

# CEMTRA Ltd.

for control and  
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REPORT ON DETERMINING THE QUALITY  
OF THE *ORSO GRIGIO* (BEAR THE GREY)  
ARCHITECTURAL-BUILDING STONE  
IN THE AREA OF CRVENE STIJENE (RED ROCKS) NEAR JAJCE

Number: 33/ag/2015

CLIENT: Rudnici boksita Jajce d.d., Jajce (Bauxite Mines Ltd., Jajce),  
Trg jajačkih branitelja bb.  
Jajce  
Bosnia and Herzegovina

Date: 21 July, 2015

Head of the testing unit:  
Mladen Masic, Geol. techn.  
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I. BASIC BACKGROUND INFORMATION

I-1	STONE ORIGIN	The Crvene stijene (Red Rocks) site is located on the northeast, at 7 km of air distance from Jajce, County of Central Bosnia, Bosnia and Herzegovina
I-2	STONE'S COMMERCIAL NAME	Architectural-building stone „ORSO GRIGIO" (BEAR THE GREY)
I-3	ORDERING PARTY	Rudnici boksita Jajce d.d. Jajce Trg jajačkih branitelja bb, Jajce, Bosna i Hercegovina
I-4	STONE'S PURPOSE	Architectural-building stone
I-5	REQUESTED TESTING	In order to produce a report/a study on the stone reserves, it is necessary to determine the quality of the architectural-building stone by using three complete laboratory analyses in accordance to Article 127 of the <i>Ordinance on data collecting, recording and determining of mineral raw material reserves, and producing reports on such reserves</i> , for the purpose of making a report on the mineral raw materials reserve (N.N. No. 48/1992 and N.N. No. 60/1992.)
I-6	SAMPLING SITE AND METHOD OF HOLE BORING	5 testing boreholes of total drilling depth of approximately 250 m were made in total. The diameter of boreholes is minimal 89 mm. The drilling of boreholes was rotational, rinsed with water rinsing, and a 100% corrod. The samples are listed on page 4.
I-7	SAMPLE DESCRIPTION	The sample consists of a greater number of the core fragments whose lengths vary from 20 to 40 cm.
I-8	CLIENT'S SAMPLE MARKING	"Orso Grigio" (BEAR THE GREY) from the second productive layer
I-9	LABORATORY MARKING OF SAMPLES	B-1514/AG/15
I-10	DATE OF SAMPLING	June 2015.
I-11	MAPPING OF BOREHOLE CORES AND SAMPLING FOR THE PURPOSE OF ANALYSES	Ivan Dragicevic, PhD. BSc. in Geol. Ivo Galic, docent, BSc. in Mining Ivica Pavicic, BSc. in Geol. Gordana Deljak, BSc. in Geol.
I-12	SAMPLES DELIVERED BY:	Tihomir Radovac, BSc. Eng., general manager
I-13	DATE OF RECEIVING SAMPLES	June 2015
I-14	DATE OF TEST BEGINNING	17 June, 2015
I-15	DATE OF TEST COMPLETION	21 July, 2015
I-16	TESTS COMPLETED ACCORDING TO THE NORMS	As mentioned in the report

I.I. LIST OF TESTED SAMPLES

Table 1

	Borehole	Interval (m)
SECOND PRODUCTIVE LAYER	K-1	10,3
		18,0
		20,0
	K-2	19,0
		31,5
		71,0
	K-5	72,0

The complete tests of the second productive layer have been performed.

II. THE RESULTS OF THE COMPLETE ANALYSIS OF THE *Orso Grigio* (BEAR THE GREY) STONE FROM THE SECOND PRODUCTIVE LAYER

II. 1. THE RESULTS OF DETERMINING THE STONE'S PHYSICAL AND MECHANICAL PROPERTIES, CHEMICAL PURITY AND PETROGRAPHIC DETERMINANT OF THE STONE

Table 2

		Methods of test	Results
II.1.1.	Determination of uniaxial compressive strength (In dry condition)	HRN EN 1926 (EN 1926)	max= 117,1 MPa
II.1.1.1			min= 106,0 MPa average= 110,4 MPa
II.1.1.2			max= 114,2 MPa min= 86,9 MPa average= 96.1 MPa
II.1.1.3	After freezing		max = 114,0 MPa min= 85,2 MPa average= 95,0 MPa
II.1.2.	Determination of flexural strength under concentrated load	HRN EN 12372 (EN 12372)	max.= 14,0 MPa min.= 12,2 MPa average.= 13,2 MPa

Table 2 continued			
II.1.3.	Determination of the breaking load at a dowel hole	HRN EN 13364 (EN 13364)	max.= 5,3 kN min.= 2,0 kN average= 3.7 kN
II.1.4.	Determination of water absorption at atmospheric pressure	HRN EN 13755 (EN 13755)	= 0,08 % (mass)
II.1.5.	Determination of apparent density	HRN EN 1936 (EN 1936)	= 2 680 kg/m <sup>3</sup>
II.1.6.	Determination of real density	HRN EN 1936 (EN 1936)	= 2 720 kg/m <sup>3</sup>
II.1.7.	Determination of open porosity	HRN EN 1936 (EN 1936)	= 0,985
II.1.8.	Determination of total porosity	HRN EN 1936 (EN 1936)	= 1.47 % (vol.)
II.1.9.	Determination of frost resistance	HRN EN 12371 (EN 12371) (40 cycles)	Mass loss: = 1,0 % (mass) Stable
II.1.10.	Determination of resistance to freezing and thawing by magnesium sulphate	HRN EN 1367-1 (EN 1367-1) (5 cycles)	Mass loss: = 0,0 % (mass) Stable
II.1.11.	Determination of wear resistance -Bohme	EN 13892-3	= 23,0 cm <sup>3</sup> /50 cm <sup>2</sup>
II.1.12.	Determination of total sulphur content, as SO <sub>3</sub>	HRN EN 1744-1	0,09 % (mass)
II.1.13.	Determination of water-soluble chloride salts using the Volhard method	HRN EN 1744-1	0,00 % (mass)

Table 2 continued			
II.1.14.	Content of: sulphides nitrates nitrites organic substances	HRN EN 1744-1 qualitatively	None None None none
II.1.15.	Petrographic examination  Determination	HRN EN 12407  (EN 12407)	Calcareous breccia

## II.2 MINERALOGICAL-PETROGRAPHICAL DESCRIPTION AND DETERMINATION

### II.2.1. K-2 borehole, the interval from 31.5 to 32.0 m

#### Macroscopic description

The color of stone varies from light yellow-brown (10YR 6/2) to grey orange-pink (5 YR 7/2) with light grey (N 7) and white (N 9) inclusions.

Fracturing: It fractures irregularly and sharply under an impact, though easier on the places of contact of two or three fragments. The surfaces of fractures are uneven and range from small to medium roughness.

The hardness of the stone is from 3 to 4 (according to Mohs).

The texture of the stone is heterogeneous and brecciated. We noted the contacts between the fragments, and long cracks and crevices within its core.

The structure of the stone is brecciated, largely composed of fragments of medium-sized rudaceous rocks and linked with finely-grained fragments and grains of arenite dimensions to fine rudaceous rocks. The dimensions of some fragments are: 48,00x50,00; 80,00x55,00; 55,00x25,00; 5,00x1,50; 65,00x30,00; 28,00x15,00; 7,00x2,00 mm or less for the fragments of 1.00 to 9.00 mm. The fragments are made of the limestone of different structural types of madstone, wackestone and packstone, that is, of the biomicrites, biopelmicrites, pelmicrites, rarely grainstones and crystal limestone, while the dolomite fragments have not been determined. Under the magnifier, it is possible to detect in some fragments small fossil detritus, various sections of shellfish (rudists), foraminiferals, snails and other fossils, as well as cement of micrite to sparite dimensions.

The binder is mostly matrix, consisting of carbonate karst of arenite dimensions to fine rudite, but also containing the remains of fossils (molluscs).

The reaction with HCl (of 10%): the stone's reactions range from strong to rapturous.

The field determination: Grey, coarsly grained limestoned (carbonated) breccia.

#### Microscopic observation and description

In the microscopic faceted section, which represents a small part of the stone mass, in the passing light of a microscope, it is possible to see a brecciated texture and structure, the aggregate of stone fragments and a binder of matrix and cement whose dimensions range from micrites to sparites, also the cracks and partially the recrystallization processes. The faceted section is painted with "Alizarin - red S", and it changed its color mostly in red.

The structure is a breccia. It consists of angular to subangular fragments of various dimensions, varying from 0.8 to 4.00 mm in diameter, and some fragments are of the following dimensions: 21,00x18,00; 12,0x9,00; 18,00x15,00, 10,0x5,0 mm (fossils). The fragments have irregular, elongated, rarely isometric sections, while the edges parts

of the individual fragments are slightly rounded due to the recrystallization process. The fragments are of limestone, identified as packstones - biomicrites, biopelmicrites, grainstones/radstone-biosparite/rudite, crystal limestone. There are approximately 80% of fragments in a stone.

The mineral composition is the calcite (proven by coloring), a tough mineral and an organic matter. It is of mostly calcite composition, approximately 100%, and it also makes both the binder and the fragments. It is found in the stone as irregular crystal grains, or as irregular, elongated and isometric sections of micrite to sparite dimensions. The micrite dimensions are: 0, 000x - 0,005 mm, and the sparite dimensions are: 0.05 x 0.03 mm - 0.57 x 0.35 mm. The sparite is mostly found in the binder, that is, in many cracks and crevices. Some sparite grains have compression joined lamellas, and some show one, rarely two systems of crack cleavages. A strong pseudoabsorption of sparites is observed.

The texture is heterogeneous and brecciated. The cracks and crevices filled with sparite calcite are rarely observed, and some are partially filled with organic matter. The stone does not contain chalcedonite, pyrite, marcasite or clay minerals.

#### Determination

According to the results of microscopic and macroscopic examination (of its mineral composition, structural and textural characteristics and dimensions, quantity and type of fragments), the analyzed stone is defined as polymict calcareous breccia of sedimentary origin. The fragments are of the limestone and of organic origin, classified according to R. L. Folk as biomicrites, biopelmicrites, biosparites to biosparudites, and according to R. J. Dunham as packstones, grainstones, radstones and crystalline carbonate rocks.

#### II.2.2. K-3 borehole, the interval from 30.5 to 31, 0 m

##### Macroscopic description

The color of stone ranges from light yellow-brown (10YR 6/2) to grey orange-pink (5 YR 7/2) with light grey (N 7) and white (N 9) inclusions.

Fracturing: It fractures irregularly and sharply under an impact, and the surfaces of fractures are uneven and of small roughness.

The hardness of the stones is from 3 to 4 (according to Mohs).

The texture of the stone is homogenous.

The structure of stone/core is grainy, detrital, while the granular support prevails. There is up to 90% of detritus, it is densely packed, partially in contact, of equal dimensions and is middle well sorted. Under a magnifying glass it is possible to see fossils, rarely an interior structure of fossils, small interclasts and peloids, as well as the basis of the crystal of micrites to sparite dimensions.

The reaction with HCl (10%): the reaction varies from strong to rapturous.

The field determination: Limestone, grainstone with changes into the carbonated micro breccia.

##### Microscopic observation and description

In the microscopic faceted section and in the passing light of a microscope, it is possible to see a homogenous texture, an aggregate of detritus and the fundamentals of sparite and micro sparite dimensions, rarely micrite. The faceted section is painted with "Alizarin - red S", and it changed its color into red.

The predominant mineral component is calcite which makes up to 100%, and also builds both the detritus and the basis. It is found as small grains of mostly irregular isometric, rarely of elongated sectional dimensions of micrites, microsparites and sparites. The dimensions of micrites are: 0,000x - 0,005 mm in diameter. The sparite crystals are of approximate dimensions,  $\phi = 0,54$  mm. Some sparite crystals show one, rarely two systems of cleavage cracks and some show compressed joint lamellas. A strong pseudoabsorption of sparites has been observed.

The structure is granular and the granular support prevails. The grains/detritus are in partial contact, and they participate in the stone's structure with approximately 80-90%. The detritus is mainly of organic origin, and consists of various sections of fossils: of foraminiferal limestone, rarely of tiny snails, and of the remains of shell fragments, as well as of other indeterminate fossils and fossil detritus.

The walls of some of the fossils are made of calcite crystals that are of micrite dimensions. The internal structure of some fossils is often of calcite and of sparite dimensions.

A few fragments of intraclasts, that is, of limestone: wackestones and packstones have been observed.

There is approximately 20% of basis, and it is built mainly of calcite, of microsparite dimensions, and to the less amount of sparites and micrites.

#### Determination

According to the results of the macroscopic and microscopic examination (its mineral composition, structural and textural characteristics, and the quantity and type of detritus), the analyzed stone is defined as polymict finely-grained calcareous breccias, dominated by poorly recrystallized limestone of organic origin, according to R. L. Folk determined as biosparites/rudites, or according to R. J. Dunham as fossiliferous grainston/radstone.

### II.3. THE RESULTS OF THE STONE'S CHEMICAL AND MINERAL COMPOSITION DETERMINATION

The chemical composition of the average stone's sample from the second productive layer has been determined by a chemical analysis.

The stone's mineral composition was calculated from the resulting analysis.

The results are listed in Table 3.



Table 3

The chemical parameter  (determined according to the HRN EN ISO 11885:2010, HRN EN 196-2)	Average sample  Complete analysis
The loss on calcination at 10000°C	43,21%
Silicon dioxide, SiO <sub>2</sub>	0,37%
Iron oxide, Fe <sub>2</sub> O <sub>3</sub>	0,22%
Aluminum oxide, Al <sub>2</sub> O <sub>3</sub>	0,72%
Calcium oxide, CaO	54,58%
Magnesium oxide, MgO	0,35%
Titan dioxide 1d, TiO <sub>2</sub>	0,01%
Sulphur trioxide, SO <sub>3</sub>	0,09%
Sodium oxide, Na <sub>2</sub> O	0,01%
Potassium oxide, K <sub>2</sub> O	0,05%
TOTAL:	99,61%
Total chloride expressed in Cl	0,00
Content of: sulphide nitrate and organic substance (qualitatively)	None None None None
SCALING FROM CHEMICAL ANALYSIS	
The mineral composition of stone	
Calcite, CaCO <sub>3</sub>	96,53%
Dolomite, CaMg (CO <sub>3</sub> ) <sub>2</sub>	1,60%
Total carbonate	98,13%

### III. CONCLUSION

Determination of the quality of architectural-construction stone under the name

#### ORSO GRIGIO (BEAR the GREY)

at the Crvene stijene (Red rocks) site, near Jajce, in Central Bosnia County, Bosnia and Herzegovina has shown that the analyzed stone falls into the category of stone of medium-high compressive strength, with very low water absorption. According to its porosity, the named stone falls into the category of the lowest porosity.

The stone is compact.

Regarding its spatial mass, the stone is heavy, and regarding its wear resistance, the stone is moderately hard.

Based on the results, it is estimated that the stone is of a very high quality and can be used as an architectural-building stone for the following purposes:

- for exterior vertical facing
- for interior vertical facing
- for indoor and outdoor horizontal coating of passenger surfaces
- for making window sills and frames
- for making staircases
- as a masonry stone.

It is possible to polish the surface and elements of the analyzed stone to a high, glassy luster, at the same time highlighting its breccia structure. Such surfaces may be garnished by special decorative patterns.

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