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PETROPHYSICAL AND SEDIMENTOLOGICAL ANALYSES OF SIKLÓS ORNAMENTAL LIMESTONES, S-HUNGARY

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Abstract

The two studied ornamental stones, 'Siklós–green' and 'Siklós-rose' are quarried in the Villány Mountains in South Hungary. The former one belongs to the Middle Triassic Zuhánya Limestone Formation while the latter one is a part of the Upper Jurassic Szársomlyó Limestone Formation. Besides pinkish, yellow and white varieties of 'Siklós-rose' also exist.

Zuhánya Limestone was formed in an outer ramp setting representing the deepest facies.

Szársomlyó Limestone contains pelagic fauna, microoncoids and peloids. The microoncoids were accumulated in a relatively shallow part of a drowned platform and were redeposited.

The petrophysical tests showed that uniaxial compressive strength of both limestones was in the order of 80 MPa. It is easy to polish them and their polished surfaces are decorative. Both stones are used as inner wall or floor cover but due to its frost resistance 'Siklós-rose' is also applicable for outer surfaces. The byproduct of ornamental stone quarries are appropriate for aggregates.

Better petrophysical properties of 'Siklós-rose' are attributed to the more homogeneous texture of the Jurassic limestone.

Keywords: petrophysics, limestones, sedimentology.

1. Introduction

Two famous and widely used ornamental stones of Hungary are quarried in Villány Mountains in Southern Hungary: Siklós–green and Siklós-rose (red) and its varieties. These stones belong to Middle Triassic Zuhánya Limestone Formation (green) and the Late Jurassic Szársomlyó Limestone Formation (rose) and cover large areas. The latter type can be subdivided into 'yellow' and 'white' types besides the 'rose' one.

By using new sedimentological interpretations and new petrophysical standards these ornamental stones are re-evaluated in this paper.

2. Former Studies

The quarrying activity had already begun in the last century in the Villány Mountains. SCHAFARZIK (1904) gave a detailed description of the quarries and the quantity of production. At that time the Triassic 'coffee-coloured compact limestones with white and red fissures' were quarried in Zuhánya quarry and were transported to Budapest for the construction of the Houses of Parliament and the Hungarian Geological Institute. The Jurassic limestone was used for walls, pavements, carvings as well as road aggregates. The quarried stones were also appreciated as hydraulic engineering materials (PÁLFY, 1901).

The Hungarian Geological Institute carried out a detailed study of ornamental stones in the late '60s and early of the '70s (HETÉNYI, R. – NAGY, E. – NAGY, I.). Parallel to the exploitation of ornamental limestones daily exploration works are also carried out in these days.

The first written document on the limestones of Siklós region is the one of BEUDANT, F. S. (1822). PETERS (1862), LENZ (1872) and BÖCKH (1876) also mentioned the limestones of Villány Mountains. The first detailed stratigraphic description of HOFMANN (1876) was revised by LÓCZY, jr. (1912, 1913, 1915) and he already mentioned the thrust structures of Villány Mountains. By recognition of Early Cretaceous bauxite (TELEGDI ROTH, 1937; RAKUSZ, 1937) new geological surveys began. The results of the detailed geological mapping (STRAUSZ, 1941, 1942) were published in a monograph with a geological map (RAKUSZ and STRAUSZ, 1953). Sedimentological and palaeontological studies were followed by KASZAP (1958, 1959, 1961), RADWANSKI and SZULCZEWSKI (1966), VÖRÖS (1972) and FÜLÖP (1966). Structural geological analyses were done by WEIN (1967a, 1967b, 1969) and more recently by CSONTOS and BERGERAT (1992) and BENKOVICS (1997).

In the past years the Triassic lithostratigraphic framework (BALOGH, 1981) was established and several fieldtrip guidebooks (CSÁSZÁR and HAAS, 1984) and summaries (KÁZMÉR, 1986) were prepared. The Cretaceous bauxite was also studied in detail (CSÁSZÁR and FARKAS, 1984; DUDICH and MINDSZENTY, 1984).

The preliminary results of petrophysical tests and some sedimentary features of ornamental stones were also discussed (TÖRÖK, 1989).

3. Geology of Villány Mountains

Villány Mountains is located in South Hungary and forms a part of Tisia megatectonic unit. It is bordered by structural lines both to the *N* (Mecsek zone) and to the *S* (Békés zone). Its eastward continuation is covered in the Great Hungarian Plain (BÉRCZI-MAKK, 1985) while it is in outcrops in the Bihor Mountains, Transylvania (BLEAHU et al., 1994).

The crystalline basement of the Villány Mountains is only known from drillings that are located to the North. The crystalline rocks are overlain by Upper Carboniferous clastic and Permian clastic sediments and volcanites.

The lower part of the Triassic (clastic sediments of Jakabhegy Sandstone Formation and Patacs Siltstone Fm.) is only known from wells while the oldest surface rocks belong to the Anisian Rókahegy Dolomite (*Fig. 1*). The dolomite is overlain by Anisian well bedded limestones (Wellenkalk) of Lapis Limestone Formation (formerly Gyűd Limestone). The fossiliferous beds of Middle Triassic Zuhánya Limestone Formation are followed by two dolomitic units of Csukma Dolomite and Templomhegy Dolomite. The Mészhegy Formation is believed to represent at least a part of the Late Triassic period and continuously evolves from underlying dolomites.

The Jurassic contains several hiatus. There is a disconformity between the Jurassic and Triassic, and the first Jurassic beds are of Liassic sandstones passing upward into limestones (Somsicshegy Limestone Fm.). Dogger is represented by a few centimetres of Bathonian and nearly half metre of Callovian iron oolitic to stromatolitic beds that are very rich in ammonites (LÓCZY, Jr., 1915; RADWANSKI and SZULCEWSKI, 1966; VÖRÖS, 1972).

The karstified surface of the nearly 300 m thick Upper Jurassic carbonates (Szársomlyó Limestone Formation) are overlain by Cretaceous bauxites (Harsányhegy Bauxite Formation). The coverbeds of bauxite horizon is formed by Cretaceous chara bearing to marine pachyodont and Orbitolina limestones (Nagyharsány Limestone Formation). The covering Middle Cretaceous Marl (Bisse Marl Formation) is only known from one outcrop (CSÁSZÁR, 1989). Lower Cretaceous basalt dykes froms (Mecsekjános Basalt Fm.).

Mesozoic sediments are overlain by Pliocene clays and red clays with vertebrate remnants. Pleistocene loess can also form very thick cover.

Villány Mountains has a very complex structure that is formed by nappes. The six northward thrusted nappes (from NNW to SSE: Babarcszőlős, Tenkes, Csukma, Siklós or Város-hegy, Villány or Fekete-hegy, Harsány) form the mountains, while the only southward thrusted nappe (Beremend nappe) is found on the surface in an isolated location S of the mountains (WEIN, 1969, BENKOVICS, 1997).

4. Methods

Field studies included detailed description of outcrops from sedimentological and structural geological point of view. Samples were taken for microfacies analysis from each bed or at least from each 0.5 m. Besides outcrops core drillings were also studied. Thin sections were prepared and alizarine red staining was used for determination of calcite/dolomite phases.

Large blocks were collected for petrophysical tests having 100 kg mass for each sample group. The petrophysical tests were performed according to the Hungarian Standard (MSZ 1981).

Mass properties were determined. For strength tests cylindrical samples (5 cm

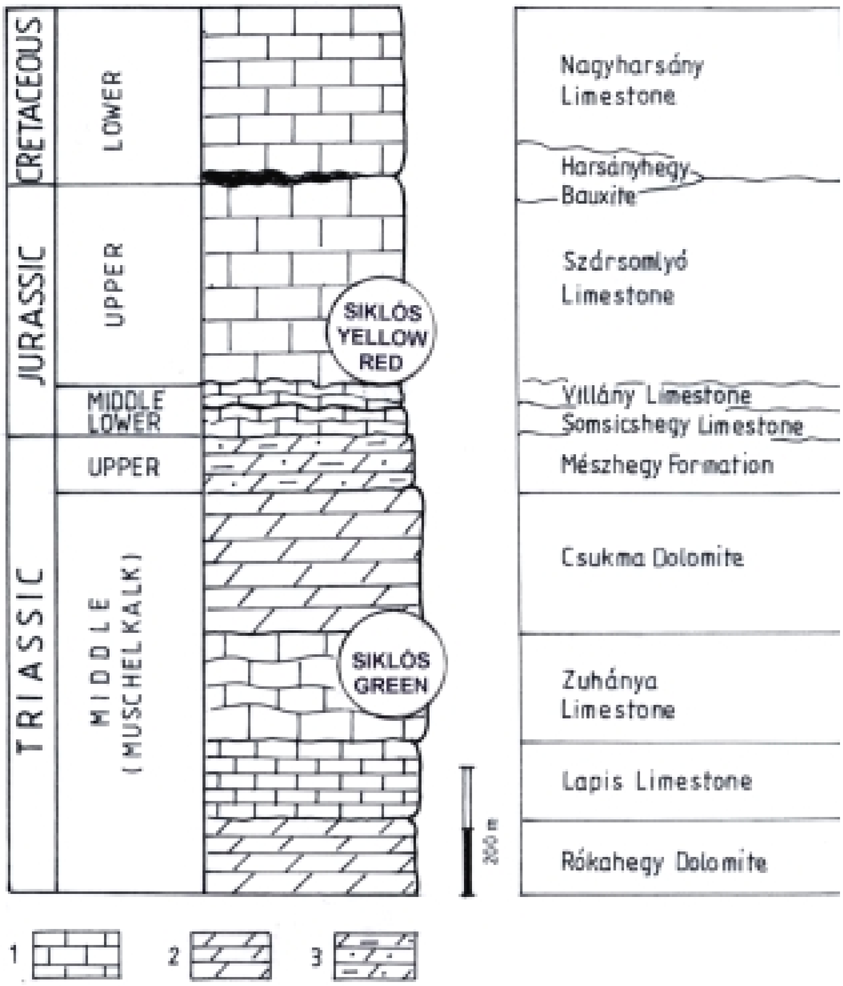

Fig. 1. Mesozoic lithostratigraphic subdivision of the Villány Mountains showing the position of Siklós–green (Middle Triassic, Zuhánya Limestone Formation) and Siklós 'red-rose', 'yellow' and 'white' (Upper Jurassic, Szársomlyó Limestone Formation) limestones in the exposed sequences. 1 – limestones, 2 – dolomites, 3 – alternating siltstones, clays and dolomites

in diameter, 5 cm height for tensile strength and 10 cm height for compressive strength) were grouped into groups of 5 according to their quality parameters (density, longitudinal ultrasonic sound velocity). In the groups the samples having different primary quality parameters were evenly distributed (MSZ 18282/2). To understand the influence of lithological variations on strength parameters each specimen was macroscopically described before and after the test. After failure the fracture surface and its orientation were analysed. Both uniaxial compressive strength and indirect tensile strength tests were performed. For aggregate tests crashed (twice crashed) 5/8 mm aggregates were used. Micro-Deval, Hummel and Los Angeles tests were carried out according to the Hungarian Standards (MSZ 18278). Durability tests (MSZ 18289) included water saturation, 25 and 50 freezing cycles and Na-sulphate and Mg-sulphate crystallisation tests.

5. Siklós–green Ornamental Limestone

5.1. Siklós Zuhánya Quarry

The quarry is located in the Siklós (Város-hegy) nappe (*Fig. 2*). The exposed brownish grey, yellow to brown mottled slightly dolomitic limestone belongs to the Middle Triassic (Anisian) Zuhánya Limestone Formation. In the quarry few up to 3 – 8 m thick limestone banks are exposed. The limestone has a steep (50 – 60°) SW dip. The topmost levels show intense karstification. In the upper quarry level the limestone beds become thinner (1 to 1.5 m) and have slightly more greyish and reddish colour. On the eastern side of the lower quarry level a major $NW - SE$ fault zone was recorded forming the tectonic boundary of Zuhánya Limestone and Csukma Dolomite. The dolomitic beds of the covering Csukma Dolomite Formation (*Fig. 1*) are also exposed in a quarry that is located to the East.

5.2. Description of Rock Types

5.2.1. Macroscopic description

Zuhánya limestone shows great variety both in colour and in bed thickness. The most common types are the brownish-grey, grey slightly greenish ones. There are mottles in the matrix having slightly lighter colour as a rule, i.e. pale yellow to pinkish mottles also occur. The mottles are irregular and have a maximum size of 20 – 45 cm. Dolomitization is typical for sparitic mottles and partial dolomitization occurs in micritic mottles. The latter ones consist of scattered dolomite rhombohedrons. The calcite micrite matrix has a minor clay content. Dense network of fissures also characterises the rock (*Fig. 3*). Most of the fissures are filled with transparent to white calcite, meanwhile minor dolomite cement also occurs. Besides the mm to cm-sized fissure fillings irregular ochre to yellow, rarely red, stylolitic seams were also observed. These are associated with wider (cm-size) green, yellow to red clayey carbonate cemented fissure fillings. Several calcite and dolomite cementation phases were identified (TÖRÖK, 1997b). The multiphase generation of fissures and mottles gives a very unique appearance to the rock (*Fig. 4*).

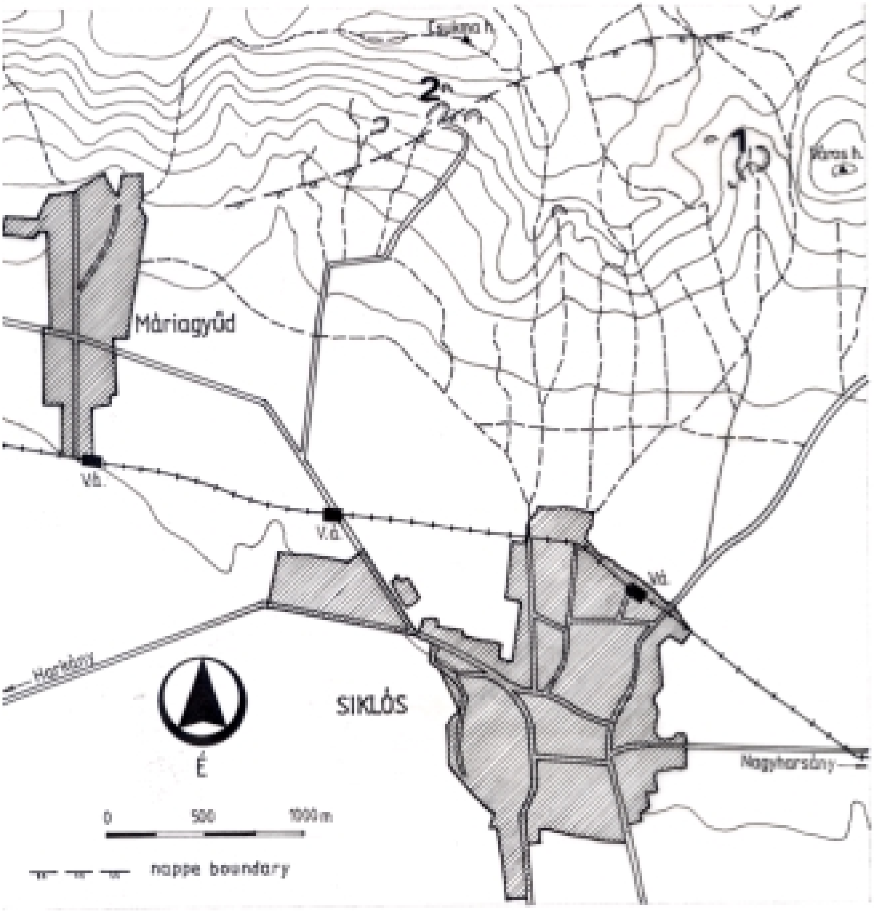

Fig. 2. Location of ornamental stone quarries in Villány Mts. 1 – Zuhánya quarry, Siklós–green, (Middle Triassic, Siklós or Város-hegy nappe). 2 – Rose quarry, Siklós-red, -yellow and -white (Upper Jurassic, Csukma nappe)

Macrofossils are represented by brachipods and crinoids. The former ones often form lumachelles or are found in ‘pockets’. The most common species is *Coenothyris vulgaris.* The bivalves are less frequent (NAGY, E. and NAGY, I., 1976). The Anisian (Pelsonian) age of the rock is evidenced by the presence of conodonts (BÓNA, 1976).

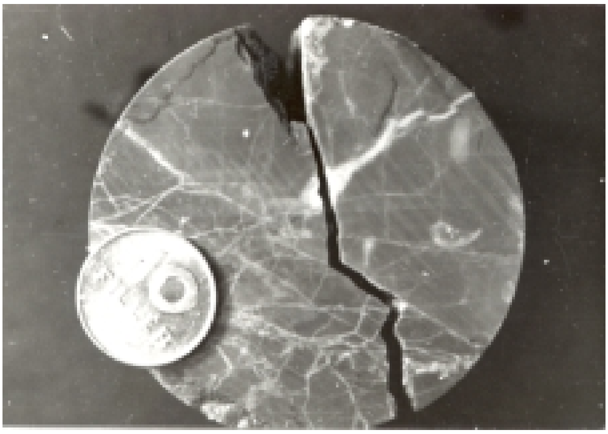

Fig. 3. Cut surface of a cylindrical specimen (Zuhánya Limestone, Siklós–green) with white calcite fissures and clayey seams. The failure related fracture follows a clayey seam in a zigzag way (coin for scale is 1.8 cm)

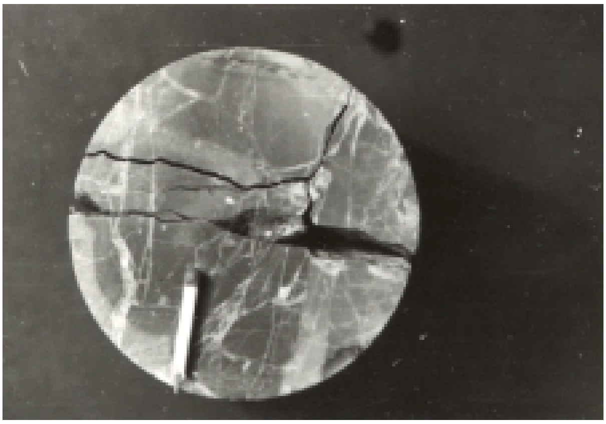

Fig. 4. Dense calcite fissure fillings give a brecciated appearance to the rock. The failure related fracture has a 90° deviation along a sedimentary boundary (Zuhánya Limestone, Siklós–green), (match for scale)

5.2.2. Microscopic description

The grey micritic matrix contains plastoclasts or cemented intraclasts and brownish microsparitic mottles. The matrix as well as the mottles are often cut by stylolitic seams (*Fig. 5*). The stylolitic seams are filled with clay. Dolomitization appears in the form of microsparitic recrystallisation or as scattered dolomite rhombohedrons in micrite (*Fig. 6*). Fractured brachiopod shells, crinoid ossicles (micritised ones), ostracods and radiolarians represent the fossil assemblage in the thin-sections. The most common microfacies type is mudstone/wackestone, while the lumachelles have matrix supported brachipod-floatstone microfacies. The rate of disarticulation of brachiopod shells is high and thus it refers to the allochthonous origin of these beds.

5.3. Depositional Environment

The carbonates of Zuhánya Limestone Formation represent the deepest facies of the entire Triassic succession of Villány Mountains. They were formed in a ramp setting at an outer to mid-ramp environment (cf. TÖRÖK, 1997a). The fauna (conodonts, radiolarians and poorly preserved cephalopods) and sedimentary structures imply this depositional environment. The deepening upward character of the sequence is evidenced by the transition from mid-ramp carbonates of Lapis Limestone Formation to outer ramp sediments of Zuhánya Limestone Formation. Upward in the succession mid and inner ramp carbonates (dolomitic limestones and dolomites) come indicating a relative sea-level fall.

It is still an open question how the brecciated mottled beds were formed. KONRÁD (1990) explains the mottles as reworked clasts that were deposited on the ‘matrix formed’ bottom. Another possibility that synsedimentary tectonism created proper morphology for the slope establishment and for the formation of ‘slope debris’. Most probably storm stirred bottom currents caused the formation of breccias.

5.4. Petrophysical Properties of Siklós–green

The results of petrophysical tests are shown in *Table 1* (cylindrical samples), *Table 2* (aggregates and durability). Siklós–green belongs to the ‘20n’ petrophysical category according to the Hungarian Standard. It means that it has a compressive strength of more than 20 MPa and its not especially frost resistant. Its compressive strength is more than 70 MPa but it shows severe drop after 25 freezing cycles decreasing by one third (*Table 1*). That is why it is not considered as a frost resistant rock. The low frost resistance is attributed to the brecciated character of the rock and to the presence of clayey seams (*Fig. 4*). This inhomogeneity causes the higher standard deviation of strength parameters, too (*Table 1*).

The aggregate tests showed that it was classified into ‘B’ petrophysical quality according to the Hungarian Standard (*Table 2*).

The Triassic Siklós–green ornamental stone is very decorative and can be easily polished. As a consequence these rocks are proper for polished slabs. Due to its low frost resistance it can only be used as inner surface covers and its external use is not recommended.

The by-products of quarry operations can be used for aggregates.

Table 1. Petrophysical test results of cylindrical samples

Quarries	Zuhánya quarry (Siklós–green)			
Petrophysical tests	Average	Standard deviation	No. of tests	Coefficient
Density (kg/m^3)				
air dry	2702	25	39	
dry	2693	26	19	
water saturated	2708	27	29	
25 freezing cycles	2708	18	19	
50 freezing cycles	2710	19	9	
Water content (V %)				
initial water content	0.34	0.22	19	
water saturation	0.66	0.43	29	
water saturated after 25 freezing cycles	0.70	0.49	19	
water saturated after 50 freezing cycles	0.91	0.72	9	
Ultrasonic sound velocities (km/s)				
air dry	6.356	0.361	39	
water saturated	6.100	0.248	29	
water saturated after 25 freezing cycles	6.098	0.254	19	
water saturated after 50 freezing cycles	6.245	0.194	9	
Tensile strength (MPa)				
air dry	7.23	1.54	5	
water saturated	6.89	2.28	5	0.95
water saturated after 25 freezing cycles	5.15	1.94	5	0.71
water saturated after 50 freezing cycles	4.37	0.63	4	0.60
Compressive strength (MPa)				
air dry	79.23	11.81	5	
water saturated	73.91	21.14	5	0.93
water saturated after 25 freezing cycles	52.97	10.68	5	0.67
water saturated after 50 freezing cycles	79.05	12.43	5	1.00
Young modulus/modulus of elasticity (GPa)				
air dry	38.55	4.93	5	
water saturated	34.64	7.05	5	0.90
water saturated after 25 freezing cycles	40.33	19.38	5	1.05
water saturated after 50 freezing cycles	49.97	13.99	5	1.30

Table 1 continued

Quarries	Rose quarry (Siklós–yellow, red)			
Petrophysical tests	Average	Standard deviation	No. of tests	Coefficient
Density (kg/m^3)				
air dry	2690	13	40	
dry	2684	15	20	
water saturated	2694	9	30	
25 freezing cycles	2694	9	20	
50 freezing cycles	2695	10	10	
Water content (V %)				
initial water content	0.14	0.04	19	
water saturation	0.34	0.09	30	
water saturated after 25 freezing cycles	0.35	0.06	20	
water saturated after 50 freezing cycles	0.43	0.12	10	
Ultrasonic sound velocities (km/s)				
air dry	6.482	0.265	40	
water saturated	6.191	0.161	30	
water saturated after 25 freezing cycles	6.174	0.158	20	
water saturated after 50 freezing cycles	6.468	0.205	10	
Tensile strength (MPa)				
air dry	5.97	1.68	5	
water saturated	7.24	1.17	5	1.21
water saturated after 25 freezing cycles	5.95	1.04	5	1.00
water saturated after 50 freezing cycles	5.94	1.40	5	1.00
Compressive strength (MPa)				
air dry	79.68	8.81	5	
water saturated	83.31	17.95	5	1.05
water saturated after 25 freezing cycles	72.13	12.81	5	0.91
water saturated after 50 freezing cycles	71.93	8.40	5	0.90
Young modulus/modulus of elasticity (GPa)				
air dry	40.55	3.66	5	
water saturated	47.00	22.03	5	1.04
water saturated after 25 freezing cycles	42.67	8.98	5	1.05
water saturated after 50 freezing cycles	35.50	6.56	5	0.88

6. Siklós-red (rose), -yellow and -white Ornamental Limestones

6.1. Siklós Rózsa Quarry

The Rózsa quarry (Rose quarry) is located in the area of Csukma nappe (*Fig. 2*). The quarried rock belongs to the lower part of Szársomlyó Limestone Formation.

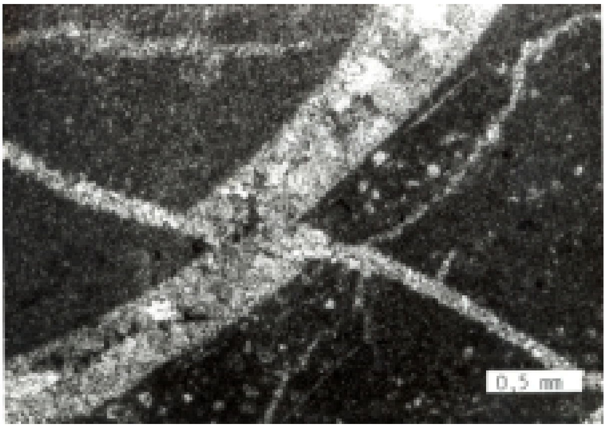

Fig. 5. Thin-section photograph of two generations of calcite fissures. The latter thin displaces the former thicker one. The microfacies is mudstone (Zuhánya Limestone, Siklós–green), (scale bar is 0.5 mm)

Table 2. Results of aggregate strength tests and sulphate crystallisation loss (twice crashed aggregates of 5/8 mm in diameter were used for the tests)

	Zuhánya quarry			Rose quarry		
	Test results		Average	Test results		Average
Los Angeles loss (m %)	20.70	20.90	20.80	24.80	24.90	24.85
Hummel loss (m %)	63.41	64.74	64.08	64.47	67.12	65.80
micro-Deval loss (m %)						
dry	4.97	6.02	5.50	6.77	6.93	6.85
wet	8.90	9.79	9.35	8.96	9.22	9.09
Sulphate crystallisation loss (m %)						
Na-sulphate	5.58	10.33	7.96	4.67	6.98	5.83
Mg-sulphate	6.71	8.35	7.53	4.71	9.48	7.10

Besides this Upper Jurassic limestone the quarry also exposes the underlying Middle Triassic dolomite (Csukma Dolomite Formation) and the Middle Jurassic iron oolitic limestone of Villány Limestone Formation. The quarry face is divided into four limestone banks of 6 metres in thickness each. The quarry names of these banks are related to their colour, namely the lowermost reddish-pinkish limestone bank is called ‘rose bank’, that is overlain by the ‘yellow bank’ and by two ‘white banks’. The rose bank lies directly on the red iron oolitic limestone. In the commercial nomenclature besides ‘white’, ‘yellow’ and ‘red’ a ‘transitional’ type is also used

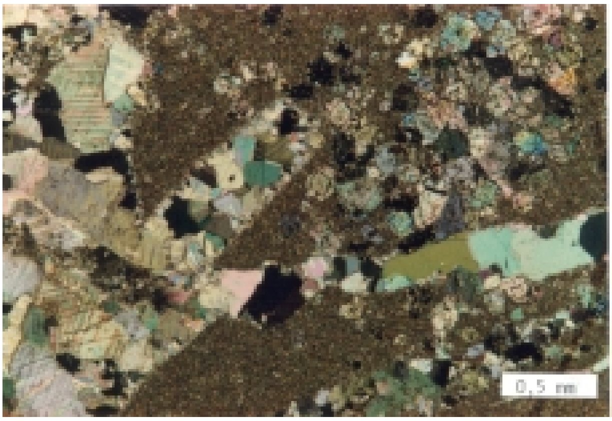

Fig. 6. Recrystallised mudstone with cross-cutting dolomite and calcite fissures. Note the groups of small scattered dolomite rhombs in the mudstone (Zuhánya Limestone, Siklós–green), (scale bar is 0.5 mm)

that describes light coloured rock with reddish to pinkish mottles. The limestone banks have steep *SE* bedding (140/26° as an average). Two major fault zones were also identified in the quarry: *NW-SE* and *NE-SW* ones. Karstification is a typical phenomenon, and especially pronounced on the topmost banks. Caves and related speleothemes are often exposed on the quarry face.

6.2. Description of Rock Types

6.2.1. Macroscopic description

Thick-bedded white to yellow compact limestone with some pink to red varieties. The latter types only occur in the basal beds above the Callovian iron oolites. The yellowish to light matrix often contains irregular patches of clasts/intraclasts having cloudy contours. Within these clasts the bioclasts are more frequent such as brachiopods, ammonites, crinoids.

Very characteristic feature of the rock is the dense network of reddish stylolites. Stylolites are irregularly distributed, not any preferential orientation was observed. Transparent to white calcite filled fissures are also common (*Fig. 7*). Their thickness varies between mm to cm. The thickest ones often show red to brownish staining. Stylolites are not related to the intraclasts since cross cutting relation is often observed.

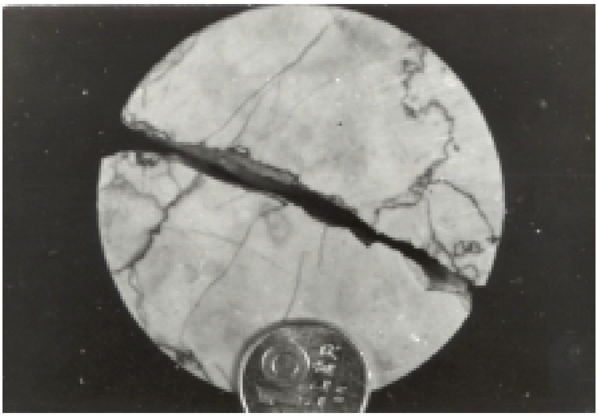

Fig. 7. Red (dark) irregular stylolite seams and very thin transparent calcite fissures on the surface of a cylindrical specimen. The fracture is straight and is not influenced by stylolites (Szársomlyó Limestone Formation, Siklós-yellow) (coin for scale is 1.8 cm)

6.2.2. Microscopic description

The microfacies types are microoncoidal packstone to grainstone (oomicrite, oosparite) (*Fig. 8*). The most typical allochemic components are coated grains showing several varieties:

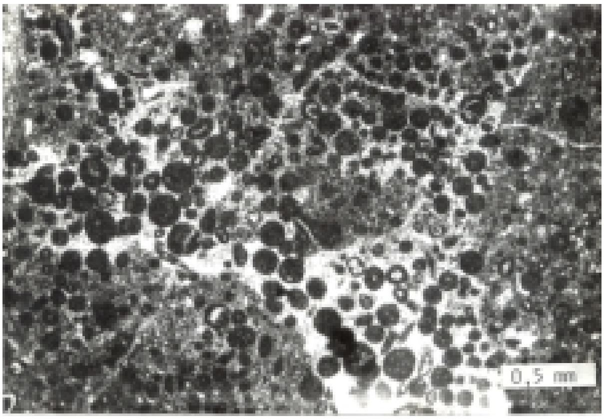

Fig. 8. Microoncoidal packstone to grainstone microfacies with broken small bioclasts that are often coated (Szársomlyó Limestone Formation, Siklós- yellow), thin-section photograph (scale bar is 0.5 mm)

1. well rounded micritic ooids-microoncoids:
    - micritic core with several concentric micritic envelope and rarely with sparitic outer laminae
    - micritic core with few micritic outer laminae
    - homogeneous micritic ooids without visible internal structure
2. irregular coated grains with thin micritic laminae or without visible internal structure (mostly of peloidal origin)
3. half-moon ooids (*Fig. 9*).

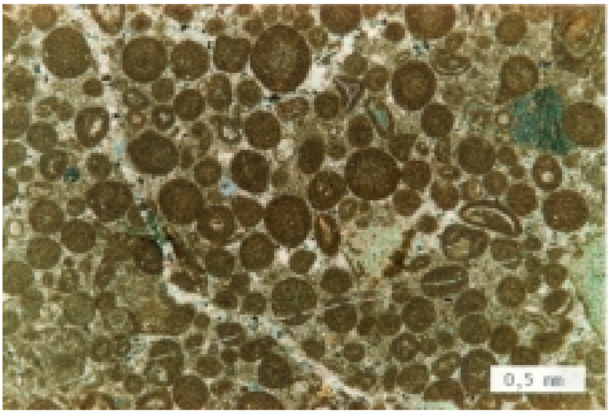

Fig. 9. Different types of coated grains: well rounded micritised microoncoids, half-moon ooid (to the left). Note that the late diagenetic calcite fissure fillings cross-cut the ooids. Thin-section photograph (Szársomlyó Limestone Formation, Siklós-yellow), (scale bar is 0.5 mm)

The size of the coated grains varies between 0.03 – 0.3 mm. Most of them are considered microoncoids rather than ooids. Besides the microoncoids peloids and rounded micritic intraclasts also occur. Microfossils are represented by ostracods, radiolarians, calcispheres. Fragments of brachiopods, bivalves, gastropods and crinoid ossicles are less common.

6.3. Depositional Environment

The carbonates of Szársomlyó Limestone Formation discordantly overlie the Bathonian-Callovian stromatolitic iron oolitic beds (Villány Limestone Formation). The ammonite fauna, the presence of iron oolites and LLH stomatolites reflect a submarine condensed deposition, e.g. a sea-mount setting of the underlying beds. The lowermost beds of the Szársomlyó Limestone Formation, out of which 20 m exposed in the Rose quarry, have microoncoidal intraclastic packstone and grainstone microfacies. The depositional environment of these beds could not have been an oolite shoal since:

1. in the core of the microoncoids pelagic microfossils are found (e.g. calcispheres, radiolarians),
2. pelagic macrofossils also occur within the microoncoids (e.g. ammonites),
3. no sedimentary structures refer to shoal deposition (e.g. cross bedding is not visible).

As a consequence the fauna and the presence of microoncoids are ambiguous. The explanation can be that the microoncoids were formed in a relatively deeper setting where water agitation was enough to produce coated grains. Another possibility is that microoncoids were redeposited from shallower settings and thus these were mixed with pelagic elements. The lack of terrigeneous clastics such as quartz particles in the cores of ooids suggests that terrestrial sources were far away. The best analogy for this depositional environment is the 'pelagic ooid' facies of JENKYNS (1972). Pelagic ooids were formed on sea-mounts that were in much deeper water than the present ooids of Bahama plateau (cf. TUCKER and WRIGHT, 1990). Similar facies types were described from the Jurassic of the Tatrids, Sicily, Southern Alps and the Himalayans (cf. JENKYNS, 1980).

6.4. Petrophysical Properties of Siklós-red (rose), -yellow and -white

The results of petrophysical tests are shown in *Table 1* (cylindrical samples), *Table 2* (aggregates and durability). According to the Hungarian Standard the samples of the Rose quarry belong to the '20f' class based on compressive strength and freezing durability, i.e. the ornamental stone is relatively frost resistant having a compressive strength of more than 20 MPa. Indeed its compressive strength is only slightly less than 80 MPa (*Table 1*) which value is characteristic of the '80f' category. The strength parameters of Siklós-red (rose), -yellow and -white stones are very similar to those of the Siklós–green (Zuhánya limestone).

The aggregates of the Rose quarry limestones are classified into 'B' petrophysical quality according to the Hungarian Standard (*Table 2*).

The ornamental stones of Siklós Rose quarry have a very nice appearance and can be easily polished. As a consequence these rocks are proper for polished slabs. Their relative frost resistance makes them available also for outer use such as cornices, retaining walls etc. Their quarry by-products are good for aggregates e.g. for road aggregates.

7. Petrophysical Properties and Sedimentary Features

Zuhánya Limestone (Siklós–green) shows higher variations in densities than the stones from Rose quarry (Siklós-red, -yellow and -white), what is related to the more variable lithology. The relative higher water contents and water saturation are also denoted to the marly, clayey seams of Siklós–green (cf. *Fig. 4*). By increasing clay content and brecciation the frost resistance is decreasing. The late-phase calcite fissure fillings have less influence on petrophysical properties than those of the clayey marly seams (Siklós–green). The dense reddish stylolites of the limestones from Rose quarry do not influence significantly the strength parameters (cf. *Fig. 7*) and during the failure tests fracture surfaces do not follow these seams.

Thus it seems that the late diagenetic zigzag like stylolites decrease much less the strength of the ornamental stones of Siklós Rose quarry than the syn- to early diagenetic clayey seams of the ornamental stones of Zuhánya quarry.

By comparing the microfacies of the two rock types it is clear that the limestones of Zuhánya quarry are finer and more micritic (mud supported cf. *Fig. 5*) than those of the Rose quarry (cf. *Fig. 8*). The latter ones also have grain supported microfacies types (microoncoid grainstone) besides the mud supported ones. Taking into account only the microfacies one would expect better petrophysical parameters for Zuhánya quarry stones (Siklós–green) than for Rose quarry stones (Siklós-red, -yellow and -white). The clayey seams have an opposite effect, i.e. they cause a decrease in strength of Zuhánya stone. The late diagenetic cementation and high rate of early compaction resulted in the 'homogenization' of the texture of microoncoidal limestones of Rose quarry and thus are responsible for higher strength. The lack of thick shell macrofossils in Rose quarry limestones also has a positive effect on strength.

The relationships of sedimentary processes and petrophysical properties are as follows by comparing both ornamental stones of Villány Mts.:

- the primary sediment composition has an important role in strength, i.e. clay content of Zuhánya stone has a negative effect on strength;
- primary sedimentary structures that cause irregularities in texture have also negative effect, such as storm stirred coquinas and pockets of brachiopod shells or crinoids;
- diagenetic processes significantly influence petrophysical parameters, e.g. compaction and cementation of Siklós Rose quarry microoncoidal limestones homogenized the depositional texture and doing so increased strength parameters.

8. Conclusions

Siklós–green ornamental stone (Middle Triassic, Zuhánya Limestone Formation) was formed in a ramp setting, at an outer ramp environment. Sediment redistribution processes caused inhomogeneities in texture, autoclastic brecciation. As a result petrophysical parameters are slightly decreased.

Siklós-red, -yellow and -white ornamental stones (Upper Jurassic, Szársomlyó Limestone Formation) are considered to be analogous to 'pelagic oolit'. They were formed in relative shallower settings and show some signs of redeposition.

Both the Middle Triassic limestones of Zuhánya quarry and the Upper Jurassic limestones of Rose quarry are easy to polish and can be used as decorative stones. The latter types are slightly more frost resistant. The by-products of quarry operations are proper for aggregates.

The higher carbonate content and the diagenetically homogenized texture of Rose quarry limestones lead to better petrophysical parameters than those of the more clayey Zuhánya limestones. Besides primary depositional texture diagenetic control is also an important factor in influencing petrophysical parameters of limestones.

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