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CONTENT

Prof. Rejhana Dervišević
Editor in Chief

Dear readers, it is our great pleasure to offer to a scientific and professional public insight at the new issue of "Journal of Faculty of Mining, Geology and Civil Engineering".

In almost six decades of our Faculty's work, besides education was also conducted a research work, achieved through numerous significant domestic, European and international projects that contributed to the development of Bosnia and Herzegovina economy, mining, geological and civil engineering profession and science. Today's organization of our Faculty with five departments emerged from all general departments for scientific and educational work and those are: Mining, Geology, Civil Engineering, Borehole Exploitation of Mineral resources, Safety Studies as well as 15 scientific fields at which scientific work has been carried out (science fields 1.5, 2.1 and 2.7; Frascati).

Work on promoting and raising the quality, as well as affirming this publication, is a great challenge for every editor in chief. To accomplish this goal, current scientific and professional work, as well as systematic work, and successful co-operation of members of the Editorial and Advisory Board, reviewers and authors are necessary.

We would like to thank to the authors that have chosen our Journal for publishing their papers. We expect to continue and extend cooperation in the future, by contributing to the affirmation of the publication, and promotion of scientific thoughts and scientific results as well.

Scientific Paper

PALEONTOLOGICAL AND STRATIGRAPHIC CHARACTERISTICS OF BADENIAN AND SARMATIAN IN THE PROFILE OF BOREHOLE DH-1 NEAR LUKAVAC (TUZLA BASIN, CENTRAL PARATETHYS)

Sejfudin Vrabac[1], Izudin Đulović[2], Elvir Babajić[3]

SUMMARY

The borehole DH-1 was drilled in 2017 in the northwestern part of the Tuzla Basin, about 4 km north of Lukavac. The profile sediments of this borehole are subdivided into Lower, Middle, and Upper Miocene. The Middle Miocene is composed of sediments of Badenian and Sarmatian. Badenian has a thickness of 427,3 m. Based on foraminifera, it is divided into Lower, Middle, and Upper Badenian. The Lower Badenian is 303,3 m thick. It is transgressive and discordant over the freshwater, lake sediments of the Lower Miocene. It is represented by layered marls in which sandstone and conglomerate strata are represented. The lower Badenian has been proved by the foraminiferal *Trilobatus trilobus-Orbulina suturalis* Zone. The Middle Badenian is 19 m thick, and represented by layers of marls and sandstones. The Middle Badenian has been proved by the *Cibicidoides ungerianus ungerianus* Zone. The Upper Badenian is 105 m thick, and consists of laminated and thin-layered marls, as well as thin sandstone layers. It is divided into the older Zone of *Bolivina dilatata maxima*, and the younger Zone of *Globigerina bulloides* (= Zone of Impoverishment). The specificity of the biostratigraphic division of the Badenian in the profile of borehole DH-1 is that here the final part of the Upper Badenian is represented by the *Globigerina bulloides* Zone (= Zone of Impoverishment). This is the first separation of the above mentioned zone both in the Tuzla Basin and the southern margin of the Central Paratethys. The Sarmatian has thickness of 230 m. It is divided into two foraminiferal zones. The older zone is *Anomalinoides dividens* Zone. It is 85 m thick, and corresponds to the Mohrensternia beds. This part of the Sarmatian consists of laminated and layered marls, with layers of sandstone and conglomerate. The younger zone of the Sarmatian is the *Porosononion granosum* Zone, which is synchronous to the *Ervilia* beds. The thickness of this stratigraphic unit is 145 m. This zone is represented by layered marls, with sandstone, conglomerate, and limestone layers. The deposition of the Badenian and the Sarmatian sediments was in the sublittoral of the Central Paratethys, and exceptional reduction of depth was at the end of the Badenian. Then a regression of the sea caused by the Moldavian orogenetic phase occurred. The regression of the sea is indicated by laminated marls, which are represented in the younger part of the Upper Badenian.

Key words: Badenian, Sarmatian, Tuzla Basin, Central Paratethys, foraminifera, molluscs.

1. INTRODUCTION

In the area of the Smolućа syncline, in the northwestern part of the Tuzla Basin, about 4 km north of Lukavac (Fig. 1), the borehole DH-1 was drilled at a depth of 1153 m. The borehole was completed in 2017 with the primary purpose of verifying that a Salt Formation is present in this part of the Tuzla Basin. The financier

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of the exploratory drilling was the company SISECAM SODA LUKAVAC (d.o.o). Since the drilling was performed with continuous core, samples were taken for macropaleontological analysis of molluscs and micropaleontological analyzes of foraminifera. In the first phase of the stady, 22 micropaleontological samples were taken at distances of 1-80 m. Based on the analyzes of these samples, freshwater lake sediments of the Lower Miocene, marine sediments of the Middle Miocene, and the Upper Micene sediments of brackish lake were separated. In the second phase of the study, another 16 micropaleontological samples were taken, at distances 5-10 m, from marine sediments of the Badenian and the Sarmatian. The aim of these studies was to more precisely define the boundaries of the stratigraphic units, as well as to verify that sediments of the Middle Badenian and the younger Upper Badenian zones are represented in the Badenian profile.

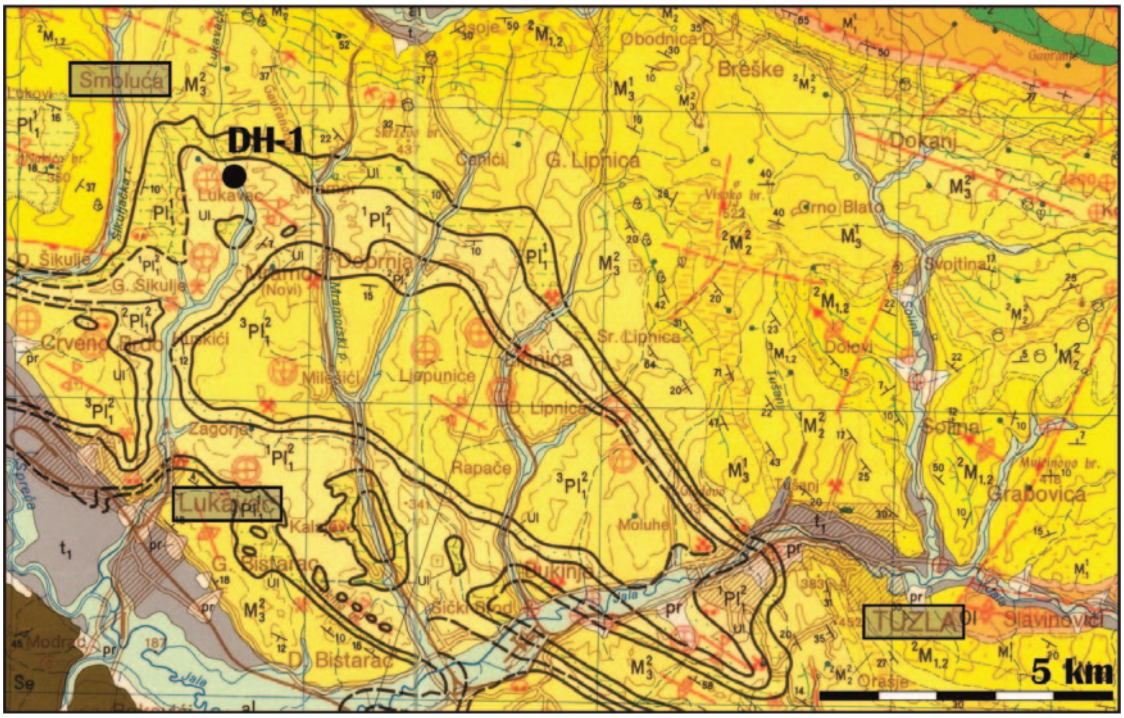

Figure 1. Geographic location of the borehole DH-1(y=6 543 769, x=4 938 591).

2. METHODS

The research was carried out using field, laboratory and cabinet methods. Of the field methods, the method of detailed geological mapping of the DH-1 well core was used. For the micropaleontological analyzes of foraminifera, 22 samples were taken in the first phase of the study, and 16 more in the second phase. Samples collected for microscopic analysis were prepared in the laboratory. In the cabinet, samples were analyzed using an appropriate microscope, foraminifera associations were determined, and foraminiferal zones of the Badenian and the Sarmatian were defined.

3. RESULTS

Based on foraminifera and macrofauna, the Middle Miocene sediments in the DH-1 well profile were divided into the Badenian and the Sarmatian (Fig. 2).

The Badenian was separated at an interval of 1077,3-650,0 m. It is divided into the Lower, the Middle and Upper Badenian. The apparent thickness of the Badenian is 427,3 m. The Lower Badenian is transgressive and discordant over the Lower Miocene frashwater clastic sediments. It is separated in the interval 1077,3-774,0 m. Its apparent thickness is 303,3 m and the dip angles of the layers are 20-30 degrees. It is represented by layered marls, in which sandstone and conglomerate strata are present. Numerous

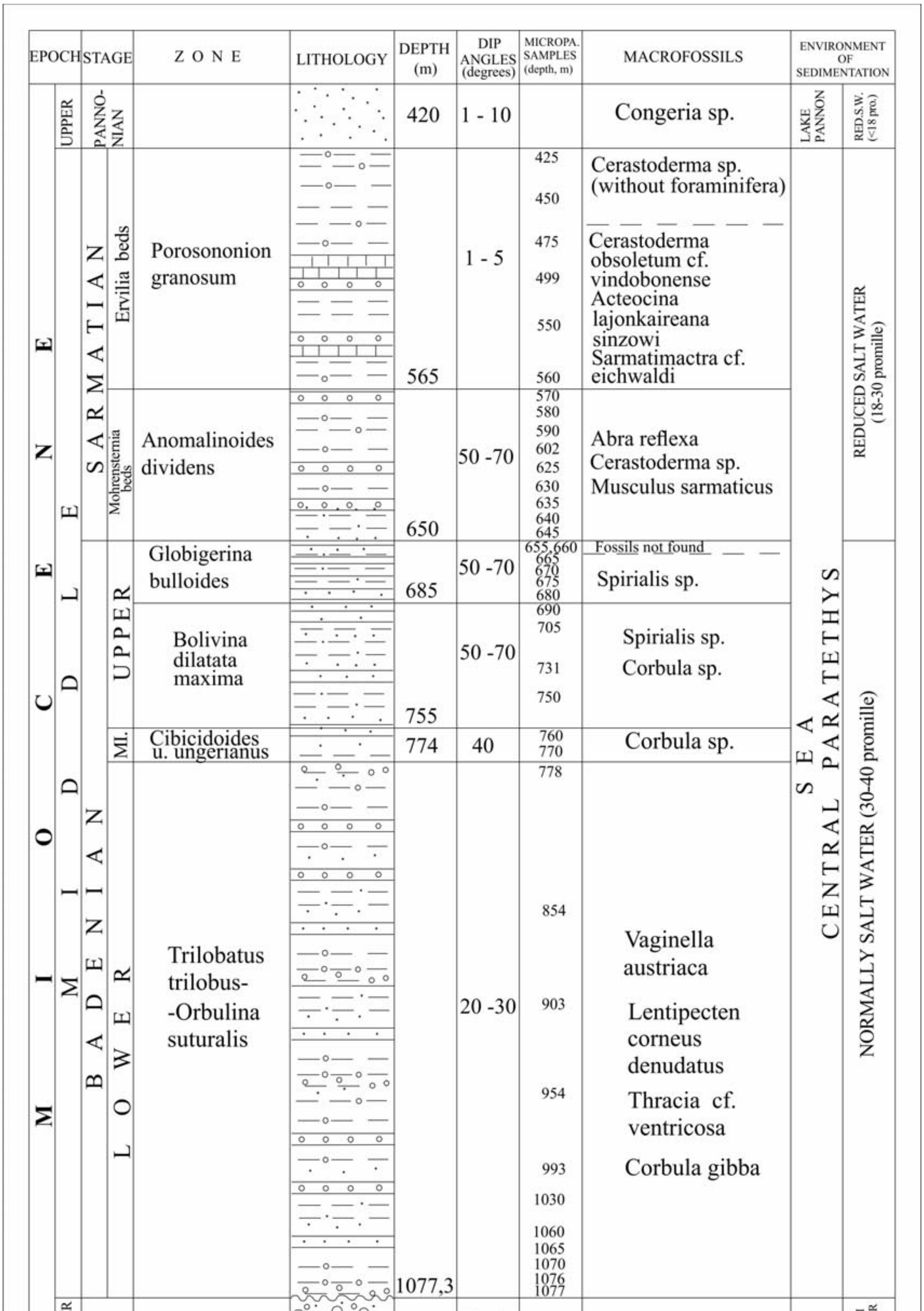

Figure 2. The stratigraphic column of Badenian and Sarmatian in the DH-1 well profile near Tuzla

prints of pteropod *Vaginella austriaca* KITTL are present in the marls in the interval 854,9-1070,0 m. Much less common are molluscs: *Corbula gibba* (OLIVI), *Lentipecten corneus denudatus* (REUSS), *Thracia* cf. *ventricosa* PHILIPPI, etc. Millimeter and centimeter fragments of carbonated plants are occasionally present in marls and sandstones of the Lower Badenian. Dark gray marls and sandstones in the interval 993,4-993,6 m in addition to carbonized plant fragments also contain lamina of coal. The Lower Badenian is evidenced by the foraminiferal Zone *Trilobatus trilobus-Orbulina suturalis.* The following foraminifers were determined in a sample of 778 m deep gray marl: *Trilobatus* (= *Globigerinoides*) *trilobus* (REUSS), *Orbulina suturalis* BRÖNNIMANN, *Globigerina* sp., *Globigerina bulloides* d' ORBIGNY, *Valvulineria complanata* (d' ORBIGNY), *Praeglobobulimina pyrula* (d' ORBIGNY), *Bulimina* sp., *Lenticulina inornata* (d' ORBIGNY), *Bolivina* sp., *Uvigerina cf. aculeata* d' ORBIGNY, *Uvigerina* sp., and *Semivulvulina* sp. (Fig. 3).

Figure 3. Association of the lower Badenian foraminifera from the sample from a depth of 778 m (sizes of shells are 0,2-0,8 mm).

Foraminifers are relatively often represented with a marked dominance of planktonic forms.

In addition to these foraminifers, in other samples from the Lower Badenian were found: *Uvigerina macrocarinata* PAPP & TURNOVSKY, *Quinqueloculina* sp., *Dentalina* sp., *Globoquadrina altispira* (CUSHMAN & JARVIS), *Nonion commune* (d' ORBIGNY), *Praeglobobulimina pupoides* (d' ORBIGNY), *Cibicidoides ungerianus ungerianus* (d' ORBIGNY), *Ammonia viennensis* (d' ORBIGNY), *Uvigerina pygmoides* PAPP & TURNOVSKY and *Borelis* sp.. It should be noted that the *Uvigerina macrocarinata* is represented exclusively in the Lower Badenian of the Central Paratethys (Cicha et al., 1998). In some samples from the Lower Badenian, echinid spines were found, as well as pyrite crystals. Pyrite is also present on individual foraminifera shells. The Lower Badenian Zone of *Trilobatus trilobus-Orbulina suturalis* is equivalent to the Lagenid Zone of the Vienna Basin (Grill, 1943; Papp & Schmid, 1985). The Middle Badenian is defined at an interval of 774-755 m. It is represented by the *Cibicidoides ungerianus ungerianus* Zone. The apparent thickness of this zone is 19 m. The dip angles of the layers are about 40 degrees. Layered marls and sandstone layers are present in this zone. The marls contain fragments of carbonated plants and prints of *Corbula* sp. shell. Pyrite is present either in the form of single crystals or in the form of incrustations on the foraminifera shells. The following foraminifers have been identified: *Cibicidoides ungerianus ungerianus* (d' ORBIGNY), *Bulimina* sp., *Bulimina subulata* CUSHMAN & PARKER, *Praeglobobulimina pupoides* (d' ORBIGNY), *Praeglobobulimina pyrula* (d' ORBIGNY), *Uvigerina* cf. *pygmoides* PAPP & TURNOVSKY, *Globigerina bulloides* d' ORBIGNY, *Fursenkoina acuta* (d' ORBIGNY), *Cassidulina laevigata* d' ORBIGNY, *Globoquadrina altispira* (CUSHMAN & JARVIS), *Valvulineria complanata* (d' ORBIGNY), *Ammonia viennensis* (d' ORBIGNY), *Elphidium* sp., *Dentalina* sp., *Oridorsalis umbonatus* (REUSS) and *Quinqueloculina* sp.. The Upper Badenian is determined at the interval of 755-650 m. It is divided into the *Bolivina dilatata maxima* Zone and the *Globigerina bulloides* Zone. The *Bolivina dilatata maxima* Zone was separated at an interval of 755-685 m. Its apparent thickness is 70 m. The dip angles of the layers are 50-70 degrees. Laminated and thin-layers marls, with thin sandstone layers, are represented in this zone. Of the macrofossils, numerous remains of the pteropod *Spirialis* sp. are present. *Corbula* sp. is also present in some places. Pyrite incrustations are present on individual macrofossils and foraminifera. This mineral is also found in the form of crystals. The following foraminifers were determined in a sample from a depth of 705 m: *Bolivina dilatata maxima* CICHA & ZAPLETALOVA, *Pappina parkeri* (KARRER), *Globigerina bulloides* d' ORBIGNY, *Bulimina elongata elongata* d' ORBIGNY, *Bulimina* sp., and *Orbulina suturalis* BRÖNNIMANN (Fig. 4).

Figure 4. Association of foraminifera of the upper Badenian Bolivina dilatata maxima Zone from a sample from a depth of 705 m (sizes of shells are 0,2-0,6 mm.

In addition to these foraminifers, in this the Upper Badenian zone are also represented: *Laevidentalina* sp., *Nonion commune* (d' ORBIGNY), *Lenticulina inornata* (d' ORBIGNY), *Asterigerinata planorbis* (d' ORBIGNY), and *Fursenkoina* sp. The *Globigerina bulloides* Zone represents the upper part of the Upper Badenian and is separated at an interval of 685-650 m. The apparent thickness of this zone is 35 m. The dip angles of the lamina are 50-70 degrees. This zone consists of gray, laminated, sandy marls. A specific feature of this zone is the extreme scarcity of fossils. Particularly noteworthy are specimens from 660 m and 655 m depth, where no foraminifera were found. Extremely rare foraminifers were found in the laminated marl sample from a depth of 675 m: *Globigerina bulloides* d' ORBIGNY and *Asterigerinata planorbis* (d' ORBIGNY) (Fig. 5). In the specimen from a depth 670 m, one *Quinqueloculina* sp. was found.

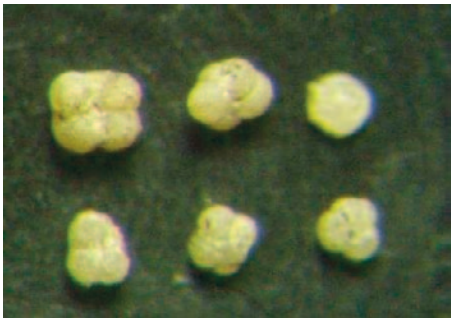

Figure 5. Foraminifers of the upper Badenian G. bulloides Zone from a depth 675 m (sizes of shells are 0,3-0,5 mm).

In the older part of this the Upper Badenian zone, the pteropod *Spirialis* sp. (Fig. 6), as well as fragments of fish scales and carbonated plants, are present.

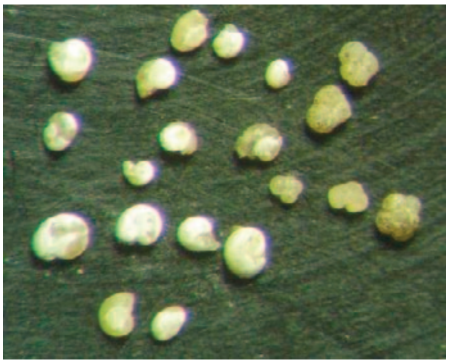

Figure 6. Pteropod shells of Spirialis sp. and globigerins from the Upper Badenian G. bulloides Zone from a depth 665 m (sizes of shells are 0,3-0,6 mm).

The Sarmatian is defined in the interval 650-420 m. It is divided into the *Anomalinoides dividens* Zone, which corresponds to the *Mohrensternia* beds, and *Porosononion granosum* Zone, which is equivalent to the Ervilia beds. The apparent thickness of the Sarmatian is 230 m. The Anomalinoides dividens Zone is separated at an interval of 650-565 m. Its thickness is 85 m. The dip angles of the layers are 50-70 degrees. In this zone there are laminated and layered marls, in which sandstone layers and very rarely conglomerates are represented. Marls contain macrofossils: *Abra reflexa* (EICHWALD), *Musculus sarmaticus* (GATUEV) and *Cerastoderma* sp.. In some samples, millimeter fragments of carbonated plants were also found. Foraminifers are rarely represented. In the specimen of laminated marl from a depth of 625 m, the following foraminifers were determined: *Anomalinoides dividens* LUCZKOWSKA, *Articulina sarmatica* (KARRER) and *Quinqueloculina* sp. (Fig. 7).

Figure 7. Foraminifers of the Sarmatian Anomalinoides dividens Zone from a depth 625 m (sizes of shells are 0,3-0,6 mm).

In this Sarmatian zone are determined also next foraminifers: *Ammonia viennensis* (d' ORBIGNY), *Bulimina elongata elongata* d' ORBIGNY, *Bolivina* sp., *Nonion commune* (d' ORBIGNY), *Elphidium hauerinum* (d' ORBIGNY), *Elphidium* sp., and *Porosononion granosum* (d' ORBIGNY). Pyrite in the form of incrustations on the foraminifera shells is present in the sample from a depth of 640 m. The younger zone of the Sarmatian *Porosononion granosum* was separated at an interval of 565-420 m. It is 145 m thick. The dip angles of the layers are 1-5 degrees. This zone is composed of layered marls, which are partially laminated, as well as layers of sandstone, conglomerate and rarely limestone. Macrofossils are represented by molluscs: *Sarmatimactra* cf. *eichwaldi* LASKAREV, *Cerastoderma obsoletum* cf. *vindobonense* PARTSCH i *Acteocina lajonkaireana sinzowi* (KOLESNIKOV). In the 475-425 m interval no foraminifera were found. In the specimen of laminated marl from a depth of 550 m, the zonal species *Porosononion granosum* (d' ORBIGNY) was determined (Fig. 8).

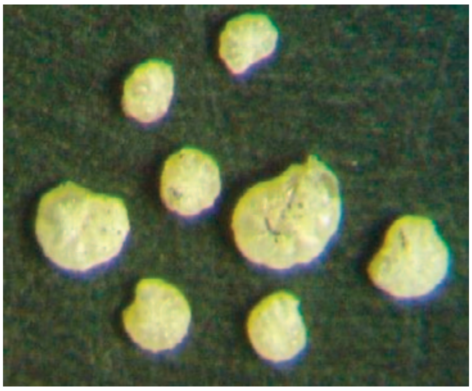

Figure 8. Foraminifers of the Sarmatian Porosononion granosum Zone from a depth 550 m (sizes of shells are 0,2-0,5 mm).

In the marls of this zone are determined also next foraminifers: *Asterigerinata planorbis* (d' ORBIGNY), *Bolivina* sp., *Bulimina* sp., *Quinqueloculina* sp., *Anomalinoides dividens* LUCZKOWSKA, *Pseudotriloculina consobrina* (d' ORBIGNY), *Elphidium hauerinum* (d' ORBIGNY), and *Globigerina praebulloides* BLOW. Ostracodes were also found in some samples. Fragments of carbonized plants, and pyrite incrustations on the foraminifera shells, were recorded in a marl sample from a depth of 560 m.

4. DISCUSSION

Earlier researchers in the northwestern part of the Tuzla Basin (Katzer, 1909; Kranjec,1965; Soklić,1986; Čičić et al., 1991), did not perform biostratigraphic analysis of the Badenian („Tortonian") and the Sarmatian. Based on the lithofacial characteristics, Kranjec (1965) distinguishes the younger „Tortonian" and the Lower Sarmatian in the area of the syncline Smoluća. Soklić (1986) in this part of the Tuzla Basin, among other things, defines the „Tortonian" (= Badenian) and the Sarmatian. On the Geological map of Tuzla, in the Smoluća syncline region, Čičić et al. (1991) defined the younger „Tortonian" and the Sarmatian. The first biostratigraphic distribution of the Badenian and the Sarmatian in this field was perfomed by Đulović et al. (2019). Due to the small number of micropaleontological samples, the boundaries of the stratigraphic units were not precisely defined on this occasion, and the Middle Badenian and the younger zone of the Upper Badenian were not separated. In order to accomplish these tasks, micropaleontological samples taken at distances of 5-10 m were used in this paper. Due to the detailed analysis of the foraminifera from these samples more precisely determined the boundaries of the stratigraphic units and separated the Middle Badenian and the younger zone of the Upper Badenian. The Middle Badenian has been proven by the *Cibicidoides ungerianus ungerianus* Zone. In other parts of the Tuzla Basin, the Middle Badenian is represented by the *Pappina parkeri* Zone (= *Uvigerina bononiensis compressa*) (Petrović et al., 1990; Vrabac, 1999). The equivalent of this zone in the Vienna Basin is the *Spiroplectammina* Zone (= Zone with Arenaceous Foraminifera) (Grill, 1943). The specificity of the biostratigraphic division of the Badenian in the profile of well DH-1 is that the younger part of the Upper Badenian is represented here by the *Globigerina bulloides* Zone. This is the first separation of the aforementioned zone in the Upper Badenian both in the Tuzla Basin and on the southern margin of the Central Paratethys. The younger part of the Upper Badenian in the middle and southeastern part of the Tuzla Basin is represented by the *Ammonia viennensis* Zone (= *Ammonia beccarii*) (Petrović et al., 1990; Vrabac, 1999). In the Vienna Basin, this zone corresponds to the Rotaliid Zone (= Zone of Impoverishment) (Grill, 1943; Papp & Schmid, 1985). In the DH-1 well profile, the Badenian was found to start with the Lower Badenian, which is discordant and transgressive over the freshwater clastics of the Lower Miocene. The Lower Badenian transgression has been proved over a large area of the southern margin of the Central Paratethys (Vrabac, 1999; Ćorić et al., 2009; Mandić et al., 2009; Pezelj et al., 2013; Mandić et al., 2019; Jovanović et al., 2019; Stefanović et al., 2019). Of particular interest is the profile of the DH-1 well, which unlike the central and southeastern parts of the Tuzla Basin, does not have a Salt Formation in the Lower Badenian, nor does the *Ammonia viennensis-Nonion commune* Zone, which is positioned in the immediate roof of the Salt Formation. In the northwestern part of the Tuzla Basin, the Lower Badenian begins with the *Trilobatus trilobus-Orbulina suturalis* Zone. This zone is widely represented both in the Tuzla Basin (Petrović et al., 1990; Vrabac, 1999; Ćorić et al., 2007), and in the Ugljevik area (Petrović et al., 1990; Vrabac, 1991, 1999) and around Belgrade (Petrović, 1962; Eremija, 1987). In the Vienna Basin, the equivalent of this zone is the Lagenid Zone (Grill, 1943). The older Upper Badenian *B. d. maxima* Zone is synchronous with the *Buliminid-Bolivinid* Zone of the Vienna Basin (Grill, 1943). This zone is also separated in the vicinity of Belgrade (Petrović, 1962; Eremija, 1987), as well as in the vicinity of Zagreb (Šikić, 1967; Pezelj et al., 2016). The Sarmatian foraminiferal zones determined in the DH-1 well profile were found in the wider area of the Tuzla Basin (Vrabac, 1999), the Ugljevik area (Vrabac, 1991), and around Belgrade (Petrović and Šumar, 1990). It should be emphasized that the youngest Badenian and the Sarmatian sediments in the well profile of DH-1 do not contain foraminifera, which is probably due to a significant decrease in salinity at the end of the mentioned stages. In many samples of the Badenian and the Sarmatian sediments, pyrite crystals are present, as well as incrustations of this mineral on fossils, which indicates reducing sedimentation conditions. The origin of pyrite can be related to the decay of plants. The Badenian and the Sarmatian sediments were deposited in the sublittoral at the margin of the Central Paratethys. A big reduction of the sea depth was at the end of the Badenian, when there was a regression of the sea caused by the Moldavian orogenetic phase. Then laminated marls were deposited in this part and in other parts of the Tuzla Basin. Laminated the Upper Badenian marls are also present in the area of Ugljevik (Vrabac et al., 2015), as well as in the profile of Gornje Vrapče near Zagreb (Vrsaljko et al., 1995), indicating that the said regression affected the wider area of the southern margin of the Central Paratethys.

5. CONCLUSION

The DH-1 well profile sediments are subdivided into the Lower, the Middle, and the Upper Miocene. The Middle Miocene sediments, represented by the Badenian and the Sarmatian, were divided into zones by foraminifera. The Badenian is represented in the interval 1077,3-650,0 m, and is divided into the Lower, the Middle, and the Upper Badenian. The Lower Badenian is represented by the *Trilobatus trilobus-Orbulina suturalis* Zone. The Middle Badenian is defined by the *Cibicidoides ungerianus ungerianus* Zone. The Upper Badenian is proven by two zones. The older is *Bolivina dilatata maxima* Zone, and the younger is *Globigerina bulloides* Zone. The younger Upper Badenian zone can be treated as the „Zone of Impoverishment" because of its extremly poor fossil association. This impoverishment is probably caused by a decrease in the salinity of seawater at the end of the Badenian. The Sarmatian is represented in the interval 650-420 m. The older part of the Sarmatian is represented by the *Anomalinoides dividens* Zone, or *Mohrensternia* beds. The younger part of the Sarmatian is composed of the *Porosononion granosum* Zone, or *Ervilia* beds. The youngest part of the Sarmatian is characterized by the absence of foraminifera, which is a consequence of the decrease in salinity of the Central Paratethys.

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Scientific Paper

THE IMPORTANCE OF THE WELL INCLINATION ANGLE MEASURING ON THE EXAMPLE OF WELL B-73 ON THE SALT DEPOSIT "TETIMA"

Adnan Hodžić[1], Sanel Nuhanović[2], Elvir Babajić[3], Muamer Muratović[4]

SUMMARY

During the drilling process, when we are exploring solid mineral deposits, especially deeper wells (over 500 m), the well may deviate from the projected drilling direction, both vertically and horizontally.
Based on this, the angle of inclination and azimuth changes, so the well acquires the character of a spatial curve. If this is not controlled, the deviation of the wellbore can lead to significant problems that are difficult to correct later. Sometimes such wells can not be drilled to the projected depth.
The „Tetima" salt mine has a very complex geological structure, as well as an unfavorable spatial position of lithological components in the roof of the salt body, which are characterized by high lying angles (up to 70 °) and their frequent change, with frequent changes in hardness (in range of sandstone-marl), and negatively affect the correct management of the wellbore.
Maintaining the projected direction is a complicated process that could be seen during the construction of the B-73 well.
This work presents the results of measuring the deflection of the well channel, which were done on the well B-73, and the measures that were taken to keep the well in the projected values.

Key words: inclination, borehole, measurement, angle of incidence, inclination angle, azimuth

1. INTRODUCTION

Well B-73, is located in the central field of the Eastern, shallower part, rock salt deposit "Tetima", and its construction was performed according to the "Terms of Reference" for AMP drilling and equipping of exploration - exploitation wells B - 73 and B - 72, on deposit of rock salt "Tetima".

The goal of drilling is to accomplish the tasks included in the "Technical project of drilling and equipping exploitation wells for the exploitation of the Tetima rock salt deposit".

Wellhead, according to the Project, is located near the left bank of the Jala river. This complicated its working surface preparation.

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Because of that, wellhead of B-73 was displaced from the river bed and B-73 has become directional well.

During the directional drilling process there are specific problems occur. They are caused by the shape of the trajectory and by the weight of the tool along the curved part of borehole. As the inclinationa angle increases, these problems become more pronounced.

Some of the most common problems are: borehole deviation, ″dog-leg″ problems, borehole instability, differential-pressure sticking and the need to drill a new borehole.

Difficult borehole cleaning of directional borehole is the main cause of these problems.

Due to the above problems, it is necessary to perform constant deviation measurements in order to identify deviations as early as possible and take appropriate actions to return the wellbore to the intended framework.

2. GENERAL GEOLOGICAL DATA OF THE SALT DEPOSIT "TETIMA" WITH SPECIAL REFERENCE TO WELL B-73

On the southern slopes of Majevica, NE of Tuzla, at a distance of 8 km, a rock salt deposit "Tetima" is located. The reservoir is of Miocene age, formed in marine - lagoon sedimentation conditions.

In the plan, the deposit has an irregular elliptical shape, with a longer axis over 2000 m and a shorter one around 1000 m. It is built of a single sonic body, layered-lenticular form, deposited in the Dokanj syncline, which, in the eastern part, takes on the characteristics of a synclinorium, due to the antiform rise of the floor, which complicates the shape of the deposit.

The exploitation field is divided into eastern and western districts, where, looking from the communication aspect, the border between the districts is natural, and that is the trough of the Jala river.

The deposit has a dinar direction of extension and sinks, ie. it increases the depth of deposition in the west direction. The bedrock depth of the formation is 400 m in the east and over 1000 m in the west, which gives an average drop of 16°.

The fall of the salt body in the southwest direction, perpendicular to the extension, is up to 30°.

The maximum thickness of the salt body is 150-200 m. The salt body is monomineral, with the appearance of various forms of rock salt in the deposit. The quality of the salt body is quite uniform, with an average NaCl content of about 92 %.

The deeper floor of the salt body is formed by laminated dolomicrites which, in direct contact with salt, turn into dark massive, and then into tract-laminated dolomites. The immediate floor is an 8-10 cm thick layer of banded anhydrite.

The roof of the deposit is represented by well-stratified, anhydrite-marl breccias, which, in addition to fragments of banded marls, include: anhydrites, marly limestone, tuffite and as a binder - dark gray Lower Baden marl. Breccia was formed after a short-term emersion, during which drying cracks occurred, both in clay-carbonate sludge and in gypsum-anhydrite sediments. The breccia layer is 5-40 m thick.

The upper and higher roof consists of massive marls (lower torton), followed by marls and sandy-marly and laminated sediments. Geological conditions at the B-73 well site are shown in Figure 1.

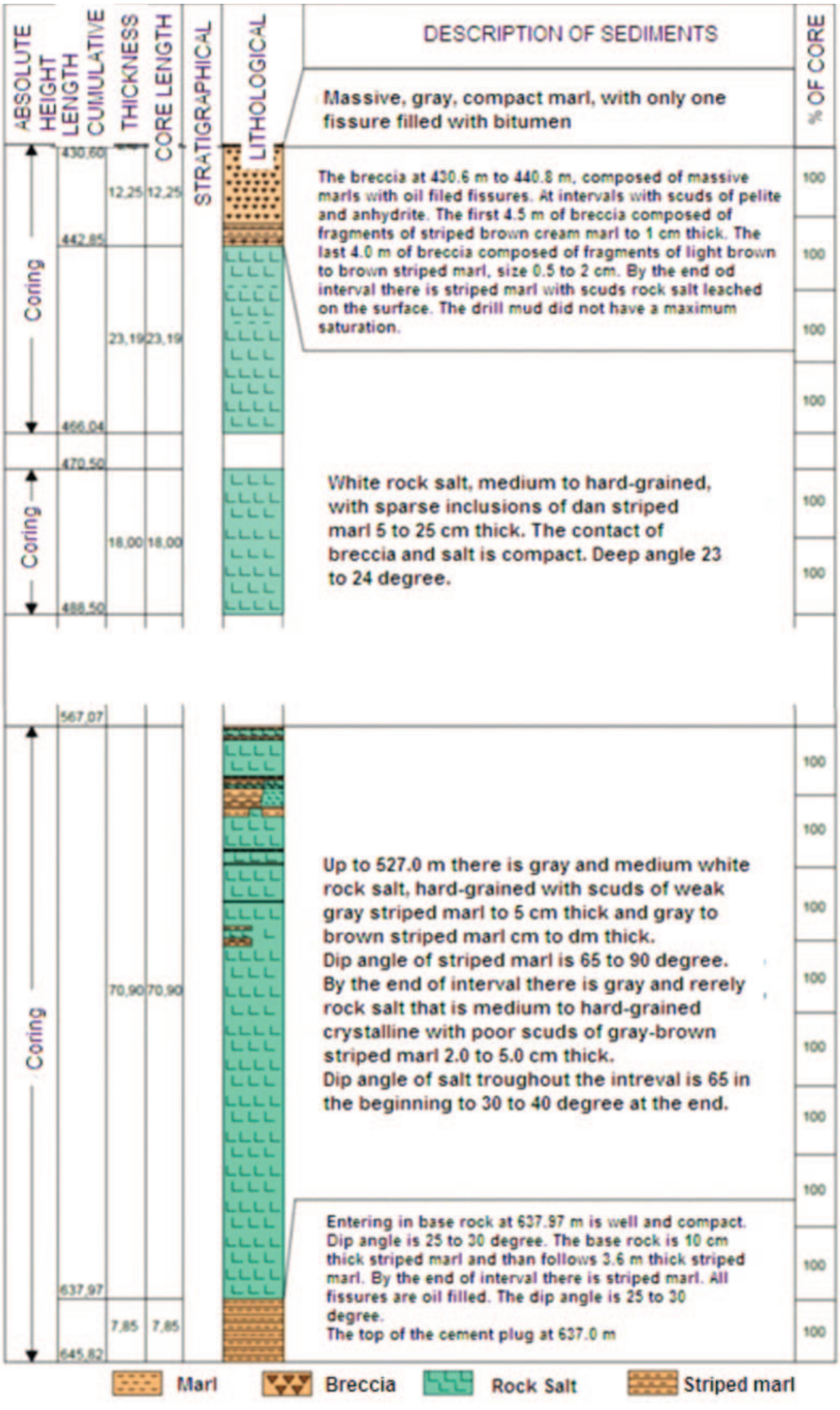

Figure 1. Lithological log of well B-73 on the rock salt deposit "Tetima"

3. CONSTRUCTION OF WELL B-73

The wellhead of the B-73 well (Figure 2) is located in the immediate vicinity of the left bank of the Jala River, which complicated the preparation of its working surface.

Therefore, the wellhead was relocated from the Jala river bed, making well B-73 directed (Table 1 and Figure 1), and the horizontal distance (spacing) between the wellhead in the field and the projected mouth is 19.34 m.

PROJECTED WELL COORDINATES B-73 (B73A)		WELL COORDINATES B-73 IN FIELD (B73B)	
X	6.560.913,87	X	6.560.933,20
Y	4.937.731,10	Y	4.937.730,44
Z	403,00 (407,65 - enbanment)	Z	407,65

Table 1. Coordinate of well B-73

Figure 2. Position of the wellhead B-73 (B-73B) in relation to the designed position (B-73A)

The borehole channel for the installation of the inlet column 20″ (508.00 mm) was drilled "dry", while simultaneously lowering a drill string, using a working column Ø 1000.00 mm and a mechanical grab, to a depth of 15.00 m.

For the installation of a surface protection column Ø 13 3/8 " (339.7 mm), the borehole channel was drilled by a rotary method, in the interval from 15.0 m to 132.80 m.

When drilling this interval, a chisel with a diameter Ø 17 ½ " (444.5 mm) of the HUGES XDG type with 28/32 nozzles was used, for soft to medium hard formations.

Due to the known natural slope of the layers, and for the given maximum allowed inclinations of 1 % of the vertical depth of the well, a combination of rigid tool stabilization and minimum drilling mode was used during drilling.

Drilling of channels for installation of technical column Ø 9 5/8 "(244.5 mm), chisel diameter Ø 12 ¼" (311.15 mm) was performed by a combination of rotary drilling and drilling with a turbine drill (interval from 134.2 - 469.5 m).

4. CASING AND CEMENTATION WORKS

The first conductor casing, spirally welded, with Ø 20″ diameter (508 mm) was installed up to 15.0 m and cemented by pouring concrete from the surface into the space between the conductor column Ø 20″ (508 mm) and the lowered working column Ø 1000 mm, with successively extraction of the working column Ø 1000 mm.

After the well was processed and prepared with a Ø 17 ½″ diameter chisel (444.5 mm), for the installation of a surface column Ø 13 3/8 ″ (339.7 mm), the surface column was calibrated and installed to a depth of 130.88 m. Cementation was performed using a cementing head.

At a depth of 467.50 m, a technical column with a diameter of Ø 9 5/8″ (244.5 mm) was installed.

Cementation was performed according to Perkins method.

The first free-hanging column (diameter Ø 7 ″) was installed to a depth of 625.66 m, and the second free-hanging column (diameter Ø 4 ½″) was installed to a depth of 636.00 m (Figure 3) [lit 2].

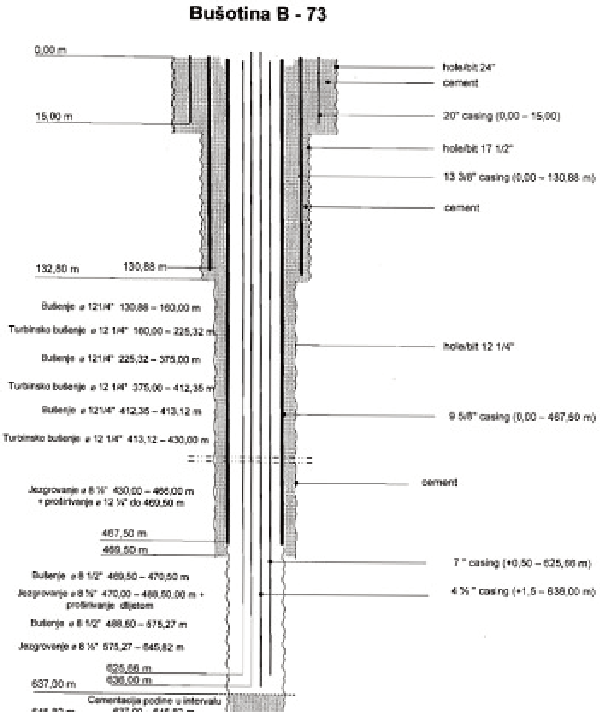

Figure 3. Construction of well B-73 on the rock salt deposit "Tetima" [lit 2]

5. ANGLE AND DIRECTION MEASUREMENTS

In the drilling process, when exploring deposits of solid mineral raw materials, especially deeper wells (over 500 m), the well can deviate from the projected drilling direction, both vertically and horizontally. At the same time, the dip angle and the azimuth change, so the well acquires the character of a spatial curve.

Due to the curvature of the well, the drill rods wear is significantly increased, due to their friction against the wall of the well, the rational drilling technology (regime) is disrupted, energy consumption increases, the number of accidents increases and their liquidation becomes more difficult and it is often impossible or significantly difficult to lower the protective tubes. Sometimes such wells cannot be drilled to the projected depth.

Regardless of the cause of the well channel curvature, it can be different in direction and intensity. In that case, it is necessary to determine, with great accuracy, the spatial position of the well channel, which is defined by the dip angle or inclination angle of the well, azimuth and depth of the well (Figure 4).

Directional drilling is a three-dimensional procedure, where the azimuth is the deviation from the magnetic north in the horizontal plane, and the inclination of the well (inclination angle) is the angle at which the well deviates from the vertical direction, represented as zero degrees of deflection.

Azimuth is defined as the orientation of the wellbore channel, ie. its projection in the horizontal plane, measured clockwise, relative to the magnetic north. The line along the vertical direction is always parallel to the Earth's gravitational field.

In the drilling phase, measurements of the angle and direction of the borehole channel were performed every 18 meters.

The measurement was performed with a photoinclinometer (Figure 5), to monitor the position of the well bottom, in order to mathematically determine the mean azimuth and deviation of the well channel based on the above two data and the length of the measured interval.

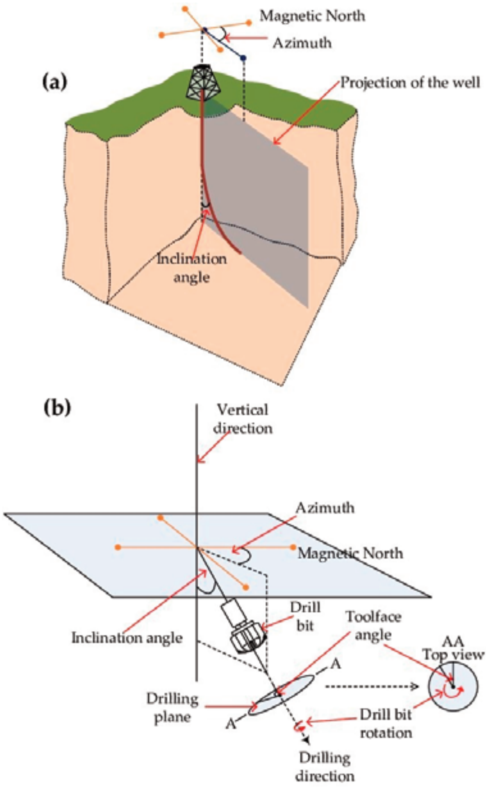

Figure 4. The spatial position of the borehole channel and basic elements determining [lit 7]

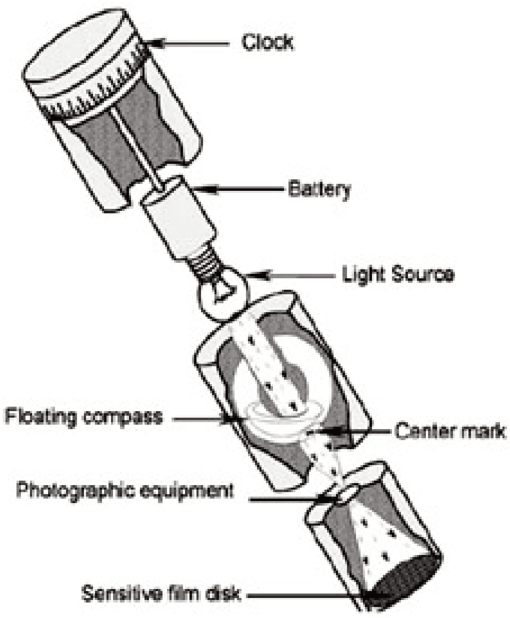

Figure 5. Photoinclinometer with basic parts [lit 8]

Based on these data, a tendency of deviation of the well from the vertical axis was observed at all times, ie. timely response was taken to bring the well within the specified angle deviation and deviation from the vertical axis of the well using a turbine.

A projection of the well deflection was made, and the analysis is presented in graphical and numerical form (Figures 6-9, Table 2) [lit 3].

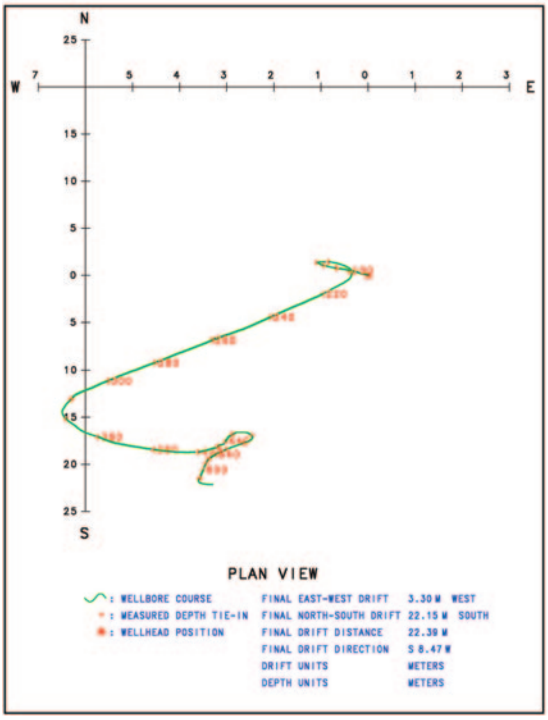

Figure 6. Horizontal projection of the B-73 well channel trajectory [lit 3]

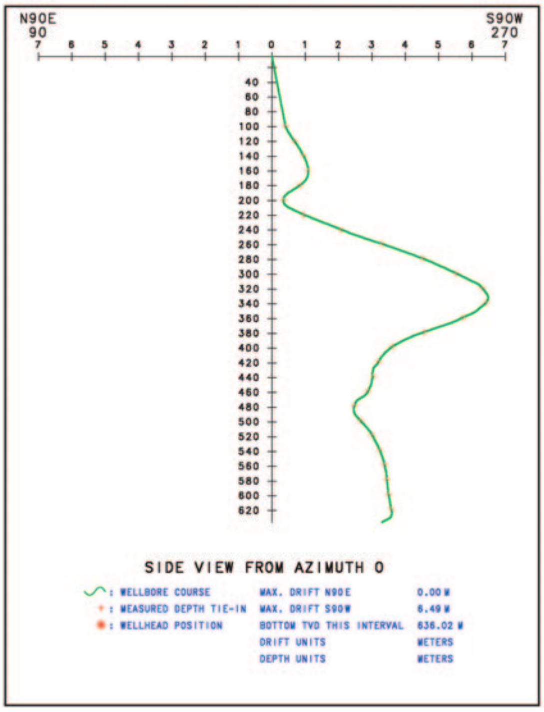

Figure 7. Vertical projection (E - W) of the B-73 well channel trajectory [lit 3]

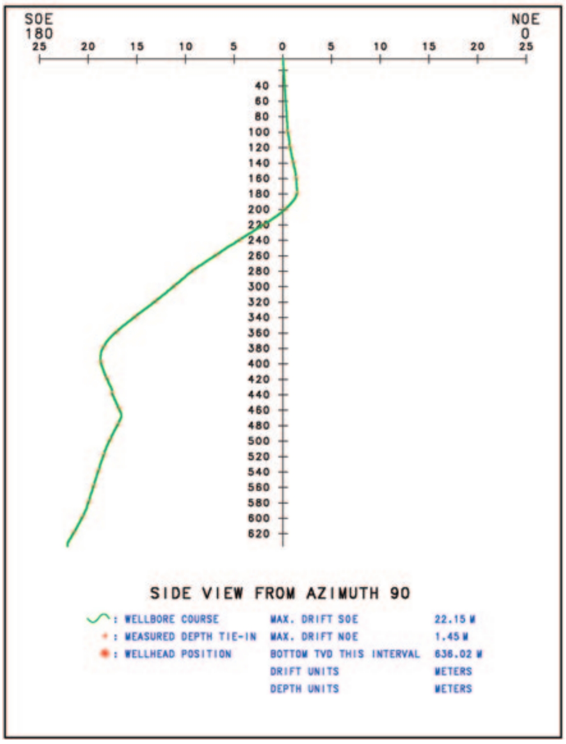

Figure 8. Vertical projection (S - N) of the B-73 well channel trajectory [lit 3]

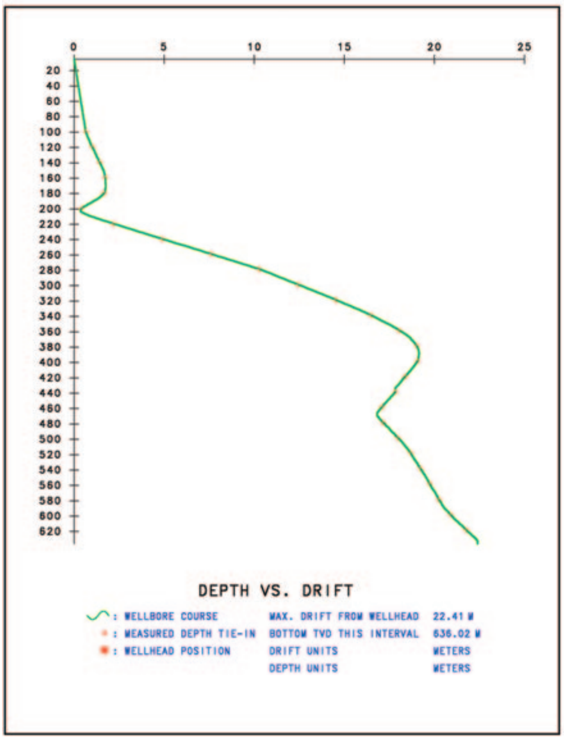

Figure 9. Vertical projection of the B-73 well channel trajectory [lit 3]

	DEVIATION			DEVIATION COORDINATES POSITION		TOTAL	
DEBTH	ANGLE	AZIMUTH	T.V.D.	N-S	I-W	N-S	I-W
5.00	0.0	0.0	5.00	0.00N	0.00E	0.00N	0.00E
100.00	0.8	321.6	100.00	0.51N	0.41W	0.51N	0.41W
120.00	1.2	311.3	119.99	0.07N	0.08W	0.76N	0.68W
140.00	1.2	329.6	139.99	0.09N	0.06W	1.07N	0.95W
160.00	0.1	321.6	159.99	0.03N	0.01W	1.35N	1.08W
180.00	1.9	116.1	179.98	0.02S	0.12E	1.42N	0.83W
200.00	5.1	180.7	199.94	0.42S	0.03E	0.23N	0.34W
220.00	7.7	203.6	219.80	0.63S	0.24W	2.00S	0.96W
240.00	7.8	205.8	239.61	0.62S	0.27W	4.47S	2.07W
260.00	7.8	207.6	259.43	0.58S	0.35W	6.87S	3.31W
280.00	7.0	210.4	279.25	0.58S	0.29W	9.26S	4.53W
300.00	6.0	205.2	299.13	0.47S	0.24W	11.16S	5.53W
320.00	6.0	190.7	319.02	0.51S	0.11W	13.10S	6.31W
340.00	6.0	170.8	338.91	0.52S	0.07E	15.18S	6.41W
360.00	5.9	150.9	358.80	0.45S	0.25E	17.12S	5.73W
380.00	4.4	124.4	378.72	0.24S	0.32E	18.47S	4.55W
400.00	2.2	68.0	398.69	0.03N	0.19E	18.71S	3.60W
420.00	2.3	13.0	418.68	0.18N	0.07E	18.09S	3.19W
440.00	2.1	7.7	438.66	0.00N	0.01W	17.56S	3.03W
460.00	2.2	14.9	458.65	0.18N	0.06E	16.82S	2.88W
480.00	2.5	171.0	478.63	0.20S	0.05E	16.98S	2.47W
500.00	2.5	208.6	498.61	0.19S	0.10W	17.79S	2.66W
520.00	1.8	206.0	518.60	0.13S	0.07W	18.44S	3.01W
540.00	1.6	200.1	538.59	0.13S	0.05W	18.96S	3.24W
560.00	1.4	189.9	558.58	0.12S	0.03W	19.46S	3.38W
580.00	1.5	184.5	578.58	0.13S	0.01W	19.96S	3.45W
600.00	2.3	184.5	598.57	0.19S	0.02W	20.60S	3.50W
620.00	2.6	185.2	618.55	0.23S	0.02W	21.48S	3.58W
637.50	2.6	64.1	636.02	0.00N	0.12E	22.15S	3.30W
FIRST MEASUREMENT POINT INFORMATION:							
5.00	0.0	0.0	5.00	0.00N	0.00E	0.00N	0.00E
LAST MEASUREMENT POINT INFORMATION:							
637.50	2.6	64.1	636.02	0.00N	0.12E	22.15S	3.30W

FINAL DEVIATION 'EAST-WEST' = 3.30 W
FINAL DEVIATION 'NORTH-SOUTH'= 22.15 S
VALUE OF FINAL DEVIATION = 22.39 M
DIRECTION OF DEVIATION = S 8.47 W

Table 2. Numerical analysis of CDS well B - 73 for characteristic measuring points [lit 3]

6. DISCUSSION

The complex geological profile of the "Tetima" rock salt deposit often causes stronger distortions in the borehole channels. The complex structure and unfavorable spatial position of lithological members in the roof of the salt body, which are characterized by high lying angles and their frequent change with a significant change in hardness (in the range: sandstone-marl), are extremely unfavorable for correct guidance of borehole channels along its projected axis in space.

This is the case on well B-73, where, during the construction of the mentioned well, there was a deviation from the projected direction.

The maximum inclination angle of the borehole channel from the vertical is 7.8°, and was measured in the interval from 215 m to 265 m, and the deviation of the bottom of the well in relation to its wellhead was 22.39 m (Figure 5).

Deviations are evident in the display of vertical projections (Figures 7 and 8).

In relation to the projected axis, the well had a deviation of 9 m, which is 2.5 m more than projected.

In order to reduce this deviation, it was necessary to change the drilling regimes, from rotary drilling to the use of turbine drills.

The packed BHA technique was also used, as well as pendulum BHA technique, with milder drilling regimes, in order to avoid greater borehole deflection.

All this gave positive results, and the well was completed within the given project framework.

7. CONCLUSION

Practical borehole trajectory has never matches with its projected trajectory. During the drilling process, deflection of boreholes trajectory is common. If that deflection is notably, especially in long wells, it can be danger for success at the end of drilling process. In the case of the completed well, if measurements have not been performed, it may preclude correct geological interpretation of deposits.

The complex structure and unfavorable spatial position of lithological members in the geological profile of B-73, which are characterized by high lying angles and their frequent change with a significant change in hardness (in the range: sandstone-marl), are extremely unfavorable for correct guidance of borehole channels along its projected axis in space.

Frequent core requirements (200 meters per hole) make this problem even more complex.

The mentioned conditions require continually measurements of trajectory spatial position for their eventually corrections.

Because of that, these measurements have special significance, that can be seen on the example of the well B-73.

During the drilling process (B-73), measurements of inclination angle and direction are done (every 18 meters). These measurements were made with an inclinometer and that data was implemented for mathematical model of average azimuth and deviation of borehole.

Based on these data it was cocluded that, due to the geological conditions (uplift of the breccia), during the execution of works, there was a deviation from the operational plan for the construction of the well, and thus the existence of a larger slope of the well (approximately 2.5 °).

The deviation of the well from the projected vertical axis in the zone of entry into the salt body was within the allowed limits. With the continuation of core / drilling in the salt body zone, despite the use of the pendulum BHA technique and light drilling regimes, there was a continuation of the increase in deflection. At the final measurement depth of 617.00 m, a deviation of approximately 9 m from the designed axis of the wellbore appeared, which is also axis of the future chamber, and it is 2.8 m more than the design value.

This overrun was remedied by introductory leaching, so that this defect was remedied.

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Scientific Paper

POTENTIALITY OF THE NORTHWESTERN PART OF THE BUGOJNO COAL BASIN

Dževad Forčaković[1], Rejhana Dervišević[2], Hamo Isaković[3]

SUMMARY

This paper presents research results on the potentiality of the northwestern part of the Bugojno coal basin, which contains very significant, but still insufficiently explored lignite reserves.
Based on the determined borders of surface distribution and the research results in the northwestern part of the Bugojno coal basin, the achieved level of exploration in the basin proved four coal layers with reserves of over one billion tons of coal.
Discussed are: geological characteristics, general characteristics of coal layers, qualitative-quantitative characteristics, spatial potential of deposit and categorization of coal layers.
Considering significant raw material potential and possibility of expanding the existing raw material base, this part of the Bugojno coal basin has specific importance for the long-term development of lignite exploitation and its use for thermal energy purposes.

Key words: potentiality, northwestern part of the Bugojno coal basin, qualitative-quantitative characteristics, spatial potentiality of the deposit, categorization of coal layers.

INTRODUCTION

Bugojno coal basin is located in the Vrbas valley between Gornji and Donji Vakuf and covers an area of about 130 km^2.Within the basin there are situated several coal layers, four of them are in the northwestern part of the Bugojno basin, and one coal layer is in the southeastern part of the basin [1].

Coal of the Bugojno basin is a quality coal of brown-black color, has brown streak and it is without a distinct lignite structure, because its general habitus resembles younger bituminous coals. It is hard and without luster, has plate or slate fracture [2].

Regional geological researches were conducted from 1983 to 1987, and detailed from 2014 to the end of 2018. Based on the elaborated and interpreted results of geological research, the potentiality of the northwestern part of the Bugojno coal basin was processed. This part of the Bugojno basin 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 larger reserves in the basin.

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GEOLOGICAL CHARACTERISTICS OF THE NORTHWESTERN PART OF THE BUGOJNO BASIN

Bugojno coal basin (Figure 1) is divided into northwestern and southeastern parts in relation to the spatial distribution of coal deposits [2].

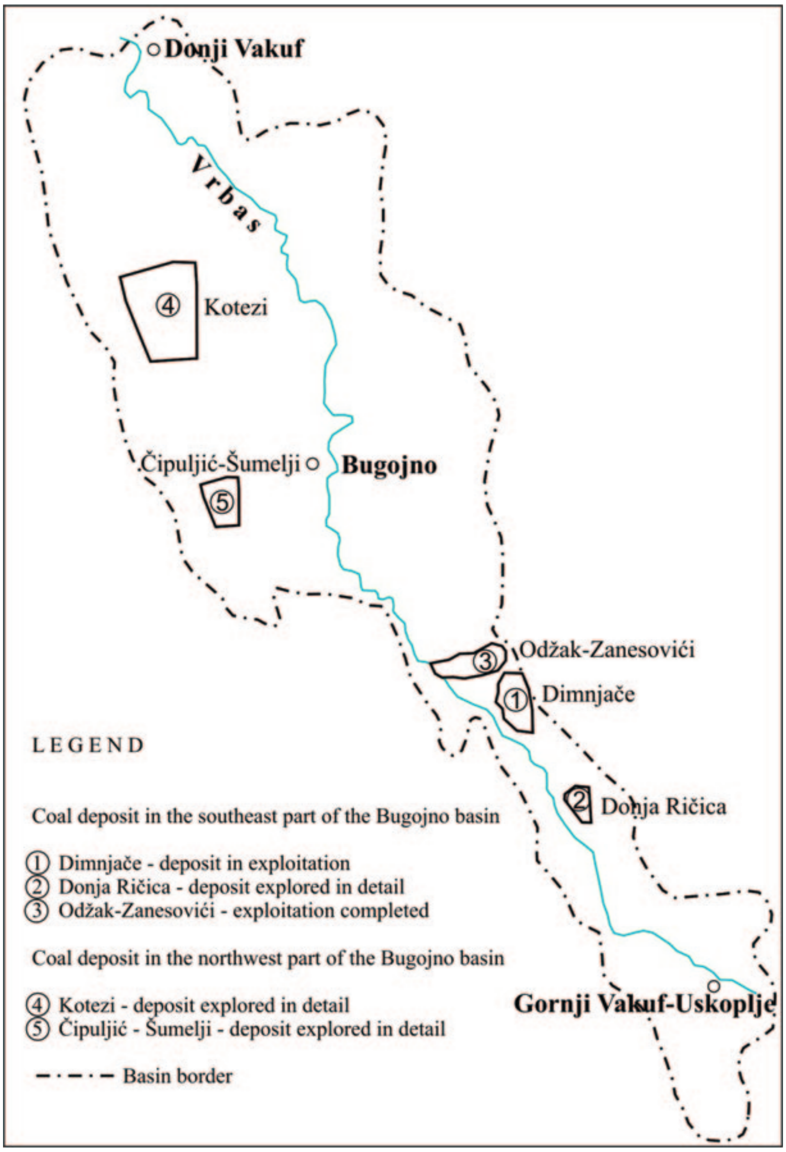

Figure 1. Distribution of the coal deposit in the Bugojno basin (Forčaković Dž.).

Neogene sediments of the northwestern part of the Bugojno basin are represented with freshwater lake formations, which lie 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 horizons: basal zone (1M2,3), zone of the second bottom coal layer (2M2,3), zone of clay, clayey sandstones and marls (3M2,3), first bottom coal layer (4M2,3), zone of marly limestones and marls (5M2,3), zone of main coal layer (6M2,3), zone of clays and sandy clays (7M2,3) and Pliocene-Quaternary (Pl,Q) [3,4,5,6,7,8].

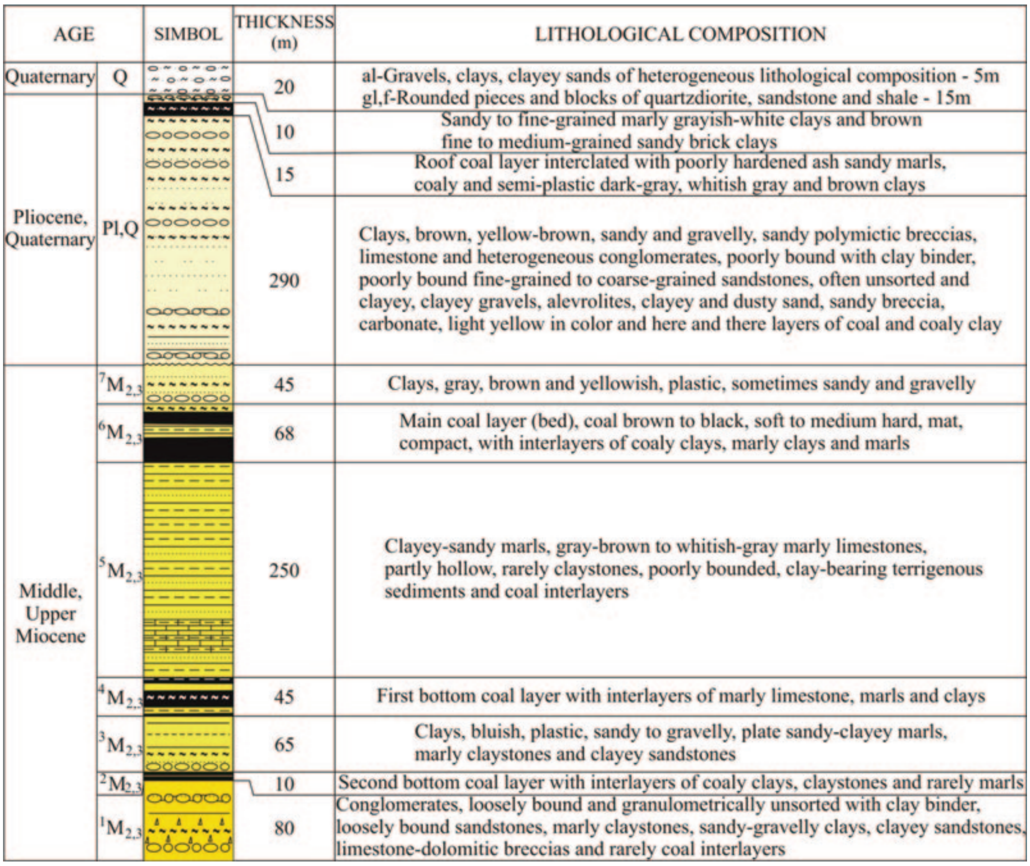

Figure 2. Geological column in the northwest part of the Bugojno basin
(According to Džonlagić Dž., complemented by Forčaković Dž.)

Within this part of the basin, two coal deposits are situated, namely: Kotezi with four coal layers and Čipuljić-Šumelji with one coal layer.

BASIC CHARACTERISTICS OF THE COAL LAYERS

The analysis of geologically investigated coal-bearing contoured productive areas of the northwestern part of the Bugojno basin identified four coal layers, in which 1,3x109 tons of coal were determined (Table 4). Based on petrographic investigations, the coal of the Bugojno basin is classified in the group of quality soft to medium hard brown lignite coals, with a relatively low degree of carbonization [1,2].

Coal layers were formed under conditions of uneven accumulation of plant material in peatlands, ie when the accumulation happened with occasional longer or shorter interruptions. Due to the sudden sinking of the bottom of the peat bog, seasonal floods of peat bogs and others, coal layers have a variable thickness and qualitative characteristics.

Coal layers	Pure coal thickness in the layer [m]	Volumetric mass [t/m^3]	Coal content [t/m^2]	Economic significance
II bottom	4,34	1,32	5,7	Ne
I bottom	5,55	1,28	7,1	Ne
Main	22,24	1,29	28,68	Da
Roof[1]	7,7	1,12	8,62	Da?

Table 1.

1 Potentially economically significant, limited in space, roofing coal layer is perspective for small-scale surface mining and could be exploited together with the main coal layer [1].

They are of different thicknesses, heterogeneous, belong to complex coal layers, and are characterized by a significant percentage of thicker or thinner barren interlayers, clay lenses, coaly clay, coaly marls, colorful marls, between 20 and 25% [9,10,11,12]. The interlayers are thicker in the upper part of the layer, while the thinner interlayers of the inorganic component are located in the lower part of the layer. The coal mass is divided by barren interlayers into two, three or more parts. Parts of the complex coal layer are heterogeneous in terms of genesis, petrographic composition and chemical-technological properties of coal [13].

These inequalities are within the limits that can be overcome during selective exploitation.

The coal content of the area in this part of the basin is shown in the diagrams (Figures 3 and 4), and was calculated from the average thickness of pure coal in layers (pure coal is coal containing up to 20 cm of tailings) and average volumetric mass (Tables 1 and 2).

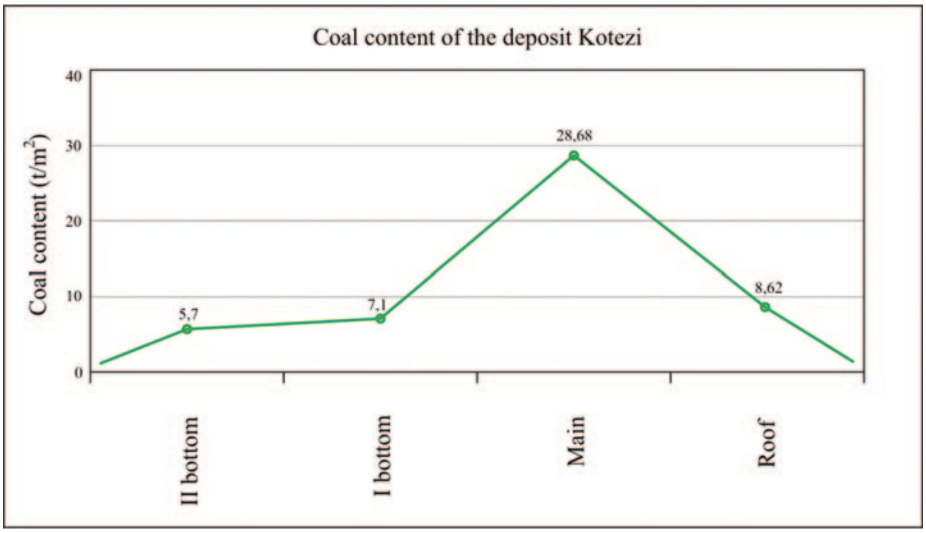

Figure 3. Diagram of coal content variation by layers of the deposit Kotezi

Table 2.

Deposits	Pure coal thickness [m]	Volumetric mass [t/m³]	Coal content [t/m²]	Economic significance
Čipuljić-Šumelji	14,98	1,28	19,18	Da
Kotezi	22,24	1,29	28,69	Da

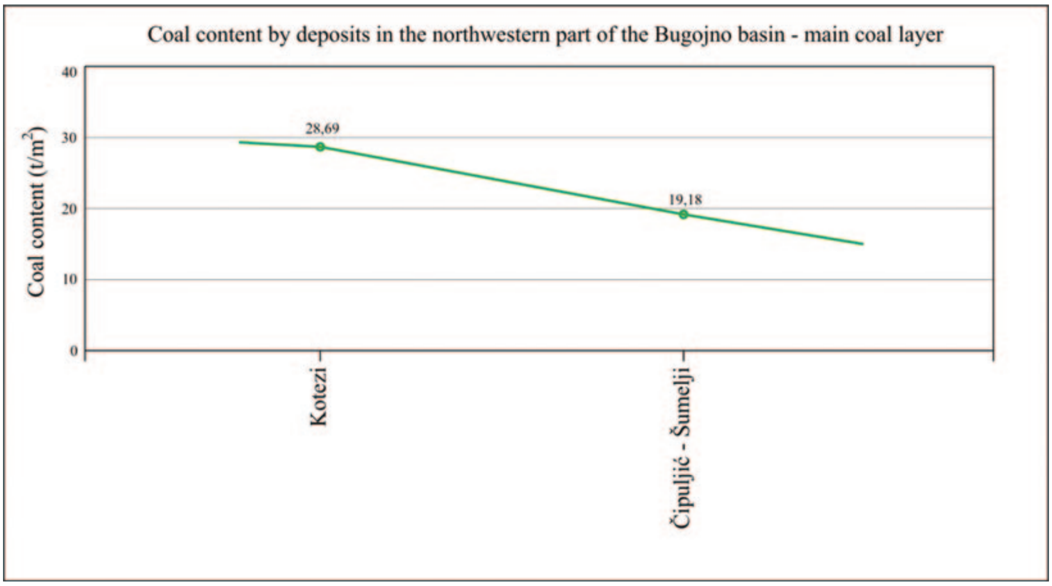

Figure 4. Diagram of coal content variation by line of strike in the Bugojno basin – main coal layer

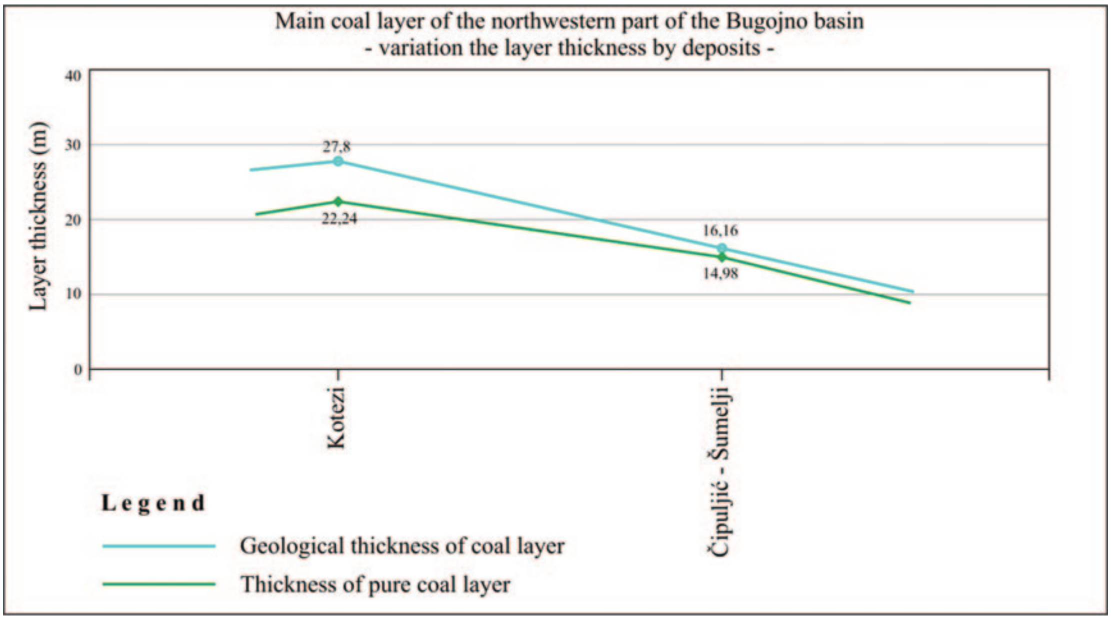

Figure 5. Diagram of variation in thickness by strike line of main coal layer in the Bugojno basin

QUALITATIVE-QUANTITATIVE CHARACTERISTICS OF COAL IN THE BUGOJNO BASIN

The quality of coal layers in the northwestern part of the Bugojno basin (Table 3) was determined by laboratory and industrial tests performed as part of detailed research.

Quality of coal layers in the northwestern part of the Bugojno basin

Table 3.

Components	Coal layers				
	Berića Gaj-Karalinka-Kotezi-Guvna-Prusac-Kotezi				Čipuljić-Šumelji
	Roof	Main	I bottom	II bottom	Main
Air-dry moisture [%]	23,95	25,92	25,50	26,12	26,41
Hygro moisture [%]	6,6	10,12	6,06	6,67	10,40
Total moisture [%]	30,55	36,04	31,56	32,79	36,81
Ash [%]	21,33	18,41	22,32	19,70	20,49
Volatile substances [%]	30,77	26,65	30,94	26,07	28,40
Combustible substances [%]	49,19	46,03	51,73	44,74	43,90
C-fix [%]	18,41	16,34	20,77	18,70	17,61
Coke [%]	38,67	33,91	40,62	42,27	35,40
Combustible sulfur [%]	0,48	1,25	1,55	1,19	1,39
Bound sulfur [%]	3,20	1,26	1,87	2,32	1,23
Total sulfur[%]	3,68	2,51	3,42	3,51	2,62
Upper calorific value [kJ/kg]	12 774	12 216	12 460	12 548	11 043
Lower calorific value [kJ/kg]	11 489	11 005	10 842	10 948	9 613

Reserves of quality coal in the main and partially roof coal layer of the northwestern part of the Bugojno basin are quite large and can serve as a solid basis for further development of mining and construction of new thermal energy capacities in this part of Bosnia and Herzegovina.

Total coal reserves of the northwestern part of the Bugojno coal basin

Table 4.

Reserve classes	RESERVE CHATEGORIES					Total [miliona t]
	A	B	C_1	C_2	D_1	
NORTHWESTERN PART OF THE BUGOJNO COAL BASIN						
Balance	37, 3	66,6	1,5	-	-	105,6
Off-balance reserves		78,8	48,6	-	-	127,4
Potential	-	-	-	656	396	1052
TOTAL	37,3	14,8	50	656	396	1, 290

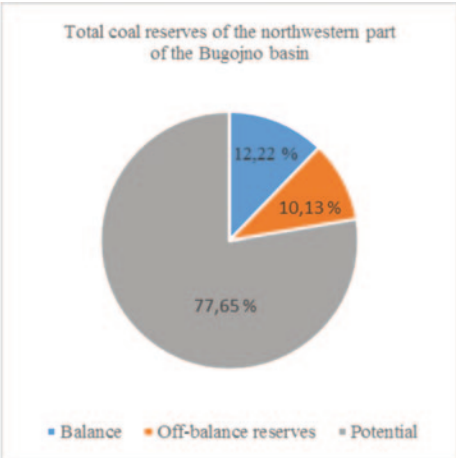

Figure 6. Graph of the percentage share of coal reserve classes

Calculated geological reserves of coal have uneven degree of exploration. In the structure of total geological reserves of coal in the northwestern part of the Bugojno basin, balance reserves participate with only 12,22 %, off-balance with 10,13 % and potential with 77,65 %. They have a very low and uneven level of exploration, which implies a large share of potential and off-balance coal reserves in total reserves.

Based on the determined boundaries of surface distribution and the results of research in the northwestern part of the Bugojno coal basin, the achieved level of research in the basin proved four coal layers with about 1,3 billion tons of coal.

Based on the analysis of the qualitative properties of coal, it can be concluded that the coal from the area of Berića Gaj-Karalinka-Kotezi-Guvna-Prusac belongs to the group of soft to medium hard quality brown lignite coals with slightly increased sulfur and ash content [2,10].

SPATIAL POTENTIALITY AND CATEGORIZATION OF COAL LAYERS

Spatial potentiality of coal in the northwestern part of the Bugojno basin (Figure 7) is divided into three categories:

- The first category is represented by the main coal layer, areas with established economic reserves of coal - economically the most important in the basin,
- The second category is represented by the roof coal layer and the main coal layer which lies deeper - areas with potential economic coal reserves, and
- The third category includes areas represented with the first and second bottom coal layers - coal reserves do not have economic significance.

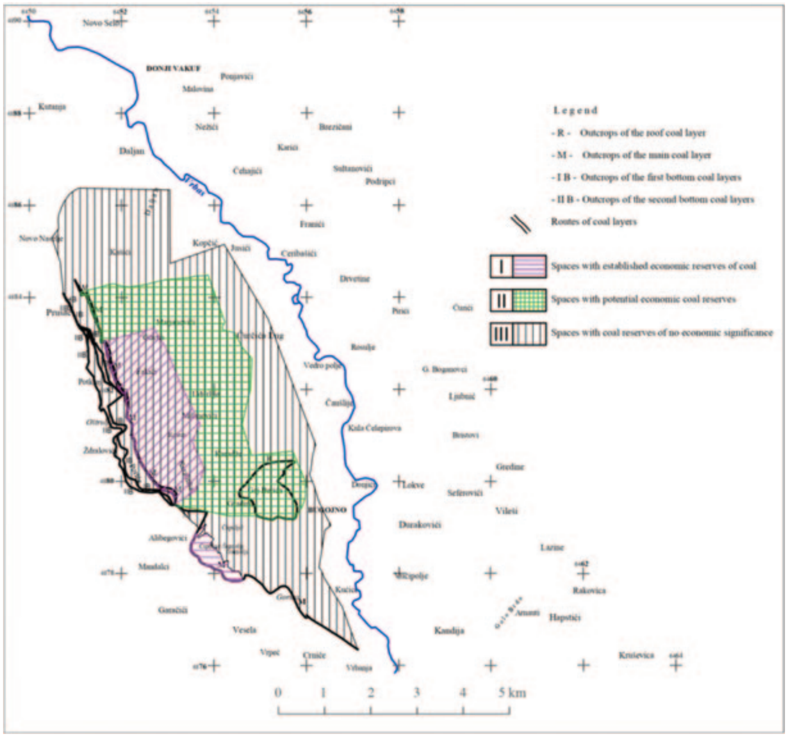

Figure 7. Map of spatial potential of coal in the northwestern part of the Bugojno basin (Forčaković Dž.).

Based on the results of extensive, complex and detailed geological research of the deposit, zoning or contouring of the area of the northwestern part of the Bugojno basin was performed for surface (up to 160 meters depth) and underground exploitation (from 160 meters to the bottom of the main coal layer).

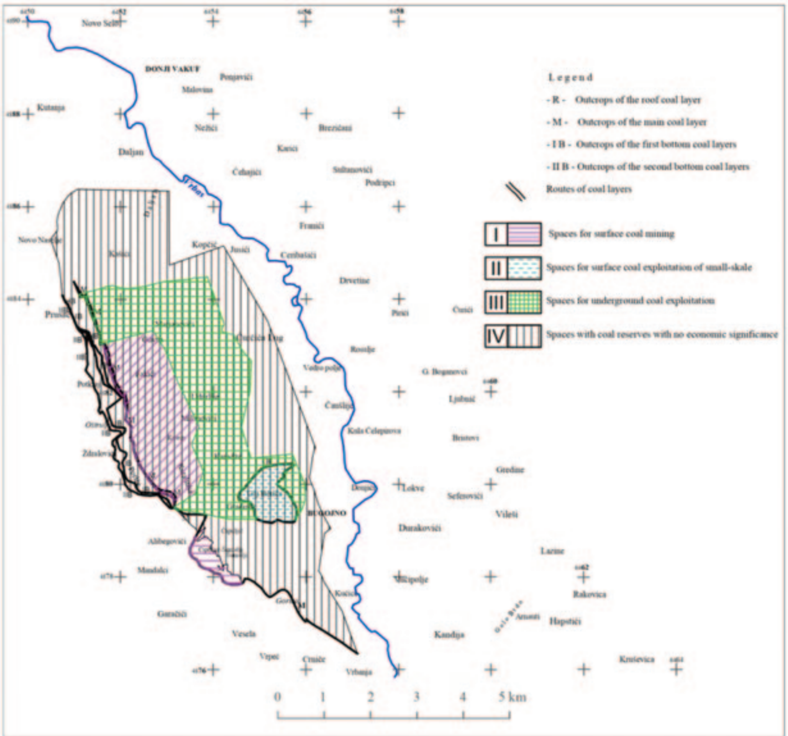

Figure 8. Map of the categorization of space covered with coal layers and the exploitability of coal in the northwestern part of the Bugojno basin (Forčaković Dž.)

These areas (Figure 8) represent future mines with surface or underground coal mining.

They are divided into four categories in terms of coal content, quality, degree of economy and method of exploitation:

The first category consists of an area represented with main coal layer up to 160 meters deep, perspective for surface exploitation,

The second category consists of an area represented with roof coal layer, perspective for surface exploitation of a smaller volume (which could be exploited together with the main coal layer),

The third category consists of an area represented with main coal layer for underground exploitation (from a depth of 160 meters to the bottom of the main coal layer), and

The fourth category consists of the first and second bottom layers, which are not economically significant.

CONCLUSION

The analysis of coal content in the northwestern part of the Bugojno basin identified parts of the basin with a significant potential in which it is possible to realize surface and underground coal exploitation.

Proven economic and potential exploitation reserves of coal presuppose the possible exploitation and opening of new mining operations for the existing ones, but also for the construction of new thermal energy capacities in this basin. It should be noted that the shown coal content of the basin is at a low level of geological research.

In addition to the necessary activities on the research of the Bugojno basin, in preparation of the following mining-technical and investment documentation for the opening of new mining plants, attention must be focused on the analysis of other limiting factors, primarily on:

- natural conditions, ie a high degree of waterlogging of the northwestern part of the basin as a consequence of spatial position of the rivers Vrbas, Poričnica, Duboki stream, Spahinac stream, Lubovski stream and hydrogeological structure of the basin,
- and the social factor, ie the degree of population in the coal-bearing area.

In this part of the basin not a single coal layer is exploited for now, and the greatest economic value in the basin has the main coal layer. The paper points out the great potential and prospects of coal deposits in the northwestern part of the Bugojno basin and represents the basis for justified and economical exploitation of lignite coal and the possibility of choosing priority sites for exploitation. Based on contemporary views and assessments, comparing the conditions on similar deposits, it can be concluded that the general geological and technical-exploitation factors are relatively favorable and indicate a possible profitable exploitation of the deposit.

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Professional Paper

REHABILITATION OF MINE TAILINGS "BARE' AT KAKANJ BOSNIA AND HERZEGOVINA

Dean Osmanović[1], Muhidin Brčaninović[2], Akif Ibrišimović[3]

SUMMARY

This paper presents the solution for rehabilitation of the tailings „Bare" in Kakanj, which was affected by the sliding of the masses in January 2015. The project solution for rehabilitation includes the following works: landslide remediation of the southern slope of the landfill, denivelation and mass distribution planning (technical reclamation) and biological reclamation. Landslide remediation and mass distribution is planned in two phases. The first phase of rehabilitation of the following landfill „Bare" started in May 2018 and lasted approx. 4 months and the second phase has not been realized yet. The appearance of the final contour of the landfill arose from a more variant view of the problem - respecting the angles of inclination of the slopes - the safety factor of the final slopes, the structure of the following areas and the necessary funds for project implementation. The design solution for conversion does not occupy new areas, because the masses planned for distribution can be placed in an empty space within the contour of the landfill. In that way, a horizontal area with size of 11.19 hectares is provided for this solution, following area is suitable for the construction of a sports and recreation center, cultivation of agricultural crops, or the formation of orchards, etc., the afforestation is planned on sloping areas to merge the landfill into the surrounding environment.

Key words: tailings, conversion, rehabilitation, reclamation, landslide

1. INTRODUCTION

Mine landfills occupy large areas of land, which not only spoil the visual appearance, but with improper construction and maintenance endanger the surrounding facilities (the occurrence of landslides, dust, etc.) which was the case with the old tailing "Bare" in Kakanj, where the material slipping caused a great material damage on residential buildings, which also had the epilogue of the death of one person. The mine, as an economic entity, is obliged to recultivate the degraded area created by mining works, which the Kakanj Brown Coal Mine (RMU „Kakanj") started at the said landfill. One of the problems that occurs when designing the conversion of old mine landfills is the lack of technical documentation, which requires higher allocations for reclamation because it is necessary to conduct additional research. Investigative works have established that the substrate of the landfill consists of clays which, with increased saturation (flooding), have a low bearing capacity due to which the deposited material slips. Higher saturation occurred due to the unprepared base of the landfill, ie the material was deposited on natural terrain without drainage systems, there was no protection of the landfill from surface waters and the period was hydrologically unfavorable. The techno-relief of the landfill itself is such that smaller accumulations of water are formed in the landfill itself, which move through the material to the substrate and spring in the foot of the landfill.

The following works are planned for the conversion of the tailings „Bare":

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- construction of drainage channels and peripheral channels,
- removal of the humus cover from the place where part of the material will be disposed of from the tailings and temporary disposal of humus,
- denivelation of masses in the western part of the landfill to the profile 13-13′ and disposal of material in the empty space within the contours of the existing tailings,
- construction of the main drainage channel in the foot of the tailings,
- denivelation and disposal of material in the eastern part of the tailings from profile 13-13 ′,
- construction of floor channels and other channels necessary for the water from the landfill to be taken to the existing watercourses and
- biological reclamation.

2. LOCATION AND ESTABLISHMENT OF TAILINGS „BARE"

The tailings is located in the settlement of the same name, which is east of the center of Kakanj, approx. 2 to 3 km as shown in Figure 1. (Adapted by the author of the paper). The Bare site in the area of the Kakanj municipality was used for the disposal of tailings generated by the separation of coal from the underground exploitation of the RMU „Kakanj". Separation of tailings at the site of the old separation as well as removal of tailings to the site of Bare was performed up to approx. In 1970, and after that, straight coal was driven to a new separation at the Doboj site near Kakanj, where straight coal was separated.

In the period 1973-1974. Year, all facilities related to the old separation and removal of tailings were destroyed. The transport of tailings was performed by cable car, whereby appropriate piles of deposited tailings were formed.

Reinforced concrete pillars from the former cable car can be found on the terrain. According to the existing urban plan of the municipality of Kakanj, this space is not planned for conversion and arrangement, and therefore not for future needs, given that it is treated as a „tailings" - degraded space.

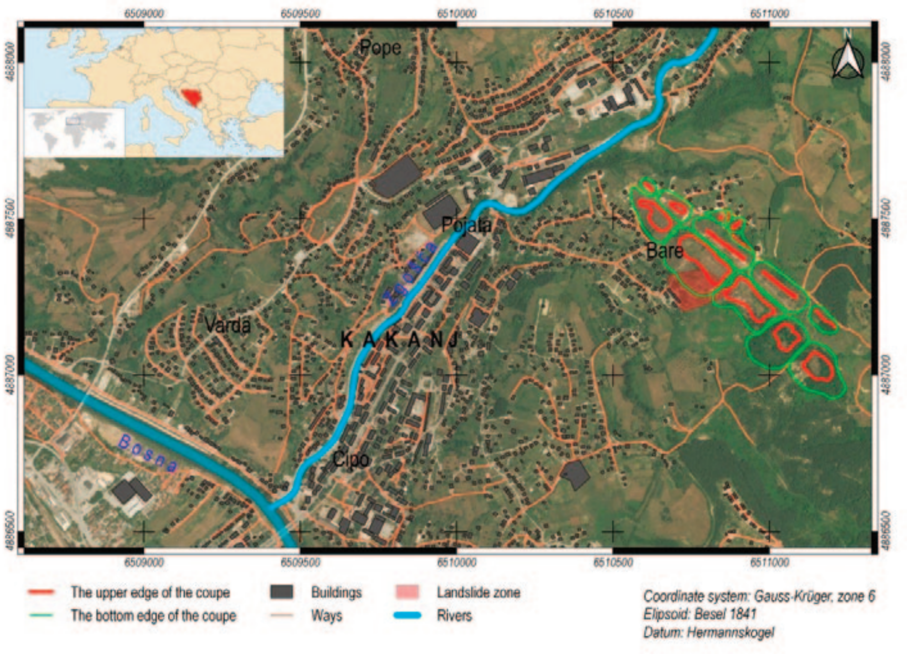

Figure 1. Location of the „Bare" tailings

3. TECHNO RELIEF OF „BARE" TAILINGS BEFORE THE BEGINNING OF REMEDIATION

As mentioned in the previous chapter, the transport of separation tailings from the separation to the tailings was done by cable car and the disposal was done by turning the transport baskets and unloading the material. During the dumping of the material, „piles" were formed, of which there are ten on the site of the tailings. Along the northeastern and southwestern contours of the tailings are individual residential buildings. In the central part of the southwestern slope, 01/04/2015 A local landslide (slope breakage) was formed in the year 2000, damaging several residential buildings located at the foot of the tailings. Figure 2 shows the contour of the tailings with the disposition of the formed cone, existing watercourses and road communication.

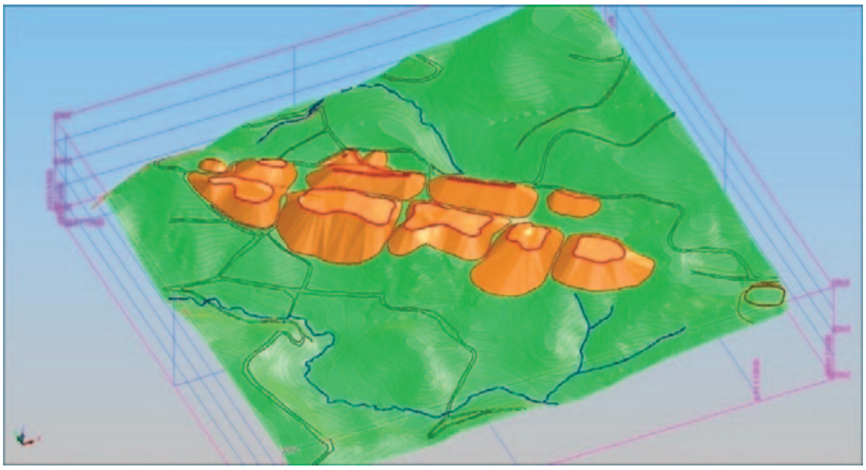

Figure 2. Digital terrain model of the "Bare" tailings before sliding [1]

The formation of landslides was influenced by precipitation for a long time, which also changed the characteristics of the material affected by the landslide process, endangered the barracks built right next to the edge of the foot of the old tailings, and continued southwest. The area of the launched material is about 1 ha, while the landslide area is about 1.7 ha (there were minor landslides before 2015) The landslide action is southwest. Figure 3 shows a photograph taken after the mass slid.

Figure 3. Photograph of the landslide in the area of the "Bare" tailings (February 3, 2016) [1]

The term techno relief refers to the forms and elements in the field that occur as a result of mining operations on the exploitation of mineral resources or disposal. Techno relief can have quite good and acceptable elements of the newly created (technogenic) form, if we work according to the designed solutions that give optimal parameters for the planes and slopes of techno relief, where they are necessary in the natural preconditions for such solutions. Upon completion of the exploitation works, the techno-relief is the basis for the final, permanent arrangement of this site and its integration into the spatial whole of the environment.

The techno relief of the tailings before landscaping had the following characteristics:

- the shape of the tailings	an elongated ellipse
- the dimensions of the space occupied by the tailings	900x200m
- lowest elevation	440 m MSL
- highest elevation	515 m MSL
- total height of techno-relief (tailings)	Huk=75 m

- number of bench on techno-relief — n=1
- bench height — He=75 m
- slope angle of the floor (average) — $\alpha e=33°$

The most acceptable solutions of the final arrangement are projected on this techno-relief, in which the biological phase and harmonization with the spatial-planning documentation represent the backbone of the project. The appearance of the techno-relief before remediation is shown in Figure 4.

Figure 4. Terrain relief at the tailings before the start of remediation (February 3, 2016) [1]

Wild fern, acacia, walnut, as well as acacia planted by the beekeeping society in the area of the southeastern part of the tailings are present in the mentioned area of the tailings. In order to repair the landslide, the analysis of the stability of the slopes defined the highest elevation of the tailings. These levels are to relieve the tailings in the area of mass sliding and based on that a possible solution is given to the design of the existing tailings terrain, in order to rehabilitate and recultivate the tailings. [1,2]

4. DESIGNED WORKS IN LANDSCAPE TECHNO RELIEF ARRANGEMENTS

Based on the analysis of the stability of the tailings, ie the defined level of unloading of tailing masses, a number of possible variants of shaping the existing technorelief were made in order to rehabilitate and recultivate the tailing. One of the conditions of any works on the tailings is the establishment of drainage systems, which would drain rainwater that seeps through the body of the tailings and descends to the substrate, and also create conditions for the planned mass to be deposited on the drained surface, Figure 5.

Projected angles the slopes range from 18° (1:3) to 26° (1:2). The recommendations regarding the slopes of the leaf deposits to be used for agricultural purposes are 1:3. [5]

The width of berm areas is determined from the conditions of machine planting and cultivation of plants and its minimum value is not less than 8 meters [6], so that the width of berm areas is adopted at a minimum of 10 to 15 m.

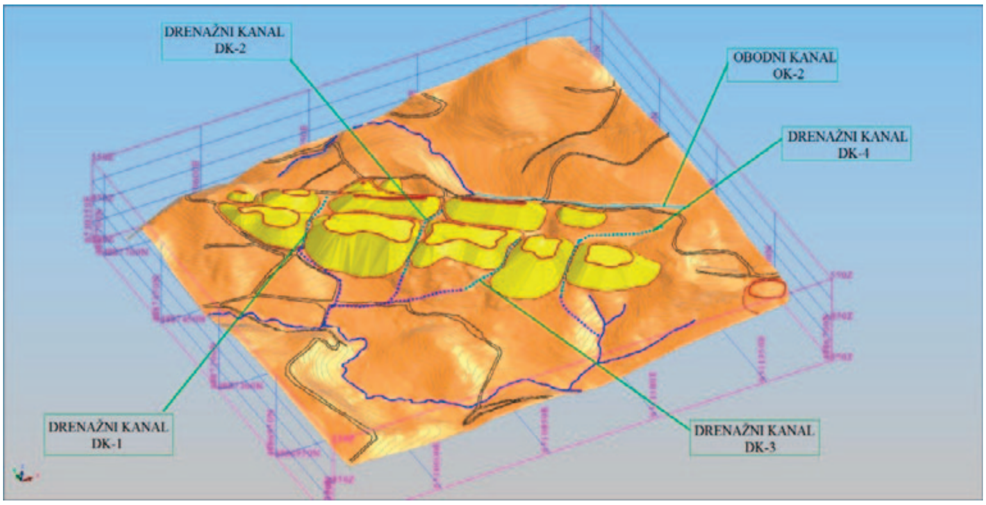

Figure 5. Tailings water protection system [1]

In order to select a variant of tailings terrain design, and in order to rehabilitate and repurpose, it was necessary to make several design variants, within to select the most favorable one. The number of variants (5) came from the need to find a solution with minimal excavation of the base from the substrate, and maximum filling of the free space within the contour of the tailings, as well as minimal work on tailings transport. The goal is to achieve a completely leveled mass, "excavated is equally delayed." For the adopted variant, it is necessary to excavate 612,720 bcm and dispose of the same amount in free space. Figure 6 shows the digital terrain model (DTM) of the first phase of landscaping, for which it is necessary to level 451,520 bcm. The remaining 161,200 bcm are leveled in the second phase, and the final appearance of the tailings is shown in figure 7.

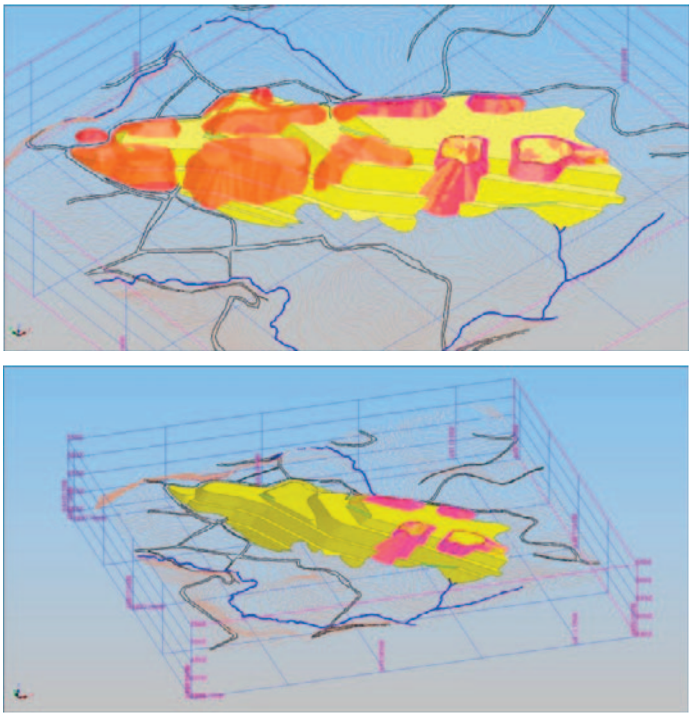

Figure 6. The first phase of remediation [1]

The conversion of the tailings is planned through the following phases of activities, Table 1. (Partially adapted by the author of the paper) The conversion covers an area of 21.55 ha of land, for which it is necessary to invest approx. 2,217,000 BAM or approx. 102,900 BAM/ha. In the picture 8. the structure of newly created areas with the plan of biological recultivation is shown (horizontal surfaces - clover-grass plantation; sloping surfaces - forest plantation).

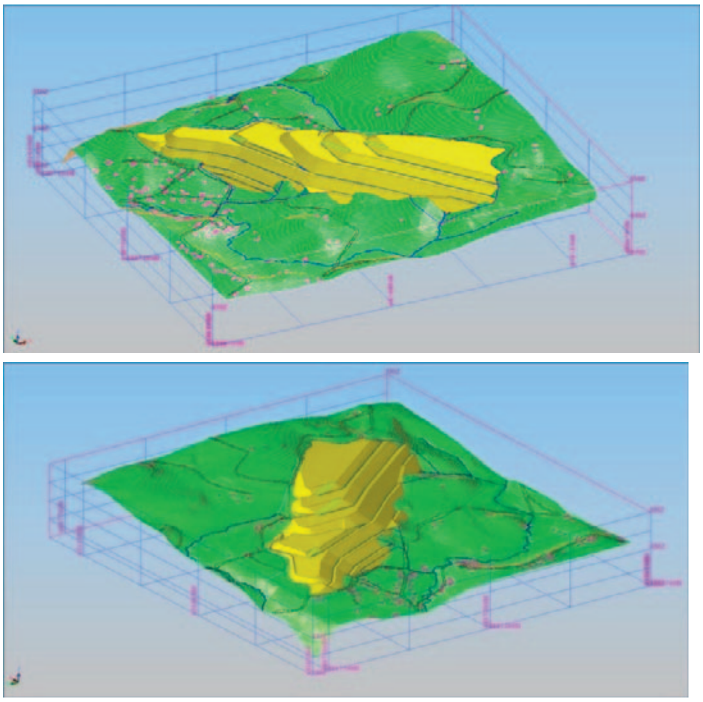

Figure 7. Digital model of the adopted variant of tailings design [1]

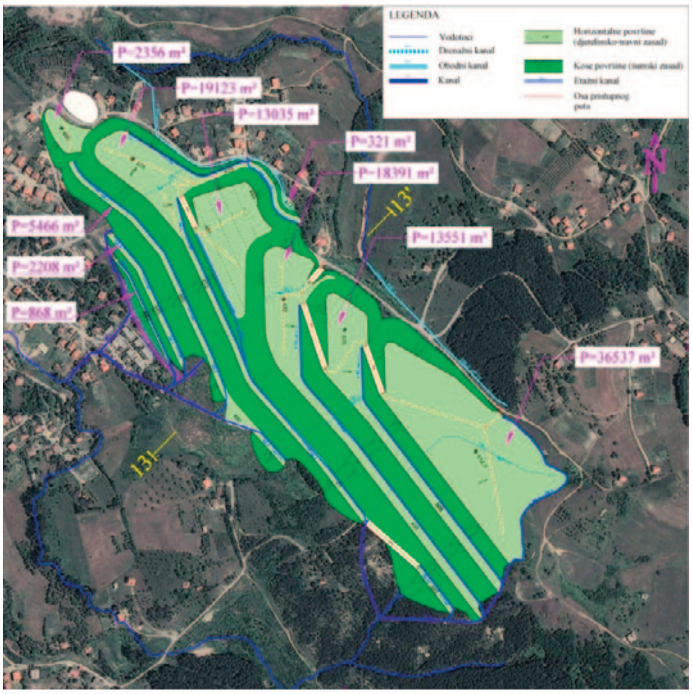

Figure 8. Structure of surfaces after remediation of tailings “Bare” [1]

Period	Duration ounths	Cost (KM)	Type of work
The first phase	5,1	1.400.000	Production of drainage channels and boundary side channels
			Removal of humus cover and temporary disposal of humus
			Denivelation of masses in the western part of the tailings to the profile 13-13' and disposal of material in the empty space within the contours of the existing tailings
			Construction of the main drainage channel in the foot of the tailings L=170 m
Second phase	1,7	437.000	Denivelation and disposal of material in the eastern part of the tailings from profile 13-13'
Additional work code technical recultivation	1,6	105.000	Construction of floor canals and other canals needed to divert water from tailings to existing watercourses and
Biological recultivation	2,8	275.000	Biological reclamation (clover grass and forestry)

Table 1. Works on the conversion of the tailings "Bare" [1]

5. TECHNORRELIEF OF TAILINGS "BARE" AFTER THE FIRST PHASE OF REHABILITATION

The investor for the remediation of the tailings is JP Elektroprivreda doo Sarajevo, ZD RMU Kakanj doo Kakanj. The contractor in the first phase of rehabilitation was Trgošped doo Kakanj, for which the investor set aside approx. 925,000 BAM.[4] The authors of the paper did not participate in the execution of works on the first phase of rehabilitation, and do not have measurable data on the performed works. However, here he will rely on a visual comparison of the performed works with the projected and the condition that was before the rehabilitation. In Figure 9.a. a photograph is shown before the start of work while in Figure 9.b. a photograph of the tailings "Bare" during the works is shown.

a)

b)

Figure 9. Photograph of the tailings "Bare" before and during the remediation [1,3]

Figure 10 shows a satellite image (adapted by the author of the paper) of the works performed at the tailings "Bare" and the projected works of the first phase of remediation.

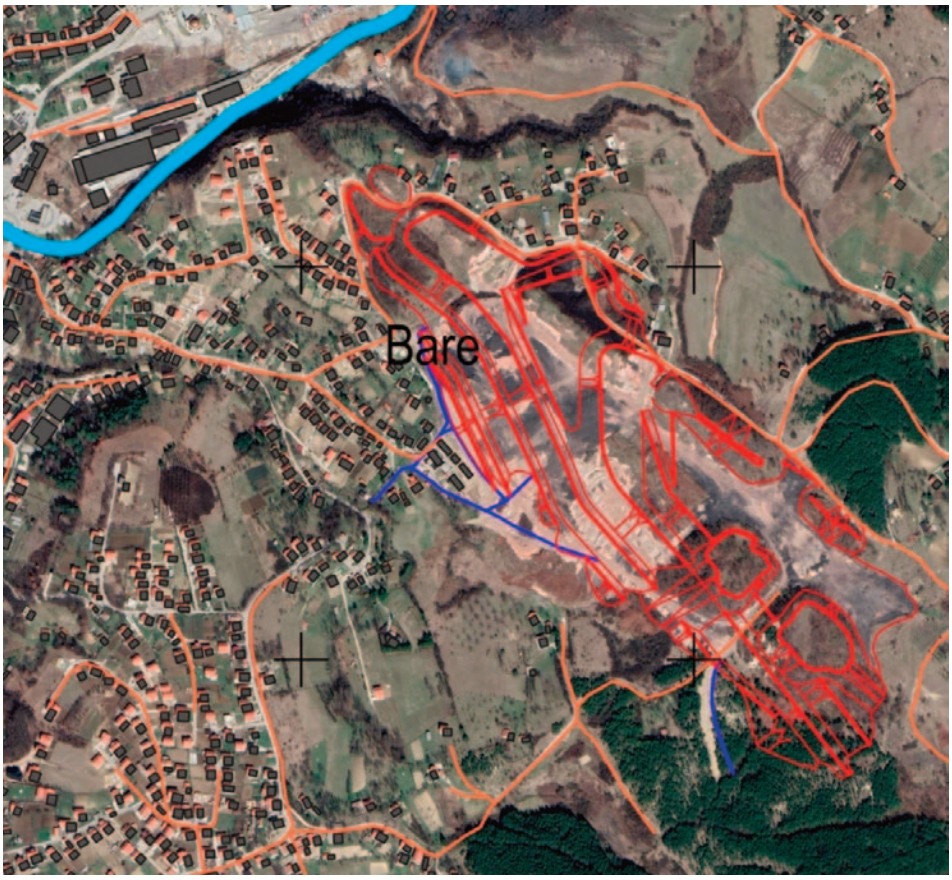

Figure 10. Satellite image of performed works at the tailings "Bare"

6. CONCLUDING REMARKS

In order to finish conversion of the tailing „Bare", (rehabilitation and reclamation), the activities would take place through two characteristic phases of work. The first phase (already completed) included a removing the landfill masses in the landslide zone, which provided conditions for technical reclamation and landslide remediation, and the second phase would refer to denivelation (removing) of the eastern part of the landfill for complete reclamation. It can be stated that the works of removing the landfill masses will have a positive impact on the stability of the landfill and it will make conditions for biological reclamation, as well as the integration of the projected tailing into the landscape. With these works, RMU „Kakanj" will fulfill the obligation to bring the desintegrated land to its original purpose, and with the proposed solutions, and probably in a better condition in relation to the initial relief. This spatial solution fits positively into the existing surrounding environment. Rehabilitated landscaped area may be of interest to the wider community such as the municipality of Kakanj, given that it is quite close to the city center, which indicates the value of this land.

The rehabilitation of green areas in the immediate vicinity of the urban area has a very favorable ecological effect for the environment and for the population is positivity reflected in the next facts:

- restoration of active agricultural and forest areas,
- restoration of flora and fauna,
- creates the possibility for setting up greenhouses, opening farms,
- creates a landscape acceptable to the local community and
- reduces the dangers of uncontrolled activation of landslides.

Necessary investments in rehabilitation and reclamation (conversion) amount to approx. 2,217,000.00 BAM, or approx. 102,900 BAM/hectar of newly created area, which indicates that the conversion is economically viable, given the price of land at this location. According to the planned engagement of the mechanization, the works on the rehabilitation and reclamation of the landfill would take about eleven months. As the existing urban plan of the municipality of Kakanj treats this area as a „taliling" - degraded area, and with the given solutions, this area will be of much greater interest for the municipality of Kakanj, ie the urban plan.

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Proffesional Paper

STABILITY ANALYSIS OF SLOPES ON NORTHERN OUTDOOR LANDFILL "DUBRAVA" COAL MINE "BANOVIĆI" USING THE METHOD OF DEFINITIVE ELEMENTS (MKE)

Benjamin Brašnjić[1], Vahid Avdić[2], Zajkan Mrkaljević[3]

SUMMARY

While designing landfill overburden one of the first problems is finding enough space. To use space to the fullest, it is needed to find the optimal geometry of the landfill (level height, level width and incline of the level). We tend to attainthe highest possible incline of the final slope to utilize the space to the fullest. The question arises about maximum incline within tolerances of safety from breaking of the incline or losing mass in body of the landfill. The answer to this question is given in the methods that analyze tension state in ladfill and landfill foundation or calculate safety coefficient. While disposing digging material there is a change in tension,or tension concentration on landfill and landfill foundation.

This paper presents stability analysis of working level on outdoor landfill „Dubrava" on PK „Grivice" RMU „Banovići". In this paper we did a comparision of stability analysis with three boundaries balance methods: Morgenstern-Price, Bishop and Janb, with changeable coefficient of pore pressure ru=0.0, ru=0.2 i ru=0.4 and coefficient of critical tension state(SRF) with same pore pressures. Calculation is made by using program Slide which is based on analysis of ground and rock stability and program Phase2 that is based on finite element method in which is integrated Mohor-Columbus breaking criteria that we will be using in this paper.

This method of modeling is significant because it provides insight in rock mass or ground behaviour, or landfill behaviour in all phases of disposing. Expected results are approximately same for values ofsafety coefficient(Fs) and critical factor influencing tension reduction (SRF) only in one point of analysis. Results are showing that for the modeled geometry of landfill, we can achieve incline stability if we dedicate attention to landfill safety from surface and underground waters, and to better preparation of landfill foundation.

Key words: landfill, safety coefficient, pore pressure, SRF, Slide, Phase2

1. PREFACE

Modeling landfill of surface digs is limited to technological solutions. This approach to the problem in the terms of big dimensions landfill, mostly using big dimension breaking incline which covers millions of cubic meters disposing of spoil. The purpose of using software for stability analysis of landfill incline(that uses methods of definite elements) is in drawing conclusions, or in interpretation of results of doing analysis which will give results for making objective foundations for modeling landfills. [8, 9].

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Specifically for northern outdoor landfill „Dubrava" which is high-altitude type (Hmax=136 m), it was necessary to do incline stability analysis and check if Fs are within tolerances stated in technical normative for outdoor exploatation.

For stability analysis we observed intersection III-III' which is considered critical intersection in which can come to development of incline breaking or loosing disposed mass according to geometrical parameters in third phase of disposing on outdoor landfill „Dubrava". We did a comparison of incline stability analysis for the given intersection in three numerical methods in terms of boundaries balance according to criterion which are used in the world today: Morgenster-Price, Bishop and Janb, and with the help of critical tension state coefficient(SRF), with existing geomechanical data. Critical tension state coefficient (SRF) is identical with a safety coefficent (Fs) in the incline stability analysis of boundary balance. SRF value is considered in two cases, when SRF≤1 incline is in state of boundary balance and every decrease of solid shear will result in incline failure.Also, there is no need to analyze safety factor of 1 unless we are using boundary states and entry parameters of factors(Eurocode). For values when SRF>1 we precisely calculate models. For models with more phases, if and only if we convert all stages that leads to the final stage, the result is correct. Incline strength parameters are decreased for a specific factor(SRF), and we calculate the tension analysis of definitive elements. This method is repeated for different values of tension decrease factor SRF, until model becomes unstable.

With numerical methods we analysed incline safety coefficient, maximal shifting and critical tension state coefficent(SRF).

Calculation is made using program Slide and Phase2 from Rocscience firm.

Main characteristics of the program are:

- ***Slide*** is a 2D program used for stability analysis for assessment of the safety factor for circular or polygonal sliding surfaces in ground or rocks.It is very easy for using, but you can create and use complex models very easy and fast.This program provides reasonable analysis spectar, including design, that supports given analysis, and probability analysis, which is based on graphical interface, that provides wide interpretation spectar using modeling and data that provides fast and accurate analysis. Files from Slide can be transfered to Phase2 for incline stability with definitive elements method.
- ***Phase2*** is 2D program that started with development and application in 1992 as Phases, his work is based on tension analysis using the definitive element method, as for underground same for surface diggings of ground or rock. It can be used for a wide variety of engineering projects,including tunnel constructions, incline stability using the definitive element method, grid modeling, probability analysis and other analytical possibilities.With this program, we can fast create and analyse complex state of model in more states.

Mines accros Bosnia and Herzegovina greatly use modern softwares for incline safety analysis.

2. LOCATION OF OUTDOOR LANDFILL „DUBRAVA" WITH DESCRIPTION OF EXISTING AND PROJECTED MINING WORKS

Outdoor landfill „Dubrava" that is used for disposing of overburden from PK „Grivice" RMU „Banovići" in Banovići, is located 5 km of aerial distance north from city Banovići(Bosnia and Herzegovina). To outdoor landfill „Dubrava" you can come with permanent roads that leads from outdoor landfill to PK „Grivice", which from a surface dig with asphalt road leads to city Banovići. Figure 1. shows the geographical location of outdoor landfill „Dubrava" and PK „Grivice".

Figure 1. Geographical location outdoor landfill „Dubrava“ and PK „Grivice“ (QGIS)

Outdoor landfill „dubrava“ from the south side is connected with permanent roads with PK „Grivice“ which is used for transport of overburden with trucks of bearing capacity of 136 and 150 tons. Current surface that VO „Dubrava“ is occupying is around 150 ha. Lowest topographic point of landfill is 380 meters above sea level, while the highest is 448 meters, with a maximum incline of backfilling around 36°. Figure 2. shows a characteristic profile trough VO „Dubrava“.

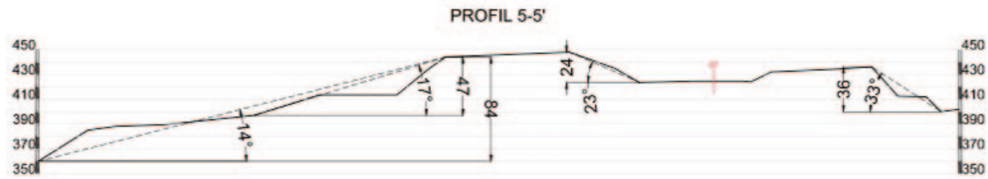

Figure 2. Characteristic profile trough VO „Dubrava“

Projected topographic points of landfill are: maximal 460 m.a.s.l., and minimal 324 m.a.s.l.

By height landfill is divided on horizontal levels of height 12-24 m which are connected to the final incline in one slope with a 36° angle of backfilling.From north to south, landfill planum is in a decrease of 1% because of gravitational drainage.

3. INCLINE STABILITY METHODS

If stability analysis shows that incline safety factor is lower than allowed, then it is needed, using stability(sanation) measures to increase its value, to achieve demanding safety factor which provides safe incline stability state.To find proper solutions, which demands technical and economical requirements, first we need to determine main causes of insufficient stability. They can be different, mostly they are [4, 5, 11]

- incline is steep or high or both at the same time, regarding the nature of material that it is formed.
- soil has the low solidity of low values of resisting parameters
- pore pressures are high
- outside pressure affects unfavourably, by the size of its value and the way of activity

Stated causes can act individually, and can be connected between them. From the way of their activity depends the choice of sanation measures, or possibility of their combination. Sanation meassures often used are:

- Change of geometry incline
- Drainage meassures
- Support constructions
- Ground reinforcing

3.1. INCLINE STABILITY METHODS ON SURFACE DIGGING LANDFILL

In principle, incline isn't that hard to stabilize, but in surface digging, three questions are often asked:

What is demanded incline stability?

For which time period is needed to secure demanded incline stability, or is it needed temporary or permanent stability measures?

How much is the price important in incline stability,is there satisfied optimal financial incline stability measure together with technical?

This three questions represent the main problem, as in construction, same in mining on surface digs.

In contrast to construction objects, that are built as static, dynamic of surface dig progression conditions that working inclines and inclines of working levels are constantly made in varying conditions of disposed mass which implies changing nature of material in function of time. To prevent landfill incline breaking(level or final incline) it is necessary to take certain sanation measures. [4, 6, 11]

4. NUMERICAL METHODS AND ENTRY PARAMETERS FOR ANALYSIS

All geomechanical results obtained in prior measurements are used as entry parameters for Slide and Phase2 programs. Stability analysis is done by boundaries balance methods by Morgenster-Price, Bishop and Janb, where is automatically done optimization of sliding surface with a lowest safety coefficient (Fs), while tension-deforming intersection analysis is done by Mohr-Colmb breaking criterium plastic behaviour of disposed material after breaking. All calculations are conducted for the pore pressure coefficient value of ru=0.0, ru=0.2 and ru=0.4. In incline stability analysis and critical tension state coefficient (SRF) we used waves spreading in consideration, induced by earthquakes, in most undesirable direction, and adopted seismologic coefficient is the VII degree by MSC (kh=0,02 and kv=0,01), according to EC8 recommendation.

Figure 3a. shows adopted calculated 2D model of terrain and disposed material, so we can simulate the incline stability analysis in Slide. Figure 3b. shows formed grid of the definitive elements in Phase2 with given model boundaries, grid type, elements type,number of nodes, after which program generates a suitable grid of definitive elements.Considering that the biggest tension and shifting change is expected in legging of landfill, a grid of definitive elements has the biggest density exactly in that zone. [4, 5, 8, 9]

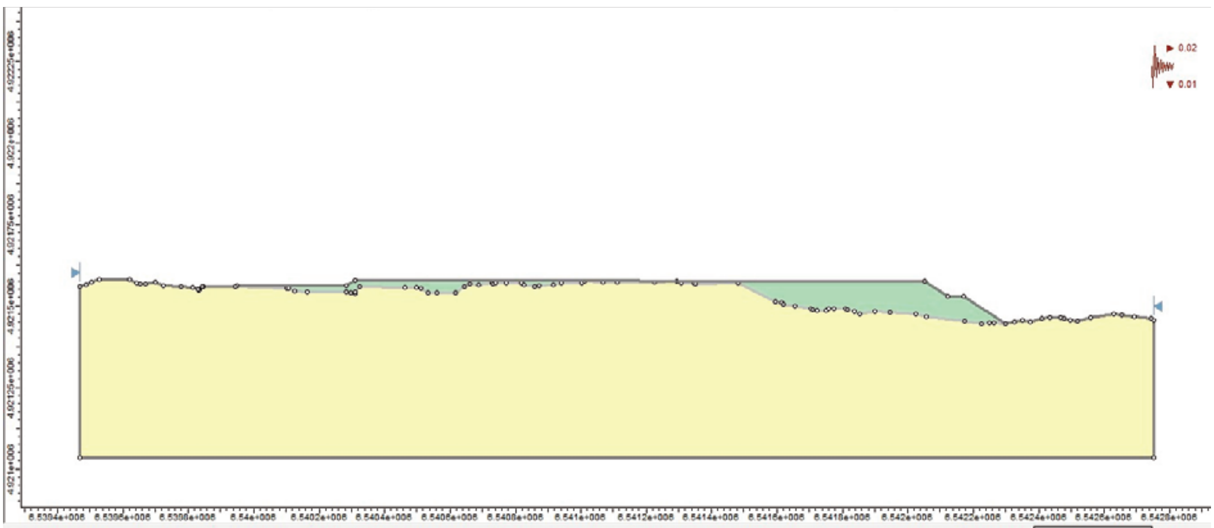

Figure 3a. Adopted calculated 2D model in Slide

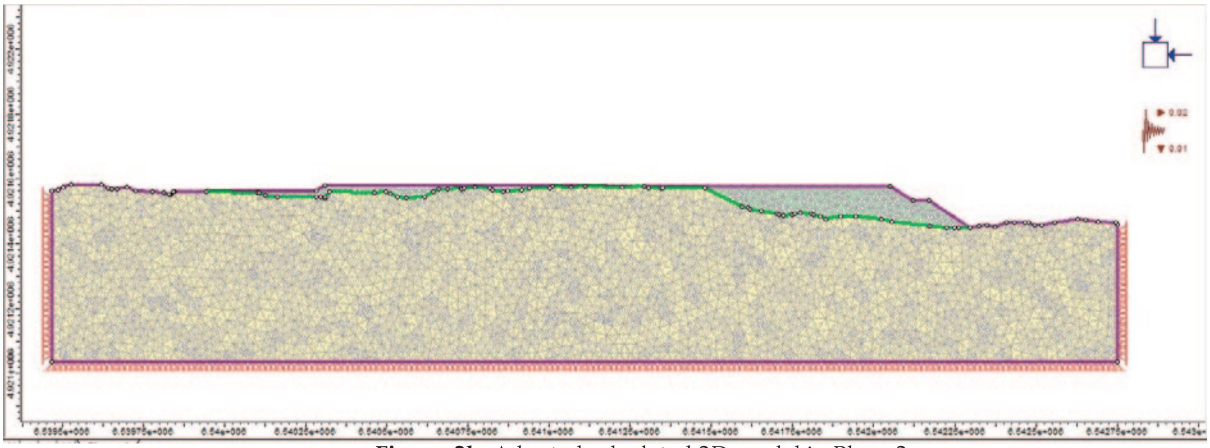

Figure 3b. Adopted calculated 2D model in Phase2

In table 1. are shown values of physical-mechanical parameters with which is done safety coefficient (Fs) and SRF with varying pore pressure coefficient (ru).

Material	Color	Unit Weight (kN/m^3)	Young's Modulus (kPa)	Poisson's Ratio	Failure Criterium	Material Type	Tensile Strenght (kPa)	Cohesion (kPa)
Terrain		25,3	1655	0,4	Mohr-Colmbovom	Plastičan	2180	30
Landfill		17.61	1570	0,26	Mohr-Colmbovom	Plastičan	1320	11

Table 1. Values of geomechanical parameters for Fs and SRF

5. DISPLAY AND ANALYSIS OF OBTAINED STABILITY RESULTS FOR FS

5.1. DISPLAY OF OBTAINED STABILITY ANALYSIS RESULTS FOR FS FOR BOUNDARIES BALANCE METHODS

Graphical shown stability analysis for safety coefficient (Fs) by numerical methods, Morgenster-Price, Bishop and Janb, and varying pore pressure coefficient (ru) are given in images 4. to 6. On the basis of profile III-III' northern outdoor landfill stability analysis is done by already mentioned numerical methods and we obtained following safety coefficients (Fs), shown in Table 2.

Profile	Nemerical methods	Coefficient of pore pressure		
		r_u=0.4	r_u=0.2	r_u=0.0
		Safety factor coefficient F_s		
III-III'	Morgenstern Price	0.683	1.009	1.322
	Bishop	0.679	1.010	1.346
	Janbu	0.609	0.871	1.153

Table 2. Obatined safety factor coefficient (Fs)

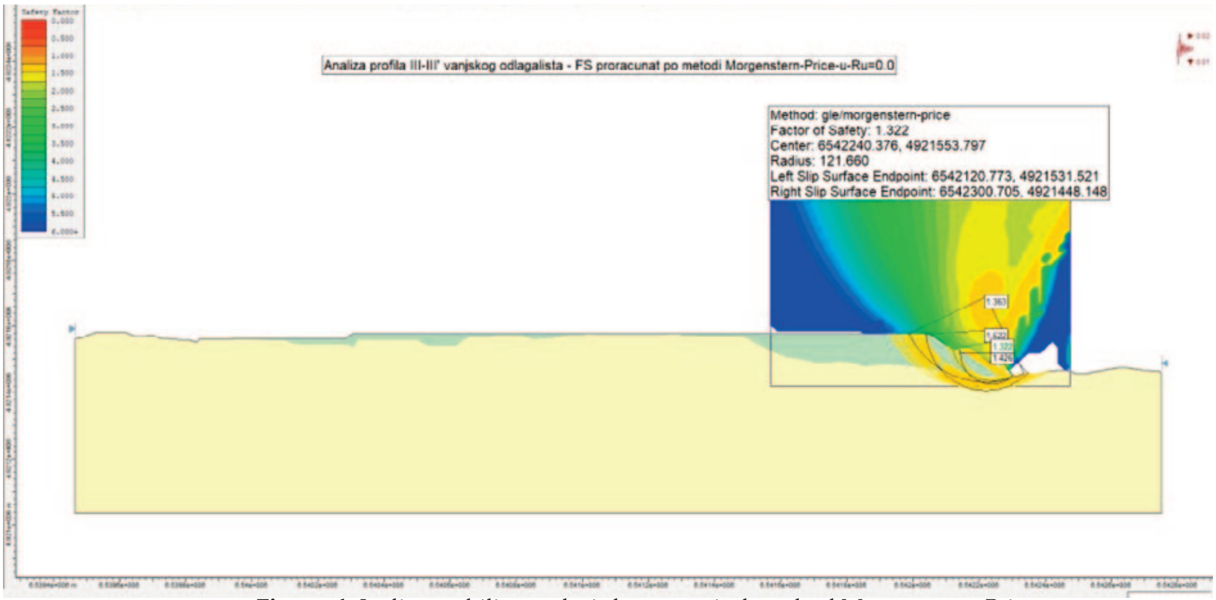

Figure 4. Incline stability analysis by numerical method Morgenstern-Price with pore pressure ru=0.0, Fs=1,322

Figure 4. shows first series of stability analysis testing on landfill „Dubrava" which will develop after disposing of waste-rock. Analysis is done by theMorgenstern-Price method without pore pressure coefficient for given variant.The safety factor Fs value for adopted four characteristic breaks are between the boundaries 1,32 and 1,52(least obtained safety factor), we adopted most critical break of 1,322 and we can see that this construction is conditionally stable and it satisfies Fs By rules of technical normative for surface exploatations.

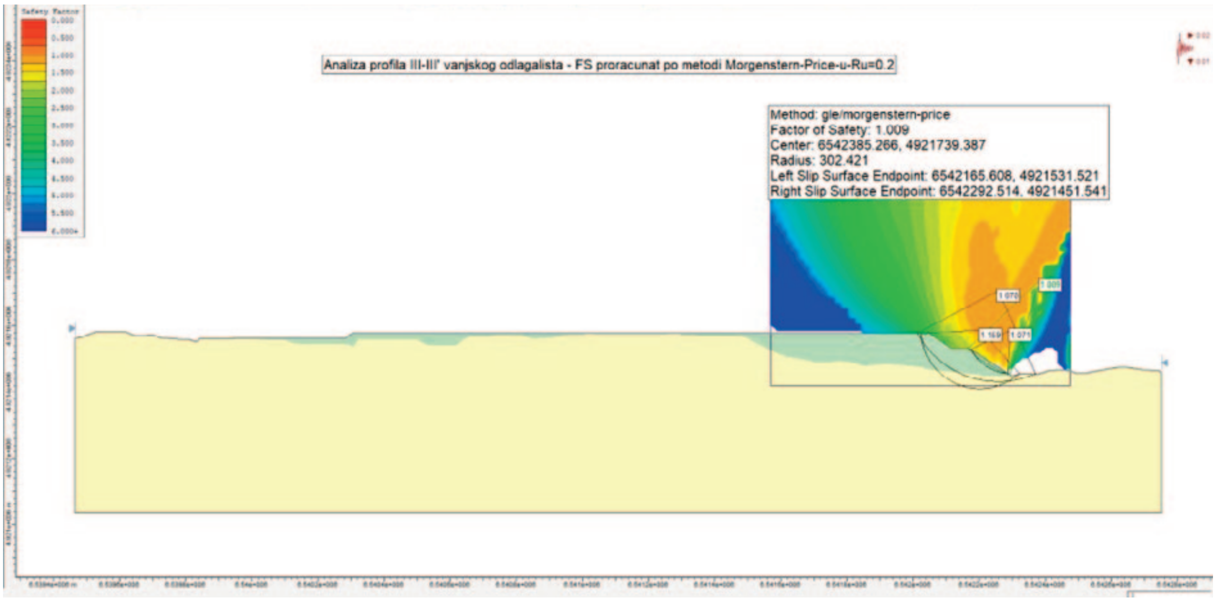

Figure 5. Incline stability analysis by Morgenstern-Price numerical method with pore pressure of ru=0.2, Fs=1,009

Figure 5. shows second series of stability analysis testing on landfill „Dubrava" which will develop after disposing of waste-rock. Analysis is done by the Morgenstern-Price method with a pore pressure coefficient of ru =0.2 for given variant. The safety factor Fs value for adopted four characteristic breaks are between the boundaries 1,009 and 1,159 (least obtained safety factor), we adopted most critical break of 1,009 and we can see that this construction is unstable.

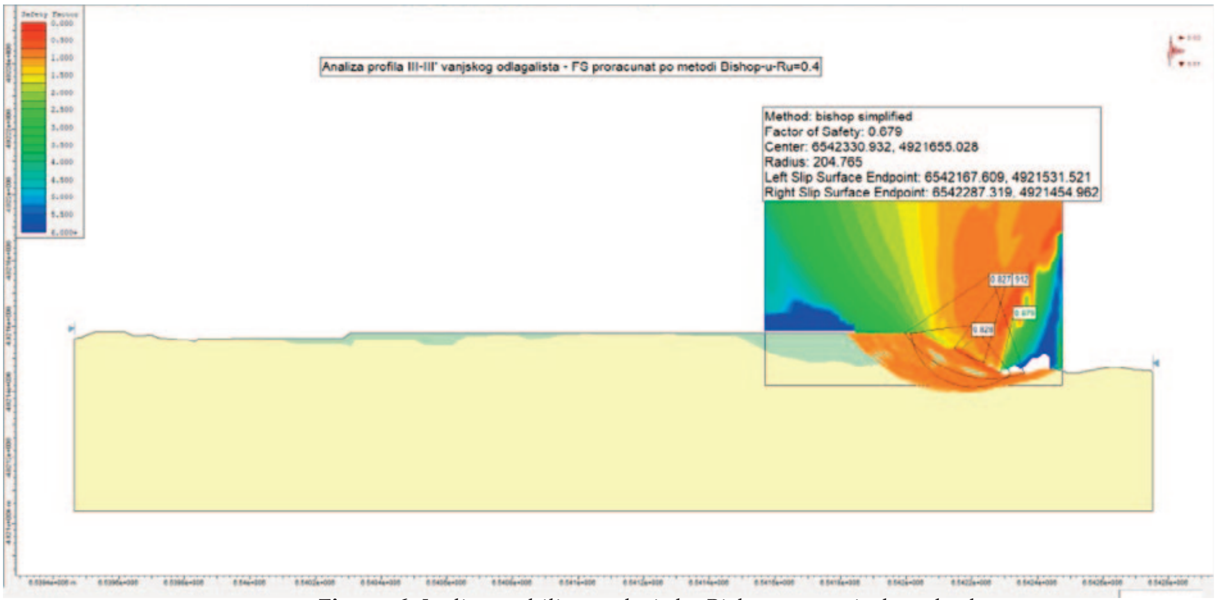

Figure 6. Incline stability analysis by Bishop numerical method with pore pressure of ru=0.4 Fs=0,0679

Figure 6. shows third series of stability analysis testing on landfill „Dubrava" which will develop after disposing of waste-rock. Analysis is done by the Bishop method with a pore pressure coefficient of ru =0.4 for given variant. The safety factor Fs value for adopted four characteristic breaks are between the boundaries 0,679 and 0,912(least obtained safety factor), we adopted most critical break of 0,679 and we can see that this construction is unstable.

5.2. DISPLAY OF OBTAINED STABILITY ANALYSIS RESULTS USING SRF

Graphic display of stability analysis using critical tension state coefficient (SRF) using pore pressure (ru) are given on figures 7. to 9. On the basis of profile III-III′ northern outdoor landfill we did stability analysis using SRF with varying pore pressure coefficient (ru) which is shown in Table 3.

Profile	Coefficient of pore pressure		
	r_u=0.4	r_u=0.2	r_u=0.0
	C ritical tension state coefficient (SRF)		
	0.63	0.93	1.25

Table 3. Obtained critical tension state coefficient (SRF)

Figures (7., 8., 9.) show maximum shifting for all given values of pore pressure coefficient, so Figure 7. shows 77 broken definitive elements with maximum shifting of 0,2 m. Figure 8. shows 181 broken definitive elements with maximum shifting of 0,6 m. Figure 9. shows 189 broken definitive elements with maximum shifting of 1 m. All figures show that bigest shiftings are made in legging of landfill.

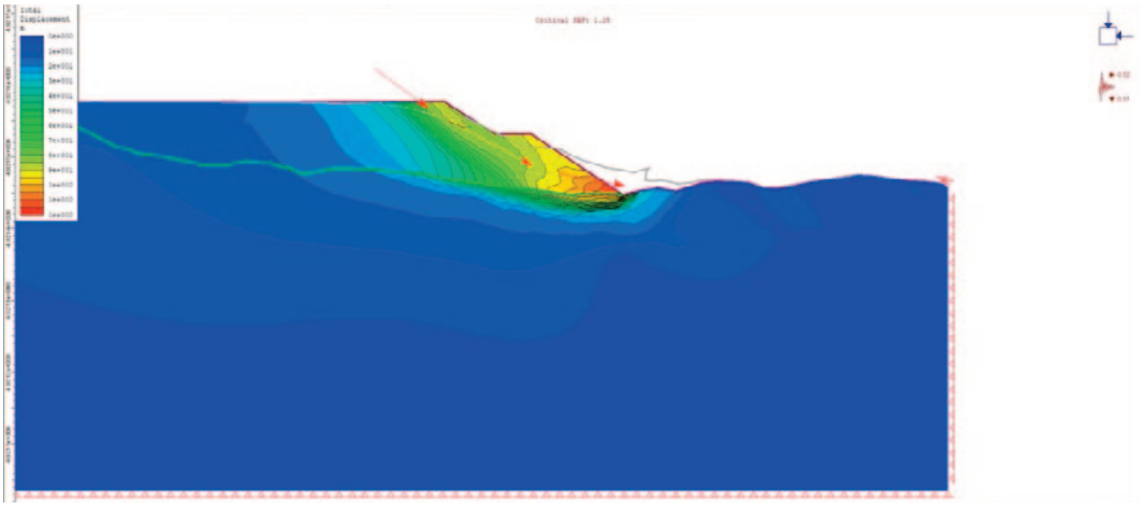

Figure 7. Incline stability analysis using material tension states with pore pressure of ru=0.0, SRF=1.25

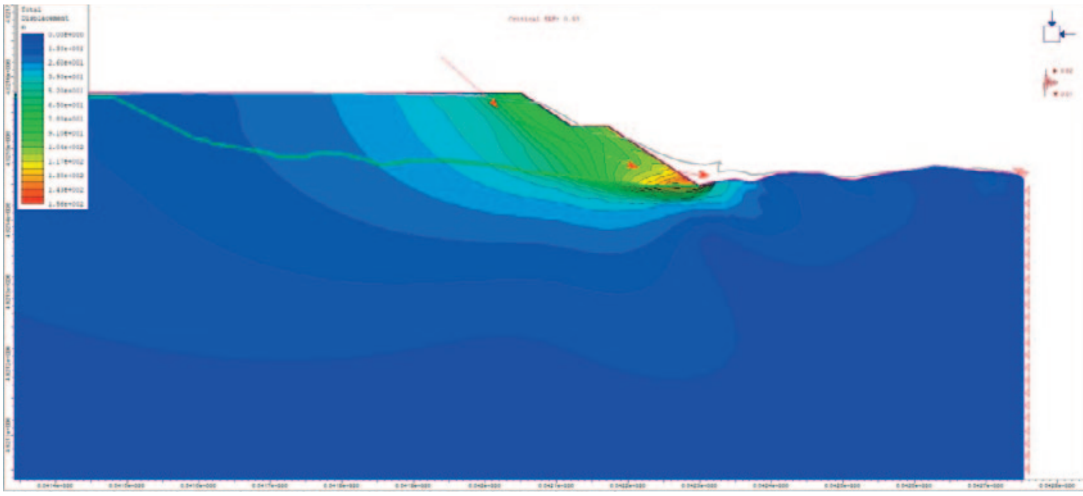

Figure 8. Incline stability analysis using material tension states with pore pressure of ru=0.2, SRF=0.93

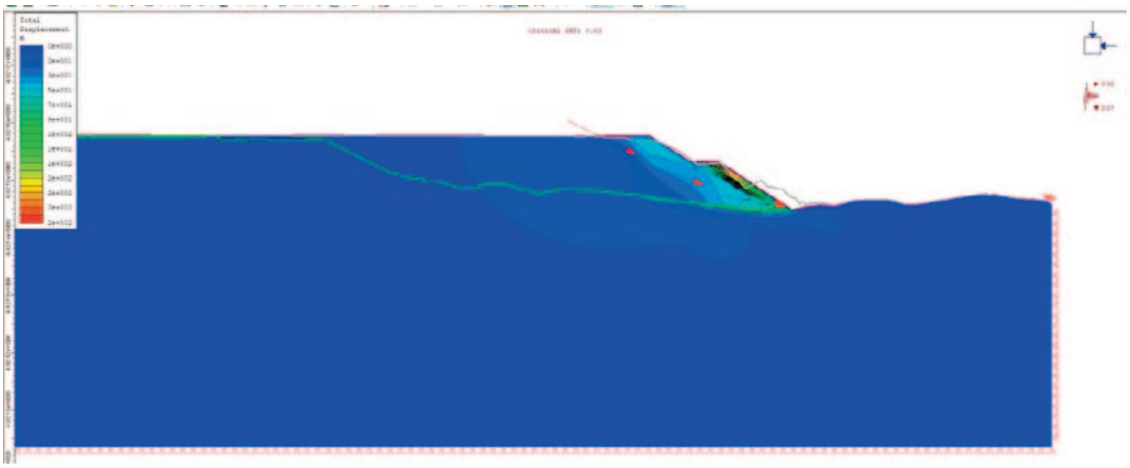

Figure 9. Incline stability analysis using material tension states with pore pressure of ru=0.4, SRF=0.63

5.2. RESULTS ANALYSIS

While analysing obtained results shown in Table2. and Table 3. we can conclude that landfill is unstable in state of high water. For that reason we need to prepare foundation of landfill, cleaning humus cover, contact with clay, and making drainage system, for collection and drainage of groundwater behind the projected contour of the landfill. An important measure to increase the stability of the landfill, especially from slipping and underwater flooding of the surrounding land, is the construction of a surface filter system around the landfill or in the part towards which the waters gravitate. In practice, the landfill can be successfully drained if it is covered with a layer of solid rocks or by making horizontal water collectors (construction of a channel 2.0 m deep in which cement or concrete drilled pipes are lowered around which filling has been done with sand or gravel).

Also on the floor levels it is necessary to make floor channels (located on the floors of plateaus that serve to drain water from the slopes of landfills and plateaus) as well as peripheral channels (which are located along the perimeter of the landfill and protect the landfill from surface waters that gravitate towards the landfill from the surrounding terrain) from endangered side.

In the plastic analysis, it is noticed that the values obtained via SRF are identical to the values of Fs. This is quite logical considering the fact that the models are in a plastic state. This means that the SRF will be equal to Fs only when a fracture occurs.

Level of underground waters must always be at least 1 m under legging of landfill. While disposing material we need to be sure that in contact with foundation always come materials with better geomechanical characteristics and materials that are good at draining water.

It is possible to dispose at the incline that is technologicaly more complex but improves stability.

Trough SRF analysis we noticed that biggest shifting are in legging of landfill, and it tells that we need to be careful especialy while modeling legging of landfill.

6. CONCLUSIONS

In this paper is shown landfill incline stability analysis trough two approaches, in finding safety coefficient (Fs) and critical tension state coefficient (SRF). Both approaches used different pore pressure coefficient (ru), which was between 0,0 to 0,4. Both approaches gave similar results, and at increasing NVP, incline stability is more and more in danger or incline stability indicator decreased. MKE analysis does not assume the state of general incline break on some plain, but it gives the real image of tension state and deformations on outdoor landfill „Dubrava". Tension deformations are observed trough Mohr-Columb breaking criterium and plastic behaviour of rock mass after breaking.

Trough analysis we deduced that by the posibility of using Fs in checking of terrain stability depending on tension states that are inside the ground, we can use SRF control that can be preeliminating indicator and can show the most probable way of incline breaking process development.

Based on comparative tests conducted on a given model consisting of 3865 elements zones of rock mass fracture were observed with 450 broken finite elements, indicating that the largest displacements occur at the foot of the landfill as seen in the pictures (Figure 7, Figure 8 and Figure 9) where at the same time the largest displacements of 0.28 m and appropriate stabilization measures need to be taken. To achieve the stability of slopes, it is necessary to apply certain measures: protection of external landfills from surface and groundwater (landfill drainage), as well as adequate preparation of the substrate, which leads to mining works on disposal. The existing geomechanical and hydrogeological parameters of the external landfill "Dubrava" have not been investigated in detail and it is necessary to perform additional geomechanical and hydrogeological research, especially with the dynamics of landfill development. For this purpose, it is necessary to conduct new research for the needs of the landfill, whereby it is necessary to determine: hydrogeological aspects of the area, geomechanical properties of the soil in the potential sliding area and beyond and perform geodetic measurements and observations.

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Scientific Paper

IMPORTANCE OW WELL TESTING IN OPEN HOLE OF GAS DEPOSIT

Sanel Nuhanović[1], Adnan Hodžić[2], Amir Sušić[3], Jovana Munjiža[4]

SUMMARY

Conventional approach to the well testing uses manometers with metallic film at the bottom of the well, which can be analysed just after its extraction from the well.
There is a problem with an open-close time of tester valve, which is determined by manufacturer's recommendation and testing operator 's experience.
The second approach means well testing in a real time, where all data are immediately available and open-close time is optimal for data collecting, which is reducing the testing costs.
Before a conventional well testing starts, it is necessary to get some preparatory works done, as it is to define the well situation, and to prepare the tools and measurement instruments.
Collected data are registered in the work proceeding, and along with a diagram, make a base for the results interpretation, that is shown in this paper.

Key words: well, gas, well testing, production

1. INTRODUCTION

The primary aim of DST is to determine possibility of deposits for some fluid, in this case it is natural gas, production. That why, it is necessary to determine characteristics of produced wells.

Based on these results, a lot of important data about the layer permeability, skin factor size, stimulation volume, pore pressure, deposit heterogeneity, drainage radius and also, sometimes, deposit boundaries, can be got.

Well testing (DST) is partially and short-time well conquest, whereby the interesting interval must be separated from the other (upper) well parts with packer, thus eliminating the influence of mud hydrostatic pressure above.

The primary method of this measurement is establishing of the well bottom depression, what causes a flow of fluids from the layer to the well.

The flow rate and stream measurements during the extraction phase, and pressure measurements during the well closing periods, enough data for all interpretation methods can be got.

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2. DESCRIPTION OF DST PROCEDURE IN THE GAS WELLS

A Drill Stem Test (DST) is a short measurement method, which is performed during drilling jobs in open hole, with the primary purpose to determine eventually deposit productivity (Figure 1.).

During a DST, the interesting interval (reservoir) is separated from the rest of well with packer.

The packer is eliminating anullar mud pressure and, in that way, interval (reservoir) pressure makes a connection with drill pipes pressure. In this case, well testing was done at 2080 m depth and 2125 m depth, with a two flows and two closing periods.

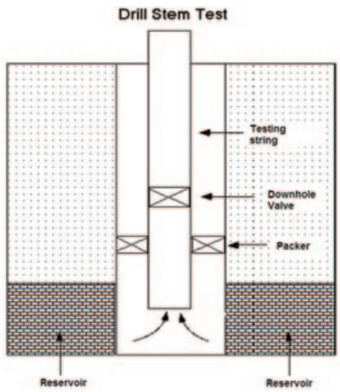

Figure 1. DST completion sheme

During the tools descending, down hole valve was closed (the mud does not enter into drill pipe). In both cases (at both depths), the initial hydrostatic pressure was registered (point A, Figure 2).

When the tools reached the desired depth, the packer was activated, down hole valve was opened and flow rate was established. Then, measurement of initial dynamic pressure of the first flow started (point B, Figure 2).

After that, the valve was closed, gas flow trough the tester tools was stopped and the final dynamic pressure for the first flow was registered (point C, Figure 2). Also, during the time valve was closed, the first static pressure was registered (point D, Figure 2).

After that, with tension and rotation of drilling tools, down hole valve was opened, gas flow trough drill pipes started and dynamic pressure of the second flow was registered (point E, Figure 2).

With the next rotation of drilling tools, after the drill pipes were set, the valve was closed and the final dynamic pressure of the second flow was registered (point F, figure 2). After that, there was a pressure rise and the final static pressure was registered (point G, Figure 2).

With a drilling tools tension, the packer was deactivated, down hole valve was closed, dual valve was opened, drill pipe fluid was replaced with the mud and drilling tools extraction started.

Closing of the testing valve and opening of the overflow "by-pass" are usually manifested with a drop in the mud level, so we must fill the well with the new mud volume to the surface level then.

The Figure 2 shows graphic, generated during the well testing in an open hole gas well, at depths 2080 m and 2125 m.

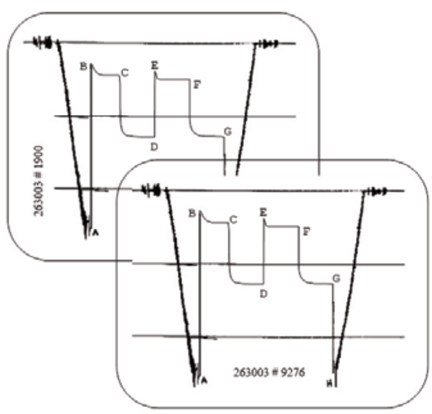

Figure 2. Testing diagrams of gas well "X-2"

Proceeding Nº: 263003					
Manometer Nº: **1900**, depth: ***2080* m** (Upper) The clock Nº: 1547, capacity: 12 hours			Manometer Nº: **9276,** depth: ***2125*** m (Upper) The clock Nº: 1547, capacity: 12 hours		
TIME (minute)	**PRESSURE (bar)**	**(T+Δt)/ Δt**	**TIME (minute)**	**PRESSURE (bar)**	**(T+Δt)/ Δt**
1st FLOW (B–C)			1st FLOW (B–C)		
0	38,46		0	36,74	
10	39,42		10	44,84	
20	46,08		20	51,78	
30	48,55		30	54,39	
40	49,24		40	55,28	
50	49,51		50	55,35	
60	49,65		60	55,62	
1st CLOSING (C-D)			1st CLOSING (C-D)		
0	49,65	-	0	55,62	-
6	134,46	11,00	6	139,54	11,00
12	137,82	6,00	12	142,97	6,00
18	139,54	4,33	18	144,41	4,33
24	140,50	3,50	24	145,37	3,50
30	141,25	3,00	30	146,20	3,00
36	141,73	2,67	36	146,60	2,67
42	142,08	2,43	42	147,23	2,43
48	142,42	2,25	48	147,71	2,25
54	142,70	2,11	54	147,92	2,11
60	142,97	2,00	60	148,19	2,00
2nd FLOW (D-E)			2nd FLOW (D-E)		
0	47,45		0	55,28	
10	49,65		10	55,28	
20	51,43		20	57,06	
30	51,09		30	56,79	
40	50,47		40	56,24	
50	50,47		50	56,31	
59	50,20		59	56,24	
2nd CLOSING (E-F)			2nd CLOSING (E-F)		
0	50,20	-	0	56,24	-
6	128,96	20,83	6	134,04	20,83
12	133,08	10,92	12	138,10	10,92
18	135,28	7,61	18	140,16	7,61
24	136,58	5,96	24	141,46	5,96
30	137,68	4,,97	30	142,56	4,,97
36	138,58	4,31	36	143,45	4,31
42	139,06	3,83	42	144,07	3,83
48	139,67	3,48	48	144,55	3,48
54	140,02	3,20	54	145,03	3,20
61	140,36	2,95	61	145,51	2,95

Table 1. Well testing values of gas well "X-2"

After a visual examination of diagrams, we conclude that all characteristic points are visible, and then we can begin with its segmenting.

Well testing was done with two flow periods and two well closings at the bottom.

At the surface, in front of nozzle (d=15,875 mm), gas was obtained with the pressure about 27,5-29 bar. Gas sample is taken for the laboratory analysis.

All diagram components are recognizable and can be used for the interpretation.

Segmented data are registered in the table 1.

3. ANALYSE OF TESTING RESULTS (GAS WELL "X-2")

The Horner's method is widely applied for data processing in cases of pressure determination in the wells, which have a constant flow rate. Around 90 % quantity analyses of the well tests is based on the Horner's method which predicts the next ideal conditions:

Radial flow – fluid is constrained to move at right angle to an axis of the well;

Homogeneous reservoir – constant characteristics of reservoir at lenght and thickness (all values then become averages of reservoir lenght and/or thickness);

Stationary flow rate – which means a reduction in speed and pressure, whereby fluid flow (stream) is constant;

Unlimited deposit – the deposit without distinct external borders during the well testing period (external deposit borders effect usually occurs only after a few days);

Single-phase flow – only one-phase fluid enter into the well (any gas produced with oil is dissolved gas and any liquid that occurs during the well testing procedure is condensate gas in drill pipes or near-wellbore area).

Flow rate, before well closing period, changes relatively slow, so we must replace the real production time with Horner's corrected production time and las detected flow rate.

The Horner's method is good aproximation, but under the condition that extraction rates were not changed before well was closed. It is recommended that the last extraction (pumping) rate, before the well will be closed, should last at least two times more than the previous one.

According to Horner's method, the measurement results are displayed by applying a pressure to the ordinate and to the abscissa ratio log ((T + Δt) / Δt). "Horner time", in logarithmic scale, and data not lying in the direction refer to the period of the fluid storage.

With a detailed (partially) reading of static pressure curves, we can get series of the points and draw a straight line. There is so-called "extrapolated static pressure", that should correspond with the real pore pressure (formation pressure).

According to the extrapolated line , existence of barriers (faults and other) within the drainage radius can be determined. The figure 3 shows extrapolated diagram.

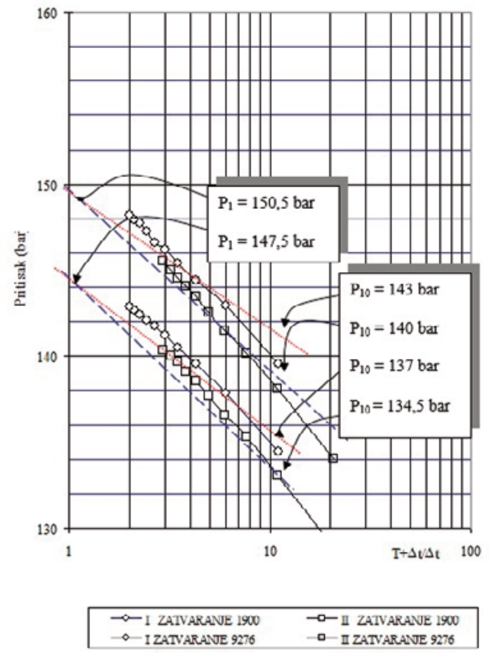

Figure 3. Extrapolation diagram, gas well "X-2"

According to the curve position, it can concluded that there is no problems. Collector permeability is very good, drainage radius is stable and there is no any natural faults or outcroppings (barriers).

The final measurement was done at the depth 2125 m, so the estimate refers to that depth is registered here (register 9760).

According to the diagram (Figure 3), maximum formation pressure is, in bars (depth 2125 m - Horner's plot – 2nd closing):

$$P_s = 150{,}50 \ [bara]$$

The slope of the increase curve linear part is used for collector permeability and other parameter estimates. It is calculated according to the next formula, and his amount is:

$$M_g = P_1^2 - P_{10}^2 = 22650{,}25 - 19600 = 3050{,}25 \left[\frac{bar}{\log .cikl}\right]$$

The pressure gradient at this depth (2125 m) is:

$$GP = \frac{P_s}{H_r} = \frac{150{,}50}{2125{,}1381} = 0{,}0708 \left[\frac{bar}{m}\right]$$

Based on the slope value of the increase curve linear part, it can be determined deposit transmissibility value:

$$T_r = \frac{k \cdot h}{\mu} = 1{,}4924 \cdot 10^{-1} \cdot \frac{Q_g \cdot Z \cdot T_s}{M_g} =$$
$$= 1{,}4924 \cdot 10^{-1} \cdot \frac{110337 \cdot 0{,}867 \cdot 373{,}15}{3050{,}25} == 1746{,}2 \ [10^{-3} \mu m]$$

The integral part of tester is sample catcher for formation fluids (for their assessment and analysis).

The fluid (gas) sample usually goes to the laboratory for potentially hydrocarbons definition.

Laboratory analysis show real changes of formation fluids pressure and temperature and also, some changes in their properties are observed. Typical group of laboratory estimates (PVT analysis) consist of volume tests, appropriate to fluid types and structure and physical properties of fluids analysis.

Methods and techniques of PVT analysis require some complex laboratory equipment, because of large spectrum of PVT conditions, that are needed in laboratory.

Laboratory analyse of natural gas consists of his structure estimate and calculate his other properties based on that structure.

Laboratory analyse of formation fluid (gas), in this case, gave the results shown in table 2.

PARAMETER	VALUE	PARAMETER	VALUE
Gas density	$\rho = 0{,}6$ kg/md^3	Gas viscosity	0,019 mPas
Layer temperature	100^{O}C	Volume factor	-
Diameter of surface nozzle	15,875 mm	Gas compressibility	Z=0,867
Pressure in front of nozzle	29,18 bara	Thickness of layer	h = 6 m
Drill pipe capacity	9,16 l/m	Drill collars capacity	3,167 dm^3/m'

Table 2. Results of the well stream laboratory analysis

Based on the measurement results (shown in table 1), the flow parameters, skin factor and theoretical collector capacity (theoretical production) will be calculated.

There are shown just results of 2nd measurement, but in table 3 shows results for all measurements.

Theoretical gas production, during the well testing time is:

$$Q_g = 306{,}118 \cdot \frac{C \cdot P_{usta}}{\sqrt{\rho \cdot T_{(K)}}} = \frac{179{,}74 \cdot 30}{\sqrt{0{,}6 \cdot 373{,}15}} = 110337 \left[\frac{m^3}{dan}\right]$$

However, very important parameter here is skin factor, which is presented by Damage Ratio (DR).

Damage ratio (DR) is numerical amount, which is used for flow prevision, if all damages are removed. Basically, damage ratio is going to be a number that, multiply with flow value existed during the test, can give a flow rate, if damage is removed (or natural permeability is improved) in relation to the initial conditions.

That flow rate will be the same by the same pressure that existed during the well testing time.

By definition, DR = 1, if near-wellbore area is not damaged and, in that case, theoretical well production (Qt) is equal with real production (Q) (his real value).

If we do not know elementary deposit parameters, then DR can be estimated by using pollution coefficient:

$$\mathrm{EDR}=\frac{P_s^2-P_{KDP2}^2}{M_g\left(\log T+2{,}65\right)}=\frac{22650{,}25-3163}{3050{,}25\cdot\left(\log 119+2{,}65\right)}=1{,}35$$

In this case, theoretical production is:

$$Q_t=Q_s\cdot \mathrm{EDR}=110337\cdot 1{,}35=148955\left[\frac{m^3}{dan}\right]$$

All results are shown in table 3.

Quantity	Equation	Manometer N°:1900 Depth: 2080 m		Manometer N°:9276 Depth: 2125 m		Measuring units
		Početni	Krajnji	Početni	Krajnji	
Testing periods – flow-closing		1	2	1	2	-
Total flow time		60	59	60	59	minut
The one cycle pressure		137	134,5	143	140	bar
Extreme dynamic pressure (P_{KDP})		49,65	50,20	55,62	56,24	bar
Production (Q_g)		106709	110337	106709	110337	m^3/dan
Formation pressure (Ps) Hornerov-grafik		147,50	147,50	150,50	150,50	bar
The slope of curve (Mg)		2987,25	3666	2201,25	3050,50	bar/logcik.
Pollution (EDR)		1,46	1,11	2,01	1,35	-
Transmissibility (T)		1724	1453	2340	1746,2	10^{-3} μm
Permeability (k)		5,46	4,6	7,41	5,53	10^{-3} μm^2
Testing diameter (Ri)		5,52	32,99	29,73	36,17	m

Table 3. Calculated values of gas layer

4. DISCUSSION AND RESULTS ANALYSIS

Testing procedures at the gas well "X-2" were done in two cycles, initial measurements at the depth 2080 m and final measurements at the depth 20125 m. Well testing consisted of two flows and two well closing periods. The flow in this measurements lasted 60 minutes.

During the test procedure, the pressu*re ranged from 134 bar (the initial measurement – register No 1900) up to 140 bar (the final measurement – register No 9276).*

Testing radius ranged from 32,99 m (the first cycle – depth 2080 m) to 36,17 m (the second cycle – depth 2125 m).

*Basic fluid characteristics were determined in laboratory and their values are: gas density is 0,6 kg/m3, gas viscosity is 0,019 mPas and gas compre*ssibility is 0,867.

The maximum formation pressure was determined during the measurement at the depth 20125 m (Horner's extrapolation diagram – 2nd closing) and he was 150,50 bar, with the remark that all parameters in this interpretation can have just assessment form, due to the length of DST procedure time.

The layer temperature was 100°C.

With a detailed reading of static pressure curves determined that flow, in any one measurement phase was uniform and, based on that, the calculation for the produced capacity of testing interval (reservoir) can be approach. The produced capacity (Qg) by the final measurement, at the depth 2125 m, was 110 337 m3/day, with the pollution coefficient 1,35.

Based on this results, theoretical capacity was estimated and it is Qt = 148 955 m3/day.

After all calculations and results interpretations it can be concluded: the layer permeability is satisfying, his skin is inappreciable, inside the drainage radius, no barriers exist, the drainage radius is stable, pore pressure does not fall to fast (Horner's diagram).

Finally, it can be considered that testing layer is perspective for gas production.

5. CONCLUSIONS

Wildcat well testing is important to define hydrocarbon saturation of deposit and determine, or at least, point to its possible commercial resources, that can be proved afterwards, by hydrodynamic measurements.

Well testing gives us enough precise answers to the questions about deposits permeability and damaged (skin effect) of near-wellbore zone.

The skin effect value can give us better knowledge about possible well production level. It is the basis for the future well works, as well stimulation, eventually canning or leaving the well works.

The most common mistake that happens during the test is its standardization, because each deposit and well are specific. It is possible to standardize some basic equipment, but not the whole procedure and tools.

Successful test provides the very important data for the future well and deposit works.

Investments in DST well testing are always justified with the results, which can be used for the future optimal well using.

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Scientific paper

RESULTS RESEARCH MAINTENANCE OF LOCAL ROADS

Zahid Bašić[1], Anadel Galamić[2]

SUMMARY

The research in this paper includes the network of local roads in the municipality of Banovići, where data on road elements and procedures for maintaining macadam roads are presented.
The types of road maintenance according to the scope of works, levels of readiness, framework standards for this type of work are presented.
The aim of this research was to determine the maintenance price of macadam roads in relation to asphalt roads for a period of 1 year and for a period of 10 years. The results of the research in this paper are presented graphically.

Keywords: road, maintenance, research, summer and winter

1. INTRODUCTION

Maintenance includes planning activities and the appropriate scope and type of work that ensures the smooth flow of traffic and preserves the use value of the road. Uninterrupted flow of traffic means planned and expected continuity, intensity, safety and comfort in the realization of traffic flows. The condition of the road and its elements should enable such traffic, ie the use value of the road should be in accordance with the purpose at the time of construction or reconstruction. Maintenance is a continuous process, which lasts as long as the journey itself as an object. This process includes all road elements (road, slopes, drainage, drainage system, equipment, etc.), including facilities on the road route (bridges, tunnels, viaducts, etc.). [1]

The basic task of maintenance is to timely identify the phenomena and identify the causes of disturbances or damage and take timely action to eliminate them, in order to prevent serious damage and jeopardize the planned (above all safe) traffic. The road protection system has a significant role, which implies its use in accordance with the rules and its operational characteristics, including various prohibitions and restrictions (activities, interventions, ...) relating to the road, but also to the road belt and belt controlled construction. [2]

1.1. TYPES OF MAINTANCE

Road maintenance can be observed from several aspects, on the basis of which its classification can be performed. The most common factors that are the subject of observation of maintenance are, the scope

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and manner of providing financial resources, specifications and scope of works, the manner of planning and program conditions, the nature of works, etc. [3]

Based on the method of providing financial resources, it differs:

- investment and
- regular maintenance.

Investment maintenance includes large-scale works performed under special programs, according to specific requirements, as special projects (for example, reconstruction of a part of a road or facility), which is a legal obligation to plan in the budget of each calendar year.

Regular maintenance is realized according to annual plans, pre-defined prices and flat-rate contracting. It can be observed according to the program conditions, the manner and scope of realization and the periodicity of execution.

According to the method of planning, organizing and performing works, maintenance can be divided into:

- preventive,
- corrective and
- forced maintenance.

Preventive maintenance is a strategic approach to road maintenance that prevents and slows down the occurrence of damage and maintains or improves its functional characteristics (without increasing the structural load-bearing capacity). The program of effective preventive maintenance implies preventive application (3 to 6 years) of appropriate treatments and works, after the completion of construction. This avoids or delays the costly reconstruction process and makes the maintenance process more efficient.

The basic problem of applying the concept of preventive maintenance is the moment of performing certain treatments and interventions. A universally valuable answer cannot be given, but the principle is accepted that preventive maintenance works should be organized and performed before the occurrence of damage. If the necessary interventions are delayed, maintenance ceases to be preventive and passes into the zone of corrective, forced, ie it can become an expensive reconstruction. If, on the other hand, preventive treatments are realized too early, damages occur due to unused road resources. By careful monitoring and assessment of the condition, preventive treatments can be periodically planned for individual elements of the road or its sections. Thus, preventive maintenance programs replace reconstructions that are 3 to 5 times more expensive. [4]

However, not all road damage can be prevented. Therefore, it is necessary to carry out corrective maintenance to eliminate the damage. Forced maintenance is most often the result of processes that are out of control and it eliminates the consequences of some extraordinary circumstances.

Our legislation distinguishes and defines:

- regular maintenance
- periodic maintenance and
- emergency maintenance.

Regular maintenance includes works and activities that are permanently carried out, such as:

- Review, determination and assessment of the condition of roads and road facilities;
- Occasional repairs of the road structure and other road elements;
- Road cleaning within the road belt,
- Arrangement of slopes and embankments (stabilization, planning, humusification, grassing, repair of wire mesh, ...);
- Arrangement and cleaning of drainage systems (ditches, gutters, culverts)
- Repair of road facilities;
- Cleaning, installation, renewal and supplementation of traffic signals;
- Cleaning, installation, renovation and replenishment of road equipment;
- Cleaning of facilities and equipment for road, traffic and environmental protection;
- Landscaping of green areas on the road and land;
- Cleaning and removal of snow and ice from traffic areas, ancillary surfaces and drainage systems;
- Maintenance of joints between concrete slabs;
- Filling cracks.

Periodic maintenance includes road construction reinforcement works, rehabilitation and enhanced maintenance.

Reinforcement of the pavement structure, mainly refers to:

- Installation of gravel or gravel curtain on pavements;
- Processing and sealing of the road curtain;
- Applying a new layer of pavement (along the entire width of the pavement);
- Correction of the shape of the existing curtain or pavement, etc.

In the area of the Banovići municipality, when it comes to the maintenance of local roads, it is carried out in two phases, as summer and winter road maintenance.

For the summer maintenance of roads, the municipality of Banovići has not prepared an operational program of maintenance works, but the said maintenance is carried out in accordance with the legislation and the description of works specified through regular and preventive maintenance.

When it comes to winter road maintenance, the municipality of Banovići has adopted an operational work program. [4]

Road maintenance works in winter conditions

According to the geographical and climatic characteristics, the municipality of Banovići belongs to the hilly and mountainous area, and taking into account this fact, it is necessary to provide, ie include the necessary actions with the Operational Program, which includes in particular:

A / Preparatory works before the onset of winter conditions

B / Preparatory works under the obligation of the contractor. [4]

Degrees of readiness

The Winter Service operates by introducing a level of readiness depending on the expected weather conditions and geographical and climatic characteristics of the area of the municipality of Banovići, and there are four levels of readiness:

First level of readiness:

The first level of readiness is introduced at the beginning of the winter service, and implies the introduction of duty at the place of readiness, establishes and ensures a permanent connection between the Contracting Authority and the Contractor, or the Supervisory Authority to ensure a sufficient number of people and machinery. timely interventions in case of need.

The contractor is obliged to provide a sufficient number of people (low skilled workers) for the needs of regular maintenance of street cleanliness depending on weather conditions.

Second level of readiness:

The second level of readiness includes the inclusion in the work of all planned vehicles with equipment for snow clearing and prevention of icing, namely a truck with a plow and a spreader, a truck with a spreader, 2 low skilled workers and the use of sufficient quantities of spreading material.

The second stage is introduced when the weather conditions require it, ie less snowfall and the appearance of ice. The works are performed according to priorities, and the priorities are:

First priority:

Work on clearing snow and preventing icing is carried out on the full profile of the road (road with sidewalks, extensions, bus stops), and in the city area it is street roads with sidewalks, stairs, footpaths, intersections, squares, squares, parking lots and other public transport surface.

The first priority includes roads with public line traffic.

Second priority:

The second priority of maintaining the winter service includes other roads.

Third priority:

The third priority of maintaining the winter service includes cleaning the access to cemeteries-cemeteries, and if necessary other public facilities, as well as emergencies such as natural disasters, accidents and others.

Third level of readiness:

The third level of winter service readiness is introduced when prolonged snowfall is expected, which requires special snow removal works from the road, when in addition to vehicles included in the second stage, stronger machines, one loader, one grader, and one milling and discarding cutter are included. snow from August and 5 low skilled snow removal workers.

Fourth level of readiness:

The fourth level of preparedness is introduced when snowfalls with strong winds have the character of a natural disaster and when the available number of people and machinery are not enough to remove snow and when with the consent of the competent municipal authority additional funds for labor and labor are introduced. Councils of local communities, companies and other organizations from the area of the municipality of Banovići, all in accordance with the operational plans listed in emergency circumstances prepared by the competent municipal authority responsible for emergency circumstances.

On the roads that are classified in the First Priority by the Operational Program as winter services, ie roads with public regular traffic, works on ensuring passability must be performed permanently in order to ensure constant passability and be completed within 8 to eight hours, counting from the moment of precipitation cessation.

On other roads of the second priority during snowfall, there must be no traffic jams longer than 6 hours, and the third priority is the real need and obligation to create conditions for safe traffic no longer than 72 hours after the cessation of precipitation.

For possible extraordinary conditions in case of heavy snowfall, heavy deposits, debris or ice, the competent authority for internal affairs will, with the consent of the municipal service responsible for communal affairs, for the safety of traffic participants temporarily prohibit or limit traffic for all vehicles or for certain types of vehicles on a particular section of road. [5] [6]

In places of higher ascents and passes already indicated, during winter conditions, if the need arises, the traffic of trailers may be prohibited until the conditions for safe traffic for the specified category of motor vehicles are created, and buses and trucks must use chains on drive wheels. .

Supervision and control of the winter service is performed by the Service for Physical Planning and Housing and Communal Affairs of the Municipality of Banovići and other persons authorized by the Mayor, especially in terms of monitoring the dynamics of work under the Operational Program for regular maintenance and emergency maintenance, material quality for sprinkling and calculation of performed works, as well as timely informing about the condition and passability of roads. [4] [9]

Necessary mechanization and workers for the work of the winter service

Based on the monitoring and experience in the past period and the real needs for organizing the work of the winter service according to the levels of readiness under the Operational Program, it is necessary to:

For the First level of readiness:

Based on 120 days, the period from November 15, 2016 to March 15, 2017, with the necessary engagement of a duty worker for non-working days - weekends and holidays 24 hours a day, and working days in II and III shifts or 16 hours) for timely contact with supervision, that is, by the ordering party of works, in order to engage the necessary machinery and personnel within the time limit that will be regulated by the Contract for the execution of works, the method of calculation is as follows:

Duty worker (38 x 24 +82 x 16) = 2224 hours

5 low skilled street maintenance workers x (65x 8) = 520 hours
Calculation work on the basis of actual time spent.

For Second level of readiness:
Based on 90 days:
Truck with plow and spreader I 300 hours
Sprinkler truck II 250 hours
6 low skilled workers x 20 days x 8 hours 960 hours

For the Third level of readiness:
Based on 60 days:
Two trucks with a plow and a spreader for 100 hours
Truck with spreader 100 hours
Graders 50 hours
Loader / ICB machine 80 hours
Snow blower 100 hours
10 low skilled workers x 10 days x 8 hours = 800 hours

For the Fourth level of readiness:
It is introduced as needed - the character of a natural disaster.
Based on 50 hours:
Two trucks with a plow and a spreader for 100 hours
Graders 50 hours
Two loaders / ICB machines 100 hours
Snow blower for 50 hours
10 low skilled workers x 10 days x8 hours = 800 hours

Preparatory works:

Scope of preparatory works according to the Operational Program of the Winter Service The needs from item A, of the Operational Program, will be performed in the regular activities of the Service for Physical Planning and Housing and Communal Affairs of the Municipality of Banovići.

Preparatory works from item B, Operational Program, winter services are the responsibility of the contractor, and they are:

- Procurement of spreading material (standard mixture of salt with fraction 0-4 mm) of salt 60 t, fraction 140 t, which makes a total of 200 tons of spreading material,
- Edge marking sticks, 300 pieces,
- Depositing of spreading material on passes and ascents in the amount of 30 tons.

The proposal for the assessment of the necessary mechanization and manpower is based on the above needs.

The operational program will be an integral part of the Contract for the performance of the Winter Service in the municipality of Banovići.

2. FRAMEWORK STANDARDS

From previous experiences, the speed of vehicles with a plow is 10 km/h on asphalt roads, while the speed of vehicles with a plow on macadam roads is 8 km/h. The speed of the vehicle with the spreader is 26km/h, the average consumption of the salt fraction is 0.29 t/km, where the spreading material is used only for paved roads, parking lots and sidewalks. The minimum number of road maintenance machines is 3 with a plow and one with a spreader (if one of them is a grader). The maximum number of machines is 7, one of which is a machine with a plow and a spreader. The minimum number of low skilled workers for work in the winter service is 4 low skilled workers, and the maximum number is 40, while the optimal number is 8 low skilled workers.

The contractor for cleaning public road surfaces and removing snow and ice from public areas is obliged to submit to the client the work schedule and movement of machines, names and surnames of drivers and auxiliary workers, winter service manager and list of low skilled workers who will be hired. needs in the winter service as well as the emergency telephone number where information on the condition of the roads and the work of the winter service can be given and received. A temporary ban or restriction of traffic may be allowed directly or indirectly only by the competent service. All other necessary elements for quality performance of the organization of road maintenance in winter conditions can be additionally regulated by a contract between the client and the contractor.

3. MAINTENANCE OF MACADAM ROADS

The works include the repair of gravel roads (patching and backfilling) on public roads that are performed manually and mechanically. [7]

Handicrafts are performed with a shovel, pickaxe and rake and civera.

The works are performed in such a way that individual pits are cleaned of mud and dirt, the edges of the pits are cut off, so that better reception and swearing of new and old gravel material is enabled. Pits up to 2 m^2 in size and up to 10 cm deep are being rehabilitated.

Mechanical work is performed with a backhoe with a leveling board for shorter sections or with a grader for longer sections. Additional gravel material was previously brought, and it can be brought every time and directly planned, so that, despite the execution of works, it is possible for traffic to take place with partial or partial closure of traffic. Arranged and profiled pavement needs to be rolled out. It is necessary to take into account that the road has a double-sided transverse slope in the minimum amount of 4.00%.

For the needs of summer maintenance of macadam roads, the municipality of Banovići has in its annual plans certain positions of necessary materials and services for summer maintenance of macadam roads. The quantities of planned stone for the needs of filling macadam roads are variable and they range annually from 1000 to 2000 t of stone, which depends on the degree of damage and which is determined by inspection of the same. The quantities of shown required hours for certain machines are fully used annually for the maintenance of macadam roads in the summer period and they are also calculated according to the norms that regulate this area. [9]

When it comes to winter road maintenance in the municipality of Banovići, it is carried out in accordance with the above operational program of road maintenance in the winter. Also, this position is planned in the annual public procurement plans of the municipality of Banovići.

Based on the available data, it can be seen that about 45,850.00 KM is spent annually for summer maintenance of macadam roads and about 23,504.62 KM for winter maintenance of macadam roads, which is a total of 69,354.62 KM.

4. SUMMER AND WINTER MAINTENANCE

Road maintenance in the area of the municipality of Banovići is carried out periodically through two positions, through summer and winter maintenance.

In the summer maintenance of roads, the following works are performed, which are performed annually:

- Less urgent interventions
- Maintenance of drainage system
- Maintenance of road profile elements
- Mowing grass and weeds
- Repair of deformations on asphalt surfaces [8]

Based on the available data, it can be seen that about 83,176.30 KM is spent annually for summer maintenance of asphalt roads and about 43,669.63 KM for winter maintenance of macadam roads, which totals 126,845.93 KM.

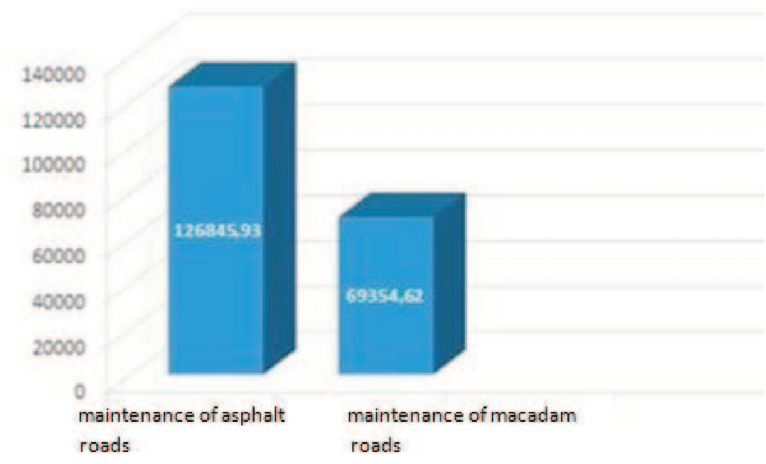

Figure 1. Schematically shows the consumption of funds for the maintenance of macadam and asphalt roads on an annual basis.

The diagram (Figure 1) shows that for the maintenance of asphalt roads in the municipality of Banovići set aside about 125,000.00 KM while for the maintenance of macadam roads about 70,000.00 KM. The shown cost is determined on an annual level, ie for 2016. [9]

5. MAINTENANCE OF ROADS FOR A PERIOD OF 10 YEARS

Based on the prepared bill of quantities and estimates of works, services and materials needed for maintenance, it was determined that for the maintenance of asphalt roads in the municipality of Banovići for 2016 allocated about 125,000.00 KM while for the maintenance of macadam roads about 70,000.00 KM, which is about 195.000,00 KM. Considering that in 2016 in the area of the municipality of Banovići the length of asphalted roads was 106,734.00 m, and macadam 68,640.00 m, it can be concluded that for the maintenance of asphalt pavement structures per meter length is allocated about 1.17 KM while for maintenance of macadam road constructions per meter length allocates about 0.98 KM.

In 2006, in the area of the municipality of Banovići, the length of asphalt roads was 63,374.00 m, and macadam 112,000.00 m, which can be concluded that for the maintenance of asphalt pavement structures in 2007 was allocated about 74,147.58 KM, while for the maintenance of macadam pavements construction allocated around 109,760.00 KM, which is a total of 183,907.58 KM. [9]

It is important to note that for the period of 10 years, ie from 2007 to 2016, the municipality of Banovići annually allocated about 500,000.00 KM for the reconstruction and asphalting of roads, ie about 4,000.00 meters of roads were asphalted annually. [9]

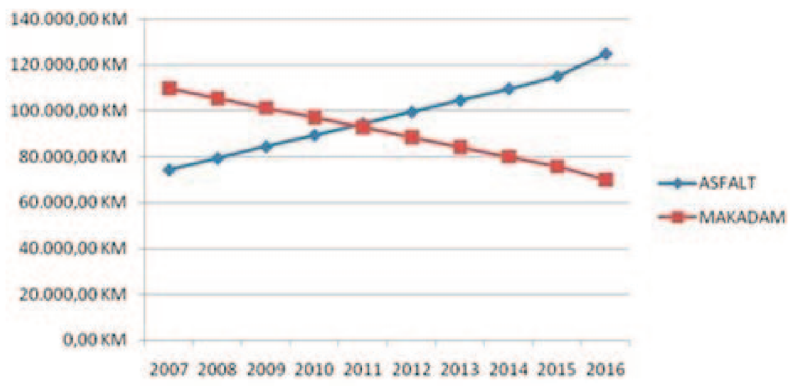

Figure 2. Maintenance prices of macadam and asphalt pavement structures

From the diagram shown in Figure 2, it can be concluded that the cost of maintaining asphalt roads since 2007. is constantly increasing, and due to the constant construction of asphalt roads, while the price for the maintenance of macadam roads is constantly decreasing. We can also see that investments for road maintenance in 2011 were equal to the value of about 93,000 KM per type of road.

6. CONCLUSIONS

The aim of this research was to determine the maintenance price of macadam roads in relation to asphalt roads for a period of 1 year and for a period of 10 years. Based on the prepared bill of quantities and estimates of works, services and materials needed for maintenance, it was determined that for the maintenance of asphalt roads in the municipality of Banovići set aside about 1.17 KM/m 'while for the maintenance of macadam roads set aside about 0.98 KM/m'.

In 2007, about 74,147.58 KM was allocated for the maintenance of asphalt roads, while about 109,760.00 KM was allocated for the maintenance of macadam road structures, which is a total of 183,907.58 KM.

In 2016, about 125,000.00 KM was allocated for the maintenance of asphalt roads, while about 70,000.00 KM was allocated for the maintenance of macadam roads, which is a total of about 195,000.00 KM.

For the stated period, ie for 10 years, about 975,228.06 KM was allocated for the maintenance of asphalt roads, while about 904,865.90 KM was allocated for the maintenance of macadam road structures, which is a total of 1,880,093.96 KM.

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