DEPOSITIONAL SYSTEMS FOR THE SEDIMENTARY DEPOSITS FROM THE LIGHIDIA PERIMETER, BOZOVICI, CARAȘ-SEVERIN COUNTY

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Abstract: In this paper it's about the mineralogical composition of the sedimentary rocks in the Miocene of the Bozovici basin. The perimeter studied is between the Lighidia valley and Agriș valley. The Bozovici basin formed during the lifting and subsidence movements of the Neozoic basement in the Southern Carpathians. The studied deposits are represented by different types of claystones, sandstones, conglomerates, carbonate nodules and coal (lignite). Data on the mineralogical and petrographic composition of the rocks in the perimeter studied were determined by facies analysis, optical microscopy and X-rays diffraction. The identified minerals and lithoclasts are represented by quartz, feldspar, micas, carbonates, metamorphic and sedimentary lithoclast in sandstones and conglomerates, and clay minerals from the smectite group (montmorillonite) and kaolinite group in claystones. The highest concentration in montmorillonite was identified in tonstein (bentonite). The mineralogical data of tonstein suggests a felsic composition of initial volcanic material that has been transformed in conditions of a negative redox potential and an acidic pH of the swamps during Badenian. The X-rays diffraction was done in the laboratory of Oil-Gas University of Ploiesti. This method was used to characterize minerals from 8 samples collected from the Lighidia quarry. The results of the facies analysis, optical microscopy and X-rays diffraction provide us the evidence of the continental environments that correspond to an alluvial fan and overbank environments that evolves in a warm and humid climate.

Keywords: Bozovici basin, lignite, facies analysis, montmorillonite, tonstein, X-rays diffraction, delta plain

1. Introduction

Bozovici basin is an intramontane post-tectonic depression from the south of the Southern Carpathian. The objective of this study it represents Badenian deposits from Lighidia perimeter, represented by clay, marl, sandstone, conglomerate, carbonate nodules and coal. The purpose of the study is to show the evidence of the seasonal lake, swamp and alluvial fan depositional environments based on the mineralogical composition resulted from sedimentary facies analysis, optical microscopy and x-ray diffraction.

This paper aims to bring a better understanding of the relationship between alluvial fan and associated overbank sedimentation, which may be important for coal seam and sedimentary deposits with big amount of montmorillonite extent and their exploitation.

2. Regional setting

The basin is located in the Caraș-Severin county along the higher course of the Nera River (Fig.1. A). It is delimitated in north of Semenic and Anina Mountains, in south and south-east of Almăj Mountains and in south-west of Locva Mountains. The perimeter studied is located in the northern part of the basin, at the exit from the Bozovici (Fig.1.B).

The length of the basin is 40 km and the maximum width is almost 15 km. The thickness of sedimentary deposits is up to 600 m.

The sedimentary deposits of the basin are transgresively and discordantly arranged over the Getic basement and their sedimentary cover. The Getic basement are represented by Sebeș-Lotru, Miniș and Buceava series and the sedimentary cover are represented by upper Jurassic and lower Cretaceous limestones and of upper Cretaceous conglomerates (Balintoni, 1997).

Sedimentary deposits of the basin are composed from Miocene deposits (Badenian) with a similar geological composition to that of Neogene deposits in the Caransebeș-Mehadia basin, of which it was bound by a narrow strip of Miocene deposits in the east part of basin. According to Iliescu et.al (1967), the Badenian deposits in the Bozovici basin are composed form three levels: 1) the lower level that are formed from two small levels: claystone level with marl and coal, and sandstone level with sandstone and claystone; 2) The Dalboset Strata that are formed from conglomerate level with sandstone; and 3) The Sopot Strata with claystone and marl with tuff strata. Petrescu et al. (1986) add a new level represented by sandstones and gravels which they attribute to the Sarmatian. The Quaternary is represented by claystones, sandstones and gravels.

2.1 Tectonic setting

The Bozovici basin formed during the lifting and subsidence movements of the basement in the Neozoic period that led to rise of some crystalline areas along to the sedimentary cover and shedding of some narrow areas that have led to the appearance of the intramontane depression, in which accumulated molasses deposits and it formed coal (Mutihac and Ionesi, 1974).

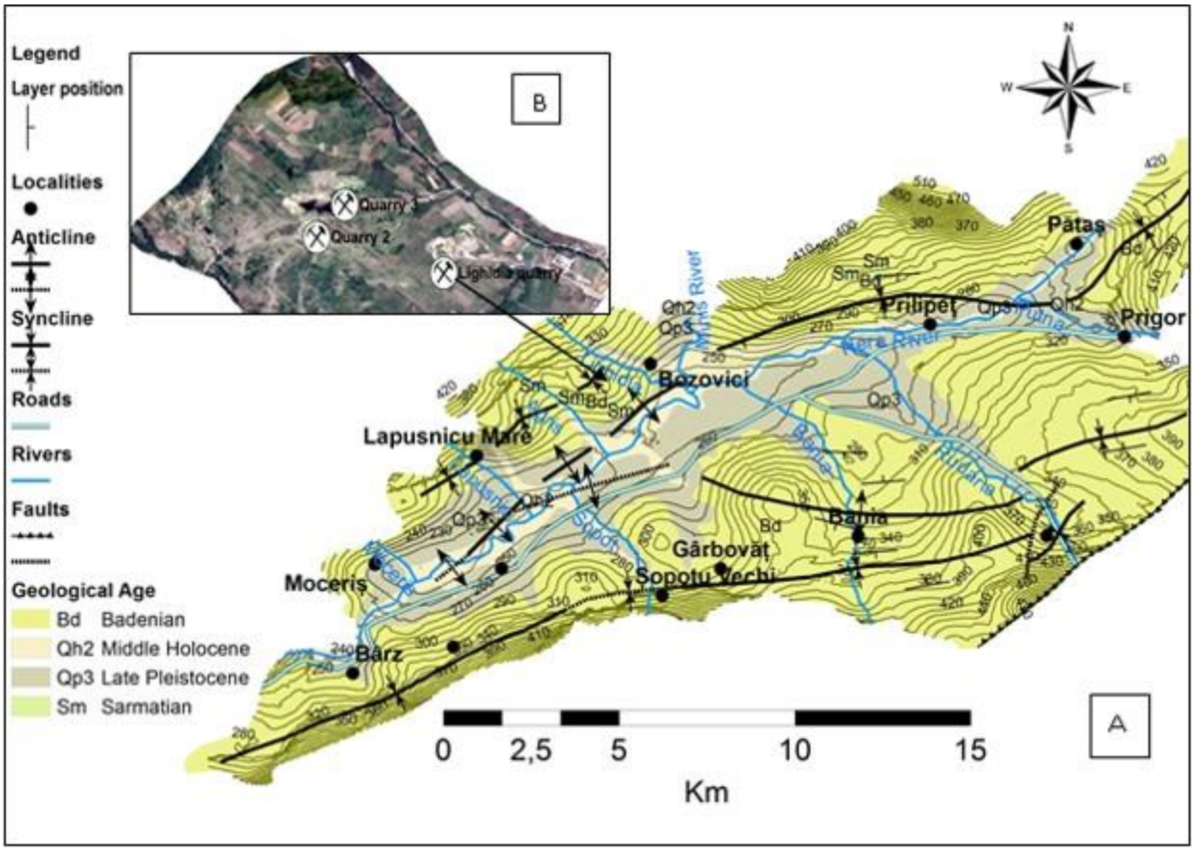

Fig. 1. A. Geological map of Bozovici basin (modified after geological maps Reșița and Baia de Arama – scale 1:200.000); B. Satelitary map of Lighidia perimeter.

The most important fault is situated in the east part of basin, which represents an overthrust fault, which delimit Getic unit from the Danubian unit (Preda et al., 1994). The overthrust of Getic unit over Danubian unit occurred during Laramic tectogenesis. Structurally the basin is represented by anticline and syncline folds that are affected of numerous fractures, which appear during Stiric tectogenesis.

3. Materials and methods

Facies analysis. In the field were determined features of the rocks related of their color, thickness, grain size, sedimentary structures, overall lithofacies characteristics and stratum of boundary, were collected samples from which were made 18 thin sections. Based on characteristics of sedimentary rocks were determined the processes and depositional environments.

Optical microscopy. In the laboratory were analyzed, with optical microscope, 18 thin sections which were made from samples that derive from facies F14, F10, F8, F3, F2, F1, P1. The study of the 18 thin sections allowed determination of mineralogical composition from sandstones and, in some wise, from carbonate nodules.

X-ray diffraction. The bulk samples were grinded in an agate mortar to a fine powder (< 2 μ). X-ray powder diffraction data were measured at 24ºC using an automated Bruker D8 Advance θ-θ diffractometer with CuKα radiation (λ = 1,54Å; 40kV; 40mA), LynxEye detector and Bragg-Brentano geometry. Kβ radiation was eliminated by a Ni filter. Primary and secondary Soller slits were 2.5º. In the measurements were used a 0.6mm divergence slit, a 0.6mm antidivergence slit and 0.1mm width detector slit. Data were obtained using 0.1º 2θ steps from 1º to 60º 2θ counting for 2 seconds per step. The device and emission source profile were modeled using NIST SRM 660a and SRM 676 profile standards.

Qualitative analyses were carried out using Diffracplus EVA software and database PDF-ICDD 2-2008. The Rietveld refinements (quantitative analysis) were carried out using the TOPAS 4.1 software. Pseudo-Voigt (pV) profile function was used for the fit of the peaks. Rietveld refinement quality was expressed by R-values indices represented by Rwp (R-weighted pattern), GOF (goodness-of-fit), DW (the weighted form of Durbin-Watson). (Young, 1996; Pecharsky and Zavalij, 2009).

4. Results and disscusion

Based on grain size, sedimentary structures, overall lithofacies characteristics and stratum boundary were separated 13 sedimentary facies and a pedofacies represented by carbonate nodules, and then compared with those defined by Miall (2006) (Fig. 2). At facies analysis have been added data determined from X-ray diffraction (Table 1) and optical microscopy analysis.

Facies A. The lithofacies consists of sand with gravel sized material (2-10 mm). Grain size is generally very coarse sand to silt, with an admixture of gravels, which consists of sub-angular to sub-rounded grains. The gravels are dispersed in sand. The lithofacies are represented by quartzite, greenschist and carbonate rock fragments. The fossils of microfauna, bivalve, freshwater gastropods remains, and tree stumps are present in this lithofacies. The thickness is between 0.8 to 100 cm and the base boundary is irregular, with non-erosional character. This deposit mould to the bed form. The massive structure and weak normal grading are interpreted as structures produced by high-viscosity mass flows. Matrix-supported massive gravel deposits are formed by mass flow under the condition of balanced viscosity and shear strength (Miall, 2006; Hatano and Yoshida, 2017). This facies is defining for alluvial fans environments, or/ and for proximal sections of the braided rivers (Anastasiu et al., 2007). This lithofacies corresponds to Gmm facies in Miall (2006).

Facies B. Dark grey claystones, massive occur in beds 5 to 100 cm thick and the base boundary is sharp. In this lithofacies occur tree stumps. The mineralogical composition determined based on X-ray diffraction of the sample of the *facies B* consists of montmorillonite, kaolinite, chlorite, quartz, albite and muscovite (Table 1). The existence of montmorillonite and kaolinite in claystone suggest a poorly drained, tropical to subtropical areas of low relief marked by flooding during humid season and substantial pore water in the soil during dry season (Hong et al., 2012). The amount chlorite is probably derived from greenschist lithoclasts and is a characteristic mineral of cold regions and dry marked by very low rates of weathering (Hallam et al., 1991). The presence of chlorite together with montmorillonite and kaolinite indicate a particularly cold and arid episode. This lithofacies represent soil development and is common in vegetated floodplains and is equivalent to Fr facies in Miall (2006).

Facies C. The coal appears seamed between claystones and have a tend to break up in flags. On the surface of coal appear dispersed sulphur. Allochthonous plant fossils are very abundant. This facies formed by quick accumulation of plants fragments in a warm and humid climate, under lower energy conditions. Coal is typically associated with fluvial floodplains environments and indicates deposition in swamps with stagnant water (Hatano and Yoshida, 2017). This facies is equivalent to C facies in Miall (2006).

Facies D. This lithofacies is represented by calcareous claystone without sandy fraction. Leaves fossils and freshwater gastropods remains are abundant. The mineralogical composition identified by X-ray diffraction consists of montmorillonite, calcite, kaolinite, quartz, albite, chlorite and muscovite (Table 1). This lithofacies formed in a specific swamp, created during the floods that had part to sorting of sandy fraction from the clay and silty fraction. The mineralogical composition suggests a warm and humid climate and the apparition of calcite suggest an unusually warm and seasonal arid climate (Hong et al., 2012) consistent with the expansion of C4 biomass (Saylor et al., 2009). This lithofacies represents a floodplain deposit somewhat more distal relative to clastic sources and is equivalent to Fsm facies in Miall (2006).

Facies E. This lithofacies consists of alternating beds of reddish-yellowish marl with micro-ripples and horizontal lamination with silt and sandy lenticular lamination. Lucchi (1992) offers us two explains of form of this facies: 1) the fine material deposited slow and continuous from suspension deposits, when the flow begins calm, and the sandy and silty fraction deposited when appear a strong current; 2) every marl level represents a decrease of the current speed, and the sedimentation beginning with sand followed by silt and mud, which suggest that the flooding of overbank area occurred progressive. This two explains indicate deposition from suspension and from weak traction currents. This lithofacies is common in overbank areas and is equivalent to Fl facies in Miall (2006).

Facies F. This lithofacies consists of interlamination of horizontally bedded sand and ripple cross-laminated sand with reddish yellowish marl. The structures that compound this facies are represented by horizontal lamination, micro-ripples, cross lamination and coal laminae. Horizontal lamination shows deposits from an upper flow regime of a grain flow, parallel with the bad of flow. Sandy ripples indicate the transition from an upper flow regime to a lower flow regime as a result of change velocity of flow current. The mineralogical composition identified in thin section is show off by quartz, feldspar (orthoclase, microcline and plagioclase), opaque minerals (probably pyrite) and lithic fragments caught in a carbonate cement that show an erosional process due to abundant flooding. These lithofacies are defining for laminated sand architecture and are equivalent with Sh and Sr facieses in Miall (2006).

Facies G. This lithofacies consists of pebble to cobble grained conglomerates, that consists of sub-rounded grains. The lithoclasts are represented by quartzite, micaschist, greenschist, sandstone and limestone rock fragments of centimetric to decimetric size. The thickness of this lithofacies is about 250 cm, and the bas boundary is non-erosional, irregular and mould to the bed form. The massive structures are interpreted as structures produced by low-strength, pseudoplastic debris flow, deposited from viscous, laminar or turbulent flows (Miall, 2006). This clast matrix supported is defining for alluvial fan environment, and/or for the proximal sections of the braided rivers and is equivalent to Gcm facies in Miall (2006).

Facies H. This lithofacies consists of grey fine to medium grained sandstone, massive. Bed thickness range from 30 to 40 cm. In the thin section were identified quartz, feldspar (plagioclase and microcline), calcite and lithic fragments caught in carbonate cement. The fossils content is represented by plant remains in bottom and gastropods in top. The lithofacies can be attributed to rapid dumping of sediment directly from turbulent suspension (Lowe, 1988; Widera, 2016). Its massive nature is considerate indicative of hyper-concentrated flows (Widera, 2016). Such beds are the deposits of gravity flows. A characteristic occurrence of this lithofacies is in small channels resulting from bank collapse (Miall, 2006). This lithofacies is equivalent to Sm facies in Miall (2006).

Facies I. Red brown and dark grey marls, massive, occur in beds between10 to 200 cm (the mostly over 100 cm) thick. The mineralogical composition determined based on X-ray diffraction of the sample of the gray marls consists of calcite, quartz, albite, chlorite, kaolinite and muscovite (Table 1), and indicate a warm and humid climate for this lithofacies. This lithofacies is interpreted to result from deposition of suspended material in deep (over 2 m), relatively long-lived lakes covering the overbank area (backswamp). The massive structure is the evidence of the low variability in settling rate and grain sized of these fines (Widera, 2016). The grey color of this lithofacies is indicative of subaqueous accumulation in anoxic conditions caused partially by decomposition of organic matter (Widera, 2016). This lithofacies is defining for the most distal floodplains facies, including deposition in floodplain ponds, and is equivalent to Fm facies in Rust (1978) and Miall (2006).

Facies J. The black shale lithofacies consists of thinly laminated black claystones, very rich in gastropods. The mineralogical composition identified by X-ray diffraction consists of calcite (62.29 % - due to fossils), quartz, chlorite, montmorillonite, kaolinite, muscovite and pyrite (Table 1), and suggest a humid and cold climate. The interpretation of this facies is that mud and gastropods settling in a deep subaqueous domain under anoxic condition (Tavares, 2015). This lithofacies is defining for sediments from lake and is characterized by sediment carried in suspension deposited below the storm wave level. This lithofacies corresponds to Fp in Teixeira (2012).

Facies K. This lithofacies consists of interlamination of claystones, siltstones and very fine grained sandstone, including same sparse plant fossils and freshwater bivalve and gastropods remains. Very small scale ripples are present in the sandstone and siltstone beds. Individual layers are between a few millimeters to a few centimeters. The mineralogical composition identified by X-ray diffraction consists of Calcite, Quartz, Muscovite, Kaolinite, Montmorillonite (Table 1), and indicate a warm and humid climate. The concretions (of the smectic claystone), fine lamination and micro-ripples suggest the transition from a cold and humid climate to a warm and humid climate with incipient processes of form soil. Alternation of sandstone layers with claystone layers suggest the repetition of transportation of sediments by traction processes followed by weakening of flows and deposition by suspension currents. Sharp layer boundaries between sandstone and fine grained layers suggest rapid changes of depositional processes due to flooding in overbank area (Hatano and Yoshida, 2017). This lithofacies is common in overbank areas, including deposition from suspension and from weak traction currents, and is equivalent to Fl facies in Miall (2006).

Facies L. This lithofacies consists of tonstein. The mineralogical composition identified by X-ray diffraction show that montmorillonite is the dominant mineral, with only small amounts of cristobalite and quartz (Table 1). Cristobalite is usually widely spread in sedimentary deposits, due to the transformation of volcanic ash under alkaline or weakly alkaline conditions (Yudovich and Ketris, 2010; Abruzov et al., 2015). The tonstein result from the weathering of volcanic ash falls in a freshwater swamp.

Facies M. This facies consists of weathering tuff. The mineralogical composition identified by X-ray diffraction highlighted calcite, cristobalite, quartz, muscovite and tridymite (Table 1). The mineralogical data for tuff show an alkaline composition by presence of calcite. The association of quartz-cristobalite-trydimite were probably inherited from primary volcanic ash (Mitoza et al., 1987, Arbuzov et al., 2015). According to Addison et al. (1983) the high amount of montmorillonite from tonstein and tuff is due of the depositional environment (salinity, pH of water and early diagenesis) and probably suggests that the environment conditions changed.

The pedofacies (P) is represented by carbonate nodules in the form of lens which are main formed from calcite and siderite and small amounts of quartz, kaolinite, chlorite, albite and muscovite (Table 1). The increasing of pedogenic carbonates under the form of nodules suggest a particularly arid episode and the large amounts of detrital quartz, albite, muscovite and chlorite suggest a seasonally high water influx and a strong physical erosion under dry climate conditions (Hong et al. 2012).

Table 1. X-ray diffraction analyses (%) of the sedimentary deposits in the Lighidia perimeter.

Samples/ Minerals	Tonstein (L) %	Altered tuff (L) %	Black shale (J) %	Smectic claystone (K) %	Marl (I) %	Carbonate nodule (P) %	Clay (B) %	Calcareous clay (D) %
Montmorillonite	92,30	76,10	4,48	70,45	-	-	45,42	35,71
Kaolinite	-	0,73	1,46	1,13	5,34	12,11	21,72	17,60
Clinochlore	-	-	24,77	-	25,43	8,30	18,81	7,50
Cristobalite	6,91	1,49	-	-	-	-	-	-
Quartz	0,79	3,91	5,08	5,21	27,53	18,29	12,30	14,13
Trydimite	-	0,03	-	-	-	-	-	-
Albite	-	-	-	0,56	1,57	2,25	1,10	2,87
Calcite	-	17,39	62,29	22,27	39,11	52,94	-	21,87
Siderite	-	-	-	-	-	5,18	-	-
Muscovite	-	0,36	0,63	0,38	1,02	0,92	0,65	0,31
Pyrite	-	-	1,30	-	-	-	-	-

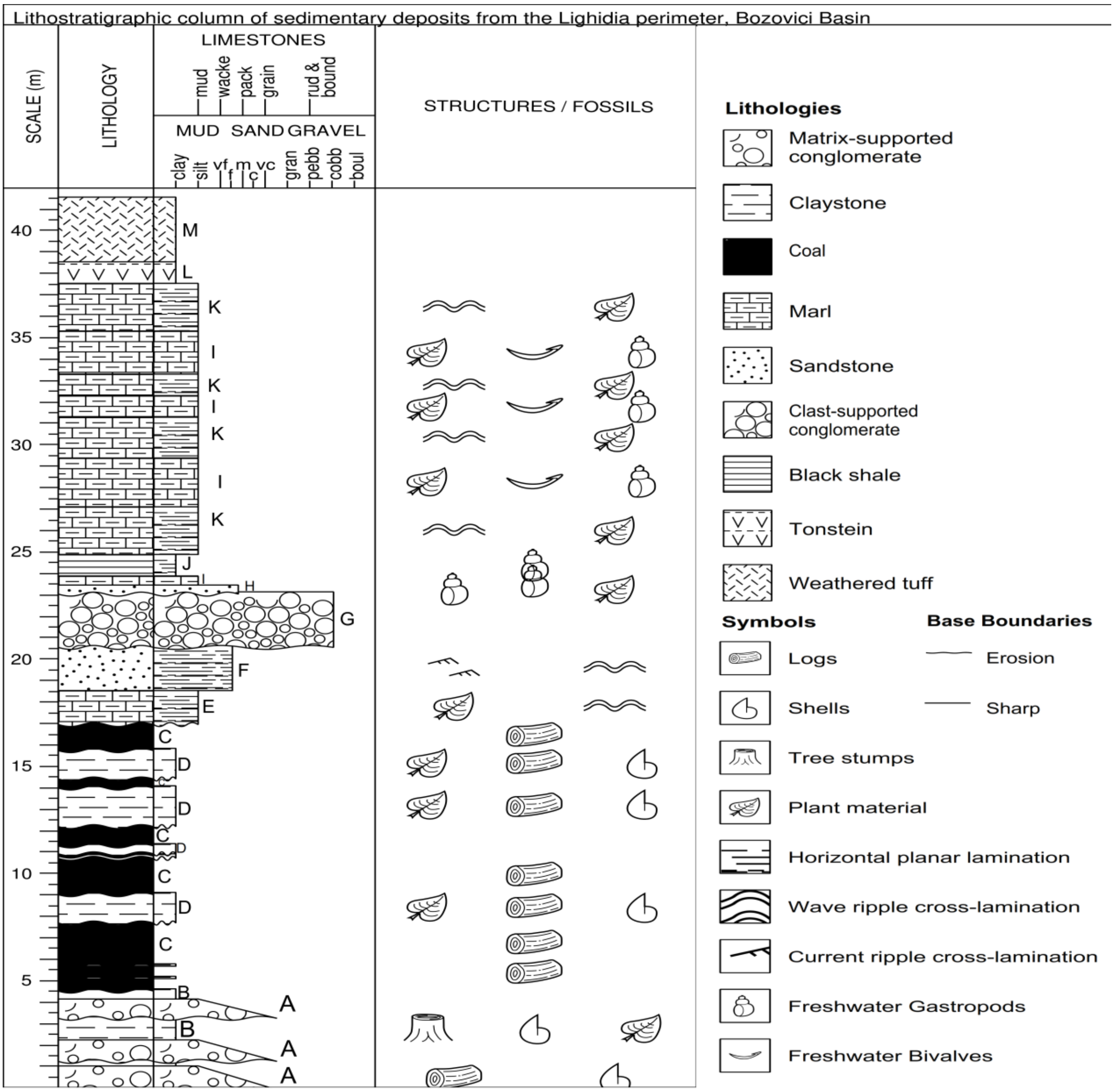

Fig. 2. Lithostratigraphic column of sedimentary deposits from Lighidia quarry, Bozovici basin with original data.

5. Conclusions

The warm and humid climate led to apparition of coal-forming swamps with stagnant water. The presence of calcite is due to the biggest amount of fossils. The black shale lithofacies was deposited in the lake center,where anoxic conditions were fitted up. The big amount of chlorite suggest a cold climate. The alluvial fan sediments in association with nearby lithofacies provide evidence of the braided-alluvial fan processes. Claystone and marl were deposited in depression located on the overbank surface.

In conclusion the rock units were deposited in the alluvial fans and subenvironments of the braided-river system. The coal seams occurred in well-drained swamps and the coal distribution was controlled by braided channels. At the end of sedimentation stage, the basin was occupied by shallow lakes and these were filled rapidly by volcanoclastic products and flood sediments.

The Lighidia perimeter consists from tonsteins and smectitised tuffs with minor kaolinite. The mineralogical composition of these is a function of depositional environment and the volcanic source was probably of intermediate or acidic composition. The economic importance of deposits from studied perimeter is due on the one hand to the existence of large amount of montmorillonite mineral form the tonstein, altered tuff and smectic clay (> 50 %), and on the other hand to the existence of lignite that are wide-spread in the wholly basin.

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