Paleogeography as a Step to Stratigraphic Synthesis: The Neogene of Central and Eastern Europe

by János Halmai and Géza Hámor

One of the first projects to be sponsored by the International Union of Geological Sciences under its Research Development Programme began in 1982 under the title "Paleogeographic Map Series of the Neogene in Central and Eastern Europe on the scale of 1:1,500,000." Proposed and coordinated by the Hungarian Geological Survey, this was itself a follow-up to IGCP Project 25, "Stratigraphic Correlation Tethys-Paratethys Neogene," and involved 94 scientists from 11 countries. In this article the authors discuss several important issues that emerged from the project and outline a possible follow-up now being considered by IUGS and IGCP. (Ed.)

Some Fundamental Requirements

In recent decades, many paleogeographic maps and charts of different regions and different time intervals have been prepared. For the most part, these maps show paleobiogeographic units and distributions of sedimentary deposits, because they were designed primarily to verify stratigraphic correlations already carried out.

The authors believe that a proper stratigraphic evaluation should involve observation of every detail and that the conclusions should be verified quantitatively using a dynamic approach to space and time. However, the general practice nowadays is to study stratotypes or parastratotypes at selected points, with checking and correlation carried out in a deductive manner. Thus some modern paleogeographic reconstructions are restricted to the time of an isolated series of events, or even to a single event (e.g. FAD of Praeorbulinae). In extreme cases an analysis is carried out based only on published data concerning an area that is never actually seen by the author of the reconstruction.

The uncertainty of such an approach may be exemplified by the well-known difficulties of correlating marine, brackish and terrestrial facies. In fact, even the correlation of marine macrofaunal, benthonic foraminiferal, planktonic foraminiferal and nannoplanktonic zonations can be extremely difficult.

We believe that event stratigraphy offers a more promising approach to paleogeographic reconstruction. This requires the use of litho-, bio- and chronostratigraphic units in order to reveal the causal relationships between the events involved and to allow for testing and possible spatial extrapolation of qualitative and quantitative results. We are convinced that the assessment of a history of vertical events and of the spatial distribution of those events will constitute a step forward. Basically, the "general" should be distinguished from the "particular," and real or apparent contradictions should be eliminated. In this way it may be possible to judge the firmness of the conclusions by determining whether they are based on the study of a profile or on serial analyses performed in a consistent way. This approach will also restrict the validity of a conclusion in a topographic sense.

The final step in a full and proper stratigraphic synthesis cannot be taken until all necessary information is available, all the possible ways of evaluation are used, and the results are fully tested. The synthesis should thus involve lithostratigraphic and biostratigraphic analysis, determination of biozones, radiometric and paleomagnetic data, and the identification of micro-, meso- and mega-cycles, sequence stratigraphy, unconformities, hiatuses, tectonic phases, orogenic cycles, geofacies and transgression-regression processes. Complete information is also required on changes in time and space along profiles, cartographic registration, tectonic control, and geodynamic-palinspastic reconstruction. Paleogeographic reconstruction must be a step towards stratigraphic synthesis.

Figure 1: At the 1985 RCMNS Congress in Budapest where the first project results were presented. Photo by L. Zambo.

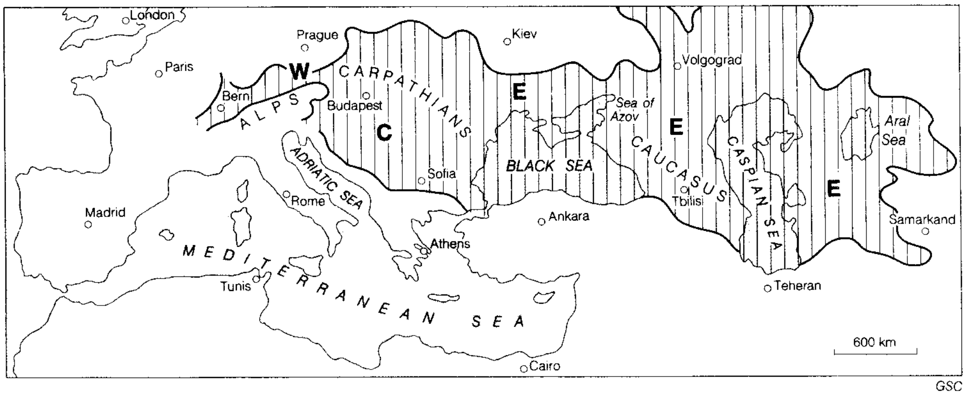

Figure 2: Sketch map of Paratethys. W - western, C - central, E - eastern regions.

The Neogene of Central and Eastern Europe

A wealth of fundamental information on the Neogene of central and eastern Europe has been published, particularly during the last 25 years, for the region is considered to have been the cradle of Neogene research. Important landmarks in this work have been the congresses organized by the Regional Committee on Mediterranean Neogene Stratigraphy (RCMNS) of the IUGS Subcommission on Neogene Stratigraphy (see Figure 1 and report on the 8th RCMNS meeting by J.E. Meulenkamp in Episodes, December 1985, p. 268-69, and list of congress publications on p. 285 of same issue).

Many descriptions of the stratigraphic stages of the Mediterranean-Paratethyan Neogene have been published (e.g. Carloni et al., 1971; Steininger and Nevessakya, 1975; Steininger et al., 1985 - for IGCP 25), especially in the monograph series "Chronostratigraphie und Neostratotypen," of which the six volumes published by the Slovak Academy of Sciences and one by the Hungarian Academy of Sciences present the joint results of IGCP Project No. 25 and RCMNS Working Group for the Paratethys. A general summary of IGCP Project 25 was also published by Senes (1985).

Thus, for the Mediterranean-Paratethyan realm we have data that when synthesized and presented in terms of the basic concepts outlined above, may enable scientists dealing with the Neogene Period all over the world to find common grounds for a simplified global chronostratigraphy, instead of the more than 100 chronostratigraphic units described, many of which are in everyday use in the Mediterranean, Paratethyan and Pacific regions. Although we seem to be very far from achieving that goal, the IUGS-sponsored project "Neogene Paleogeography of Central and Eastern Europe" may allow us to take a few steps forward.

The Project Area

The Atlantic-Boreal, Mediterranean-Tethyan, Paratethyan and Indo-Pacific paleogeographic units were already in existence by the end of the Oligocene, and their development throughout the Miocene was sometimes independent, sometimes shared. Nevertheless, each unit today is the end result of a different geodynamic environment and evolution, with the Paratethys of particular importance because of the wealth of information available.

In broad terms Paratethys formed in the zone of contact between the Eurasian and African plates (Fig. 2). Because of the pulsation of the plates (convergence, divergence, vertical movements, etc.), such marginal basins are extremely active tectonically, and they respond rapidly to geological events of continental or global scale. As a result there are rapid temporal and spatial changes in facies throughout Paratethys, as well as variations in space and time between its various faunal and floral associations. Correlations are accordingly difficult between Central and Eastern Paratethys and between Paratethys and the Mediterranean. Other important features of Paratethys are the extremely important role of magmatism, changes in sea level, transgression processes, unconformities and hiatuses. The fact that at the time of the Middle Miocene maximum water coverage, the Paratethys was about twice the size of the Mediterranean today emphasizes the importance of the study area.

The IUGS project area extended from the Rhine Graben in the west to the Urals-Caspian Sea in the east and from 42°N to 52°N latitude. This area includes almost the whole of the Paratethys in Europe, the most important regions of possible marine communication with the Atlantic-Boreal, the western and central Mediterranean, the Indo-Pacific areas, and such areas of fundamental importance for geodynamics as the Alps-Carpathians-Dinarides zone, the Caucasian orogenic zone, and the southern part of the Eurasian Plate, including the Russian Platform.

The map scale used was 1:1,500,000, that of the topographic base-maps provided by the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) in Hannover, F.R.G., and, incidentally also used for the Hydrogeological Map of Europe (Fig. 3).

Time Horizons and Map Legend

The time horizons mapped in the project were selected so that they included short spans of time, wherever possible

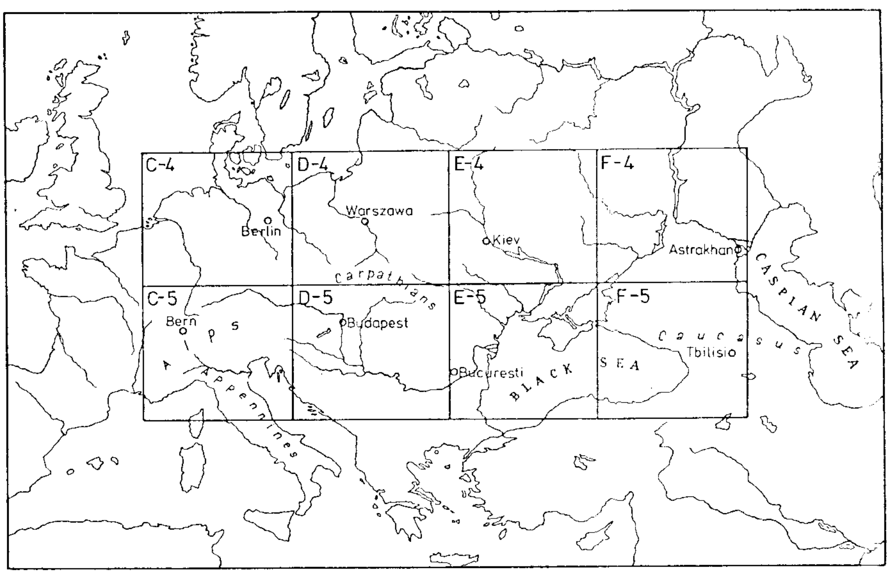

Figure 3: Regional coverage of the topographic base maps used in the project.

portraying important geological events such as the Oligocene/Miocene and Miocene/Pliocene boundary (see Hámor, 1983, for a discussion of the methodology involved). Examples of other events portrayed include the effects of the worldwide Early Miocene transgression, the establishment of marine communication between the Mediterranean and the Paratethys, and the peculiar Late Miocene-Pliocene geohistory of the Paratethys. Paleogeographic changes due to tectonic deformation, the causes responsible for them, and the process of folding of the Alps-Carpathians-Dinarides system were also investigated, and attempts were made to establish the synchroneity or heterochroneity of the major faunal-floral zones, and to check the paleobiogeographic concepts used. Efforts were also made to determine the causes and roles of volcanic events and salinity crises, as well as the reasons for the difficulties in correlating between the Mediterranean and the Paratethys and the Eastern and the Central Paratethys.

A detailed legend was worked out for the project maps (Table 1), using both surface and drill-hole data. Among the more than 60 elements used are many that may involve controversy, such as those dealing with geofacies and environment. However, compared with other paleogeographic charts, this scheme with its "dynamic" legend referring to volcanism, tectonism and so forth, has the advantages of restricting the hypotheses involved, representing true data, and using statistically evaluated quantitative data on lithofacies and radiometrics. The result is an integration of the paleontological, geological and geophysical information and a high level of understanding of the geological history of the area mapped (Fig. 4). The most important factor is that the paleogeographic reconstruction is based on realistic facies studies and that it represents both the paleomorphology and the paleoenvironment.

TABLE 1: Legend Used in the Project Maps.

GENERAL SYMBOLS

1. total thickness of the formation belonging to the represented time interval
2. geofacies boundary
3. lithofacies boundary
4. shoreline (distinct or suggested)
5. shoreline (supposed)
6. direction of transgression
7. direction of regression
8. direction of marine transport
9. direction of terrestrial transport
10. fauna remains
11. flora remains
12. reef/bioherm

LITHOFACIES

1. psephite
2. psammite
3. pelite
4. calcirudite
5. calcarenite
6. calcilutite
7. dolomite
8. evaporite (in gen.)
9. coal, lignite, bituminous rock
10. diatomite
11. siliceous rock
12. basic lava
13. intermediate lava
14. acid lava
15. basic pyroclastic
16. intermediate pyroclastic
17. acid pyroclastic

Note: lithofacies 1-3 to be shown when more than 33%, 4-16 when more than 50%

Geofacies and/or lithofacies in "window": deposits of the same sedimentary cycle covered by syngenetic overthrust

Tectonics in "window": syngenetic overthust covered by the orogen

GEOFACIES/PALEOENVIRONMENT

1. land effected by (heavy) erosion
2. land with sediments unknown
3. desert
4. fluviatile
5. lacustrine-paludal
6. deltaic
7. brackish - pannonian type
8. brackish - meotian-caspian type
9. lagoon
10. littoral
11. near shore
12. off shore

SEDIMENTATION TYPE

1. turbidite

VOLCANISM

1. volcanic center
2. mud volcano
3. volcanic fissure
4. terrestrial volcanism
5. submarine volcanism
6. MaBP/number of radiometric measurements

TECTONICS

1. present-day "front" of the Carpathian-Alpine range
2. present-day boundary between the Vorland-Molasse and Subalpine-Molasse
3. area uplifted, folded as a result of active compression
4. active tensional graben structure
5. active fault
6. active transcurrent fault
7. active overthurst
8. basin structure
9. basin axis
10. active uplifting area
11. active subsiding area
12. magmatic massive uplifted.

Project Organization

The actual map compilation involved the meticulous work of specialists from 11 different countries, many of whom had made important contributions to IGCP Project 25. To organize the institutional input in the particular countries involved (Austria, Bulgaria, Czechoslovakia, Federal Republic of Germany, Hungary, Italy, Poland, Romania, Switzerland, U.S.S.R., and Yugoslavia) was crucial, for the collecting of data for the maps and their compilation required great efforts.

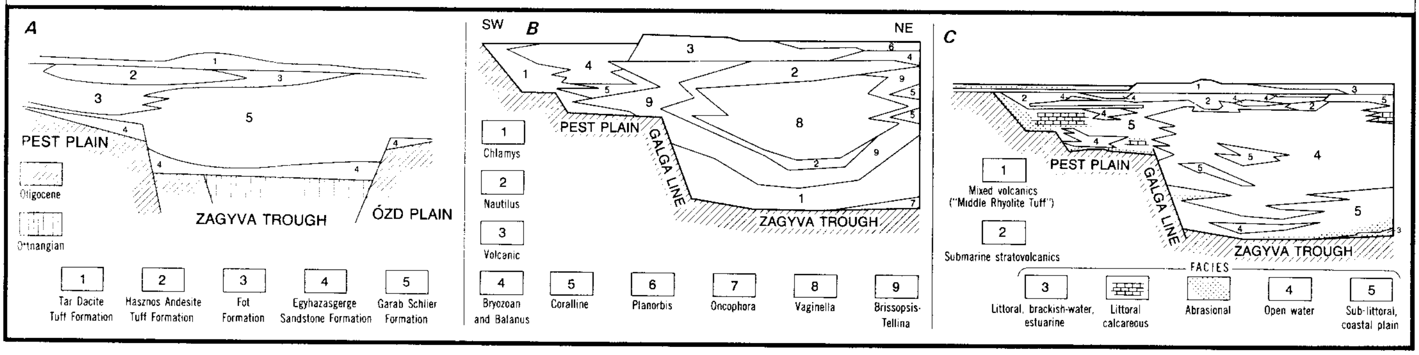

Figure 4: Integrating geological data on the Nograd-Cserhat area, northeast of Budapest. A - Miocene formation boundaries for the Early Styrian (Karpathian) Sedimentary Cycle. B - Biofacies section. C "geofacies" section. After Hámor (1983), Figs. 1, 3 and 4.

Most of the compilation was done in the countries concerned but, of course, bilateral and multilateral consultations were indispensable, with official meetings held in Veszprém (Hungary, 1982), Bratislava (Czechoslovakia, 1983), Budapest (Hungary, 1984), Visegrád (Hungary, 1985), Budapest (Hungary, 1985), and Salgótarján (Hungary, 1986). Important sessions were also held in Florence (Italy, 1984), Moscow (1984), the Caucasus (U.S.S.R., 1985), and Salzburg (Austria, 1986). Consultations were held with international organizations such as RCMNS, the Sedimentological Commission of the Carpathian-Balkan Geological Association (CBGA), the Molasse Working Group 3.3. of the Socialist Academies' Problem Commission IX ("Geodynamics and Metallogeny of the Earth's Crust"), and IGCP Projects 25 and 124.

Project Results

Final drafts of seven maps and four "satellite maps" have now been completed (Fig. 5), and publication by the Hungarian Geological Survey is scheduled for late 1987-1988. An accompanying summary explains the choice of the particular time horizons (based e.g on biostratigraphy, radiometric data, paleomagnetic results, superposition), the tectonic event responsible for the particular paleogeographic setting, and the major elements of the paleogeographic situation represented (e.g. facies conditions, transport direction, thickness-genesis interpretation, paleobiogeographic connections; syn- and post-depositional tectonic deformation, and palinspastic relationships).

The maps are the first to show the paleogeography of such a big area on the basis of the same principle (method, legend etc.). They represent the first test in space of the Paratethyan regional stage system as a control of its earlier usage in time, and the first revision of the orogenic cycles (in the sense of Stille) in time and space.

The project should inspire further research into stratigraphy, for example, into difficulties in correlating marine, brackish and terrestrial deposits and different faunal-floral associations, and between Mediterranean, the Tethys and the Paratethys. The maps also document the extent of agreement between migration and "local" evolution. They introduce a new approach and new elements in stratigraphic correlation such as magmatic processes, tuff horizons, geodynamic events, unconformities, changes in sea level, transgression and regression processes, changes in the evolution of faunal-floral associations, and the equivalence of FAD and LAD dates.

The maps show the possible connections between different paleogeographic units (Boreal, Mediterranean, Paratethys, Indo-Pacific), and the directions of fauna (marine, especially mammal) migrations. The Adriatic-Dinaric area, a region critical for Mediterranean-Paratethys connection, requires continued research for there is disagreement about the timing and extent of the Miocene connections here. The same holds true of the Central versus Eastern Paratethyan connections in Late Miocene-Pliocene time (endemism or migration?) and the role of the Indo-Pacific influence (Early-Middle Miocene).

Finally, the project seems to corroborate the three major geohistorical events (more or less Early-Middle-Late Miocene), thus offering the possibility for the establishment of three Miocene superstages and for continued studies of their global correlation.

Together with the results of IGCP Project 25, the maps illustrate and summarize the achievements of nearly 150 years of research devoted to the Neogene, especially the results of the last 25 years when correlation studies were carried out with large-scale international cooperation. The project should prove helpful launching new research programs, for the methodology used can be adapted to various time horizons in other parts of the globe.

If an appropriate tectonic concept is adopted, such maps will be suitable for palinspastic reconstructions, and for adopting an acceptable kinematic model (in time and space) for the Alpine-Carpathian system. The maps may also help to determine active regional tectonic zones and their changes in time, basin configuration and evolution, facies zones for coal and petroleum source rocks, and possible reservoir rocks.

Proposed Follow-Up

Developing a geodynamic concept and carrying out palinspastic reconstructions would have been a logical follow-up of this paleogeographic project. However, it seems preferable to concentrate now on the study of some major basins in the vertical sense, so as to produce a well-established palinspastic reconstruction and to unravel the evolutionary history. Such a basin analysis may provide further aid for stratigraphic correlation and for the assessment of the energy resources.

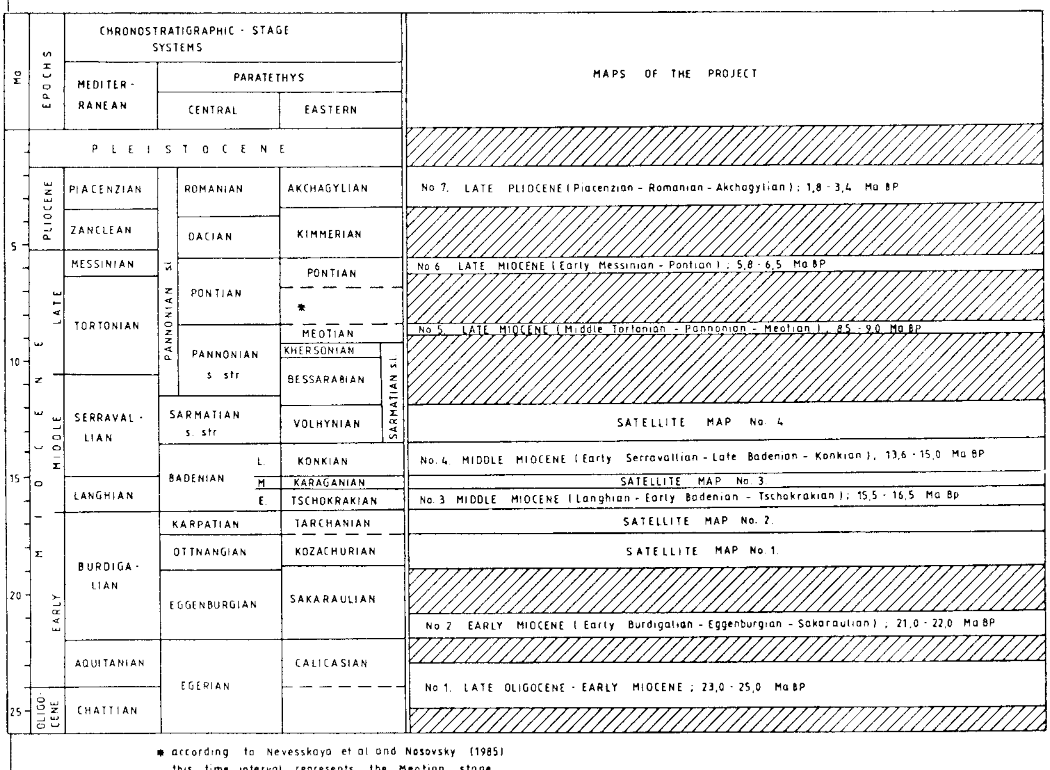

Figure 5: The time slices illustrated in the project maps. The chronostratigraphic correlations are based on Steininger, Rögl and Dermitzakis (1987), Nevesskaya et al. (1985), and Nosovsky (1985).

One aim would be to establish the pre-sedimentary evolution of the basin, with respect to tectonic deformation of the basement and position to plate margins. Other aspects to be considered would include the stratigraphy, depositional environments, diagenetic processes, subsidence history, and the syn-sedimentary and post-sedimentary tectonic evolution in terms of basin configuration and heat-flow conditions.

The intracontinental basins to be studied need not necessarily be physically contiguous, within a zone extending from Western Europe well into the Soviet Union, candidates include the Molasse, Po, Vienna, Pannonian, Transylvanian and the Caucasian basins, the Appenine, Carpathian and Alpine foredeeps. A top-priority task of such a project would be to identify similarities in time, scale and other characteristics that may have been crucial in controlling the geological history of basins of different facies, paleogeographic connection and structural setting.

The final products of such a follow-up project would include maps, block-diagrams of basin, explanatory texts and papers. These would address the causal relationship between the locations of basin formation and tectonic deformation and the exact date of the inauguration of the basin. Sedimentation and burial history, rate of deposition and times of non-deposition, changes in the configuration of a basin and the dating of vertical movements (autochthonous and allochthonous positions and their changes) would all be important. A correlation would be made of changes in geological events of different basins for the determination of large-scale geodynamic events, and possible trends of palinspastic reconstructions would be determined.

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References

Baldi, T., Senes, J. (eds.), 1975. Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys. OM Egerien. Bd. VEDA, Bratislava Verlag der Slowakischen Akademie der Wissenschaften, 577p.

Carloni, G.C., Marks, P., Rutsch, R.F. and Selli, R., 1971. Stratotypes of Mediterranean Neogene Stages. Giornale di Geologia, v. 37, no. 2, Bolgona, 266p.

Cicha, I., Senes, J., Tejkal, J. (eds.), 1967. Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys. M3 Karpatien. Bd. I VEDA, Bratislava Vydavatel'stvo Slovenskej akadémie vied, 312p.

Hámor, G., 1983. The Quantitative methods of paleogeographical reconstruction. Földtani Intezet Kiadvanyainak (Hungarian Geological Institute) Special Papers no. 2, 70p.

Nevesskaya, L.A., Voronina, A.A., Goncharova, I.A., Ilyina, L.B., Paramonova, N.P., Popov, S.V., Tchepalyga, A.L. and Babak, E.V., 1985. History of Paratethys. Abstracts of 8th Congress of the Regional Committee on Mediterranean Neogene Stratigraphy. Hungarian Geological Survey, Budapest, p. 416-419.

Nosovsky, M.F., 1985. Correlation of the U.S.S.R. South Neogene and Carpathian-Balcan region. Abstracts of 8th Congress of the Regional Committee on Mediterranean Neogene Stratigraphy. Hungarian Geological Survey, Budapest, p. 424- 426.

Papp, A., Jambor, A., Steininger, F.F. (eds.), 1985. Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys. M6 Pannonien. Akademie Kiado, Budapest, 636p.

Papp, A., Rögl, F., Senes, J. (eds.), 1973. Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys. M2 Ottnangien. v. 3, VEDA, Bratislava Verlag der Slowakischen Akademie der Wissenschaften, 841p.

Rögl, F. (ed.), 1985. Mediterranean and Paratethys Neogene. Report on Activity of the Regional Committee on Mediterranean Neogene Stratigraphy, Working Groups and Bibliography 1979-1984. Hungarian Geological Survey, Budapest, 293p.

Senes, J., 1985. Stratigraphic correlation Tethys-Paratethys Neogene IGCP Project 25 (history and aims, organization, results). Geologicky ZbornikGeologica Carpathica, v. 36, no. 6, p. 725-746.

Steininger, F.F. and Nevesskaya, L.A., 1975. Stratotypes of Mediterranean Neogene Stages, v. 2. VEDA, Bratislava, 364p.

Steininger, F.F., Rögl, F. and Dermitzakis, M. (eds.), 1987. Report on the round table discussions: "Mediterranean and Paratethys Correlations." Proceedings of 8th Congress of the Regional Committee on Mediterranean Neogene Stratigraphy. Annals of the Hungarian Geological Institute, Budapest. v. 70, p. 397-421.

Steininger, F.F., Senes, J. (eds.), 1971. Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys. M1 Eggenburgien. v. 2, VEDA, Bratislava Vydavatel'stvo Slovenskej akadémie vied, 827p.

Steininger, F.F., Senes, J., Kleemann, K. and Rögl, F. (eds.), 1985. Neogene of the Mediterranean Tethys and Paratethys (Stratigraphic correlation tables and sediment distribution maps). Institute of Paleontology, University Press of Vienna, v. 1, 189p, v. 2, 524p.