Inherited and Syndepositional Structural Control on Slope Progradation in the Neogene Lake Pannon, Southwestern Pannonian Basin, Hungary*

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Abstract

The prograding shelf margin of Lake Pannon reached and ran across the studied segment of the Pannonian Basin between 8.8 and 8 Ma from the north-northwest to the south-southeast. A complex strike-slip type deformation created a dissected lake floor topography during the Middle and Late Miocene, which had a great influence on the prograding lake margin. The elongated troughs drew the prograding slope parallel with their axis, while the elevated edges acted as barriers and deflected it. The uneven basement relief determined local water depth of the lake, reflected by the varying heights of the slope, thus controlled the distribution and thickness of shelf, slope and basin centre deposits. In addition to this structural control, climatic influence was also revealed. The advancing clinoforms show alternating rising and flat shelf-edge trajectories which indicate stepwise lake level rise without significant lake level drop. As a result, the structural elements controlled not only the development of structural traps for hydrocarbon accumulations, but the facies and thickness distribution of the reservoir, seal and source rocks as well.

Introduction

The Pannonian Basin is located in eastern Central Europe and surrounded by the Alpine, Carpathian and Dinaric mountain belts. From the end of the Middle Miocene to the Early Pliocene it was filled by a long-lived, large, brackish lake, called Lake Pannon (Magyar et al., 2012). Large amounts of sediments, transported to the basin from the uplifting mountains to the north, gradually filled the lake by large deltaic/fluvial systems, and resulted in the overall southward progradation of the northern shoreline. The study area is located in the southwest part of the basin and underlain by one of the most important tectonic belts of the basin, the Mid-Hungarian Zone, which played a key role in the tectonic history of the area (Csontos and Nagymarosy, 1998; Fodor et al., 2005). The aim of this study was to understand the controlling effects of relative lake-level changes and pre-existing and synsedimentary structural movements on slope sedimentation (Törő et al., 2012).

Depositional History

Deposition occurred in a long-lived, sea-like lake, where due the high sediment input deltas of major rivers had built a flat-lying morphological shelf, similar to that of marginal marine systems. As a result of high sediment input and low accommodation on this shelf, deltas easily reached the shelf-margin and 200-600 m high shelf-margin clinoforms with 5-10 km slopes were created (Magyar et al., 2012). Across the gently dipping shelf-slope, large amounts of sediments were transported to the basinal areas through canyons and leveed channels by turbidity currents (Sztanó et al., 2012). Far from the slope fine-grained shales and marls were deposited in an open lacustrine environment. However, the progradation of these clinoforms was not uniform. The rate and direction of slope progression was influenced by the variable lake floor morphology, created by former and coeval structural movements. This structural influence was studied based on the interpretation of about 1800 km of 2D reflection seismic profiles in an overall northeast-southwest and northwest-southeast oriented grid. Major slope surfaces were mapped in order to understand and visualize local variability in the slope progradation. The restoration of paleo-horizontal surfaces on the sections was used to remove post-depositional deformation and to understand the interplay of sedimentation and tectonics. The shelf edge trajectory method was used to trace relative lake-level changes. The interpretation of seismic sections was complemented by the biostratigraphic, lithologic and well-log data of 22 exploration wells from the study area.

Examples

The retro-deformation of the seismic sections revealed that the characteristic morphological features (deep basins and elevated highs) of the lake floor topography were mostly generated before the birth of Lake Pannon. Based on the structural analysis of the seismic sections, this dissected morphology was the result of the complex structural evolution of the area before and to a smaller extent during the slope progradation. These structural elements exhibit a complex transpressional-transtensional deformation, which has influenced the thickness variations of the open lacustrine marls and deep-lacustrine turbiditic sandstones, and also the direction of slope progradation locally.

The sub-basins drew the prograding slope, while the elevated edges acted as barriers and deflected it, resulting in significant thickness variations both in deep-water lacustrine and shelf-slope strata over short distances. The uneven lake floor relief also influenced the local water depth of the lake and this is reflected by the varying height of the slope. In general, based on the regional seismic mapping, the slope prograded towards the south and the slope advanced 35 km within ca. 0.7 million years. The infill of deep sub-basins locally was governed by slopes prograding from two different directions, i.e. from northwest and northeast. The migration of the northeastern slope was sub-parallel to a structural high, which strongly controlled its progradation.

The relative lake-level changes during the progradation are marked by the shelf-edge trajectory of the advancing clinoforms: the shelf margin is constructed of alternating aggradational and progradational units, which indicates repeated rising and stagnant lake levels. At one location it was possible to identify two overlying slope sequences, which indicate a major relative lake-level rise. Features indicating relative lake-level fall were not apparent on the studied sections. However, unconformities could be identified. Interpretation of perpendicular seismic profiles suggests that these are not the result of lake level drop and erosion (a premature conclusion frequently invoked in the Pannonian Basin), but the results of the superposition of slopes, prograding from two markedly different directions.

Conclusions

The overall aim of this study was to determine the controlling factors on the Late Neogene sedimentation of the Lake Pannon through the mapping of the recent basement morphology, and the structural and sedimentological analysis of 2D seismic sections. During the Middle and Late Miocene a complex transpressional deformation along the Mid-Hungarian Zone created an uneven lake floor morphology, showing deep confined sub-basins surrounded by elevated highs with high topographic relief. At the time of slope progradation these deep basins acted as traps, resulting in the accumulation of thick turbiditic and basinal marl sediments. The underwater highs acted as barriers, and influenced the thickness of the slope sediments as well as the direction of their progradation. The shelf-edge trajectories across the area show stepwise lake level rise, indicating periodic base-level variations without significant lake level drop. As the elevated basement areas are proven structural traps, and the deltaic systems on the shelf and the turbidite systems of the deep sub-basin interiors are potential stratigraphic traps for hydrocarbon accumulations, these results can be used to better understand the controlling factors on the petroleum system of the Pannonian Basin.

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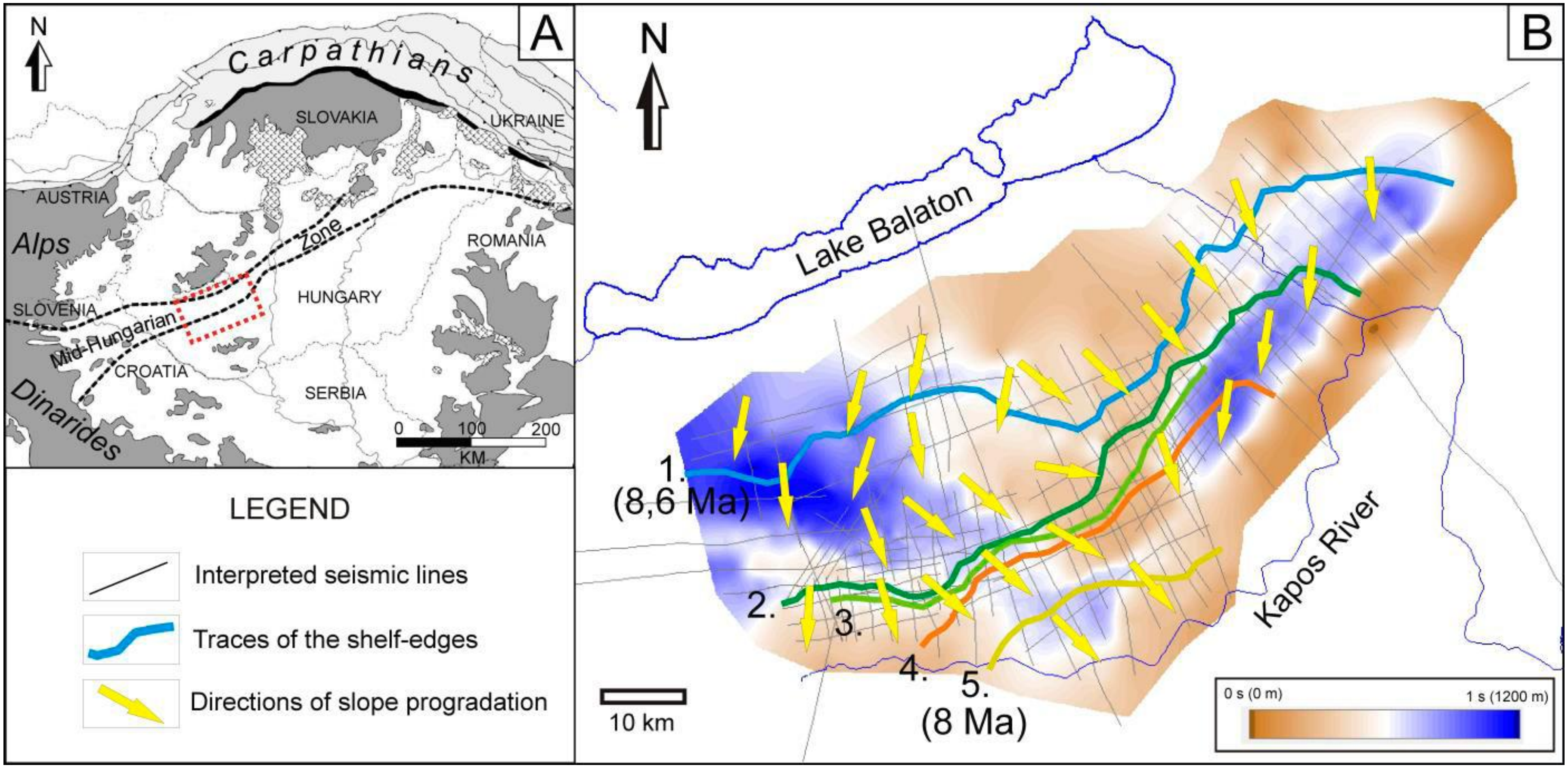

Figure 1. (A) Simplified structure map of the Pannonian Basin and its surroundings with the location of the study area (red dashed rectangle) and the Mid-Hungarian Zone (dashed lines). (B) Traces of the shelf-edges (colored lines) and the directions of slope progradation (yellow arrows) on the paleotopographic map of the lake floor (the ages are based on the data of Magyar et al., 2012).