

MOGUĆA PROMJENA U IZVORU KLASTIČNOG DETRITUSA U STRUKTURI KLOŠTAR U VRIJEME GORNJEG PANONA I DONJEG PONTA *POSSIBLE CHANGES OF CLASTIC DETRITUS SOURCE IN THE KLOŠTAR STRUCTURE DURING LATE PANNONIAN AND EARLY PONTIAN*

Kristina Novak Zelenika, *INA d.d. Zagreb, SD Naftaplin, Tomislav Malvić, INA d.d. Zagreb, SD Naftaplin, RGN fakultet Sveučilišta u Zagrebu, Josipa Velić, RGN fakultet Sveučilišta u Zagrebu*

Ključne riječi: struktura Kloštar, gornji panon, donji pont, izvor materijala, Moslavačka gora, Istočne Alpe

Key words: *Kloštar structure, Upper Pannonian, Lower Pontian, clastics source, Moslavačka gora Mt., Eastern Alps*

Sažetak

Polje Kloštar je izdužena antiklinala pružanja sjeverozapad-jugoistok. Uzdužni normalni rasjed dijeli strukturu u dva dijela, sjeveroistočni i jugozapadni. Za vrijeme gornjeg panona i donjeg ponta odigrao je ključnu ulogu u nastanku ležišta. Predstavlja granicu između ležišta II. (gornji panon) i I. (donji pont) pješčenjačke serije. Zanimljivo je da je I. pješčenjačka serija razvijena samo sjeveroistočno od rasjeda, a II. jugozapadno.

U vrijeme gornjeg panona, kao i donjeg ponta druga transtenzijska tektonika je prevladavala u cijelom području hrvatskog dijela Panonskog bazena. Manje rasjedne depresije otvorile su se unutar regionalnih depresija, stvarajući nova područja za sedimentaciju s akumulacijom približno jednakom brzini tektonskog tonjenja. U gornjem panonu talože se ukupno tri ležišta II. pješčenjačke serije („ α “, „ β “ i „ γ “). Nakon taloženja najplićeg ležišta „ γ “ nastao je normalni regionalni rasjed uzrokujući spuštanje sjeveroistočnog dijela strukture. To područje (zapadno od Moslavačke gore) postalo je tada najdublji dio strukture gdje je istaloženo ukupno 11 ležišta.

U vrijeme gornjeg panona i donjeg ponta glavni izvor materijala predstavljaju Istočne Alpe. Klastiti iz tog izvora bili su više puta pretaloženi, dok na poslijetku nisu dospjeli u Savsku depresiju. U gornjem panonu glavni depocentar strukture Kloštar nalazio se vrlo blizu obalne linije duž Moslavačke gore. Stoga je razumno zaključiti da je dio klastičnog materijala erodiran od tamo te najvjerojatnije transportiran kratkim aluvijalnim lepezama. No u donjem pontu, zbog podizanja razine mora, ponovno su turbiditi bili jedini izvor klastita. To bi značilo da je izvor klastičnog materijala bio (a) regionalni + lokalni u gornjem panonu i (b) regionalni u donjem pontu.

Najčvršći dokaz bio bi različiti mineralni sastav jezgara tih sedimenata. Nažalost, takve mineraloške analize nisu dostupne. No, proučavane su jezgre pješčenjaka te uočene sljedeće razlike: (a) gornjopanonski pješčenjaci kompaktniji su i čvršći; (b) također karakterizirani većim udjelom tinjaca (slabo trošenje), što omogućava pretpostavku da je u gornjem panonu postojao dodatni izvor materijala konstantno zapunjavajući strukturu Kloštar klastitima, uz djelovanje turbidita.

Abstract

Kloštar Field is elongated anticline with NW/SE strike. Longitudinal normal fault divides the structure in two parts (NE and SW). This fault had a key crucial role in Upper Pannonian and Lower Pontian reservoirs sedimentation, and spatially it represents border between 2nd (Upper Pannonian) and 1st (Lower Pontian) sandstone series. Interestingly, 1st sandstone series is located only NE from the fault and 2nd just SW.

In Upper Pannonian, as well as in Lower Pontian the second transtension period lasted in the entire Croatian part of Pannonian Basin. Smaller pull-apart depressions were opened inside particular depressions, creating new areas for sedimentation with rate approx. equivalent with tectonic deepening. In Upper Pannonian reservoirs of the 2nd sandstone series were deposited, with 3 reservoirs („α“, „β“ i „γ“). After sedimentation of „γ“ reservoir, mentioned normal fault downlifted NE part of the structure. This area (W from Moslavačka gora Mt.) started to be the deepest part of structure where 11 particular reservoirs had been deposited.

In period of Upper Pannonian and Lower Pontian the main material source was Eastern Alps. Clastics from there had been several times redeposited until reached the Sava Depression. But, obviously, in Late Pannonian, main depocentre in the Kloštar structure had been located close to shoreline along Moslavačka gora Mt. It can be very reasonably assumed that part of clastic material had been also eroded from this uplifted basement with local transport probably in short alluvial fans. But, due to sea level rising turbidites were only mechanism in Early Pontian. It means that we can be divided source of material on (a) regional + local in Late Pannonian and (b) regional in Early Pontian.

The most strong prove would be different mineralogical compositions of cores from these sediments. Unfortunately, there are no available such mineralogical analysis. However, there are studied cores from sandstones and some differences are observed as follows: (a) sandstones from Late Pannonian are more compact, hard; (b) Also are characterised by more mica (small weathering). It means that we can logically assumed additional material source in Pannonian which continuously filled Kloštar structure with clastics, supporting turbidites.

1. Introduction

The Kloštar Field is located about 35 km east from Zagreb, on the western slope of Moslavačka Gora Mt. Field borders are on the area which is on 110 to 180 m elevation. Regionally, in geological and gas-petroleum sense, structure of the field is located in the Sava Depression. Currently, a research project is active in Croatia that include connection between stratigraphical and geomathematical analytical methods on the data from Croatian Neogene sediments ("Stratigraphical and geomathematical research of HC systems in Croatia", project manager Prof. Dr. Josipa Velić, project MZOŠ no. 195-1951293-0237).

One of the goals is turbiditic depositional environments analyses in Croatian part of the Pannonian Basin, which were active during Late Pannonian and Early Pontian, when main sandstone HC reservoirs were deposited. Elongated monocline of the Kloštar Field is one of such goal. Regional normal fault divides the structure in two parts (NE and SW) and also separates 2nd (Upper Pannonian) and 1st (Lower Pontian) sandstone "series". 1st sandstone series is located only NE from the fault and 2nd just SW (Figure 1).

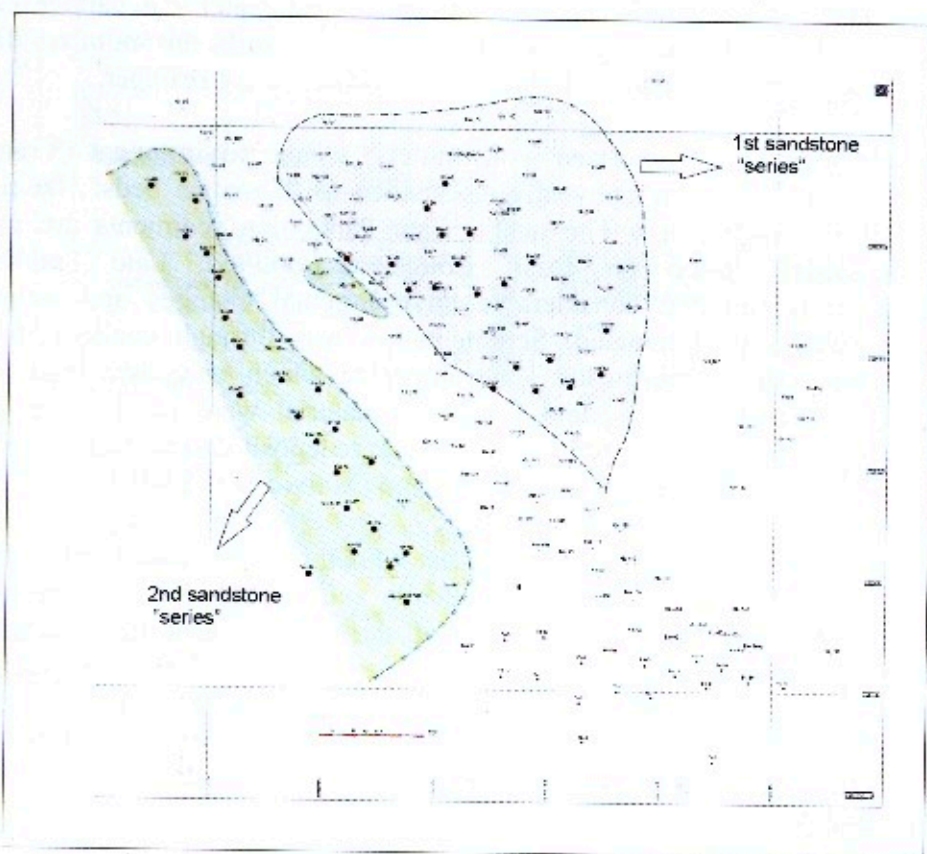


Figure 1. Distribution of the Pontian and Late Pannonian sandstone reservoirs

2. Short stratigraphical and sedimentological model of the Sava Depression and the Kloštar Field

Evolution of the Sava Depression began in Lower Miocene or, more sure, according to Čorić et al. (2009) in Middle Miocene, i.e. Badenian. Its development continued during the whole Miocene, Pliocene and finally Quaternary. Beginning of regional transgression in the whole depression was recorded in Middle Miocene sediments. Sedimentation area covered the lowest parts of the Sava, Drava, Slavonia-Srijem and Mura Depressions (e.g. Vrbanac, 1996; Malvić, 2003). It is still questionable how many mountains in Northern Croatia were covered by sea. The highest like Medvednica and Papuk must have been the islands, but lower, like Moslavačka gora or Krndija, were or islands or shallow marine/lake palaeorelief highs during Miocene.

Regional unconformity divided Palaeozoic or Mesozoic basement from Miocene. Badenian sedimentation started with conglomerates, sandstones, siltstones, and continued to marl-sandstone inter-layering. Badenian is time when 1st transtension got stronger, pull-apart basins were opened in the Sava Depression. Marine sedimentation was dominant. Siliciclastic material was deposited in shallow sea through alluvial deltas. Environment at the end of Badenian was calmer. Main reason for such environment was transtension weakening. In this calm condition of shallowing, Sarmatian began when terrestrial influence got stronger,

Lower Pannonian is characterized with brackish e lake environment (Vrbanac, 1996), which are biostratigraphically also called as "Croatia beds", based on fossil snail *Radix Croatica*. The next . Late Pannonian sediments are called "Banatica beds", based on fossil *Congerina Banatica*. Late Pannonian sedimentation represented considerable environmental changes and turbiditic currents mechanisms dominated. Sedimentation was through cyclic turbiditic flows in brackish to freshwater environments, which area was constantly decreasing (Vrbanac, 1996). Main source of material were the Eastern Alps. Detritus was transported with turbiditic currents, redeposit several times before it was eventually deposited in the Sava Depression (Malvić et al. 2005).

Late Pannonian sediments extend on the whole area of the Kloštar Field. Sandstones and marls are interbedded vertically and laterally. Oil and gas prone sediments are in the southwestern part of the field, within three sandstone "series", called "Alfa" (the oldest), "Beta" and "Gama" (the youngest) (2nd sandstone "series"). At the end of "Gama" reservoir sedimentation, regional normal fault appeared. Northeastern part of the field was downlifted and southwestern part was uplifted. So in the north-eastern part sedimentation began (1st sandstone "series").

Lithologically Early Pontian sediments are represented with sandstone and marl. Sandstones are deposited through turbiditic currents in the deepest part of sedimentation area. In the calm period, when turbiditic currents were not active,

marls were deposited. Biostratigraphically they are called “Abichi beds”, based on fossil *Paradaena abichi*. Lithology of the Early Pontian sediments is fine-grained sandstones and marls. Sandstones were mainly deposited in northern and western part of the field, while marls were also in southern and eastern part. There are 17 sandstone reservoirs, and the most important are “T”, “U” and “V”. In Late Pontian depositional mechanisms are local in small palaeo-deltas. Depositional area was slowly filled. Biostratigraphically they are called “Rhomboida beds”, based on mussel *Congeria Rhomboida*.

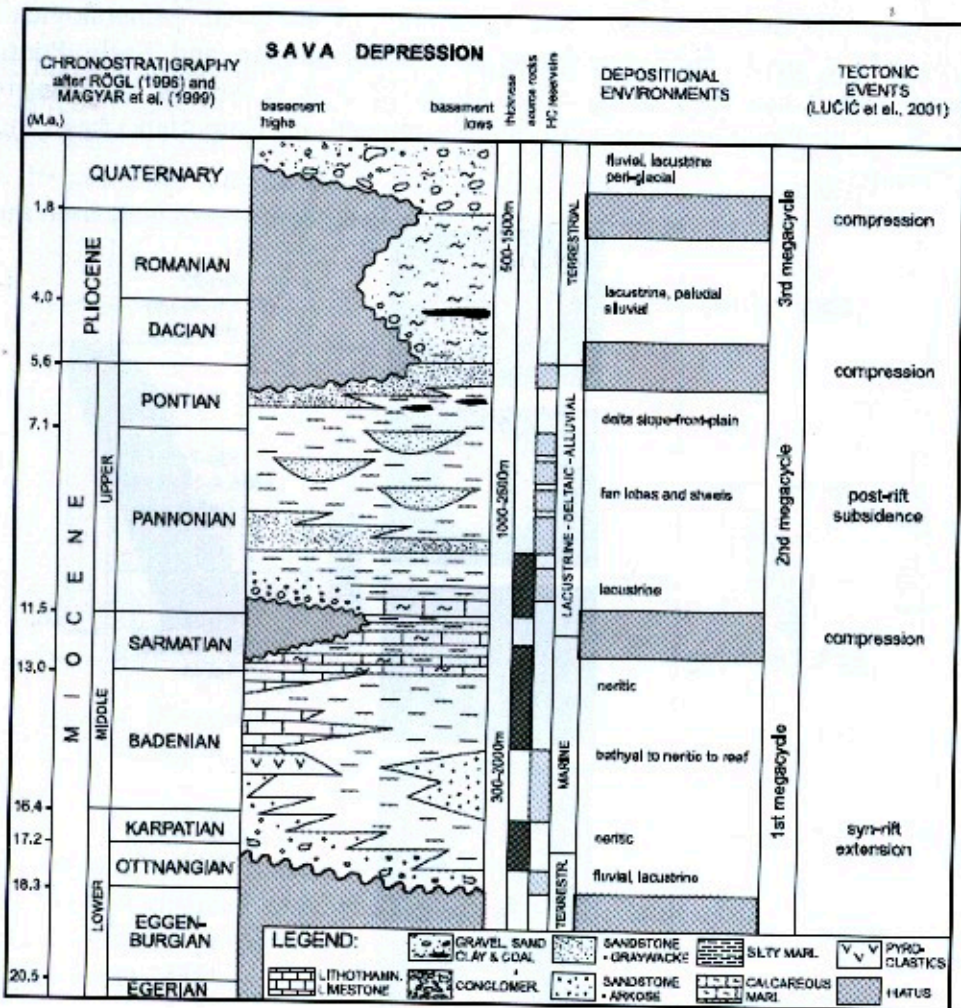


Figure 2. Compilation geological section of the Sava Depression
 (from: Saftić et al., 2003)

In Pliocene and partly Pleistocene sedimentation was continued in residuals of Pannonian Lake, filling it with marly clays, marls and rarely sandy marls and sands in deltas, somewhere interbedded with thin coal layers. They are called “Paludina beds”, based on snail *Paludina*. In the Late Pleistocene and Holocene coarse-grained clastics (gravel and sand), clays and lignite were deposited.

Climate changes and basin inversion were active in Quaternary (Frish et al., 1998), and sediments, which were deposited, are typical for glacial and interglacial. The youngest beds are unconsolidated loess, clay, humus, gravel and sand. Compilation geological section of the Sava Depression, which contains chronostratigraphy, lithology, depositional environment and tectonics, is shown in Figure 2.

Lithofacies and depositional environment of Upper Pannonian and Lower Pontian also had been analysed in certain number of cores. Goal was to observe the differences in mineral components between Late Pannonian and Early Pontian cores (Figure 3). Unfortunately, there were only 13 analyzed. Mineralogically, there is only a small difference between Late Pannonian and Early Pontian sediments and it can only indicate on Moslavačka gora Mt. as local detritus source. So, Late Pannonian cores are more compact and (important) have more mica minerals.






Early Pontian		Klo-22 (977,5-983,5) 5th m
Late Pannonian		Klo-74 (1366,4-1372,4) 2nd m
Early Pannonian		Klo-9 (1378,8-1384,3) 1st m
Badenian		Klo-67 (1520,6-1524,6) 1st m
Palaeozoic basement?		Klo-1 (1212,5-1217,9) 1st m

Figure 3. Some of analyzed cores in the Kloštar Field

To prove the assumption about local material source, cores and Indicator Kriging maps were observed together, because such maps could show material transport and turbiditic currents direction.

3. Indicator Kriging maps of the Kloštar Fields selected sandstone reservoirs

According to Vrbanac et al. (2010) main direction of turbiditic currents in Late Pannonian was northwest-southeast. Assumption we used was that largest porosities are in the channel centre and using porosity distribution maps we should see the direction of the main depositional channel. Mapping was performed by Indicator Kriging method. Input data were average porosities from Late Pannonian and Early Pontian reservoirs. Those were collected in 17, i.e. 19 wells (Figures 4 and 5).

The highest probabilities for higher porosities of the "Beta" reservoir can be best observed in probability maps for values less than 16 and 18 % (Figure 4). The inputs were divided into 6 classes, based on cutoff values, which were 13, 15, 16, 18, 19 and 20%. Depositional channel direction and detritus transport direction from northwest to southeast is clearly observable (Figure 4).

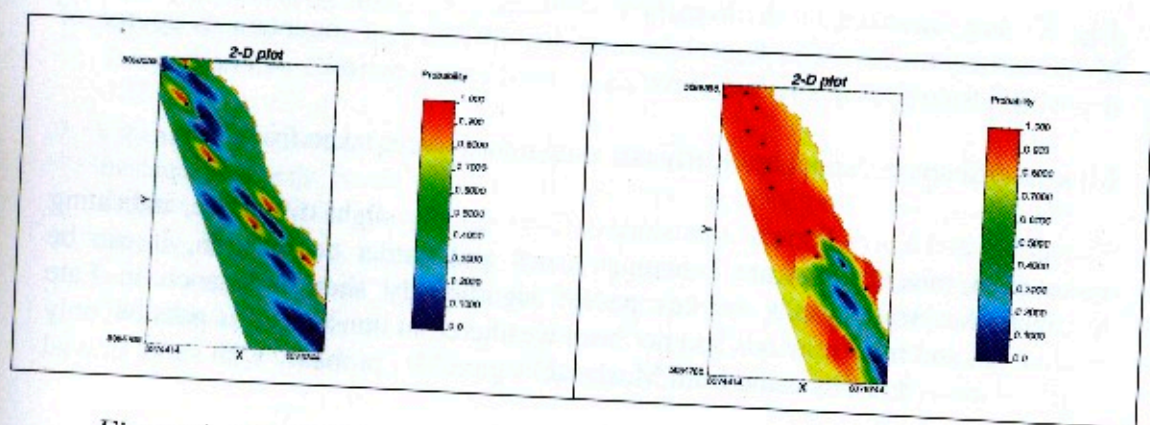


Figure 4. Probability maps of the "Beta" reservoir porosity, which show probability that the mapped value is smaller than 16% (left) and 18% (right)

Again according to Vrbanac et al. (2010) main direction of turbiditic currents in Early Pontian changed somewhere to north-south. Same assumption was used for the Early Pontian porosity mapping (Figure 5), with totally six cutoffs of 14, 18, 19, 20, 22 and 24%.

Northwest-southeast direction, i.e. depositional channel direction, can be very well observed in probability map for cutoffs 19 and 20% (Figure 5). There is possible to reconstruct direction of material transport, because higher porosity values on western part of the reservoir are obvious. It is because coarse material, transported from north, reached the fault palaeotopography, energy was decreased and the coarsest material had been deposited there. However, transport of medium and fine-grained detritus continued parallel with fault line, along to margin of depositional channel, toward southeast (Figure 5-left).

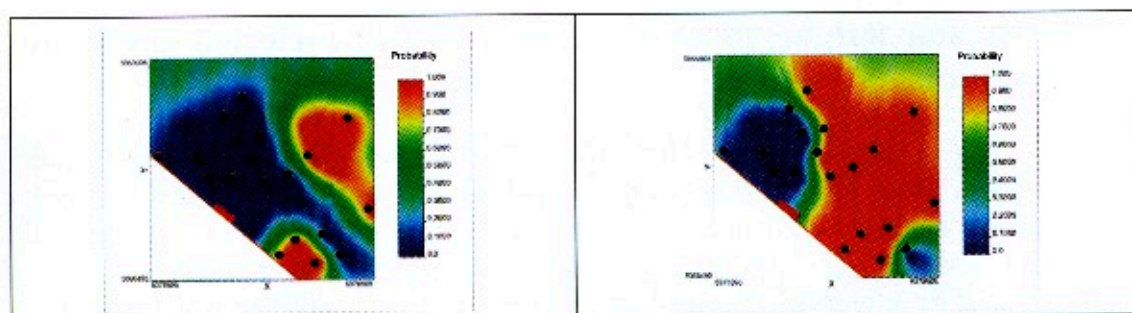


Figure 5. Probability maps of the "T" reservoir porosity, which show probability that the mapped value is smaller than 19% (left) and 20% (right) - (from: Novak Zelenika et al., 2010)

4. Conclusions

The Kloštar structure is hydrocarbon field in the Sava Depression, close to Moslavačka gora Mt. It is logical to consider influence of mountain as source of deposited inside Kloštar structure through 2nd transtension period.

Mineral differences cannot be clearly observed in well cores taken from Late

Pannonian and Early Pontian sandstones. There is only slight difference, indicating more mica minerals in Late Pannonian cores and harder compaction. It can be assumed that some sands detritus passed significantly shorter distance in Late Pannonian, and mica minerals had not been weathered in transport. It is possible only if part of sands and silts came from Moslavačka gora Mt., probably with short alluvial fans.

Indicator Kriging maps clearly showed changing of depositional directions from Pannonian to Pontian. NW-SE direction in Late Pannonian was very well seen on probability maps, when turbiditic currents came from the westernmost part of the Sava Depression and continued mostly parallel with structurally determined shapes. But later, in the Early Pontian transport direction pattern is characterized with N-S strike.

There is not enough proves that uplifted palaeorelief on the Sava Depression margins, through Pannonian and Pontian, had remarkable influences on quantity and mineral composition of detritus. For now it stay as probably assumption for the Kloštar structure and hypotheses for the entire depression. Such local detritus sources could be probably active on depression, tectonically active margins, where small alluvial fans existed.

References

1. Ćorić, S., Pavelić, D., Rögl, F., Mandić, O., Vrabac, S., Avanić, R., Jerković, L. and Vranjković, A. (2009): Revised Middle Miocene datum for initial marine flooding of North Croatian Basins (Pannonian Basin System, Central Paratethys). *Geologia Croatica*, 62, 1, 31-43.
2. Frisch, W., Kuhleemann, J., Dunkl, I. and Brügel, A. (1998): A palinspastic reconstruction and topographic evolution of the Eastern Alps during the Tertiary tectonical evolution. *Tectonophysics*, 297, 1-15.
3. Malvić, T. (2003): Vjerojatnost pronalaska novih zaliha ugljikovodika u bjelovarskoj uleknini. Doctoral thesis, University of Zagreb, Faculty of mining, geology and petroleum engineering, 123 p.
4. Malvić, T., Velić, J. and Peh, Z. (2005): Qualitative-Quantitative Analyses of the Influence of Depth and Lithological Composition on Lower Pontian Sandstone Porosity in the Central Part of Bjelovar Sag (Croatia). *Geologia Croatica*, 58, 1, 73-85.
5. Novak Zelenika, K., Malvić, T., and Geiger, J. (2010): Mapping of the Late Miocene sandstone facies using Indicator Kriging. *Nafta*, 61, 5, 225-233.
6. Saftić, B., Velić, J., Sztano, O., Juhas, G. and Ivković, Ž. (2003): Tertiary subsurface facies, source rocks and hydrocarbon reservoirs in the SW part of the Pannonian Basin (northern Croatia and south-western Hungary). *Geologia Croatica*, 56, 1, 101-122.
7. Vrbanac, B. (1996): Palcostrukturne i sedimentološke analize gornjopanonskih naslaga formacije Ivanić Grad u Savskoj depresiji. Doctoral thesis, University of Zagreb, Faculty of science, 121 p.
8. Vrbanac, B., Velić, J. and Malvić, T. (2010): Sedimentation of deep-water turbidites in main and marginal basins in the SW part of the Pannonian Basin. *Geologica Carpathica*, 61, 1, 55-69.