence boundaries generally do not coincide with the chronostratigraphical boundaries in sections continuously sedimentated. Haq et al. (1987, 1988) established a global Mesozoic and Cenozoic biostratigraphic and sequence stratigraphic framework and sea-level change cycle chart based upon the data of outcrops, drilling wells, seismics and datings of the marine strata from various areas in the world. It is noticeable in their cycle chart that most of the sequence boundaries are lower than the related chronostratigraphical boundaries by about a lowstand system tract or a shelf margin system tract. Therefore, traditional sequence boundaries do not accord with boundaries of chronostratigraphic units, such as system, series and especially stage.

The main cause of such discordance is the different principles as to the delineation of chronostratigraphical boundary and traditional sequence boundary. Most chronostratigraphical boundaries, especially the boundaries of stages, are based mainly on biostratigraphy. The irreversibility and periodicity in the evolution of organisms provide an objective and practicable standard for the subdivision and correlation of geological time. The chronostratigraphical boundaries are established mostly on biological replacement events in the geological history. As organisms are very dependent on living environments, during the evolutionary history remarkable reduction of the ecological space owing to the fall of sea level would aggravate survival competition and then largely extinguish earlier organisms. With the advent of transgression, new ecological space quickly enlarged and new biota originated and developed, indicating the beginning of a new stage. As a result, the chronostratigraphical boundary is generally the sedimentary surface between the lowstand sea level and the subsequent transgression, that is, the transgressive surface (TS). The traditional sequence boundary, however, is produced during the fall of sea level, so it is often lower than the related chronostratigraphical boundary.

If the sequence boundary is delineated by the transgressive surface (TS), it will accord with that of chronostratigraphic boundary and the field distinction of sequence will become much easier as well.

The above-mentioned situations apply to the case that the transgression surface serves for the chronostratigraphical boundary. Nevertheless, some chronostratigraphical boundaries may not be defined by the transgressive surfaces, in which case there are no definite relations between them and the sequence

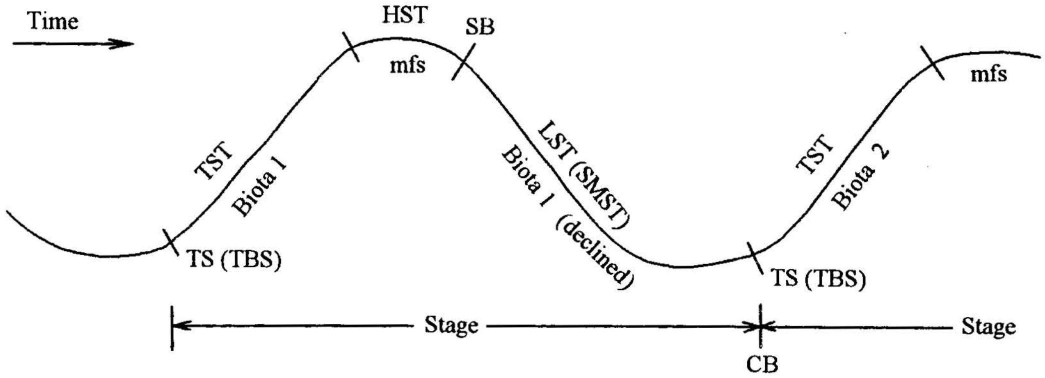

Fig. 2. General relationship between sequence stratigraphical boundary and chronostratigraphical boundary (time curve).

LST: lowstand system tract; TST: transgression system tract; HST: highstand system tract; TS: transgressive surface; TBS: transgressive bio-surface; mfs: maximum flooding surface; CB: chronostratigraphical boundary; SB: sequence boundary

boundaries. In order to ameliorate the markers of chronostratigraphical boundaries, probably we should consistently apply the transgressive surface to the demarcation of chronostratigraphical boundary.

3.2 In traditional sequence boundaries the positions of SB1 and SB2 in the curve of sea-level change are different, whereas the position of transgressive surface in the curve is relatively fixed

In theory, a sequence represents a sea level cycle. Traditionally the top and bottom surfaces of a sequence are placed between highstand sediments and subsequent lowstand (or shelf margin) sediments while the top and bottom of the sequence based on the transgressive surface are situated between the lowstand (or shelf margin) sediments and subsequent transgressive sediments. These two ways to define the sequence are mutually related, but the latter is conceptually better than the former. This is because in the curve of sea-level change the falling rate and range of sea level represented by the first-type sequence boundary are different from those by the second-type sequence boundary, so that the positions of SB1 and SB2 in the curve of sea level change are different (compare Fig. 2 and Fig. 6 of Posamantier et al., 1988). On the other hand, the position of TS in the curve is relatively fixed.

3.3 Usually the traditional sequence boundary is not a transforming surface of the strata structure, but the transgressive surface is

It is often noticed that in the strata without important hiatus the sequence boundary, especially SB2, is neither an easily identifiable event surface nor a clear transforming surface of the strata structure. Since sediments of low sea level, including SMST on SB2 and part of LST on SB1, and the underlying highstand sediments are both progradational, there is no apparent transforming surface of strata structure between them. The stacking patterns of their parasequence sets are similar as well. On the other hand, the transgressive surface is a distinct and important transforming surface of strata structure. The lower part of the transgression system tract above the transgressive surface consists of a rapidly retrograded parasequence set whereas the upper part of the shelf margin system tract or the lowstand system tract is a progradational or aggradational parasequence set, so the boundary is easy to be recognized.

3.4 In platform or ramp, transgressive surface is the only choice

In the second-type sequence and in the first-type sequence with ramp shelf margin, due to extensive erosion and planation of exposed land during the lowstand time, the lowest part of the transgression system tract corresponds to the most rapid onlapping of the deposition (refer to Fig. 12 of Posamantier et al., 1988). This is also the time when the new biota spread most quickly and the deposits with the new biota rapidly covered all kinds of earlier sedimentary facies (see Fig. 1-12 of Yang et al., 1991). Therefore, the transgressive bio-surface is roughly equivalent to the transgressive surface, which is not only suitable for the chronostratigraphical boundary but also of wide comparability.

3.5 Transgressive surface is readily recognized in seismostratigraphy

The development of sequence stratigraphy is closely related to seismostratigraphy (Vail et al., 1977). The basic study of seismostratigraphy is to identify the sequence mainly based on the physical surfaces within the strata reflected by seismic records, which are unconformities and bedding surfaces with velocity-density changes. In fact, the transgressive surface is typically such a surface. It is a physical surface with stratigraphic structural changes in areas with continuous deposition, and accords with the unconformity in exposed areas on land and with the hiatus surface in basin. In the concept of sequence stratigraphy, a transgressive surface is also a hiatus or unconformity, which is shown in Fig. 2: there is an unconformity at a and on a regional scale there is a downlap surface, downlapping on the lowstand system tract at b and c.

It is thus evident that subdivision of sequences on the basis of transgressive surfaces not only is advantageous to the application of sequence stratigraphy in practice but also promotes the integration of sequence stratigraphy with chronostratigraphy, which is of great significance to the development of the sequence stratigraphical theories. Meanwhile, the study of sequence stratigraphy will surely improve and change those chronostratigraphical boundaries which do not accord with the objective reality.

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