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Influence of Lithofacies and Diagenetic Processes on the Physical and Mechanical Properties of Carbonate Rocks - Case Study from Sinawin-Sha'wa Area, Libya

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Abstract
Geological investigations were carried out in the Sinawin-Sha'wa area, in northwestern Libya, in order to find suitable rocks for aggregate in asphalt mixtures for Nalut - Ghadamis Road reconstruction. By combined field work and micropetrographical analysis four different carbonate lithofacies were determined within Upper Cretaceous sedimentary sequence: lithofacies A - micritic limestones; lithofacies B - dolomitic marls; lithofacies C - dolobiomicrites; lithofacies D - biosparites and biosparudites. Diagenetic processes of cementation, recrystallization, dolomitization and silicification were identified within these lithofacies. Stone samples, taken from three lithofacies A, C, and D, were analyzed in order to determine its physical and mechanical properties (apparent density, open porosity, water absorption, uniaxial compressive strength). In addition, aggregate produced by crushing of the rock from lithofacies D is tested on resistance to crushing and abrasion (LA test). Samples from lithofacies B were not included in the testing of physical and mechanical properties since it is estimated as not suitable rock material for crushed aggregate. Samples from lithofacies A, C and D showed significant differences in the physical and mechanical properties. These differences stem from differences in mineralogical and petrographical composition as well as from diagenetic processes. Stone of lithofacies D were estimated as the most appropriate rocks available in the area, for aggregate in asphalt mixtures.

Keywords
lithofacies, diagenesis, carbonates, physical and mechanical stone properties, Sinawin - Sha'wa, Libya

1. Introduction

In the Sinawin-Sha'wa area, in northwestern Libya (**Figure 1**), geological investigations were carried out. The intention was to determine potentially suitable lithofacies for crushed aggregate and asphalt mixtures production, in order to reconstruct regional Nalut - Ghadamis Road (**Figure 2**). Upper Cretaceous limestones and dolomites from Mizdah and Zimam formations (**Figure 3**) were investigated (**IRCT, 1979; Salem et al., 1991; Troger and Rohlich, 1991**). Northwestern Libya is the rocky-desert, mostly flat area, occasionally cut by stream-flows (so-called *wadi's*) and these carbonate rocks are the only available rock material in this region. Specific lithofacies and diagenetic processes in these rocks were assumed to be the major factor influencing their physical and mechanical properties. The relationships between these factors were investigated in this case study.

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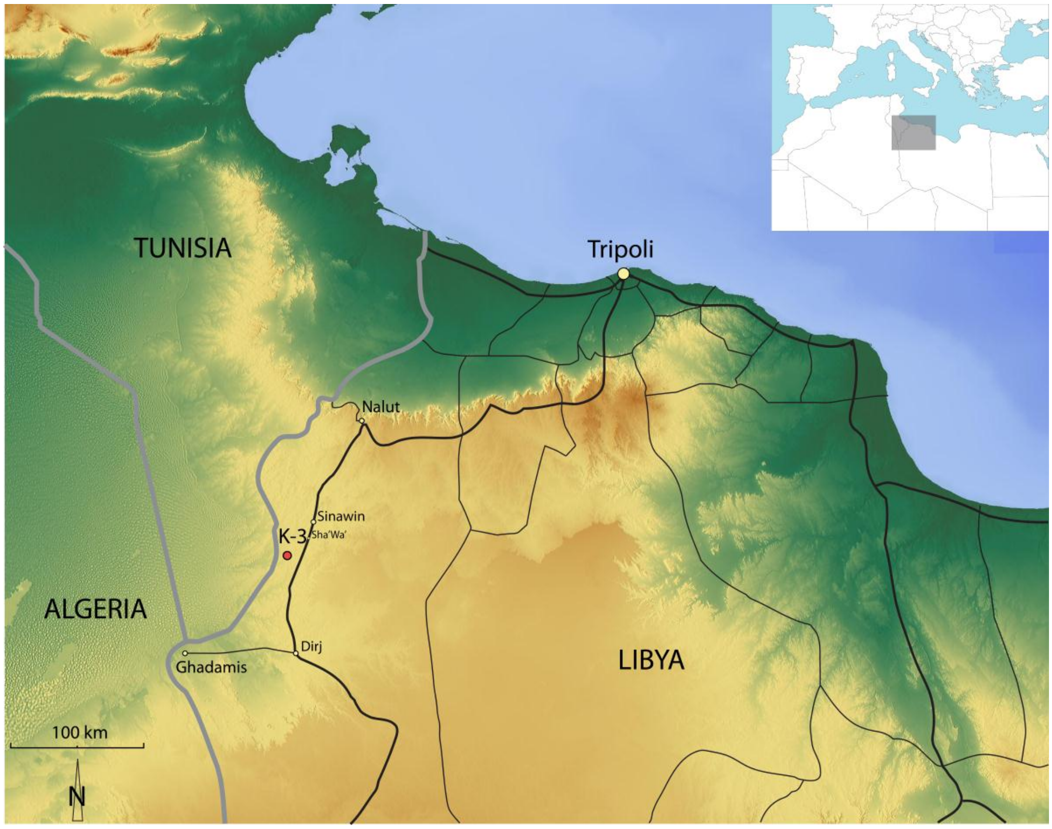

Fig 1. Geographical map of northwestern Libya, showing the position of K-3 Quarry site

Fig 2. The Nalut – Ghadamis Road (cca 300 km long), in the rocky-desert area of northwestern Libya

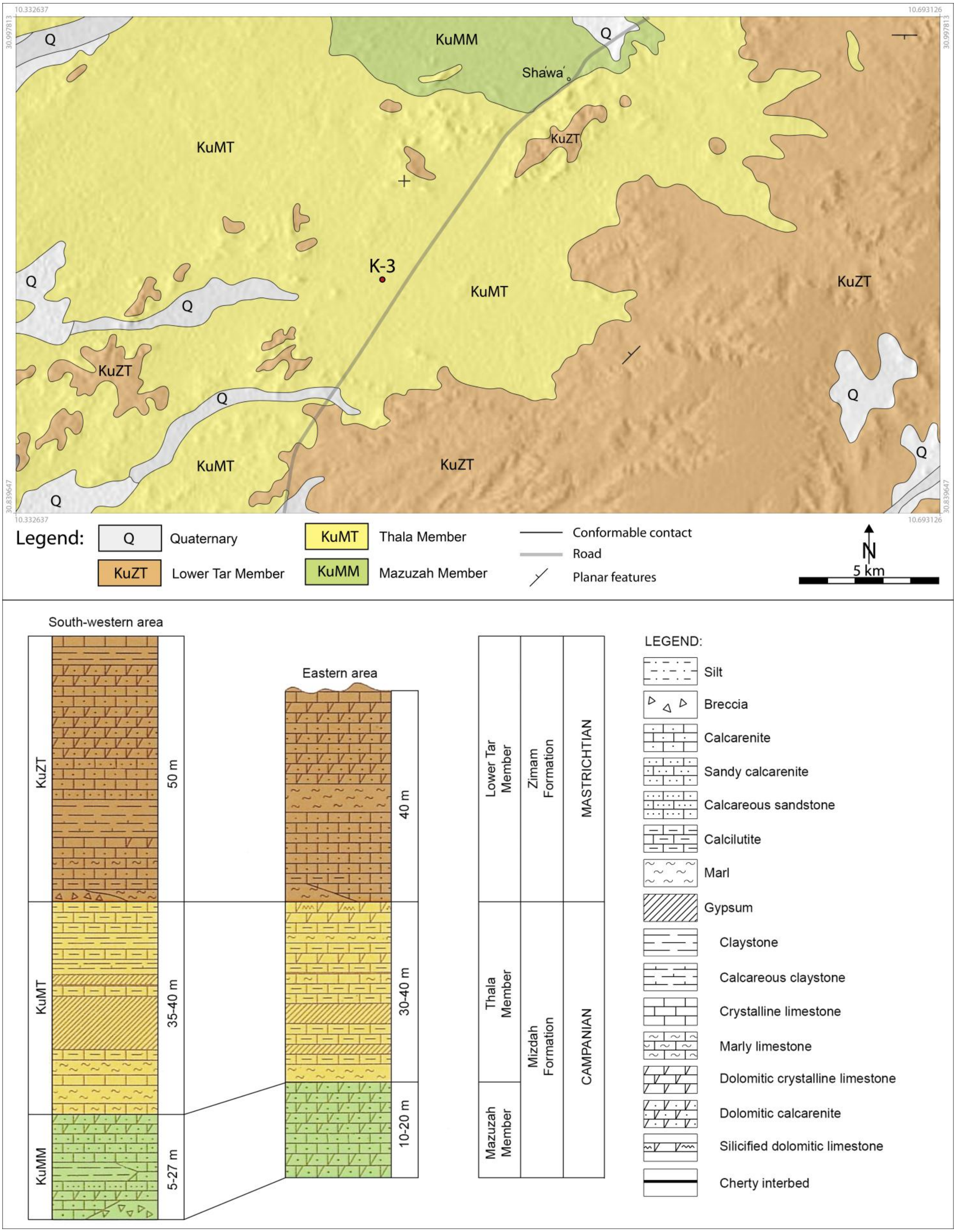

Fig 3. Geological map and the geological column of Sinawin- Sha'wa area (redrawn and adapted from Geological Map of Libya 1:250.000, Sheet Sha'wa – IRCT, 1979). Position of the K-3 Quarry site is marked on the map.

2. Methods

2.1. Methods for lithofacies and diagenetic analysis

At the location of K-3 Quarry (**Figure 4**), sedimentary rock sequence is recorded, and the specimens for micropetrographical analysis and testing of physical and mechanical properties, were collected as well. Geological field methods for the description of the sedimentary sequence (**Stow, 2005**), lithology, sedimentary structures and textures (**Collinson and Thompson, 1989**) and diagenetic features as well (**Demicco and Hardie, 1994**), were applied. Rock specimens for micropetrographical analysis were taken at every significant change in lithology, within the observed sedimentary rock sequence.

Fig 4. Panoramic view of the K-3 Quarry, in which carbonate rocks for the analysis were sampled

In order to distinguish and describe various carbonate rocks in the field, classifications after **Dunham (1962)** with the modifications after **Embry and Klovan (1972)** and **Flügel (1982)**, were applied in the field work. Classifications after **Folk (1959, 1962)** were applied in micropetrographical analysis of thin sections. In order to distinguish and to describe different carbonate particles and cements, all thin-sections were treated with the chemicals named Alizarin Red S and K-Ferricyanide, according to the procedures described in **Müller (1967)**. Field work description, combined with micropetrographical analysis, were used to determine lithofacies (after **Flügel**, **2004** and **Tišljar, 2001**). Primary parameter considered was the lithotype, but the other important parameters were also taken into account (i.e. sedimentary structures, diagenetic features and depositional environments). Determined lithofacies were named as A, B, C and D lithofacies. Semiquantitative mineralogical analysis (X-ray powder analysis, *abbr.* XRD) is applied only for the semi-lithified rock material, sampled compositely in some particular parts of the observed sedimentary rock sequence (lithofacies B). Determined mineralogy helped to define the sedimentary environments and diagenetic processes as well. These samples were not further tested for the physical and mechanical properties of the same lithofacies.

2.2. Test methods for determining of physical and mechanical stone properties

The stone samples, taken from different lithofacies (lithofacies A, C, and D) were further tested in order to determine physical and mechanical properties, according to the ASTM standards that have been approved by the technical documentation for the construction of Nalut - Ghadamis Road. The following physical and mechanical properties of stone and aggregate samples have been analyzed: *apparent density* (ρ_b), *open porosity* (p_o), *water absorption* (A_b), *uniaxial compressive strength* (σ) and *resistance to crushing and abrasion by Los Angeles test (LA test)*. All the tests for physical and mechanical properties were carried out in the Industrial Research Center Tripoli (*abbr.* IRCT). During the determination of apparent density (ρ_b) and open porosity (p_o) samples were subjected to water absorption (A_b), according to the **ASTM C 97-06** standard. The samples were first weighted in a dry state (m_d). Afterwards, samples were gradually saturated with water, where ρ_{rh} is density of water. Weight of saturated samples (m_s) and the weight of the samples soaked with water (m_h) were measured.

Apparent density (g/cm^3) is the ratio of the dry sample weight and the sample volume, together with the pores. It is expressed by the equation:

$$\rho_b = \frac{m_d}{m_s - m_h} \cdot \rho_{rh} \qquad (1)$$

Water absorption (mass. %) at atmospheric pressure is expressed by the equation:

$$A_b = \frac{m_s - m_d}{m_d} \cdot 100 \quad (2)$$

Open porosity (vol. %) are interconnected pores that can be filled with water at the atmospheric pressure. It represents the ratio between the volume of the pores that are filled with water and the total volume of the pores, and it is calculated by the equation:

$$p_o = A_b \cdot \rho_b \cdot 100 \quad (3)$$

Determination of uniaxial compressive strength, according to the **ASTM C 170-06** standard**,** is carried out using hydraulic presses. Load was uniformly applied over the entire surface of the samples until the break of material. Uniaxial compressive strength of the sample (Ϭ) is the ratio between the breaking load (F) and surface (A) of the sample, and it is expressed by the equation:

$$\sigma = \frac{F}{A} \quad (4)$$

Where are:
F – breaking load (N),
A – surface of the samples (mm^2),
σ - uniaxial compressive strength (MPa)
The samples from lithofacies D were further subjected to the determination of resistance to crushing and abrasion in the Los Angeles machine, according to the **ASTM C 131-81** standard. The degree of resistance to crushing and abrasion is expressed by the coefficient of "Los Angeles" (*KLA*). The coefficient is the ratio between the weights of the sample which is less than 2 mm and the weight of the sample before the test, according to the formula:

$$KLA = \frac{m_o - m_1}{m_o} \cdot 100 \quad (5)$$

Where are:
KLA - the coefficient of Los Angeles (%),
m_o – weight of samples before testing (g),
m_1 - weight of samples which remained on a 2 mm sieve after the testing and sieving (g).

3. Results

3.1. Results of the lithofacies and diagenetic analysis

The following lithofacies were determined by combined field work and micropetrographical analysis: lithofacies A - micritic limestones (lagoonal micrites and biomicrites); lithofacies B - dolomitic marls; lithofacies C – dolobiomicrites; lithofacies D - biosparites and biosparudites. Diagenetic processes of cementation, recrystallization, dolomitization and silicification were identified within these lithofacies.

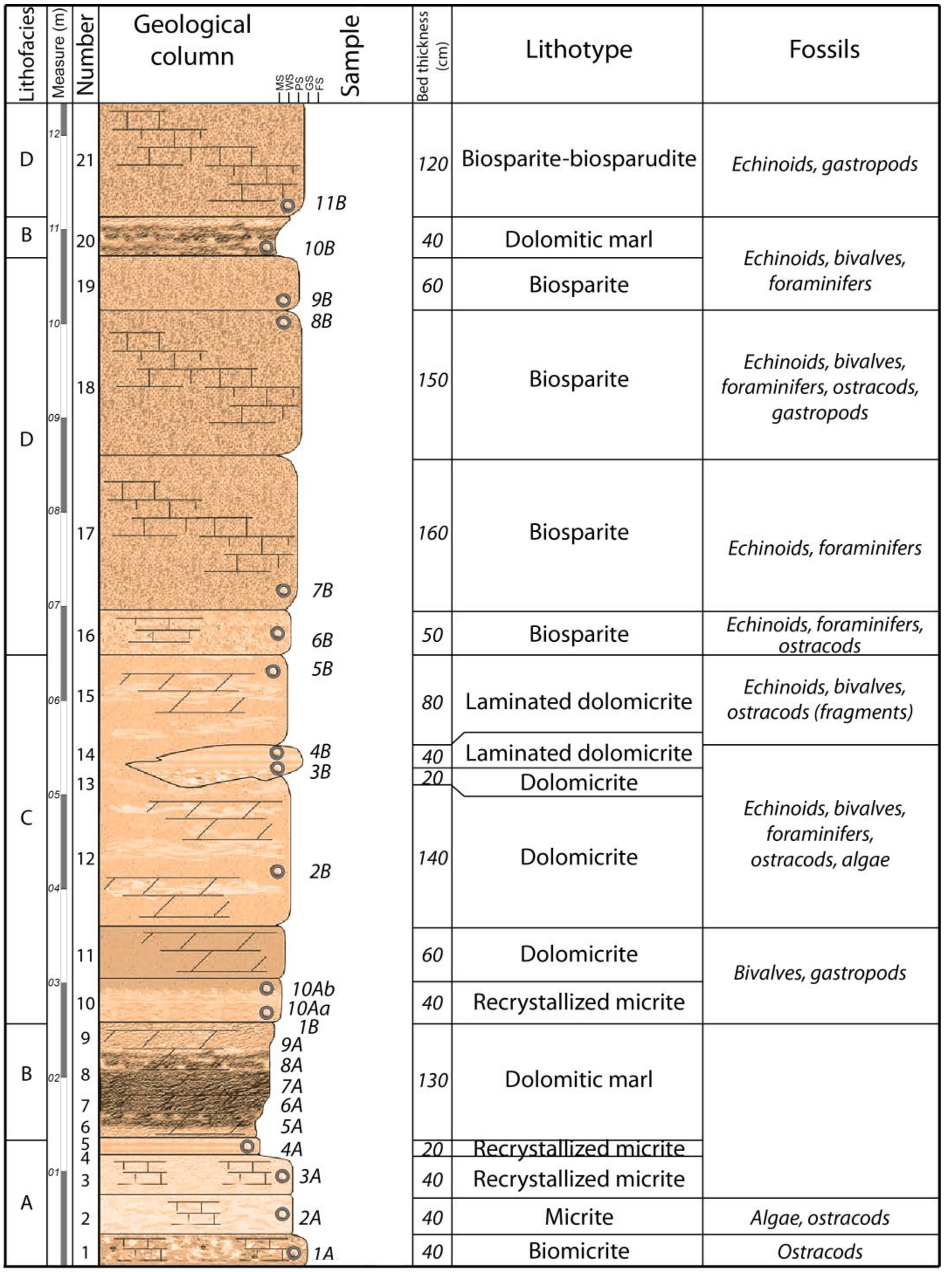

Fig 5. Geological column representing recorded Upper Cretaceous sedimentary sequence at K-3 Quarry site. Horizontal scale-limestone types after Dunham (1962): ms-mudstone, ws-wackestone, ps-packstone, gs-grainstone, fs-floatstone. Numbers on the left side represent successive numbers of the beds present in the quarry.

3.1.1. Lithofacies A: micritic limestones (lagoonal micrites and biomicrites)

This lithofacies is represented by poorly-lithified, porous (pore sizes between 0.04 and 0.2 mm) micritic limestones (see specimens 1A, 2A, 3A and 4A in the geological column – **Figure 5;** and beds marked as 1, 2, 3 and 4 in **Figure 6**). It contains a significant amount of organic matter. Diagenetic process of recrystallization is partly developed within this lithofacies. Micritic component is recrystallized to microsparite. Although this process affected lithofacies A only in a minor way (towards the transition to lithofacies B), the open porosity significantly increased. Due to recrystallization, organic matter is accumulated in discrete clumps, contributing to the anisotropy that resulted in different physical and mechanical properties (**Figure 7)**. Dolomitization also took place in this lithofacies and additionally increased open porosity.

Fig 6. An outcrop in the K-3 Quarry showing rock sequence with lithofacies A (beds marked as 1, 2, 3 and 4), lithofacies B (unmarked beds between 4 and 10) and lithofacies C (beds above mark 10, see Figure 5)

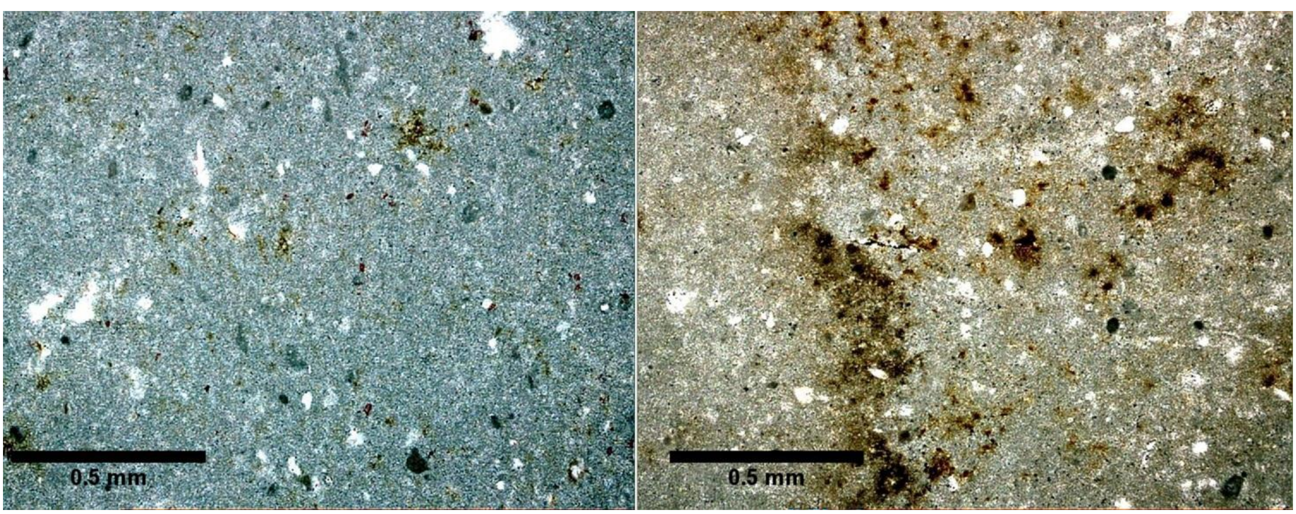

Fig 7. Microphotographs of lithofacies A - recrystallized micritic limestones, containing organic matter (accumulated in discrete clumps)

3.1.2. Lithofacies B: dolomitic marls

This lithofacies is represented by semi-lithified dolomitic marls (see specimens 5A, 6A, 7A, 8A and 9A in the geological column – **Figure 5**; and loosely-lithified sedimentary sequence between beds marked as 4 and 10 in **Figure 6**). According to the mineralogical semi-quantitative analysis, this lithofacies predominantly contains dolomite and clay. Calcite and gypsum are subordinately present (**Figure 8)**. Since this is a potentially not suitable material for the intended use as crushed aggregate in asphalt mixtures, samples from this lithofacies were not taken for further testing of their physical and mechanical properties.

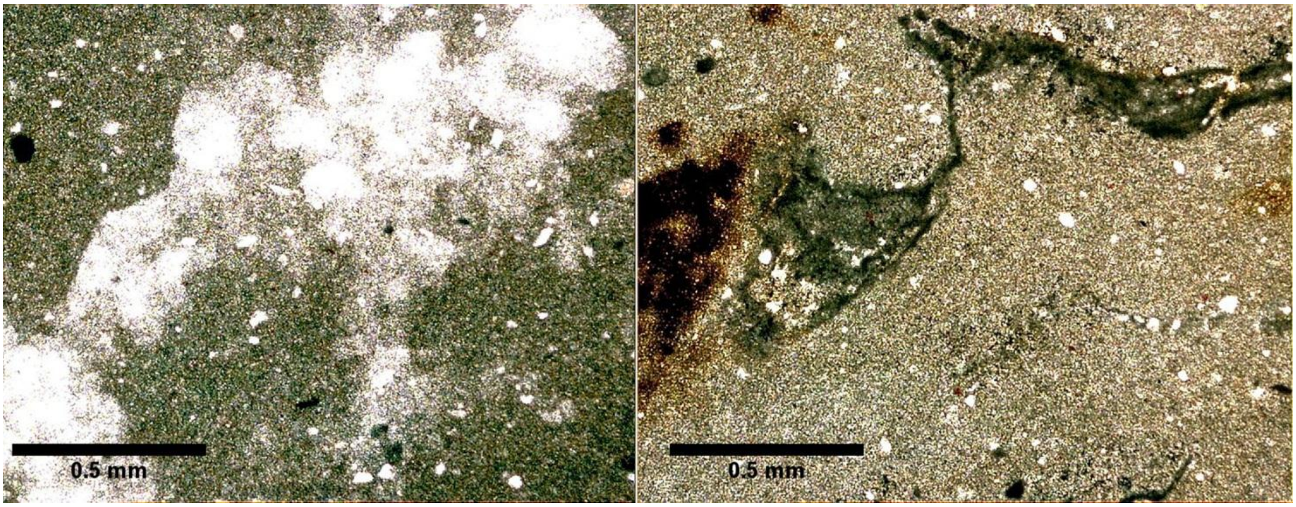

Fig 8. Microphotographs of lithofacies B – dolomitic marls, containing clumps of gypsum and clays

3.1.3. Lithofacies C: dolobiomicrites

This lithofacies is represented by recrystallized and/or dolomitized biomicritic limestones, namely dolobiomicrites (see specimens between marks 9A and 5B in the geological column – **Figure 5**; and the beds above mark 10 in **Figure 6**). In the micrite, different fossils of benthic foraminifera, algae, ostracods, bivalves, echinoids and gastropods can be found (**Figure 9**). Small amount of siliciclastic grains is also incorporated in these rocks. Thin lamination, as alteration of primary micritic/biomicritic laminas and recrystallized/dolomitized laminas, is observed within this lithofacies. Laminas occasionally contain dissolution cavities, partly cemented with calcite or dolomite cements. Diagenetic process of dolomitization took place in this lithofacies and significantly transformed primary biomicritic limestones into dolobiomicrites. Dolomitization slightly increased open porosity of these rocks, due to reduction of dolomitic crystals.

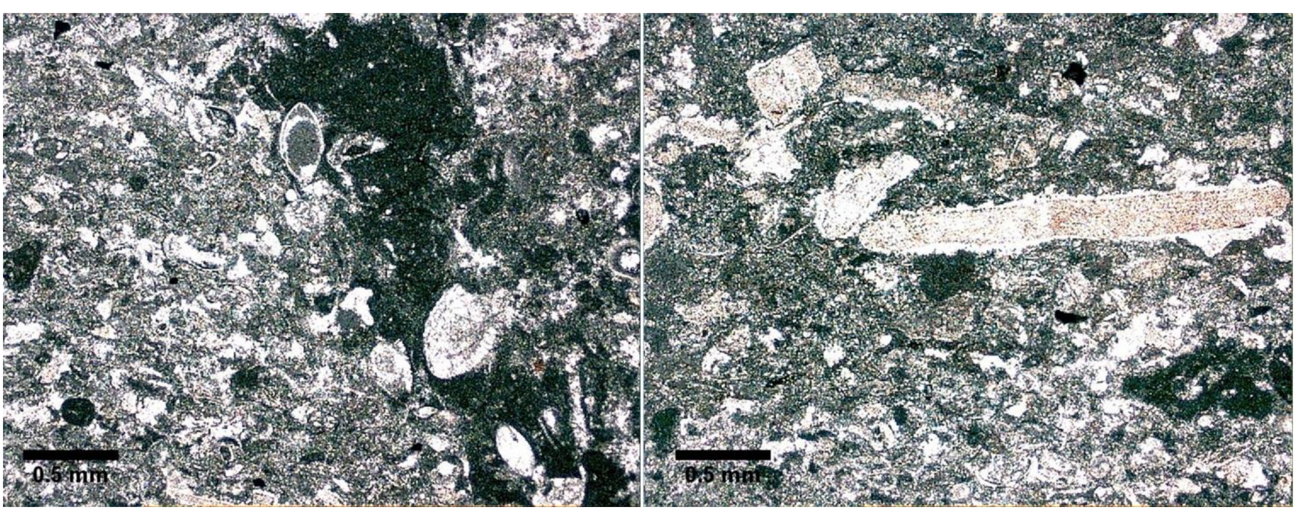

Fig. 9. Microphotographs of lithofacies C – dolobiomicrites showing abundant fossil assemblage of dolomitized bioclasts

3.1.4. Lithofacies D: biosparites and biosparudites

This lithofacies is represented by bioclastic limestones of grainstone and rudstone types and subordinately of packstone type (see specimens marked as 6B, 7B, 8B, 9B and 11B in the geological column – **Figure 5**; and the beds marked as 9B and 11B in **Figure 10**). They are composed of fossils and fragments of benthic foraminifera, bivalves, echinoids, gastropods and ostracods, which are cemented with the mosaic calcite cement (**Tucker and Bathurst, 1990**). Whole fossils and their fragments appear occasionally as bioclasts larger than 2 mm (**Figure 11**), contributing to their classification as biosparudites. Marine cementation with mosaic sparite and selective silicification (**Figure 12**), are the main diagenetic processes observed in lithofacies D.

Fig 10. An outcrop in K-3 Quarry showing rock sequence with lithofacies D (beds marked as 9B and 11B), and lithofacies B (unmarked beds between marks 9B and 11B, see also Figure 5)

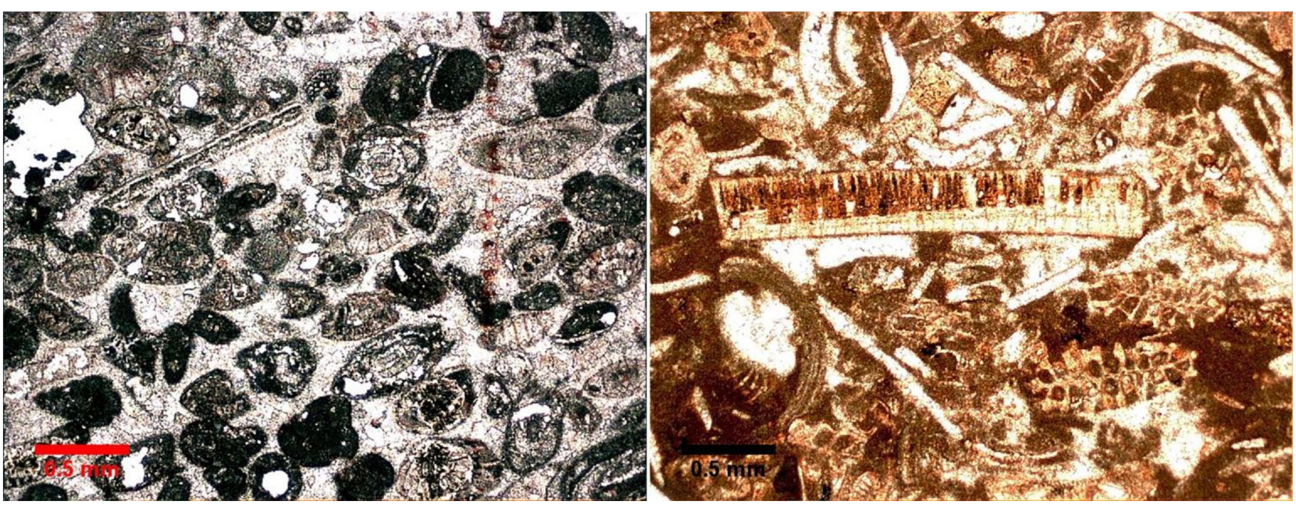

Fig 11. Microphotographs of lithofacies D – biosparites and biosparudites, containing fossils cemented with sparitic calcite

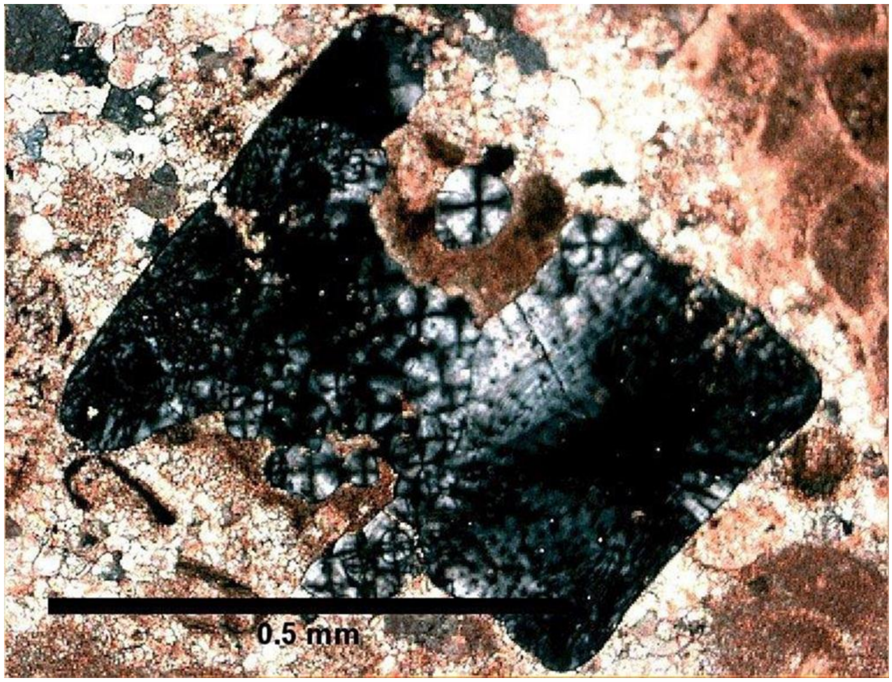

Fig 12. Microphotograph (crossed-polarized light) of lithofacies D, showing silicified echinoid fossil, with the needles visible as circles with dark crosses

3.2. Results of the testing of physical and mechanical properties

The stone samples from the lithofacies A, C and D were tested on the following physical and mechanical properties: apparent density, open porosity, water absorption at atmospheric pressure and uniaxial compressive strength (**Table 1**). Samples from lithofacies B, semi-lithified dolomitic marls that contain significant amount of clay, were not tested for physical and mechanical properties. This lithofacies is evaluated as potentially not suitable for the aggregate in asphalt mixtures.

Correlation between water absorption property for samples from the lithofacies A, C and D with the other three observed properties, can be clearly seen on the diagrams for: the apparent density (**Figure 13a**), the open porosity (**Figure 13b**), and the uniaxial compressive strength (**Figure 13c**). The results reveal important differences in tested properties among the differentiated lithofacies. Samples of lithofacies A show the smallest values of apparent density (2.029 g/cm^3), while the samples from lithofacies D have the highest value of apparent density (2.534 g/cm^3), which suggests their high density and compactness. Significant differences were also determined for open porosity values. Samples of the lithofacies D have values of the open porosity about 3.05%, which is seven times lower than the values of lithofacies A and five times lower than the values of lithofacies C (**Table 1**).

Therefore, as expected, samples of lithofacies D, absorb water twelve times less than the samples from lithofacies A and five times less than the samples from lithofacies C. The increased water absorption is particularly affected by increased open porosity, while the samples with increased apparent density have lower values of water absorption (**Figures 13a** and **13b**). Correlation between the open porosity values and water absorption values, for all tested samples, is linear (**Figure 13b**). Compressive strength values, for all tested samples, ranging from 21 to 89 MPa. Along with the increased water absorption values, all samples showed decreasing trend of the uniaxial compressive strength (**Figure 13c**). These lower values of the compressive strength for the samples from all lithofacies were somewhat expected, because of their great values for open porosity and water absorption (**Figure 13c** and **Table 1**).

Table 1. The values for apparent density, open porosity, water absorption and uniaxial compressive strength of the samples from the lithofacies A, C and D

Sample label	Apparent density (g/cm^3)	Open porosity (vol.%)	Water absorption (mass.%)	Uniaxial compressive strength (MPa)
3A (lithofacies A)	1.994	25.22	12.65	33
2A (lithofacies A)	2.065	19.45	9.42	21
1B (lithofacies C)	2.156	17.31	8.03	32
2B (lithofacies C)	2.194	14.48	6.6	49
5B (lithofacies C)	2.221	14.77	6.65	54
11B (lithofacies D)	2.482	4.62	1.86	48
6B (lithofacies D)	2.558	2.07	0.81	89
9B (lithofacies D)	2.562	2.46	0.96	54

Based on the testing results, the stone from lithofacies D was determined as relatively suitable for using as an aggregate. Therefore, the crushed aggregate for further testing was produced from this lithofacies. Resistance to impact and abrasion by Los Angeles test were tested on these aggregate samples. The Los Angeles coefficient (*KLA*) or resistance to abrasion and impact is 31.34%.

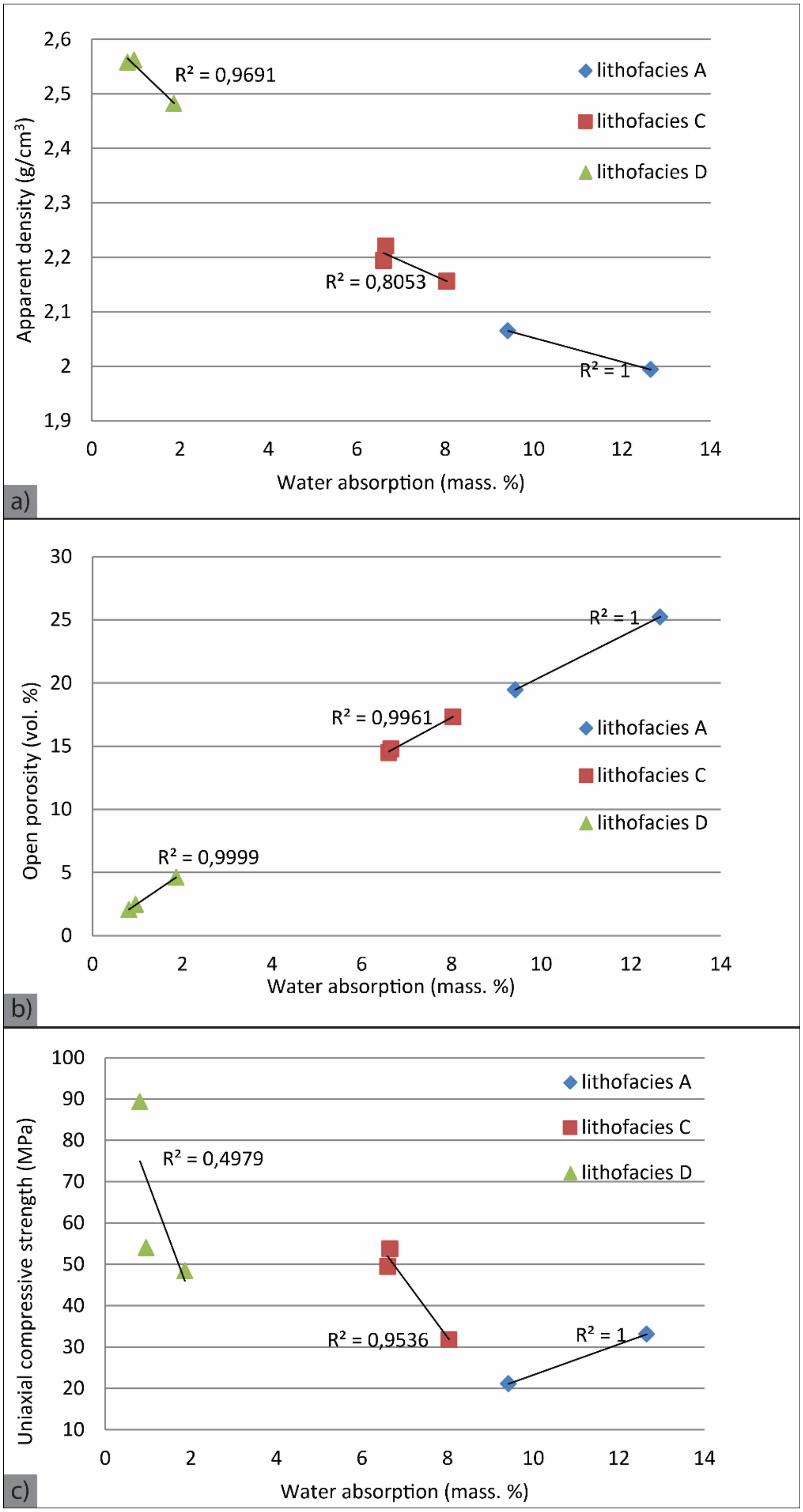

Fig 13. Diagrams for the correlation between: a) apparent density and water absorption b) open porosity and water absorption c) uniaxial compressive strength and water absorption, for samples from lithofacies A, C and D

4. Discussion of the results

Combined results of field work and micropetrographical analysis showed that observed rock sequence in K-3 Quarry contains shallow-marine limestones and dolomites. These rocks were interpreted as originated in the following environments: (1) lithofacies A, B and C – in shallow lagoons (subtidal), with occasional shallowing up to the supratidal environments and dolomitization in evaporitic conditions; (2) lithofacies D – in shoals with agitated water and early marine cementation. The following diagenetic processes were observed within determined lithofacies:

- recrystallization of micritic limestones is observed in lithofacies A and C;
- dolomitization partly affected lithofacies A and significantly changed lithofacies B and C;
- selective silicification is observed in lithofacies C and D;
- early marine calcite cementation is observed in lithofacies D.

4.1. Lithofacies A

The specimens of lithofacies A were micropetrographically determined as micritic limestones (lagoonal micrites and biomicrites), with the significant amount of organic matter. Depositional environment was calm and shallow lagoon with poor water circulation. In these poorly lithified micrites with mesospores between 0.04 and 0.2 mm, the water moves by the action of capillary forces (**Benavente et al., 2001**). The pores are partially filled with organic matter, but they are well connected, and thus open porosity of samples is 22 vol.%, and the absorption of water is about 10 mass.% (**Table 1**). Recrystallization of carbonate mud into microsparite, particularly towards the transition to lithofacies B, increased the open porosity values. The upper parts of lithofacies A (**Figure 5**) were additionally modified by dolomitization in the evaporitic conditions. Dolomitization increase the secondary intergranular porosity in carbonate rocks, theoretically up to 13% during the total dolomitization of limestone (**Chilingar et al., 1979**). Samples of lithofacies A showed the smallest values of apparent density and the highest values of water absorption (**Table 1**), because they are porous and poorly lithified. They were classified in the category of stone with large water absorption and the category of stone with low uniaxial compressive strength (the categories cited by **Crnković and Šarić, 2003**). In general, stone with increased values of open porosity and high water absorption values also shows not suitable values of physical and mechanical properties (**Fort et al., 2002**). According to this, stone of lithofacies A does not meet the quality criteria for the production of aggregate in asphalt mixtures.

4.2. Lithofacies B

The specimens of lithofacies B were micropetrographically determined as dolomitic marls. They are slightly lithified and contain also significant amount of clay. Lithofacies B was formed by the dolomitization of micritic limestones from lithofacies A, under intensive evaporation and dehydration in coastal lagoons and shallows. Traces of gypsum, as indicators of intensive evaporation process, were also observed. Low lithification and sedimentary textures indicate possible emergence of sediments. In the upper part of the geological column (**Figure 5**) lithofacies B also appears, with less prominent dolomitization and containing some siliciclastic grains. Samples from lithofacies B were not included in the testing of physical and mechanical properties, since it is potentially not suitable material for crushed aggregate.

4.3. Lithofacies C

The specimens of lithofacies C were micropetrographically determined as dolobiomicrites, characterized by recrystallization and/or dolomitization of primary micritic and biomicritic limestones. These rocks were deposited in the shallow lagoon environment, with variable water energy. Numerous, poorly sorted bioclasts possibly contributed to the open porosity, which is 15%, and also to the lower compressive strength values, which are around 45 MPa (**Table 1**). Diagenetic processes with the significant influence on the properties of lithofacies C were recrystallization of the primary micrites and biomicrites, dolomitization and selective silicification as well. Recrystallization and dolomitization increased open porosity, and selective silicification possibly reduced open porosity in this lithofacies. Silicification processes possibly increased compressive strength. The samples of lithofacies C therefore have values for apparent density, open porosity, water absorption and the uniaxial compressive strength between values of lithofacies A and D (**Table 1**). Nevertheless, the samples of lithofacies C were classified in the category of stone with a large water absorption (7 mass.%) and in the category of stone with low compressive strength (the categories cited by **Crnković**

and Šarić, 2003). Therefore, they were also determined as not suitable for the production of aggregate in asphalt mixtures.

4.4. Lithofacies D

The specimens of lithofacies D were micropetrographically determined as biosparites and biosparudites. These limestones contain sparitic calcite cement, indicating high energy of water in the environment and possibly early cementation of allochems. Limestones contain fossils and their fragments (benthic foraminifers, bivalves, echinoids, gastropods and ostracods), which are cemented with marine mosaic calcite cement. In lithofacies D, also as in lithofacies C, selective silicification within the individual parts of the echinoid fossils is observed. The source materials for silicification were possibly siliciclastic grains, incorporated in this lithofacies. The silicification partially reduced open porosity and possibly increased the compressive strength of stone. Marine cementation with mosaic calcite cement was observed in the specimens of lithofacies D. The cementation process has an influence in a reduction of porosity, which is essential for the consolidation and has a positive effect on the compressive strength of stone (**Garcia Del Cura et al., 2005**). Diagenetic processes developed in lithofacies D generally reduced pore spaces, comparing with lithofacies A and C. Although cementation process has a positive effect on physical and mechanical properties of lithofacies D, it is also possible that a significant amount of fossils and their fragments partly reduced the compressive strength values and resistance to abrasion and impact as well. The samples of lithofacies D have the largest uniaxial compressive strength (about 63 MPa) and a minimum value of water absorption (about 1.21 mass.%) among the all tested lithofacies (**Table 1**). They were classified in the category of stone with medium water absorption and low compressive strength (the categories cited by **Crnković and Šarić, 2003**). Additionally, the lithofacies D showed the highest apparent density values (2.534 g/cm^3), implying their high density and compactness. According to the results of the resistance to abrasion and impact, samples from lithofacies D have weight loss up to 31.34 %. Therefore, stone of lithofacies D showed, to some extent, satisfactory properties for the intended use.

4.5. Comparison of lithofacies characteristics

Samples from the lithofacies A, C and D showed significant differences in the physical and mechanical properties (apparent density, open porosity, water absorption, uniaxial compressive strength and resistance to abrasion and impact by the Los Angeles method). These differences resulted from different petrographical and mineralogical characteristics of these lithofacies and from diagenetic processes developed in lithofacies as well. According to the above-mentioned parameters, stone of lithofacies A and C were not qualified as suitable for aggregate in asphalt mixtures. Increased water absorption values in lithofacies A and C were the main criteria for such estimation. According to the technical documentation for the construction of Nalut - Ghadamis Road, one of the essential parameters for the use of stone as an aggregate for asphalt mixture production is the water absorption, which shall not exceed 2.00 mass.%. According to the water absorption parameter, as the one of the main criteria of the quality fractionated aggregate, stone of lithofacies D (biosparites and biosparudites) were estimated as the most appropriate rocks available in the area, for the production of aggregate in asphalt mixtures. For usability assessment as stone aggregate, and especially for the development of pavement and road constructions, it was necessary to determine mineral composition, structural and textural features and diagenetic processes as well, that may affect its physical and mechanical properties (**Tomašić et al., 1997**). During the exploitation, the selectivity of the stone in relation to the petrological characteristics that may affect the physical and mechanical properties should be taken into account (**Tišljar et al., 1997**). Observed parameters are considered as the essential characteristics for the evaluation of rocks in the production of aggregates for asphalt mixtures (according to **Smith and Collis, 2001**).

Observed lithofacies originated in various sedimentary environments: micritic lithofacies A, B and C in calm and shallow lagoons, and grainy lithofacies D in shoals with agitated water. Lateral changes in environments and environmental conditions resulted in different diagenetic processes developed within lithofacies. Diagenetic processes, together with the primary lithofacies characteristics, influenced physical and mechanical characteristics of carbonate rocks. Partial recrystallization of lagoonal micritic limestones, observed in lithofacies A, changed their physical and mechanical properties in the undesirable fashion for crushed aggregate in asphalt mixtures. Occasional shallowing of the lagoons, up to the supratidal, triggered dolomitization in evaporitic conditions, which affected lithofacies A, B and C. Lithofacies B therefore showed extremely bad physical and mechanical stone properties. Dolomitization also significantly changed lithofacies C, continuing to weaken their physical and mechanical stone properties by increased open porosity. Early marine cementation in shoals with agitated water developed within grainy lithofacies D, contributing to their relatively favorable physical and mechanical stone properties. Selective silicification partly developed in lithofacies C and D, due to the presence of sliciclastic grains as a source for, and echinoid fossils as a preferred place for selective silicification. Silicification additionally strengthened physical and mechanical stone properties of this lithofacies, but only in a minor way.

5. CONCLUSIONS

According to the discussion above, it can be concluded that the great diversity of physical and mechanical properties and the quality of the stone in K-3 Quarry is influenced by lithofacies characteristics and diagenetic processes. According to the petrographic characteristics and diagenetic processes and their physical-mechanical properties as well, micritic lithofacies A and C significantly differs from grainy lithofacies D. Physical and mechanical properties of lithofacies A and C showed that these lithofacies are not suitable for the production of aggregate. On the contrary, physical and mechanical properties of grainy lithofacies D (high values for apparent density and uniaxial compressive strength and low values for water absorption) qualify this lithofacies as relatively potential for crushed aggregate production. Considering the climate factor (Libyan Desert is one of the most arid places on Earth), technical documentation for Nalut - Ghadamis Road construction allowed higher values for water absorption (2 mass.%, instead of usual 0.5 mass.%). Only lithofacies D can be used in the desert conditions for crushed aggregate production and their usage in road reconstruction (**Figure 14**). Diagenetic processes of recrystallization and dolomitization in evaporitic conditions of micritic lithofacies influenced physical and mechanical stone properties in a negative way (increased open porosity) for crushed aggregate in asphalt mixtures production. On the contrary, cementation and silicification processes improved these properties within grainy carbonate lithofacies.

It is therefore usually recommended to analyse and differentiate lithofacies and diagenetic processes, in order to get better results and conclusions about the usability of carbonate rocks for crushed aggregate and their further usage for different purposes. The results and the conclusions of this case study are somewhat limited to the specific field conditions, available rocks and intended use of stone, described in the study.

Fig 14. Crushed aggregate of carbonate rocks in the asphalt mixtures of Nalut-Ghadamis Road

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Utjecaj litofacijesa i dijagenetskih procesa na fizičko-mehanička svojstva karbonatnih stijena – primjer iz Sinawin-Sha'wa područja u Libiji

Sažetak: U sjeverozapadnoj Libiji, na području u Sinawin-Sha'wa, provedena su geološka istraživanja kako bi se pronašle odgovarajuće stijene za proizvodnju agregata za rekonstrukciju regionalne ceste Nalut - Ghadamis. Terenskim radom i mikropetrografskim analizama utvrđena su četiri različita litofacijesa u gornjokrednim karbonatnim naslagama: litofacijes A - mikritni vapnenci; litofacijes B - dolomitični lapori; litofacijes C - dolobiomikriti; litofacijes D - biospariti i biosparuditi. U tim litofacijesima uočeni su dijagenetski procesi cementacije, rekristalizacije, dolomitizacije i silicifikacije. Na uzorcima litofacijesa A, C i D ispitana su sljedeća fizičko-mehanička svojstva: prostorna masa, otvorena poroznost, upijanje vode i jednoosna tlačna čvrstoća. Od uzoraka litofacijesa D proizveden je drobljeni agregat na kojem je ispitana otpornost na udar i habanje metodom Los Angeles (LA test). Uzorci iz litofacijesa B nisu uvršteni u ispitivanja fizičko-mehaničkih svojstava, budući da se radi o potencijalno nepovoljnom materijalu za agregate. Prema dobivenim rezultatima, uzorci litofacijesa A, C i D su pokazali značajne razlike fizičko-mehaničkih svojstava. Navedene razlike su posljedica različitih mineraloško-petrografskih obilježja litofacijesa i dijagenetskih procesa kojima su izmijenjeni. Uzorci litofacijesa D jedini pokazuju zadovoljavajuća svojstva za proizvodnju agregata za asfaltne mješavine.