Quantitative approach to biochronology. CONOP and Unitary Associations, a comparison between two deterministic methods

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Abstract

Biochronological correlation is an indispensable tool for basin analysis and geological studies in sedimentary terranes. In some cases the zonations on which correlations are based are precise and correct enough to permit well-constrained results. But in many cases the results are poorly constrained and produced by an ill-defined zonation with poor resolution. This is generally caused by discontinuous fossil record and contradictory identifications resulting in cyclic relationships between taxa.

A quantitative approach to biochronological correlation can improve the resolution. Some recently published examples (Cody et al., 2008; Sadler et al., 2009) can reach a very high and amazing level of resolution. Cody et al. (loc.cit.) for example calculated a biochronological scale for the Neogene based on Antarctic diatoms (including paleomagnetic data), which reaches a resolution level that is more than one order of magnitude greater than empirical zonations previously established. These results were based on the method known as “constrained optimization” (Kemple et al., 1995) and obtained using the program CONOP (Sadler 2006).

We tested the reliability of the results proposed by Cody et al. using an alternative quantitative method known as Unitary Associations (Guex 1991) and the software UAgraph (Hammer et al., 2009, available at http://folk.uio.no/ohammer/uagraph).

From one point of view, the two methods are similar because both are deterministic quantitative tools. They differ in the sense that CONOP produces sequences of events and is based on an heuristic-like search for solutions which are closest to the best one (simulated annealing), whereas Unitary Associations constructs discrete sequences of coexistence intervals of species and is based on graph theoretical algorithms.

Both methods must deal with cyclic relationships between taxa. In CONOP's philosophy, the stratigraphic problem is considered as NP-complete and for this reason an heuristic-like approach is needed. On the other hand, the Unitary Associations philosophy considers that the number of computing operations necessary to obtain a result is linearly proportional to the number of samples and to that of the taxa involved (see Galster et al., 2010 for a comparison between the two methods).

Our comparative results show that CONOP's solutions have a level of resolution comparable to UA's results if we restrict the analysis to the maximal intersections of the resulting ranges and the level of resolution is slightly higher than the ones produced by empirical approaches.

The scaled sequence of first and last occurrences (FO and LO) given by CONOP is essentially based on an algorithm which does not allow treatment of the inter FO's and LO's cyclic relationships. A consequence of this is that the outputs do not precisely match the local sequences observed in the input. In other words, this program produces best-fit interval values that are not univocally related to the amount of implications of the events (FO/LO) within cyclic relationships.

The Cody et al. (2008) data have been analysed with the UAgraph software, producing a first solution with a resolution comparable to that of an empirical approach or to CONOP solution reduced to its maximal intersections. In a second run, we have selected some non-diachronous first and last occurrences of taxa together with some paleomagnetic and radiochronologically dated events. This allowed us to increase dramatically the stratigraphic resolution of the final output.

Our main conclusion is that the use of first and last occurrences should only be done after an analysis of the diachroneity of the datums, i.e. events occurrences that are located above some maximal intersections in some localities and below the same intersections in other localities. Detection of cyclic relationship is essential for estimating the quality of the record and the reliability of the resulting zonation. UAgraph is a unique tool, for dealing with this kind of problem.

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