DOI 10.51558/2303-5161.2022.10.10.19 Scientific Paper

GEOLOGICAL CHARACTERISTICS OF THE KOTEZI MINING DISTRICT IN THE BUGOJNO COAL BASIN

Izudin Đulović[1.], Rejhana Dervišević[2.], Dževad Forčaković[3.]

SUMMARY

This paper presents geological characteristic of the deposit Kotezi of the Bugojno coal basin. Regional geological researches were conducted from 1983 to 1987, and detailed from 2014 to the end of 2018.
After field research and laboratory tests, the analysis and interpretation of the obtained results was carried out. Based on the determined borders of surface distribution and the research results of the coal deposit Kotezi, proved are four coal layers: II bottom, I bottom, main and roof.
Coal of the deposit Kotezi belong to the younger coals, soft to medium hard, no luster (matt), brown to black colored, and have brown streak. Their fracture is plate-like and particleboard. He do not have a distinct lignite structure, except in the lower layers. With their general habitus, they resemble younger brown coals, and belong to humic coals which are relatively low in carbonation.
Coal deposit Kotezi is the most important deposit in the Bugojno basin, which is very important due to continuity of coal exploitation.
Considering the raw material potential and the possibility of expanding the existing raw material base, the Bugojno coal basin has particular importance for the long-term development of lignite exploitation and its use for thermal energy purposes.

Key words: the Bugojno coal basin, Kotezi, coal layers, raw material potential.

1. INTRODUCTION

The deposit of coal Kotezi is located on the territory of municipalities Bugojno and Donji Vakuf. From a structural-geological point of view, it belongs to the northwestern part of the Bugojno coal-bearing basin (Figure 1).

Western boundary of the deposit is represented by peripheral parts of the settlements Poriče, hamlet Miličevići and settlement Ždralovići. Settlements Potkraj and Prusac are in the northwest. Settlements Fakići and Guvna, as well as hamlets Grabovci and Krčevine are all located on the north. On the south the peripheral parts are settlements Karadže and Gaj Berića, while the eastern border is represented by the settlements Milanovići and Udurlije and the hamlet Orčevići. In the central part of the productive area are settlements Gornji and Donji Kotezi. The deposit is about 5 km long along the longer axis, and about 3 km along the shorter axis [1,2].

Regional geological researches were conducted from 1983 to 1987, and detailed from 2014 to the end of 2018. [3-13]. Mining district Kotezi contains very significant but insufficiently explored lignite reserves. It should be considered that only shallower parts of the deposit have been explored, so it is justified to predict significantly higher reserves in the deposit.

1. Univerzitet u Tuzli, RGGF, Urfeta Vejzagića 2, Tuzla, Bosna i Hercegovina Tuzla, e-mail: izudin.dlulovic@untz.ba
2. Univerzitet u Tuzli, RGGF, Urfeta Vejzagića 2, Tuzla, Bosna i Hercegovina Tuzla, rdervisevic@gmail.com:
3. Muamer Muratović, project assistant, muamer_muratovictuzla@hotmail.com

Figure 1. Panoramic view of the coal deposit Kotezi (Forčaković Dž. 2021)

2. GEOLOGICAL CHARACTERISTICS

Neogene sediments are represented with freshwater lake formations, situated discordantly over the older basement. This basement consists of Middle Triassic and partly Upper Cretaceous sediments.

In the development of the Neogene, the Middle and Upper Miocene were separated (Figure 2), which is divided into seven lithostratigraphic units: basal ($^{1}M_{2,3}$), the second bottom coal layer ($^{2}M_{2,3}$), clay, clayey sandstones and marls ($^{3}M_{2,3}$), first bottom coal layer ($^{4}M_{2,3}$), marly limestones and marls ($^{5}M_{2,3}$), main coal layer ($^{6}M_{2,3}$), clays and sandy clays ($^{7}M_{2,3}$) [2,7,11,12,14,15]. Miocene is followed by Pliocene-Quaternary (Pl,Q) and Quaternary (Q) sediments.

The deposit is elliptical in shape, running direction northwest-southeast. Coal layers dip slightly to the northeast at an angle of 0-27°. This represents an unfavorable circumstance due to the increase in the depth of the main coal layer, because the thickness of the overburden cover, i.e. the overburden coefficient increases.

AGE		SIMBOL	THICKNESS (m)	LITHOLOGICAL COMPOSITION
Quaternary	Q		20	al - Gravels, clays, clayey sands of heterogeneous lithological composition - 5m gl,f - Rounded pieces and blocks of quartzdiorite, sandstone and shale - 15m
Pliocene, Quaternary	Pl,Q		10	Sandy to fine-grained calcitic grayish-white clays and brown fine to medium-grained sandy brick clays
			15	Roof coal layer interclated with poorly hardened ash sandy marls, coaly and semi-plastic, dark-gray, whitish gray and brown clays
			290	Clays, brown, yellow-brown, sandy and gravelly, sandy polymictic breccias, limestone and heterogeneous conglomerates, poorly bound with clay binder, poorly bound fine-grained to coarse-grained sandstones, often unsorted and clayey, clayey gravels, alevrolites, clayey and dusty sand, sandy breccia, carbonate, light yellow in color and here and there layers of coal and coaly clay
Middle, Upper Miocene				
	$^{7}M_{2,3}$		45	Clays, gray, brown and yellowish, plastic, sometimes sandy and gravelly
	$^{6}M_{2,3}$		68	Main coal layer (bed), coal brown to black, soft to medium hard, mat, compact, with interlayers of coaly clays, marly clays and marls
	$^{5}M_{2,3}$		250	Clayey-sandy marls, gray-brown to whitish-gray clayey limestones, partly hollow, rarely claystones, poorly bounded, clay-bearing terrigenous sediments and coal interlayers
	$^{4}M_{2,3}$		45	First bottom coal layer with interlayers of clayey limestone, marls and clays
	$^{3}M_{2,3}$		65	Clays, bluish, plastic, sandy to gravelly, plate sandy-clayey marls, marly claystones and clayey sandstones
	$^{2}M_{2,3}$		10	Second bottom coal layer with interlayers of coaly clays, claystones and rarely marls
	$^{1}M_{2,3}$		80	Conglomerates, loosely bound and granulometrically unsorted with clay binder, loosely bound sandstones, marly claystones, sandy-gravelly clays, clayey sandstones, limestone-dolomitic breccias and rarely coal interlayers

Figure 2. Sinthesized geological column of the coal deposit Kotezi (Forčaković Dž. 2021)

There are four coal layers of different economic importance in the deposit: II floor, I floor, main and roof.

According to the composition, depth and exploitability of coal layers in the Kotezi deposit, the following are distinguished:

- Roof coal layer - quite complex structure (conditionally exploitable) - It is spread over a relatively small area Karadže-Gaj Berića-Gradina.
- Main coal layer - relatively complex structure (exploitable) - Has the greatest distribution in deposit.
- The first bottom coal layer - very complex structure (non-exploitable). Only in the area from Silin to the west of Guvna, where it stretches along the Rigavac stream bed to Zgonovo near Prusac, could it be exploitable, because the outcrops were mostly discovered in the Rigavac bed, and it is 7.4 m thick (borehole B-43).
- Second bottom coal layer - extremely complex structure (non-exploitable). It has a smaller distribution than the first bottom coal layer.

Basal unit ($^{1}M_{2,3}$)

Going from the northwestern peripheral belt of the basic highlands, from the outcrops towards the morphologically lower parts of the terrain (towards Vrbas river), the basal unit ($^{1}M_{2,3}$) is covered by thick deposits of younger coal-bearing Middle and Upper Miocene and Pliocene-Quaternary sediments.

In the lithological composition of the basal unit, coarse-grained to fine-grained and clayey terrigenous sediments alternate: weakly bound and granulometrically unsorted conglomerates with a clayey binder, weakly bound sandstones, marls, calcitic clays, sandy-gravelly clays, argillaceous sandstones, limestone-dolomite breccias and rarely interlayers of coal with a thickness of 0.1-1.0 m, as well as plate-like interlayers of sandy marls.

Sediments of the basal unit are predominantly gray-green in color. Their dip is about 12°. No macrofauna was found in them, and the microfauna is modest. Determining pollen particles from samples of the basal unit, from the borehole B-18: *Verucatosporites favus, R. Pot. (Polypodiaceae), Pityesporites mikroanalatus R. Pot. (Pinus), Subtriporopollenites simlex, R.Pot. (Carya), Polyporopollenites undulosus, Wolf (Ulmus)* and by the method of correlation with the results of analyzes from coal layers and sediments that build the floor of the upper coal layers, it can be concluded that the basal unit and the coal-bearing lithostratigraphic members were deposited during the Middle - Upper Miocene [16]. Lithological composition of the basal unit has significant practical value for borehole suspension. Thickness of this lithostratigraphic unit is up to 80 m.

The second floor coal layer ($^{2}M_{2,3}$)

The second floor coal layer lies concordantly on the basal unit and belongs to the oldest coal layer in the basin.

Its natural outcrops with elements of spatial orientation 110/14 were registered at the locality near the village of Ždralovići, along the western edge of the basin [27]. The outcrop zone is located in the southwestern part of the basin immediately above the settlements of Alibegovići, Poriče, and towards Ždralovići and Prusac, while the northeastern and eastern borders are formed by the Lubovo and Spahinac streams.

The greatest depth of the second floor layer was determined northeast of Fakić in the area of borehole B-31, where it lies to a depth of 424.5 meters, and the shallowest part is south of Prusac (locality Potkraj) in the area of borehole GO11, where it lies to a depth of 13 m. Floor sediments were drilled at 14 meters, and they consist of sandy dark brown and calcitic green clays.

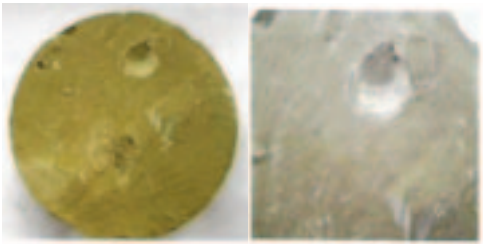
In the phase of regional geological research until the end of 1987, it was drilled with 16 boreholes. During 2017 and 2018 (Phase of detailed geological research) it was drilled with 6 more boreholes (K40, K45, K80, K118, GO11 and GO12) [10,18].

Geological thickness of the coal layer is variable. The average thickness of the layer is 5.6 m, and the average thickness of clean coal is 4.34 m. Interlayered tailings consist of clays, carbonaceous clays and, more rarely, marls. East of the Spahinac stream, the second floor coal layer suddenly loses thickness and disappear. No fossil content was determined in material taken from this lithostratigraphic unit. The thickness of this lithostratigraphic unit is up to 10 m..

Unit of clays, clayey sandstones and marls ($^{3}M_{2,3}$)

This lithostratigraphic unit represents the immediate and higher cover of the second floor coal layer. The sedimentation cycle begins with plastic clays, followed by the sedimentation of calcitic clays, argillaceous sandstones, and sandy to gravelly clays of predominantly gray-green and dark red color.

Packages of plate-like sandy marls with poorly preserved and fragmented fossils of freshwater fauna are subordinately represented in the northwestern part of the Bugojan coal-bearing basin. In the gray sandy marl of borehole K45 at a depth of 348.4 m, a fossil fragments of bivalve lids Pisidium sp. (Figure 3) [14] were found.



a) b)

Figure 3. Lid of bivalve *Pisidium sp.* (a-core, b-enlarged part of the core, the length of the lid is 11 mm) in the core of the borehole K45 from a depth of 348.4 m (Vrabac S., and Đulović I. 2017)

The first floor coal layer ($^{4}M_{2,3}$)

This zone is built of coal and interlayers of sandy-clayey limestone with shells, marls, bituminous sandy marls and clay (Figures 4 and 5).

It was drilled with a total of 28 boreholes (5 boreholes were drilled in 2017 and 2018: K40, K45, K80, K118 and G5).

In the phase of regional geological research until the end of 1987, it was drilled with 23 boreholes. The thickness of the first floor coal layer varies between 1.1-42.0 m. The average thickness of the layer is 12.1 m, and the average thickness of clean coal is 6.1 m. Distance between the second and first floor coal layers varies between 1.56 m (exploratory borehole BŽ-1) and 184.9 m (borehole B-32). The thickness of this lithostratigraphic unit reaches 42 m.

Unit of clayey limestones and marls ($^{5}M_{2,3}$)

Outcrops of sandy-clay and tufa limestones and marls are rarely found on the surface. They were discovered on the left bank of the Poričnica riverbed in the cuts of the ascent road towards the hamlet of Miličevići and in the vicinity of Prusac, Guvna, Ždralovići and Gorica (the cut of the road to the former Tito's villa). This superpositional lithostratigraphic unit is represented between the first floor layer and main coal layer.

Sedimentation of this lithostratigraphic unit begins with sandy marls with ostracods and rarely represented freshwater macrofauna.At the location of borehole B-9, the immediate cover of the first floor coal layer is represented by clayey limestones with shells, Pisidium sp. et al. In the immediate roof of the first floor coal layer, plate-like to thin layered microcrystalline limestones with calcite veins (lake "chalk") [7] can be found.

The most common lithological unit in this zone is clayey limestone, gray-brown to whitish-gray in color. In places it is a poriferous fossil-bearing clayey limestone. In addition to clayey and microcrystalline limestone, marls, sandy marls and less common clays are present in the zone, followed by weakly bound, clayey, terrigenous sediments and interlayers or layers of coal 1-2.2 m thick. The content of $CaCO_3$ in limestones is very high (93-98%), which indicates the possibility of their application in the paper and rubber industry.

The zone of clayey limestones and marls is the most fossil-bearing. However, the freshwater microfauna from clayey limestone layers is characterized by thin soft shells. That is why it is poorly preserved. It is often broken, crushed, and identification of the species is very difficult even in the selected samples.

As part of detailed geological investigations of the Kotezi coal deposit in the northwestern part of the Bugojno coal-bearing basin, micropaleontological investigations were also carried out. Damaged shells of the gastropod Valvata cf. Abdita Brusina (Figure 4) were found in the material from well K45, with a maximum size of 0.8 mm [14].

Figure 4. Shells of the gastropod Valvata cf. abdite Brusina from the core of the borehole K45 from a depth of 139.0-139.2 m (Vrabac S., and Đulović I. 2017)

In the gray marl of borehole K45 at a depth of 179.1 m, a fossil with damaged lids of the bivalve Sphaerium cf. Ožegovići Brusina was found (Figure 5).

Figure 5. Lids of the bivalve Sphaerium cf. Brusina burns (lids length up to 24 mm) in the core of the borehole K45, from a depth of 179.1 m (Vrabac S., and Đulović I. 2017)

In the light gray sandy marl from borehole K80, at the interval 121.8-122.0 m, a gastropod shell fragment (?Lymnaea) and fragments of carbonized plants were found (Figures 6 and 7) [14].

Figure 6. Fragment of gastropod shell (?Lymnaea), borehole K80 (Vrabac S., and Đulović I. 2018)

In the gray sandy marl of borehole K80, at the interval 296.8-297.0 m, a fragment of a Quercus sp. leaf impression was found. (Figure 7), as well as fragments of bivalve lids and a fragment of a gastropod mold [15].

Figure 7. Fragment of a Quercus sp. leaf impression, K80 (Vrabac S., and Đulović I. 2018)

As part of detailed geological investigations of the Kotezi coal deposit in the Bugojno coal-bearing basin, micropaleontological investigations were also carried out (Vrabac and Đulović, 2018). In the material from the borehole K80, at the interval 296.8-297.0 m, damaged shells of the gastropod Valvata cf. abdita Brusina (Figure 8) with a size of 0.7 mm [15] are found.

Figure 8. Shell of the gastropod Valvata cf. abdita Brusina (Vrabac S., and Đulović I. 2018)

Based on the paleontological remains of molluscs and ostracods from the coal-bearing deposits of the Kotezi region, which were determined during the research in 2017 and 2018, it is not possible to precisely define the stratigraphic affiliation of the coal-bearing sediments. Considering that the leading fossils, which belong to proboscideans and rodents, indicate the Middle Miocene and Upper Miocene age of the coal-bearing sediments of the Bugojno basin, it is justified to include the investigated coal-bearing sediments of this area in the Middle and Upper Miocene ($M_{2,3}$) [14,15].

The thickness of this lithostratigraphic unit is significant and tends to increase from the western part of the basin towards the center of the basin. In the western part of the basin, it reaches from 137 m (borehole BP-2, locality Guvna) to 247.95 meters (borehole B-18, locality Kotezi). Its lithological composition has significant practical value for suspending boreholes on the main coal seam. The thickness of the lithostratigraphic unit ranges up to 250 m.

Main coal layer ($^{6}M_{2,3}$)

The main coal layer in the northwestern part of the Bugojno basin is located on layers of sandy marls, marls or clayey limestones (Figure 9). The immediate roof consists of sandy clays, which in places have the characteristics of plastic, greasy clays. They are most often contaminated with heterogeneous, slightly rounded or angular unsorted roof deposits and, less often, carbonized fragments of flora.

During the geological research until 1984, the main coal layer was determined in some boreholes as roof, floor, etc. The dual interpretation of the same coal layer created difficulties in programming the execution and suspension of further exploration works, until its extent and spatial position in the deposit were determined.

According to the results of geological research conducted in 1985, this layer was determined as the main coal layer in the northwestern part of the Bugojno basin [16]. Based on the correlation with the rest of the Bugojno basin, this layer was determined as the main coal layer ($^{6}M_{2,3}$).

The greatest thickness of the main coal layer with barren interlayers was found at borehole B-26 (locality Kotezi)and it is 68.6 m. The thickness of clean coal is 44.55 m [19]. The average thickness of the main coal layer is 24.8 m, while the average thickness of pure coal in the layer is 19.82 m.

The main layer contains interlayers which are represented by clays, marls and rarely clayey limestone. In the lower part of the layer, the barren parts consist mainly of marls, clayey limestones and carbonaceous marls. The upper part of the layer is most often intercalated with clayey matter and carbonaceous marls.

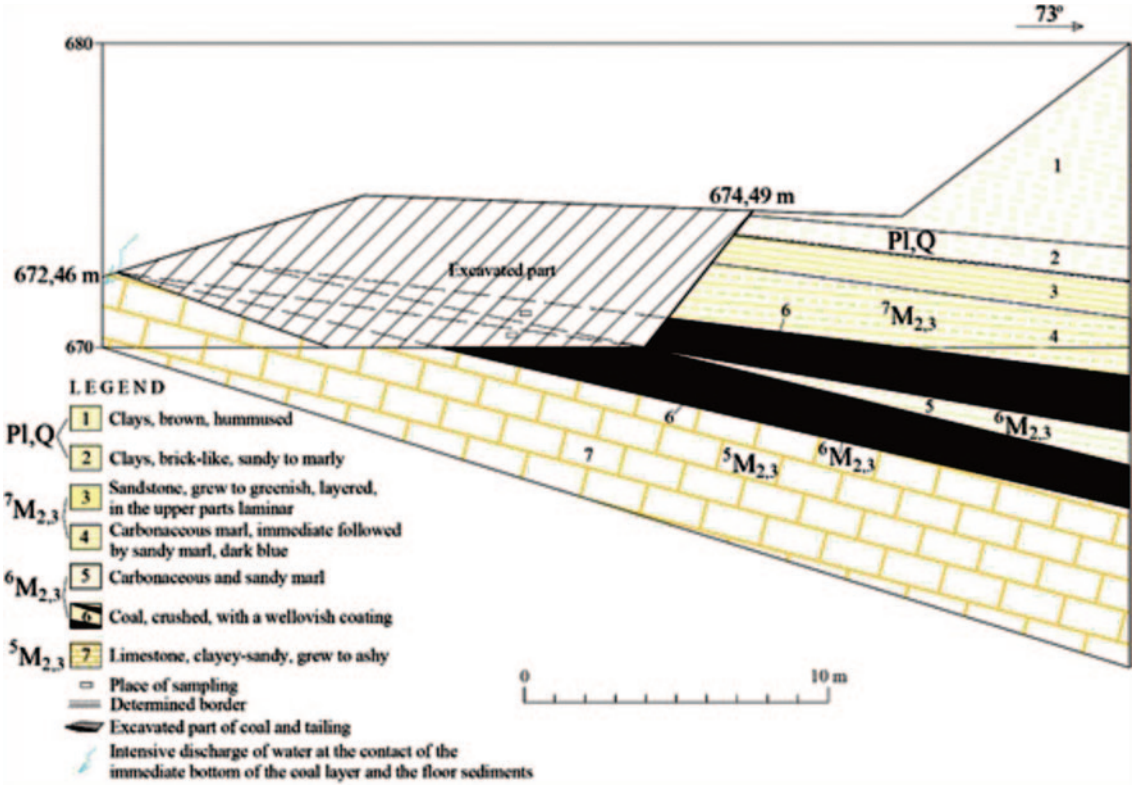


Figure 9. Geological open pit R11, above the Poriče (Forčaković Dž. 2018)

The distance between the main and first floor coal layers is between 8.6 m (exploratory borehole B-2) and 220.5 m (exploratory borehole K80). Petrographic composition includes clayey limestones, gray-brown to whitish-gray in color, poriferous fossil-bearing clayey limestone, marls and sandy marls and rarer clays, as well as weakly bound, clayey, terrigenous sediments and coal interlayers. According to the data, the thickness of the pure coal, i.e. the stratification of the layer, is greater north of the Spahinački fault, which cuts the deposit transversely in the west-southwest-east-northeast direction (WSW-ENE).

In the central and western part of the deposit on the southern fault block of the Spahinački fault, the thickness of coal is greater. Going towards the Vrbas-Voljevac fault, it decreases again, and along the Poriča fault on the uplifted northern block, the main coal layer is distinguished by intense stratification, and the outcrops give the impression that it has no economic value. However, it should be borne in mind that the coal layers are largely burnt when they come into contact with air and moisture, due to their flammability. This is confirmed by the remains of the burned part - which stands out for its brick-red color. Going to the deeper parts of the deposit, the thickness, purity and heat value of the coal give it the main economic importance. Favorable geological factors which show that in certain parts of the deposit the coal of the main coal layer will be able to be profitably exploited by the surface method adequately increase its economic importance.

The following fauna was found in the main coal seam: *Prososthenia* sp., *Sphaerium* sp., *Sphaerium ožegovići* Brusina, *Pisidium* sp., *Orygoceras* sp., *Planorbis pulići* Brusina, fish teeth and bones, *Congeria zoisi* Brusina, *Melanopsis* sp., *Valvata* cf. abdita Brusina, *Planorbis* sp., *Limnea* sp., *Chara* cf. *escheri* Unger, *Oogonije Chara*, Candona sp. [7,10,20,21].

According to the total determined subfossil remains and the finding of Middle and Upper Miocene forms: Betula, Tilia, Ulmus, Salix, etc., it can be concluded that the main coal layer and floor layers were created in the Middle and Upper Miocene. The thickness of this lithostratigraphic unit (6M2,3) varies up to 68 m thick.

Unit of clays and sandy clays ($^{7}M_{2,3}$)

This lithostratigraphic unit is composed of grey, brown and yellow-brown clays which are mostly plastic, greasy, and in places are sandy and fine gravelly or coaly. Sometimes these clays alternate laterally with sandy marl or it is a sandy clay.

The immediate roof of the main coal layer is almost always composed of thinner deposits (0.1–7 m) of greyish, quite crumbling clayey limestone with a lot of faunal remains (gastropodes). These deposits are often sandy, with quartz and chert as admixtures. Over these deposits comes a much thicker series of marls with a higher or lower content of $CaCO_3$ and terrigenous matter.

The following fauna was found in the roof of the main coal layer: *Congeria friči Brusina*, *Melanopsis cognata* Brusina, *Melania verbasensis* Neum, *Lytosthoma grammica* Brusina, *Sphaerium sp., Sphaerium ožegovići* Brusina, *Pisidium* sp., *Dreissena* sp., *Congeria zoisi* Brusina, *Congeria dalmatica* Brusina, Melanopsis pygmaea Hornes, *Stenothyra stenostoma* Brusina, *Lithoglyphus* sp., *Orygoceras* sp., *Prososthenia eburnea* Brusina, *Limnea* sp., *Planorbis manteli, Valvata* sp., *Prososthenia* sp., *Planorbis* sp., *Lithoglyphus*? panicum Neum, *Lithoglyphus* cf. *triapoli* Brusina, *Candona (Pseudocandona)* sp., *Cypris* sp. [9,20-24].

Based on the available age data, this unit is assigned a Middle and Upper Miocene age ($^{7}M_{2,3}$). It is considered that Pliocene sediments were deposited upwards from this lithostratigraphic unit. Thickness of this lithostratigraphic unit ($^{7}M_{2,3}$) reaches 45 m.

Pliocene-Quaternary sediments (Pl,Q)

The deepening of the lake followed the deposition of plant material from which the main coal layer will be formed. It is followed by the clay unit ($^{7}M_{2,3}$), as a coal immediate roof. Then begins the cycle of deposition of fine to coarse-grained sediments, which represent the final part of lake sedimentation. The complex of loosely bound and unbound lithological members of the Pliocene period consists of: clays, brown, yellow-brown, reddish, greenish and gray-blue colors siltstone, sandy and gravelly in all granulations, often unsorted, sometimes calcitic and passing into sandy marls, then sandy to gravelly calcitic clays, sandy polymictic breccias, limestone and heterogeneous conglomerates that are weakly bound by a clay binder. Beside limestones and quartz diorites in the composition of heterogeneous conglomerates, there are also dolomites, Verfen sandstones and Permotriassic sericitic slates and siltstones. Composition of the Pliocene sediments also includes loosely bound sandstones that are fine-grained to coarse-grained, often unsorted and silty, then silty gravel, siltstones, clayey-dusty sand. Interlayers of coal and carbonaceous clay are present in places. The highest (youngest) parts of the complex of terrigenous sediments, according to current knowledge, belong to the Quaternary period.

Roof coal layer

According to its superpositional position, it is estimated that the deposition of Pliocene sediments ends with the sedimentation of the roof layer and its immediate roof. Roof coal layer was isolated in a relatively small area, between the settlements of Karadže, Gaj Berić and Bugojno. Its dimensions are 1.3 km along the strike direction and 1.2 km along the dip direction [1]. In the current phase of research, and in the absence of fossil remains, based on the superpositional position of this coal layer, it is considered to be Pliocene age [7].

Roof coal layer was drilled with a total of 5 boreholes. The thickness of roof layer based on data from boreholes BŽ-21, B-11, B-34 and K128 is 12.17 m. The thickness of pure coal is 7.7 m. It is characterized by intense stratification. Interlayer tailings consist of weakly hardened ash-gray sandy marls, followed by carbonaceous and semi-plastic clays of dark gray, brown and whitish-gray colors. Njegovu neposrednu podinu izgrađuju poluplastične do sitnošljunkovite kalcitične gline sivo- Its immediate floor is made up of semi-plastic to fine-grained calcitic clays of gray-whitish and brown or dark gray color, and the immediate roof is made of sandy to fine-grained calcitic clays of gray-white color and brown fine- to medium-grained sandy clays that have the characteristics of good brick clay.

The distance between the roof and the main coal layer is between 221.15 m (exploration borehole B-11) and 258.78 m (borehole B-34). Petrographic composition of these sediments includes gray, brown, and yellow-brown clays that are mostly plastic, greasy, and in places sandy and fine gravelly or carbonaceous. These clays sometimes alternate laterally with sandy marl or it is calcitic-sandy clay, loosely bound sandstones which are fine-grained to coarse-grained, often unsorted and clayey, then clayey gravels, siltstones and clayey-dusty sand.

Thickness of the Plio-Quaternary sediments in the deeper parts of the basin reaches up to 336.5 m (borehole B-9, locality Udurlije).

Quaternary (Q)

Due to the neotectonic uplift of the Bugojno basin, lake waters receded. After the long Neogene lake phase of deposition, a spacious river basin and fields remained.

During the Quaternary period in the area of the Bugojno basin, the process of raising the terrain and retreating of the lake waters took place more slowly, so the lake sedimentation regime continued through the Pleistocene. Quaternary sediments appear along Vrbas, riverbeds, small streams and larger streams, then at the foot of steep slopes, etc. Terrigenous unbound or semi-bound rocks (clays, silty-clay sands, crumbling and silty sandstones, silty conglomerates and breccias, and unsorted gravel deposited by the arrival of occasional torrential flows into lake waters) could not be separated from similar depositional formations in the Pliocene. Considering that the lower border of Quaternary lithological members on the wider surface of the research area and lake deposits is not defined, they are defined as Pliocene-Quaternary sediments (Pl,Q). In the other isolated Quaternary formations, the following facies are represented: river terrace sediments (t_1, t_2 and t_3), deluvial facies (d), proluvial facies (pr), floodplain facies (ap) and alluvium (al). Lithological composition of these facies is variable and depends on the geological structure of the substrate, as well as the age and way of creation [17].

Quality

Quality of the coal layers of the coal deposit Kotezi (Prusac-Guvna-Kotezi-Karalinka-Gaj Berića) was determined by laboratory and industrial tests (Table 1) performed within the framework of geological research [10-12,25,26].

Table 1. The average values of immediate analyzes of the coal layers of coal deposit Kotezi

Components	Coal layers			
	Prusac-Guvna-Kotezi-Karalinka-Gaj Berića			
	II bottom	I bottom	Main	Roof
Air-dry moisture [%]	24,99	22,37	28,11	23,95
Hygro moisture [%]	6,67	6,06	10,12	6,6
Total moisture [%]	31,66	28,43	38,23	30,55
Ash [%]	23,6	19,52	18,18	20,49
Volatile substances [%]	26,07	30,94	26,65	30,77
Combustible substances [%]	44,74	51,73	46,03	49,19
C-fix [%]	18,70	20,77	16,34	18,41
Coke [%]	42,27	40,62	33,91	38,67
Combustible sulfur [%]	1,45	2,19	1,0	0,48
Bound sulfur [%]	2,32	1,87	1,26	3,20
Total sulfur [%]	3,77	4,06	2,26	3,68
Upper calorific value [kJ/kg]	13.000	12.700	11.000	12.800
Lower calorific value [kJ/kg]	11.300	11.500	10.000	11.500

Reserves

According to the complexity of the geological structure and the degree of tectonic disorder, the Kotezi coal deposit is classified in the II group, and according to the variability of the coal layers (morphology,

thickness and quality) in the II subgroup [10,28]. Based on the results of regional and detailed geological research, the coal reserves of the Kotezi deposit were calculated and confirmed final with the date 07/31/2018 (Table 2).

Table 2. Overview of coal reserves by layers of the Kotezi deposit

[10^6 t]

Deposit	II bottom			I bottom			Main							*Roof			
Kotezi	A	B	C_1	A	B	C_1	A	B	B_{vb}	C_1	C_{1vb}	C_2	D_1	A	B	C_1	C_2
Total	-	-	9,3	-	-	16,8	35	59,5	73,8	1,57	48,6	104	12,5	-	-	-	10,7

*Contoured only in the area Karadže-Gaj Berića-Gradina

Through the synthesis of relevant data, the contoured areas with the balance coal reserves of the main coal layer in the amount of over 90 million tons were determined. Based on the projected production of about 300 x 10^3 tons of coal with predicted exploitation losses of 10%, the established reserves can ensure continuous production for several decades.

4. CONCLUSION

In the area of the Kotezi, the Middle and Upper Miocene were separated, which is divided into seven lithostratigraphic units: basal ($^1M_{2,3}$), the second bottom coal layer ($^2M_{2,3}$), clay, clayey sandstones and marls ($^3M_{2,3}$), first bottom coal layer ($^4M_{2,3}$), marly limestones and marls ($^5M_{2,3}$), main coal layer ($^6M_{2,3}$), clays and sandy clays ($^7M_{2,3}$). Miocene is followed by Pliocene-Quaternary (Pl,Q) and Quaternary (Q) sediments.

The deposit contains four coal layers of different economic importance: II floor, I floor, main and roof.

Mining district Kotezi contains very significant but insufficiently explored lignite reserves. It should be borne in mind that only shallower parts of the deposit have been explored, so it is justified to predict significantly higher reserves in the deposit.

Coal deposit Kotezi is the most significant deposit in the Bugojno basin, which is very important due to the continued exploitation of coal from the main coal layer.

Considering the raw material potential and the possibility of expanding the existing raw material base, the Bugojno coal basin has particular importance for the long-term development of lignite exploitation and its use for thermal energy purposes.

Determined content of $CaCO_3$ in limestones ($^5M_{2,3}$) is very high (93-98%), which indicates the possibility of their application in the paper and rubber industry. The use of limestone for these purposes must be verified by additional laboratory and industrial tests.

Lithological composition of the clayey limestone and marls (unit $^5M_{2,3}$) has significant practical value for stopping boreholes on the main coal layer.

Based on the paleontological remains of molluscs and ostracods from the coal-bearing deposits of the Kotezi region, which were determined during the research in 2017 and 2018, it is not possible to precisely define the stratigraphic affiliation of the coal-bearing sediments. Considering that the leading fossils, which belong to proboscideans and rodents, indicate the Middle Miocene and Upper Miocene age of the coal-bearing sediments of the Bugojno basin, it is justified to include the investigated coal-bearing sediments of this area in the Middle, Upper Miocene ($M_{2,3}$).

REFERENCES

[1] Forčaković, Dž. (2014). Potentiality of coal in deposits of Bugojno basin. Master's thesis. University of Tuzla. RGGF-Tuzla. 1-74.

[2] Forčaković, Dž. (2020). Qualitative characteristics of the coal deposit Kotezi in the Bugojno basin. Archives for Tehnical Sciences. Bijeljina, pp. 21-28.

[3] Čičić, S. (1976). The Bugojno basin. Edition of mineral raw materials of Bosnia and Herzegovina. I tom. Geoinženjering - Sarajevo. 151-158.

[4] Pržulj, M., Đulović, I. (1991). Elaborate on classification, categorization and calculation of reserves in the coal deposit Čipuljić-Šumelji. Geoinstitut - Sarajevo. 1-62.

[5] Selimović, E., Musić, A., Forčaković, Dž. (2014). Elaborate on classification, categorization and calculation of reserves in the coal deposit Čipuljić-Šumelji, municipality Bugojno, 15.03.2014. year, Geotehnos d.o.o. Sarajevo. 1-84.

[6] Žugić, M. (1958). Elaborate on the raw material base of the Brick and tile Company Vrbas-Bugojno. FSD Geoinstituta Ilidža.

[7] Džonlagić, Dž. (1987). Final annual report on regional geological researches of coal in the Bugojno basin. Geological Survey - Sarajevo. 1-658.

[8] Mitrović, Đ. (1967). Elaborate on reserves of lake chalk deposits in Prusac near Donji Vakuf, FSD Geoinstituta Ilidža.

[9] Brkić, E. (2012). Geological composition of Bugojno basin. Master's thesis. University of Tuzla. RGGF-Tuzla. 1-84.

[10] Hajdarević, M., Rožnjaković N. (2018). Elaborate on classification, categorisation and calculation of coal reserves in the main coal layer of the deposit Kotezi, municipalities Bugojno and Donji Vakuf. Geoservice Živinice. 1-150.

[11] Forčaković, Dž., Dervišević R., Isaković H. (2020). Potentiality of the northwestern part of the Bugojno coal basin. Journal of faculty of mining, geology, and civil engineering, 8. University of Tuzla. 26-34.

[12] Forčaković Dž., Dervišević R. (2021). Potentiality of the Bugojno coal basin, Bosnia and Herzegovina. Archives for Tehnical Sciences. Bijeljina, pp. 39-49.

[13] Forčaković Dž. (2021). Engineering geological characteristics of coal deposit Dimnjače (Bugojno basin). Geo-Expo 21. 19-28.

[14] Vrabac, S., Đulović, I. (2017). Report on macropaleontological and micropaleontological researches of core samples from boreholes K-40, K-58 i K-45 from revir Kotezi in the Bugojno coal basin. FSD RGGF-a University of Tuzla. 1-9.

[15] Vrabac, S., Đulović, I. (2018). Report on macropaleontological andi micropaleontological researches of core samples from borehole K-80 from revir Kotezi in the Bugojno coal basin. FSD RGGF-a University of Tuzla. 1-9.

[16] Milojević, R., Tomić, B. (1981). The Bugojno basin coal research project in the period from 1981-1985. years. FSD Geoinstituta Ilidža. 1-78.

[17] Vujnović, L., and all. (1975). Interpreter BGM shet Bugojno, Geoinžinjering – Institute for geological research. Sarajevo. 1-58.

[18] Hajdarević, M., Rožnjaković N. (2018). Geological map of the Kotezi coal deposit 1:5 000. Geoservis d.o.o. Živinice.

[19] Muftić, M., Luburić, F. (1965). Contribution to the knowledge of lithostratigraphic and tectonic relationships of the lake Neogene in Bosnia and Herzegovina. Geological gazette 7. Geological Survey Sarajevo. 103-130.

[20] Maglov, M. (1986). Report on paleontological rewiev of sediments on the task of regional geological research of lignite coal in the Bugojan Basin in 1985. RO Geoengineering -Sarajevo. OOUR Geological Survey -Ilidža. 1-8.

[21] Maglov, M. (1984). Report on the results of paleontological identification analyzes (macro and micro) of fossil fauna from the core of boreholes B-100, B-101, B-102, B-103, B-104, B-105, and B-107 of the Šumelji-Čipuljići research area (SO Bugojno)-Bugojno coal-bearing basin. RO Geoengineering-Sarajevo. OOUR Geological Survey-Ilidža. 1-5.

[22] Selimović, E., Musić, A., Forčaković, Dž. (2014). Elaborate on classification, categorization and calculation of reserves in the coal deposit Donja Ričica, municipality Gornji Vakuf-Uskoplje, 01.05.2014. year. Geotehnos d.o.o. Sarajevo. 1-94.

[23] Jovanović, O. (1984). Report on rusults of palynological analysis (pollen) of coal from borehole B-102 investigation space Šumelji-Čipuljići (Bugojno)-Bugojno coal basin. RO Geoinženjering-Sarajevo. Geological Survey Ilidža. 1-5.
[24] Jovanović, O. (1986). Report on rusults of palynological analysis (pollen) tests on coal and marl samples from boreholes, from the creation of a detailed geological map of the Bugojno coal basin. Geological Survey Ilidža. 1-7.
[25] Operta, M., Forčaković, Dž., Misilo, M. (2013). Geological composition and morphological-tectonical charateristics of the Uskopalje valley. Proceedings of the V conference of geologists of the Bosnia and Herzegovina with international participation. Pale – Jahorina. 57-71.
[26] Zaimović, M., Hodžić, N. (2018). Study on the quality of coal from the Kotezi exploration area. RGH-Inspekt. Sarajevo. 1-91.
[27] Rulebook on cassification, categorization and calculation of reserves of solid mineral row materials and keeping records on them FBiH (Off. newspapers of FBiH 36/12). 1-131.