KÁZMÉR, M. (ed.): Shallow Tethys 6 Symposium Proceedings, 25-29 August 2003
Hantkeniana 4, 13—15, Budapest, 2004

Tethyan benthic faunal spreading and climatic cycles

Giuliano PICCOLI[1]

2 figures

A mathematical model, of exponential type, links the amount of benthic species shared by interconnected sea basins to their mutual distance. The parameters of the equation depend on the obstacles to benthic organisms spreading, both of physical and biological type. The mean values of the spreading possibility in the different epochs through the Tethys history show a cyclic variation, due to climatic reasons controlled by astronomical factors.

A mathematical model in benthic paleobiogeography, proposed by the author and his collaborators, links the amount of species shared among connected sea basins with their mutual distance. The method consists in processing the paleontological data, it is to say the list of fossil species recorded for each investigated basin, and compare the amount of shared species with the distance between the basins of each considered couple. It was developed, at the beginning of the research, for the Cenozoic Tethys, with its subbasins and connected sea areas as Paris basin in France, SW Japan and Eastern Australia. Later on it was extended back in time to the Mesozoic and the Permian, for the whole time span of existence of the Tethys. The organisms inquired for this research are the shallow benthic molluscs and the brachiopods, added to the molluscs because of their greater diffusion in the Paleozoic and early Mesozoic.

Several types of equations fit the experimental data, but the best resulted to be the exponential model. This model shows that the amount of species shared among the considered basins decreases with the increase of their reciprocal distance, in proportion with the stock of spreading species; it drops down to zero within a short time when the connection ceases. It never reaches negative values, which would be nonsense, nor requires an infinite number of migrating species, which would be another nonsense; some models do that. 243 species of brachiopods have been used in calculations for the Permo-Triassic, 468 for the Jurassic, 159 for the Cretaceous, and 45 for the Cenozoic; 452 species of benthic molluscs have been considered for the Permo-Triassic, 499 for the Jurassic, 1659 for the Cretaceous, and 2453 for the Cenozoic. It must be said that even shorter fossil lists in respect to those used in the present calculations could give reliable results.

The equation which expresses the exponential model is $dN/N=-kdL$ and its integrated form results $N=N_o$ e exp-kL, where N is the number of species at the considered distance L, N_o is the number of species at the origin (L=0), k is a proportionality coefficient linked to the hampers for species spreading, both of physical and biological nature (because of its negative value; if positive it would be linked to the ease of diffusion). Among the physical hampers there are geographic barriers, climatic difference and its gradient, water temperature, salinity and clearness, anoxia, prohibitive depth for larvae settling, among the biological hampers we list species competition, predation and parasitism, seasonal shortage of food supply, and in recent time eutrophication due to human activity. The aim of the method is to improve paleogeography through paleobiogeography.

Apart from separate calculations and diagrams for each origin epoch by epoch, a general average evaluation was accomplished for each epoch. The result can give an idea of the conditions in the Tethys from time to time: the variation of the average diffusion length illustrates the amount of the hampers to benthyic organism spreading through geologic time. Tethys developed more or less along the parallels and the conditions can be reasonably compared with those of the present day Indo-West Pacific bioprovince, which hosts the biological Tethyan heredity.

[1] Department of Geology, Paleontology and Geophysics, University of Padova, Via Giotto 1, I—25137 Padova, Italy. E-mail: giulianopiccoli@hotmail.com

The heaviest faunal turnover in the Earth history, at the boundary between Permian and Triassic, does not prevent the validity of the proposed method both before and after such event. The spreading of marine animals was easy and wide in the Sakmarian, Scythian and Carnian, as far as the Permo-Triassic is concerned. The diagrams of the reported figures show the connected results of the calculations.

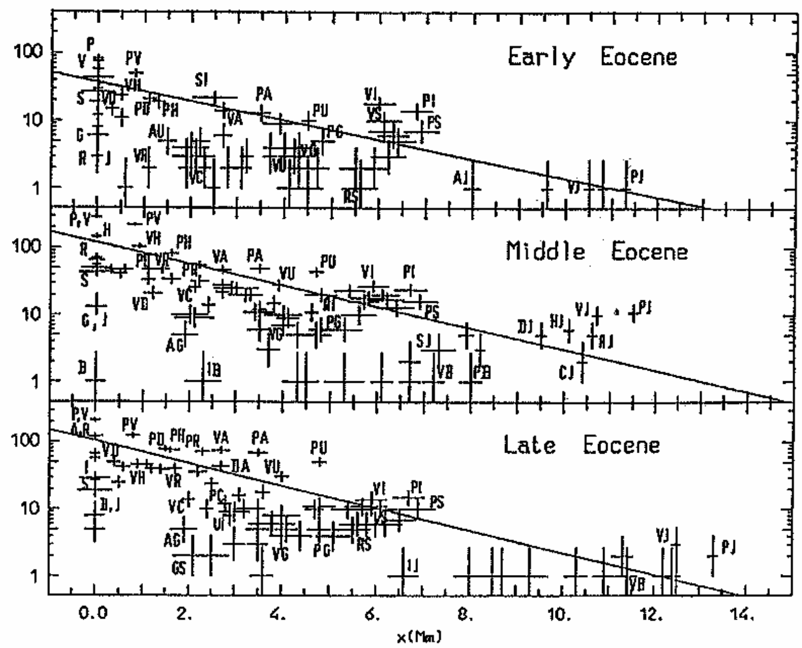

Fig. 1 - Example of the results of the exponential model, for the Eocene: number of species shared among basins versus interbasinal distance, in semilogaritmic scale (Piccoli et al., 1991). The exponential curves plotted in such scale become straight lines. The steeper is their slope, the shorter is the organism diffusion. The difference among the examples for the Eocene seems to be evident. The letter marks indicate the considered Tethyan and connected sea basins (P = Paris basin, V = Venetian region, D = upper Danubian basin, H = Pannonian basin in Hungary, R = Romania, especially Transylvania, A = Armenia and southern Georgia, U = Ustjurt-Uzbekistan in Central Asia, C = Cyrenaica and Libya in general, S = Somalia and eastern Ethiopia, G = lands around the Persian Gulf, I = India and Pakistan, B = Burma (Myanmar) and Assam, J = Java and nearby Indonesian islands.

The model registers the low spreading possibility of the considered organisms after the end-Triassic extinction, which was drastic especially in the European realm of the Tethyan belt. The effects of the rapid changes in coastal onlap in the Liassic lead to an increase of hampers for the marine benthic organisms diffusion, followed by a more favourable situation in the Dogger-Malm: The opening of the Spanish Corridor in America is perceived by the method. Thereafter, the widening of the young Atlantic Ocean caused the splitting of the Tethys in two separate branches, an American section and an Euro-Afro-Asian section. From that time we disregarded the American area in the calculations, with its different fait.

The wide sea onlap onto land in the early Cretaceous was followed, after some time, by the maximum spreading ease for the shallow benthic animals in the Tethys history, especially in the Cenomanian. The Turonian oceanic anoxia and the Maastrichtian cooling and regressions lead to the lowering of the spreading possibility. The main extinction at the K/T boundary does not prevent the validity of the exponential method.

After the Cretaceous, a continuous decrease of faunal diffusion ease occurred in the Paleogene. The drop was not linear, but had a wavy course, in connection with the climatic cycle of about 26 million years (see below). It was soon followed in the early Neogene by the final disruption of the Tethys, caused by the motion of the Afro-Arabian tectonic plate up to the collision with the Euro-Asian plate, as it is well known. Two separate basins were formed thereafter, the Mediterranean Sea and the Indian Ocean. The post-Tethyan Quaternary, with its glaciations, is out of the limit of the present research.

The use of the method allowed evaluating and correcting some current paleogeographic reconstruction. This is for instance the closure time of the direct connection between Paris Basin and Mediterranean via Rhone Valley; after its closure, in the early Oligocene, the way of spreading became that of Gibraltar Strait and its length increased from about 800 km to 4000 km. The model indicates the time of this event, because the shared species decreased accordingly.

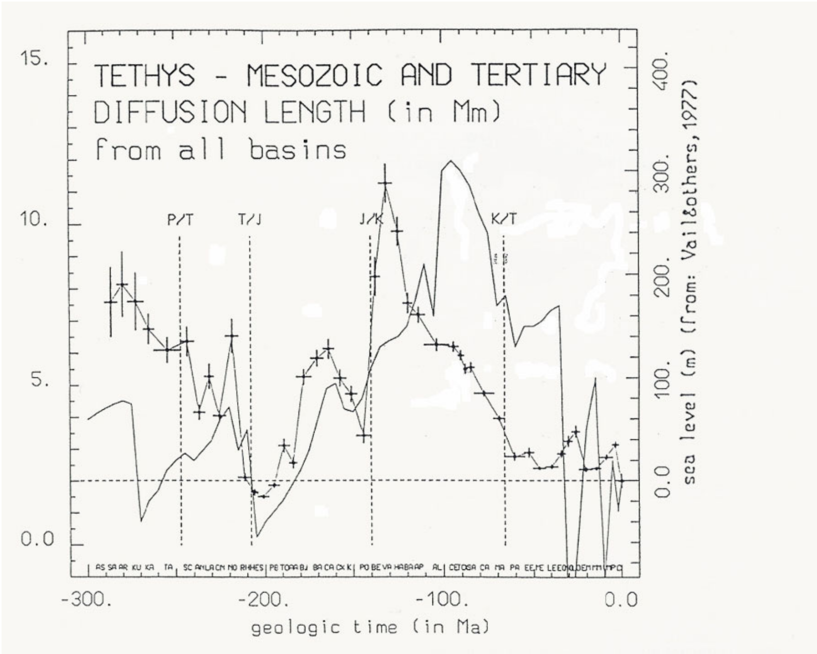

Fig. 2 - Comparison of the mean diffusion length of brachiopods and benthic molluscs on the Tethys continental shelfs with the Vail curve of eustatic sea level changes through time (Baggio, Sartori, Piccoli, 1999).

The resolution power of biostratigraphy gave the size of our time grid. It ranges between 3 and 5 million years. The turnover of faunas through geologic time does not affect the results obtained with the method, nor do the dramatic extinctions that occurred at era boundaries.

The variation in time of the parameters of the exponential equation is ruled by the climatic cycle of 26 million years, due to astronomical factors, it is to say to the well-known galactovertical movement of the Solar System during its turning around the Milky Way centre. It came out to be valid as back as 100 million years ago, after the results of our study. For older times a more complex cycle, with harmonics of an upper order, seems to control the climatic fluctuations. According to some astronomers, the movement of the stars nearest to the Solar System should be the responsible for such a gradual difference from the Permian onward.

For references see:

PICCOLI G. (2002): Quantitative faunal exchange in the Tethys and climatic cycles. – Memorie di Scienze Geologiche 54, 9—17, 4 figs, Padova. It contains a long list of pertinent publications.