Miocene sequence stratigraphic key surfaces and depositional systems tracts in the Western Carpathian basins (Central Paratethys, Slovakia)

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Abstract. Some important sequence-stratigraphic key surfaces were distinguished within the Miocene sedimentary record in the Western Carpathian basins. The key surfaces enabled us to divide individual depositional systems tracts within their relative time framework. The obtained sequence-stratigraphic model shows the dependance of sequences geometry on the relative sea-level changes, being influenced by eustacy, sediment flux and tectonics. The Carpathian-Pannonian depositional cycles are interpreted in comparison with sedimentary sequences, and they show a good fit with the Haq's Cycle Chart (HAQ et al. 1988, HAQ 1991).

Key words: Miocene, Central Carpathian basins, sequence stratigraphy

Introduction

The Western Carpathian Neogene basins are partly separated branches of the Paratethyan sea, and thus they show differences in geodynamic development and related facial assemblages.

One of the ways, how to correlate the variable sedimentary facies in their relative time framework is the sequence stratigraphy, based on key surfaces and depositional systems tracts.

Based on field profiles, boreholes and seismic lines we collected data on the geometry of sedimentary bodies, their lithology, genetic sedimentology, biostratigraphy and related changes in paleoenvironments.

The places with well developed subaerial exposure surfaces, acting as type-1 sequence boundaries, we correlated with sedimentologicaly and stratigraphicaly interpreted type-2 sequence boundaries. Based on the acceptance of falling stage systems tracts the sequence boundaries in basinal settings are interpreted at the interfaces of basin floor fans and lowstand wedges. The bases of the transgressive systems tracts are marked by flooding surfaces on the coastal plains. The interpretation of maximum flooding surfaces in seismic profiles helped us to divide the transgressive and the highstand systems tracts and thus reconstruct the internal geometry of sedimentary sequences.

Correlative study

Within the Miocene sedimentary record we recognized a cyclicity of sedimentation, resulting in the Carpathian-Pannonian Cycles (CPC.0–CPC.7).

At the basins margin, the principal recognized boundaries were interpreted generally as follows: Eggenburgian transgressive surface (ca. 21 Ma), Late Ottnangian transgressive boundary (ca. 17.8 Ma), Late Karpatian transgressive boundary (ca. 16.8 Ma), boundary within the Upper Lagenide zone of Lower Badenian (ca. 15.1 Ma), Middle/Upper Badenian boundary (ca. 14 Ma), Early Sarmatian transgressive boundary (ca. 12.8 Ma) and B/C Pannonian zones boundary (ca. 10.8 Ma).

From the paleoenvironmental point of view, most of the identified sequences show a decrease or increase of salinity at their end, and are in a good correspondence with the climatic cyclicity, observed in the Central Paratethys. The number of cycles, as well as their approximate boundaries, surprisingly well fit with the Haq's Cycle Chart (HAQ et al. 1988, HAQ 1991).

Late Egerian cycle CPC.0

The lower sequence boundary of this CPC.0 cycle can be hardly interpreted, because of the lack of typical subaerial erosion surface within the Egerian sediments. In the Central Western Carpathian Neogene basins, there is known mostly conform transition from the underlying falling stage systems tract into the lowstand systems tract, or an onlap surface, where the flooding surface unconformly divides the pre-Neogene basement from the transgressive depositional systems tract.

Eggenburgian to Early Ottnangian cycle CPC.1

In the Central Carpathian Neogene basins, the sedimentation of the CPC.1 cycle deposits was preceded by a large-scale erosion of older, mostly Paleogene sediments, reaching the Mesozoic fundament. Therefore the lower CPC.1 cycle boundary is largely displayed as an unconformity. The same surface was acting as a flooding surface. The stage of maximal flooding can be interpreted below the Eggenburgian – Ottnangian boundary. The late highstand to falling stage systems tract is marked by prograding and offlaping Ottnangian shoreface sands and coastal plain facies associations.

In the East Slovakian Basin the Ottnangian part of the cycle is missing, due to the regional tectonic uplift of the area.

Late Ottnangian to Karpatian cycle CPC.2

The CPC.2 cycle is based by a subaerial erosive surface (type-1 sequence boundary) on the basins margin. The lowstand systems tracts are represented by fluvial gravels and deltaic sands in the Vienna and Danube basins. In the East Slovakian Basin, the lowstand systems tract is interpreted in the coarse-clastic sediments at the base of Teriakovce Formation.

In the Vienna Basin, the transgressive and highstand systems tracts merged and/or the upper part of the cycle is eroded. In the Novohrad–Nógrád Basin the Medokýš Beds are onlapping the older terrestric sediments and thus they represent a transgressive systems tract. The upper part of the cycle is eroded. In the East Slovakian Basin, the transgressive systems tract is interpreted based on the covering of coarse-clastic sediments by offshore facies association within the Teriakovce Formation (Vass & Čverčko, 1985). An abrupt decrease of subsidence rate caused the origin of the Soľná Baňa Formation – an evaporite event during the basin isolation, due to relative sea-level fall, thus representing the falling stage systems tract.

Early Badenian cycle CPC.3

The base of the cycle is distinctly erosive with incised valleys at the basins margin. The subaerial exposure surface in the East Slovakian Basin is visible on the top of the Karpatian evaporitic complex.

The lowstand systems tracts are represented by fluvial-deltaic Jablonica and Aderklaa conglomerates in the Vienna Basin. Similar continental to deltaic deposits originated in the Danube, Novohrad-Nógrád and East Slovakian basins. The transgressive and highstand systems tracts are built by marine clays with a maximum-flooding-related downlap surface within the Lower Lagenide zone (Weissenback, 1996).

Lower to Middle Badenian cycle CPC.4

In the Vienna Basin depocentres, the lower cycle boundary is interpreted as an onlap surface, i. e. type-2 sequence boundary (Weissenback, 1996). However, at its eastern margin, there is a distinct unconformity between the lowstand-related continental Devínska Nová Ves Conglomerates and the underlying marine clastics of the previous CPC.3 cycle (Vass et al., 1988). In the Danube Basin, the marine offshore sediments of the Upper Lagenide zone are lying conformly on the older deposits. In the East Slovakian Basin, the CPC.4- cycle lower bounding surface is also a conformity within the Hrabovec Tuffs Formation, whichs upper portion can represent the lowstand systems tract.

The transgressive and highstand systems tracts are represented mostly by Spiroplectammina-bearing marine clays and minor organodetritic limestones in the westren part of the basin system. In the Novohrad-Nógrád Basin, the transgressive marine deposits are followed by volcaniclastic sedimentation. In the East Slovakian Basin the Middle Badenian Vranov Formation shows a gradual deepening of the marine depositional paleoenvironment from the transgressive to the highstand depositional systems tract (Zlinská, 1992).

Unlike in the Vienna and Danube basins, in the East Slovakian Basin, there is well pronounced the falling stage systems tract, without a distinct separation from the following lowstand systems tract. These sediments are represented by shallow lagoonal evaporites of the Zbudza Formation (Vass & Čverčko, 1985).

Upper Badenian cycle CPC.5

In the Vienna Basin, the definition of the lower bounding surface of this cycle use to be difficult, however, in some seismic lines we can recognize a new onlap surface at the Middle/Upper Badenian boundary, showing a type-2 sequence boundary, followed by the deposition of pelitic offshore sediments

In the Danube Basin northwestern part, the lowstand depositional systems tract is represented by thick accumulation of alluvial clastics – Doľany Conglomerates, overlying the pre-Neogene basement. The transgressive and highstand systems tracts deposits are open-marine with gradual shallowing-upward trend.

In the East Slovakian Basin, similarly as in the basins in the eastern part of the Central Paratethys, the recognition of the CPC.5 cycle is clear. There, the evaporitic lowstand systems tract was flooded and covered by thick open-marine Lastomír Formation (Vass & Čverčko, 1985), representing the transgressive systems tract.

The Upper Badenian sedimentation in the Vienna, Danube and East Slovakian basins finishes by the deposition under hyposaline conditions. At the margins of the Vienna and Danube basins, there the parasequence stacking pattern shows an offlap termination of sedimentary sets, thus characterizing the falling stage systems tract. This systems tract is represented by clastic aprons with abundant redeposited Badenian fauna at the eastern margin of the Vienna Basin. In the East Slovakian Basin, this period is characterized by a rapid progradation of the Klčovo Formation deltaic front onto its prodeltaic part (Kováč et al., 1995).

Sarmatian to Early Pannonian cycle CPC.6

The lower boundary of the cycle shows a subaerial exposure surface at the Vienna Basin margin. Similarly, at the southeastern margin of the Danube Basin, the incised river valleys document a disconformity at the base of Sarmatian sediments. In the East Slovakian Basin, the lower cycle boundary is interpreted at the maximal progradation of the Klčov paleodelta.

The lowstand systems tract is represented by onlapping clastic aprons with abundant redeposited Badenian fauna at the eastern margin of the Vienna Basin. In the Danube Basin, the lowstand systems tract is characterized by fining-upward fillings of the incised valleys and by prograding fan deltas. In the East Slovakian Basin, this systems tract shows a retrogradation of the upper part of the Klčovo paleodelta.

The Sarmatian transgressive systems tracts in the Central Carpathian basins start by the deposition of shallow, brackish-water clays and sands with characteristic large elphidia. The transition between the transgressive and the highstand systems tracts, i. e. the maximum flooding time, could be traced, based on well correlable marls of the Elphidium hauerinum biozone (Grill, 1941).

The relative sea-level fall at the end of Sarmatian caused the isolation of the basinal systems and distinct decrease of the brackish-water fauna in the Vienna and Danube basins. The East Slovakian Basin began to be a fresh-water lake in this time. The falling stage systems tract in the Vienna Basin is characterized by the progradation of the paleo-Danube delta.

Pannonian cycle CPC.7

The base of the CPC.7 cycle shows a distinct erosive surface, sometimes reaching through the Pannonian zones A and B up to the Sarmatian sediments. This type-1 sequence boundary at the Pannonian B/C zones boundary is correlable with the Danube Basin. The maximal sea-level fall at this boundary enabled the imigration of the Hipparion horse ancestor through continental bridges.

In both the Vienna and Danube basins the lowstand systems tracts are represented by thick deltaic sand bodies.

The transgressive and highstand depositional systems tracts are built by sandy and clayey sediments. These systems tracts are separated by the maximum flooding surface, interpreted based on the maximum bloom of dinoflagellates within the Pannonian zone E (Kováč et al., 1998).

Based on seismic profiles, the upper cycle boundary may be interpreted as a subaerial exposure surface in the upper part of the Pannonian zone E (Kováč et al., 1999).

Discussion and conclusions

The recognized CPC cycles boundaries are of different types. The main differencies are among the subaerial erosion surfaces, i. e. type-1 sequence boundaries, the onlap surfaces and the progradation-retrogradation trends boundaries. From this reason, the cycles boundaries are not always corresponding with the real sedimentary sequences boundaries. The changing sediment flux, relative sea-level amplitudes and the role of tectonics make many variations of sequence stratigraphic models within individual basins. The reconstruction of these variations needs good well-log data and seismic profiles, which are not always available in the sufficient amount.

The correlated surfaces, simplified to cycles-bounding surfaces may be sequence boundaries and/or flooding surfaces, which means, that they are not always the same time lines.

The interpreted depositional systems tracts show differencies on the individual basin margins, depending on differencies in sediment flux and local tectonics. Therefore the correlation was made only in the cases, when it was possible, and the depositional systems tracts were simplified to whole basins.

However, the interpretation of collected data show a possibility to make a rough reconstruction of the relative time framework of the depositional history of the Central Western Carpathian Neogene basins.

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