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Invertebrate Palaeontology and Sequence Stratigraphy: complementary methods and evidence to explain the geological record

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Summary

The fossil record and the stratigraphic record are two components of the geological record different in nature, and they can be separately interpreted and tested in many cases of Invertebrate Palaeontology. Abundance, diversity and stratigraphic persistence are outstanding features of the fossil invertebrates. Therefore, the complementarity (as the capacity of two contrasted theories together to explain a body of phenomena, although each separately accounts for only some aspects) or the consilience (as the fact or condition of being inferred from different phenomena) between Palaeontology and Sequence Stratigraphy through the study of fossil invertebrates is specially useful for the interpretation of the geological record and the palaeoenvironmental changes.

Keywords: Invertebrate animals, fossil record, stratigraphic record, palaeontological cycles, palaeoenvironmental cycles

Invertebrate animals have inhabited the Earth over 600 million years. During that time-interval, populations, species and clades of invertebrate animals have quickly evolved, giving rise to a great variety of taxa. Most of these taxa are extinct and known only from the fossil record. Animals of these extinct or extant taxonomic groups are abundant and have a wide distribution. Moreover, fossil invertebrates show relatively high stratigraphic constancy and persistence. Therefore, knowledge of the fossil invertebrates provides relevant information for dating and chronocorrelation of strata and for the understanding of palaeoenvironmental changes that have taken place, and still are taking place, on Earth's surface. A variety of foci appear to be significant identifying issues and trends in research on Invertebrate Palaeontology and Stratigraphy. We would like to place our remarks in three palaeontological topics of stratigraphic and geological interest, related to the nature of the fossil record: 1) Dissociability of the fossil record, 2) Palaeontological cycles, and 3) Methodological complementarity between Invertebrate Palaeontology and Sequence Stratigraphy.

Palaeontology has become an applied science in Stratigraphy and Geology through the usefulness of the fossils in the interpretation of the geological record. The most widespread geological application of

Palaeontology has been in the dating and chronocorrelation of strata through the fossils they contain. Taphonomic, palaeobiological and biochronological data are relevant in interpreting time-space relationships of fossiliferous rocks, and they are of biostratigraphic, chronostratigraphic and geochronological interest. In addition, palaeontology and fossils are valuable in palaeoenvironmental interpretations. Taphonomic and palaeobiological data are significant in interpreting palaeoenvironmental conditions and changes, and they are of stratigraphic and geological interest. For example, models of taphofacies relate preservational features of fossiliferous deposits to palaeoenvironmental parameters. Stratigraphic and palaeontological evidence obtained from the geological record, about changes in substrate consistence, sedimentation rate, sediment accumulation rate, turbulence water and bottom-water oxygenation, among other, provide insights into the palaeoenvironmental changes (Brett *et al.*, 2011). However, a particular feature of the fossil record can condition the validity of the palaeontological interpretations. The fossil record show stratigraphic disorder (Kowalewski, 1996). At the present time, palaeontological interpretations cannot suppose that the detailed (bed by bed) order of succession shown by the fossils in the stratigraphic record represent the chronological order of the producer taxa. Fossils from the same stratigraphic level can represent successive palaeobiological entities. For example, remains of chronologically successive organisms or taxa can occur in the same stratigraphic level, composing condensed assemblages. On the other hand, fossils contained in successive stratigraphic levels may not represent successive palaeobiological entities. For example, remains of the same organism, population or community may occur in several successive stratigraphic levels. Moreover, palaeontological interpretations cannot suppose that fossils and rock bodies of the same geological interval represent the same time interval and the same palaeoenvironment. The time-partiality or the continuity of the fossil record, understood as the proportion of geochronological intervals represented in the fossil record, is not controlled or limited by the continuity of the stratigraphic record. The fossil record and the stratigraphic record at a particular geological interval can represent different time-intervals and separate palaeoenvironments. In particular, the fossil record can supply data on palaeoenvironments and processes which have left no traces in the stratigraphic record. Consequently, the fossil record and the stratigraphic record should be considered as two separable components of the geological record. These two geological components are different in nature, and they can be separately interpreted and tested (Fernandez-Lopez, 1999).

Time-space relationships among fossils from a bed or from the same facies can be established taking into account taphonomic and palaeobiological criteria. For example, the succession order of the fossils from a condensed association can be ascertain considering exclusively taphonomic and palaeobiological criteria. This method allows to identify palaeontological successions composed of fossils, which represent time intervals different to those of the stratigraphic levels and palaeoenvironments of the including deposits. Local biostratigraphic successions, composed of successive fossiliferous rock bodies, and local palaeontological successions, composed of successive fossils, can differ in number of successive components and in chronological order. Palaeontological successions can be more resolutive, showing higher geochronological completeness, than biostratigraphic successions or successive facies. The concept of palaeontological succession is so important to interpret the fossil record, as the concept of stratigraphic succession is needed to interpret the stratigraphic record. Models of taphofacies relate preservational features of fossiliferous deposits to environmental parameters. Taphonomic attributes of fossils are very predictably in facies analysis and stratigraphic cycles because of the dependence of fossil preservation upon rates of sedimentation and environmental conditions. However, it is useful to distinguish between taphofacies, composed of rock bodies of the stratigraphic record, and taphorecords, composed of fossils of the fossil record (Courville & Collin, 2002; Pavia & Martire, 2009; Zunino *et al*., 2012). From a palaeontological point of view, it is also important to distinguish between fossils and producer organisms or, in a general way, between taphonomic entities and palaeobiological entities. Fossils are not palaeobiological entities. Fossils are remains or traces produced by biological entities of the past. Consequently, in the palaeontological researches should be distinguished among components of three different categories: the stratigraphic record, the fossil record or the taphonomic entities, and the biosphere or the biological entities. Palaeontological and stratigraphic data enable to analyse and explain palaeoenvironmental changes, cyclical and of different order of magnitude, which affected the development of palaeontological and stratigraphic cycles. Palaeoenvironmental changes, which have conditioned the development of stratigraphic cycles, have also affected to the production of 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 (Catuneanu *et al.*, 2011), Palaeontology can provide a model encompassing a number of scales of process, represented by palaeobiological and taphonomic cycles. Palaeontological cycles include palaeobiological and taphonomic cycles, two references different in nature. 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 region or sedimentary basin can show cyclical variations in their ecological, evolutionary and biogeographical features. A palaeobiological cycle comprises two or more successive palaeobiological entities (i.e., organisms, populations or communities) showing cyclical variations in their ecological, evolutionary or biogeographical features, as a result of a palaeoenvironmental cycle. Palaeobiological cycles are genetic terms comprising organisms, biological populations and communities of the past (Oloriz *et al*., 2012).

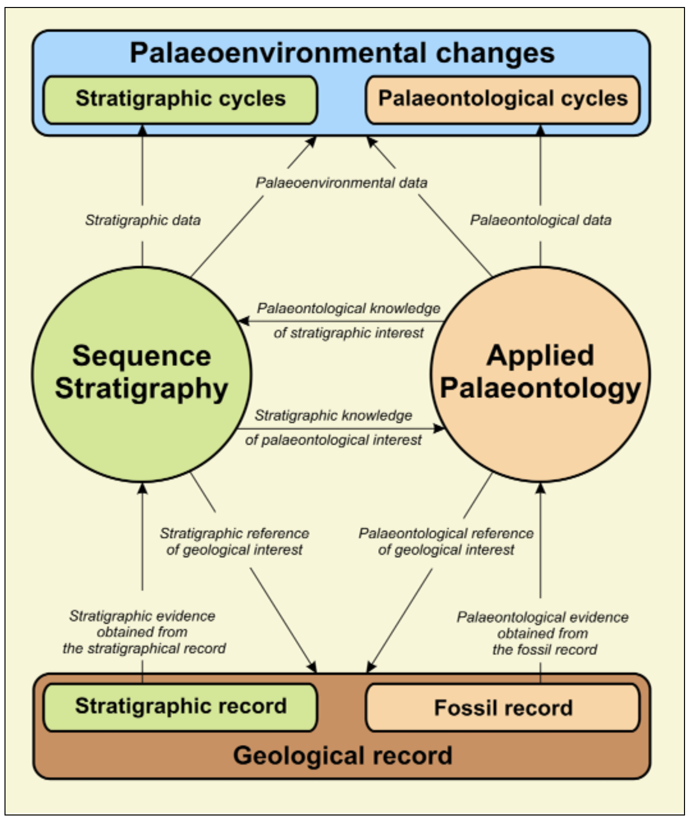

Fig. 1 – Flowchart of knowledge between Sequence Stratigraphy and Applied Palaeontology. The stratigraphic record and the fossil record are two dissociable components of the geological record, containing complementary information useful for establishing an integrated interpretation of the geological record. Stratigraphic and paleontological data independently allow to analyse and explain the cyclicity of the geologic record and the palaeoenvironmental cycles.

The successive fossils of a certain region or sedimentary basin can show cyclical variations in their preservational features, as a result of cyclical environmental fluctuations, too. In particular, some variations of the preservational features and the distribution of the fossils in the carbonate epicontinental platforms enable to distinguish taphonomic cycles resulting from relative sea-level changes. A taphonomic cycle comprises two or more successive fossil-assemblages or recorded-associations showing cyclical variations in their preservational features, as a result of a palaeoenvironmental cycle. 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 associations of the fossil record (Fernandez-Lopez, 2012). For example, on the basis of the changes in the preservation state of the successive ammonite fossil-assemblages, it is possible to distinguish taphorecords, taphocycles, megataphosequences or supertaphocycles resulting from relative changes of sea level. These are genetic terms of evolutionary taphonomy comprising preserved elements, taphonic-populations or taphonic-associations of the fossil record (Fernandez-Lopez, 2007). Gaps in the fossil record, associated with gaps between successive stratigraphic cycles and identified by means of ammonites, have generally smaller geochronological amplitude than the contemporary stratigraphic gaps. Therefore, gaps in the fossil record are more accurate than stratigraphic gaps to ascertain the episodes of regional emersion in the epicontinental platforms.

Although it seems to be generally accepted that the stratigraphic record has been driven by palaeoenvironmental cycles, relatively few studies have assessed the cyclicity of the fossil record. However, stratigraphic cycles represent palaeoenvironmental fluctuations that also influenced on palaeobiological entities and the preservation of their remains and traces (Fig. 1). By analogy with the model developed in Sequence Stratigraphy, Palaeontology can provide a model encompassing a number of scales of process represented by palaeobiological and taphonomic cycles. Palaeontological knowledge is of stratigraphic interest, providing data to identifying discontinuities and cycles in the stratigraphic record. Conversely, stratigraphic knowledge is of palaeontological interest, because it provides a predictive framework within which to test palaeontological cycles and discontinuities. At the present time, Sequence Stratigraphy and Palaeontology, in particular Invertebrate Palaeontology, can develop an integrated and predictive conceptual system within which to analyse the stratigraphic record and the fossil record, and within which it is possible independently to interpret and to test the cyclicity of the diverse components of the geological record as well as the palaeoenvironmental cycles.

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