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APPLIED PALAEONTOLOGY AND SEQUENCE STRATIGRAPHY IN CARBONATE EPICONTINENTAL PLATFORMS*

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Abstract: Taphonomic and palaeobiological data enable the interpretation of relative changes of sea level, cyclical and of different order of magnitude, occurred in carbonate epicontinental platforms. These palaeontological data are of stratigraphic interest since they provide an independent test of the cycles distinguished in sequence stratigraphy.

Key-words: taphonomy, Palaeobiology, stratigraphic cycles, sea-level fluctuations, sedimentary palaeo-environments, palaeobathymetry.

Résumé: Les données taphonomiques et paléobiologiques permettent l'interprétation de changements relatifs du niveau de la mer, cycliques et d'ordre différent de magnitude, produits dans les plates-formes epicontinentales. Ces données paléontologiques sont d'intérêt stratigraphique car ils fournissent une épreuve indépendante des cycles stratigraphiques distingués dans l'analyse séquentielle.

Mots-clès: taphonomie, paléobiologie, cycles stratigraphiques, fluctuations eustatiques, paléoenvironnements sédimentaires, paléobathymétrie.

INTRODUCTION

Palaeontology has become an applied science in geology through the usefulness of the fossils in the interpretation of the geological record. The development of applied palaeontology had its roots in "stratigraphic geology", when palaeontology was applied to engineering and mining projects at the beginning of the nineteenth century (cf. Schenck, 1940). The most widespread application of palaeontology has been in the dating and chronocorrelation of strata through their fossils. Nevertheless, fossils are valuable also as indicators of palaeoenvironmental conditions. Sequence stratigraphy has been developed during the last twenty years (Baum & Vail, 1998). At the present time, stratigraphy and palaeontology can provide an integrated framework within which to analyse the geological record and within which to infer palaeoenvironmental changes. Stratigraphic and palaeontological evidence obtained from the geological record, about changes in substrate consistence, sedimentation rate, turbulence changes and bottom-water oxygenation, may provide insights into the palaeoenvironmental changes. Stratigraphic and palaeontological cycles represent palaeoenvironmental fluctuations. Sequence stratigraphy and applied paleontology seek to establish a geochronologic framework within which to interpret the geological record and the effects of palaeoenvironmental fluctuations.

The focus of this paper is on the influence that palaeoenvironmental fluctuations exerted on palaeobiological entities and the fossil record, as well as the uses of palaeontological data for the interpretation of stratigraphic cycles and palaeoenvironmental changes, in carbonate epicontinental platforms. The identification of palaeontological cycles is of utmost importance in interpreting transgressive/regresssive cycles of epicontinental platforms, when no evidence of the coastal onlap is observed but the fossiliferous deposits of outer platform are widely developed.

PALAEOENVIRONMENTAL AND STRATIGRAPHIC CYCLES

Stratigraphic cycles result from cyclical palaeoenvironmental changes *(e.g.,* eustatic, climatic and/or tectonic fluctuations). Palaeoenvironmental and stratigraphic cycles are of variable duration (Fig. 1). Sequence stratigraphy recognizes systematic patterns of relative sea-level variation of different magnitude, as represented by stratigraphic cycles of different order (Wilgus *et al.,* 1988; Baum & Vail, 1998; Carter, 1998). In the stratigraphical record it is possible to distinguish stratigraphic sequences and cycles of different order, due to relative sea-level changes. Elementary stratigraphic sequences, parasequences, sets of parasequences, depositional systems, systems tracts, depositional sequences, transgressive/regressive cycles and megasequences or supercycles are genetic terms of stratigraphy, comprising rock bodies of the stratigraphical record.

The continuity of the stratigraphic cycles and their boundaries can be tested using biostratigraphical, biochronological, taphonomic and palaeobiological criteria. Discontinuities in the stratigraphical record may impose truncations on the fossil range data, as well as clustering of first and last appearance datums (FADs and LADs, respectively). Biostratigraphical gaps and biozone truncations *(i.e.,* gaps of the stratigraphical record) may aid in the identification of sequence boundaries and allow to appraise their relative magnitude. Registratic gaps *(i.e.,* gaps of the fossil record) identified by means of ammonites have generally smaller geochronological amplitude than the contemporary stratigraphic gaps, and they enable to ascertain, with greater precision, the episodes of regional emersion in the Mesozoic epicontinental platforms (Fernández-López, 1997b).

Some taphonomic criteria are useful to identify diverse types of sedimentary grounds and sequence boundaries. For example, the occurrence of verticalized remains of nektic organisms may imply very soft- or soupy-grounds. Azimutally reoriented skeletal remains are common at firm- and hard-grounds. Truncation or capping of fossils provides evidence for stratigraphic discontinuity or denudation of the substrate.

Palaeobiological criteria are also useful to identify changes in consistence of successive sedimentary grounds and sequence boundaries. For example, the occurrence of scarce benthos in laminated sediments may imply very soft- or soupy-grounds. Bioturbation textures are common in soft-grounds. Dwelling burrows, such as *Thalassinoides, are* well developed in firm-grounds. Borings and encrusters are very useful in identifying hard- and rock-grounds. Abrupt juxtaposition of disparate biofacies provides evidence for stratigraphic discontinuity.

PALAEONTOLOGICAL CYCLES

Stratigraphic cycles represent palaeoenvironmental fluctuations that also influenced on palaeobiological entities and the preservation of their remains and traces. By analogy with the model developed in sequence stratigraphy, palaeontology can provide a model encompassing a number of scales of process, as represented by palaeobiological and taphonomic cycles. Palaeontological cycles include palaeobiological and taphonomic cycles. Palaeobiological cycles comprise palaeoecological, Palaeobiogeographical and evolutive cycles.

The identification of palaeontological cycles enable to test the genetic differences between the fossil record and the stratigraphical record. The stratigraphical record and the fossil record are different in nature, and they can be studied separately. The fossil record may supply relevant data on palaeoenvironments and processes which have left no traces in the stratigraphical record (Fernández-López, 1997b). The identification of such palaeontological cycles is of utmost importance in interpreting the environmental cycles of Mesozoic epicontinental platforms, when no stratigraphic record is preserved but reelaborated elements are widely recorded.

Models of taphofacies attempt to relate preservational features of fossiliferous deposits to environmental parameters. Taphonomic attributes of fossils are very predictably in stratigraphic cycles because of the dependence of fossil preservation upon rates of sedimentation and environmental energy (Brett, 1995,1998).

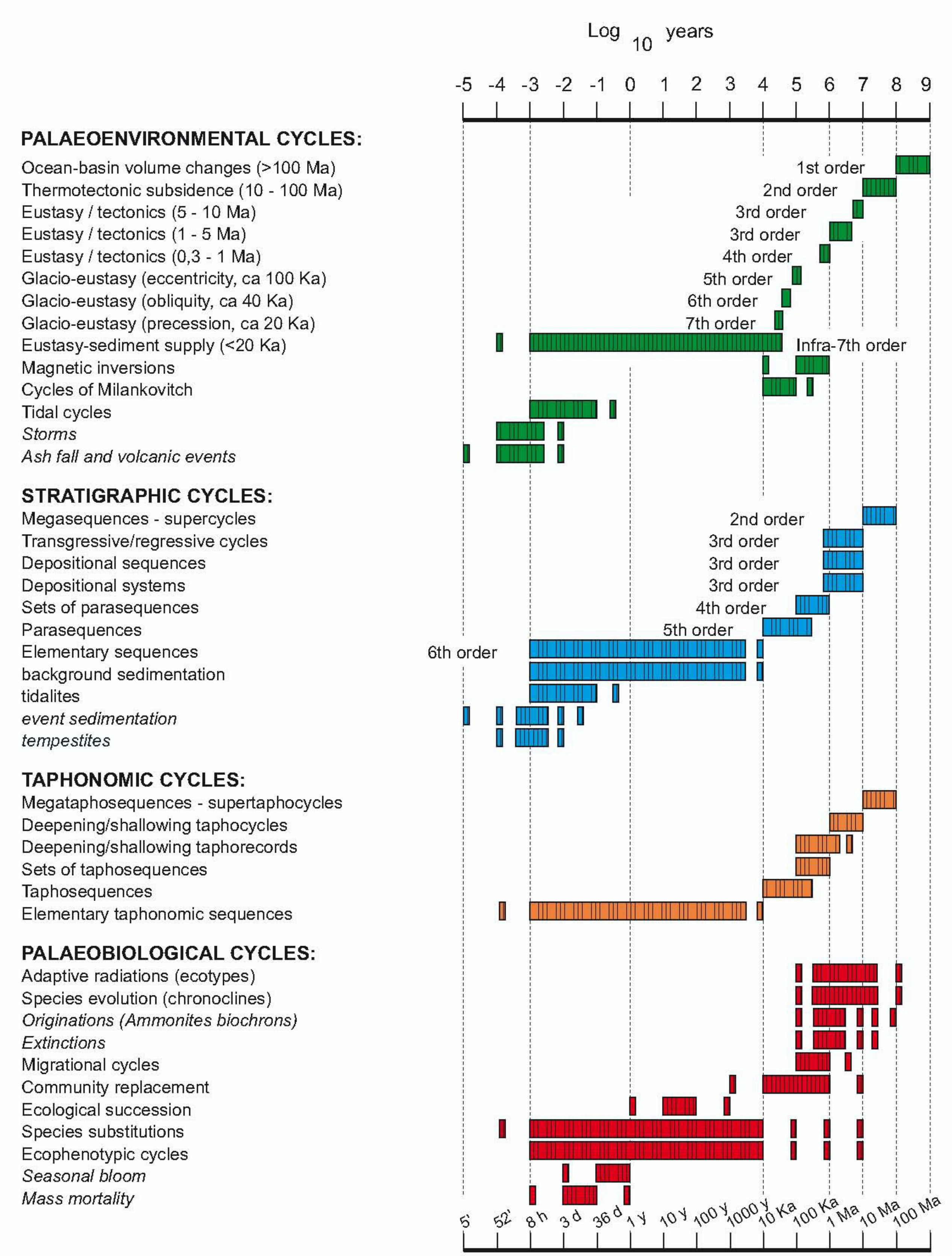

Fig. 1 - Separate orders of sea-level cycles in relation with processes and cycles distinguished in sequence stratigraphy and palaeontology; in carbonate epicontinental platforms.

As a result of cyclical environmental fluctuations, the successive recorded associations of a particular region or sedimentary basin can show cyclical variations in their preservational features. Conditions which are conductive to stabilize, transform or replicate the biogenic remains or the trace fossils can occur cyclically. In particular, some variations of the preservational features and the distribution of the recorded associations in the carbonate epicontinental platforms enable to distinguish taphonomic cycles resulting from relative sea-level changes. A *taphonomic cycle* comprises two or more successive recorded-associations showing cyclical variations in their preservational features, as a result of a palaeoenvironmental cycle (Fernández-López, 1997a, 1997b). Elementary taphonomic sequences, taphosequences, sets of taphosequences, deepening/shallowing taphorecords, deepening/shallowing taphocycles, megataphosequences and supertaphocycles are genetic terms of taphonomy comprising preserved elements, taphonic populations or preserved associations of the fossil record.

Certain patterns of palaeobiological change are correlated with palaeoenvironmental fluctuations through the development of stratigraphic cycles. As a result of palaeoenvironmental cycles, the successive palaeobiological entities of a particular region or sedimentary basin can show cyclical variations in their ecological, biogeographical and/or evolutionary features. A *palaeobiological cycle* comprises two or more successive palaeobiological entities *(i.e.,* organisms, populations or communitites) showing cyclical variations in their ecological, biogeographical or evolutionary features, as a result of a palaeoenvironmental cycle. Palaeobiological cycles are genetic terms comprising organisms, biological populations and communities of the past. Some variations of the palaeobiological entities in the carbonate epicontinental platforms enable to distinguish palaeobiological cycles resulting from relative sea-level changes.

Palaeoecological responses to environmental fluctuations include ecophenotypic cycles, species substitutions, ecological successions and community replacements. A gradational series of variant forms within a taxonomic group can be produced by nongenetic modification of the phenotype as a result of environmental changes through a sedimentary cycle. Iterative ecophenotypic changes of this type constitute successive palaeoecological cycles.

Species substitutions in response to changing environmental parameters may involve changes in taxonomic compositions of associations and relative abundance of (ichno-)species.

Long-term (10's to 100's of Ka) community replacement and lateral shifting of taxonomic gradient (or community-level tracking and lateral shifting of tracking biotas in Brett, 1998; not ecological succession) commonly involves a predictable, facies-related recurrence of species. Migration of facies belts in responses to sea-level fluctuations may yield a predictable pattern of community replacement through stratigraphic cycles.

Patterns of biodispersal may be related to fluctuations of sea level. Major rises in sea level may connect formally isolated biogeographic areas permitting the rapid spread of planktic marine larvae across several sedimentary basins The appearance of exotic species within a particular sedimentary basin can be related to relative sea level rises. Episodic immigration events in carbonate epicontinental platforms, in relation to sea level rises, are typical of nektic forms such as ammonoids and benthic forms with planktic larvae.

Evolutionary responses to palaeoenvironmental fluctuations include originations, extinction, species evolution and adaptive radiations (Hallam, 1992; Sageman *et al.,* 1997). In epicontinental platforms, origination and extinction, cronoclines and ecotypes are commonly related to factors such as relative sea-level, climate, oxygenation and sediment-supply fluctuations that produce stratigraphic cycles. Evolutionary bioevents commonly are associated with boundaries of parasequences and stratigraphic cycles of third order in shallow epicontinental platforms.

Flooding and deepening of epicontinental areas increase habitable ecospace and favor origination of shallow-marine forms and adaptive radiations of stenotopic taxa. In epicontinental platforms, extinctions may be associated with habitat-area reduction during sea level falls, or with anoxic events during sea level rises. Extinctions events, accelerate in situ evolution, and migration may result from the bottom-water anoxia during peak transgressions in shallow epicontinental platforms (Wignall, 1994).

Phyletic evolution, chronoclines or gradational series of evolutive changes in the successive members of a taxonomic group, from primitive forms towards derivate forms, may be a response to environmental changes generating stratigraphic cycles. Some case studies have documented long-term anagenetic changes that appear to relate to parasequences and transgressive/regressive cycles.

Evolutionary changes in response to changing environmental parameters may involve the developement of new ecotypes within a taxonomic group. Evolution of stenohaline species during shallowing phases involved r-selection, favouring paedomorphs, while k-selection operated during deepening phases giving rise to peramorphic forms (cf. Hallam, 1987).

CONCLUSIONS

Taphonomic and palaeobiological data enable the interpretation of relative changes of sea level, cyclical and of different order of magnitude, occurred in carbonate epicontinental platforms. These palaeontological data are of stratigraphic interest since they provide an independent test of the cycles distinguished in sequence stratigraphy. Palaeontological knowledge provide data to identifying stratigraphic cycles and discontinuities. Conversely, the stratigraphic knowledge provide a predictive framework within which to test palaeontological cycles and discontinuities.

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