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Original scientific paper

SILICA VEINS IN GAJ-LAZINE LOCALITY (CENTRAL SERBIA) AS GEMSTONE

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A b s t r a c t: Gemstone occurrence Gaj-Lazine is located in central Serbia, 3.5 km SE of Stragari. Prevailing gemstone type is opaque chalcedony–jasper and colourless chalcedony. Subordinate crystalline quartz and carbonate minerals are also present. They all appear as single veins and, more often, intricate stockworks, filling up fractures in serpentinite of the Vardar zone ophiolitic sequence. Genetic processes of this occurrence are connected to the Neogene calc-alkaline magmatic activity of the Vardar zone and hydrothermal activity triggered by it. Economic significance of this gemstone deposit is high for jasper and minor for other present gemstone types, due to their minor occurrences.

Key words: gemstone; silica veins; jasper; chalcedony; Vardar zone

INTRODUCTION

Gaj-Lazine locality is situated 3.5 km SE from Stragari, by the road Stragari–Bare in central Serbia (Fig. 1). Prospecting works from 1981 to 1983 [1, 2] resulted in discovering of jasper-chalcedony-quartz veins in hydrothermally altered serpentinite. Favourable dimensions of these veins enable the use of these silica veins as gemstone raw material. Thus, further special prospecting work has been conducted in this locality during 2004 as part of the first author's Magisterium thesis works [3]. Additional explorations were performed during 2014 for the purpose of solving the problem of deposit genesis.

Fig. 1. Geographic location of Gaj-Lazine site (inset: position in Serbia).

GEOLOGICAL SETTING

The gemstone occurrence Gaj-Lazine is a part of Stragari-Vučkovica gemstone district [3] located within the central Serbia Vardar zone ophiolite belt, on the Central deep regional fault [4]. The complicated geotectonic evolution of the Vardar zone [5] has caused the opening of the Jurassic Vardar Ocean, formation of the ophiolitic sequence with ultramafic rock of the ocean floor, ocean closure and obduction of the ophiolitic sequence. Ultramafic rocks from lower parts of the ocean floor have been compressed and obducted over younger rock formations, and regionally altered to serpentinite in the oxidizing conditions of terrain surface levels. The deep regional fault marking the suture zone has remained the zone of the increased tectonic instability and the stage for the Tertiary magmatic activity of calc-alkaline character triggered by subduction (Late Paleogene–Early Neogene granitoid formation and Late Paleogene–Neogene volcanic formation of the central axis of the Balkan Peninsula according to Cvetković et al., [6]). Hydrothermal activity driven by magmatic heat, through fracture and fault zones, has caused alterations of the host rock formations and deposition of mostly siliceous hydrothermal veins (jasper, chalcedony, quartz), with variable content of carbonates (magnesite, dolomite, aragonite). These processes are generally termed listwenitization [7]. The influx of silica is due to its extraction from the lower zones of serpentinites [8] or other rock formations through which hydrothermal solutions have circulated, and its precipitation in shallower environment due to changes in chemical (redox, pH, saturation state) and physical (T, P) conditions [9,10]. Oxygen isotopic composition analyses of specimens from the southern continuation of the Vardar zone, in deposits of the same type, within the same geologic setting, have indicated the temperature of the mineralizing fluid of 65–80°C [11, 12].

Gaj-Lazine gemstone occurrence is cropping out in the area of about 106×140 m. It has formed within the tectonic contact of Jurassic serpentinite with Cretaceous sediments – conglomerate and brecciated limestone of Turonian-Sennonian age (Fig. 2). Serpentinite is intensely listwenitized and fractured along the fault, permeated by numerous irregular silica veins forming intricate stockworks. Further from the fault, serpentinite is unaltered. Between these two zones, there is a narrow transition zone of serpentinite with silicified yellowish magnesite veins.

It is interesting to note that ultrapotassic volcanic rock dikes are also found in this locality (Fig. 3). These rocks are connected to the complex geotectonic processes in the Vardar zone postcollisional setting, occurring along the WNW–ESE trending deep fracture along which are also situated the ultrapotassic rocks of Mionica, Ozrem, Rudnik Mt. and Bogovina [13]. Geographically, the Gaj-Lazine occurrence fits perfectly into this line. These dikes also contain silica veins. Ultrapotassic rocks of the Balkan Peninsula witness about the postcollisional and relaxational regime, the presence of the fundamental fault, reaching the metasomatized lithosphere domains.

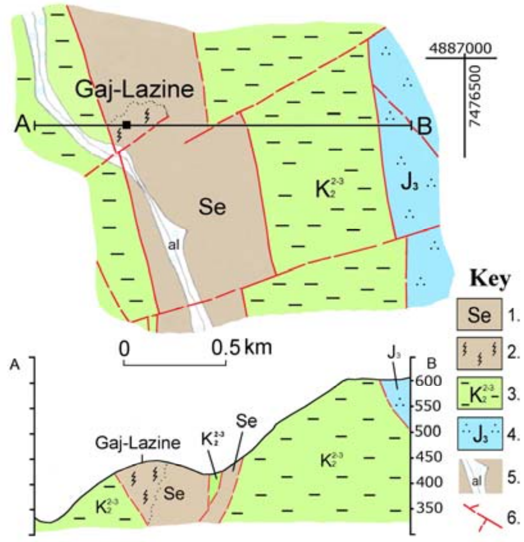

Fig. 2. Geologic map of the terrain around Gaj-Lazine with cross-section along the line A-B [3], modified.
Key: 1. serpentinite; 2. listwenitization zone in serpentinite; 3. conglomerate, limestone (Upper Cretaceous – Turonian, Sennonian); 4. diabase-chert formation; 5. alluvium; 6. fractures

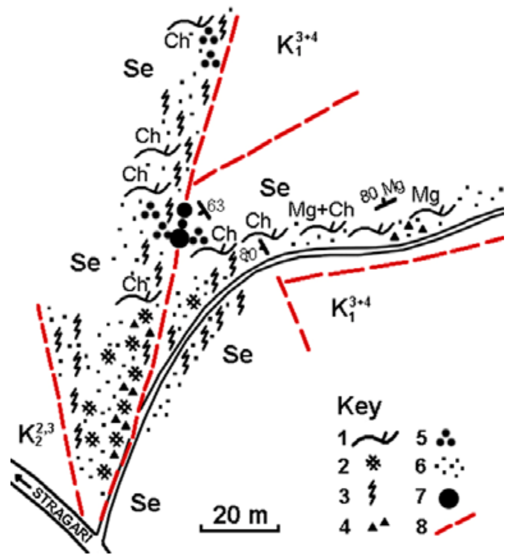

Fig. 3. Schematic geologic plan of Gaj-Lazine gemstone occurrence.
Key: Se – serpentinite; K_1^{3+4} – conglomerate, limestone; $K_2^{2,3}$ – brecciated limestone; 1. veins (Ch – chalcedony, Mg – magnesite); 2. skeletal chalcedony stockwork; 3. jasper veins; 4. quartz crystal druses; 5. opalized serpentinite; 6. hydrothermally altered serpentinite; 7. ultrapotassic dikes; 8. fractures and faults

GEMSTONE VARIETIES

The gemstone deposit consists of elongated, irregular ore bodies (complex veins) along fractured contacts of serpentinite and Cretaceous sediments. The tectonic contact fault is generally trending NNE–SSW and is (sub)vertical, since the observation during the last ten years has revealed that as the erosional level deepens, its location remains constant. Complex vein thickness varies from 50 cm to few metres in places where serpentinite is more intensely fractured. Within the vein ore body, gemstones appear as stockworks and single veins of varying orientation and thickness.

Silica veins in this site mostly appear as small, irregular-shaped fracture fillings and stockworks in altered serpentinite. The predominant gemstone type is chalcedony: opaque (jasper) and translucent (colourless chalcedony). Less frequent are quartz (rock crystal) and silicified magnesite.

Jasper forms veins and stockworks with occasional lenticular thickenings and irregular masses up to 15×5 cm. Rarer are the jasper veins up to 20 cm thick (Fig. 4). Fractured jasper surfaces are conchoidal and smooth, as is typical for silica masses formed from a colloid state (Fig. 5). Its colours are most often buff-brown and red (dark red or burgundy) (Fig. 5 a,b). The buff to red jasper ratio is estimated to 70:30%. A certain percent of jaspers is mottled (Fig. 5 c), usually with red pigment present only a few millimetres deep, transiting into buff towards the centre of the vein. Very often, jasper amygdules contain colourless chalcedony veinlets up to 5 mm thick. Opaque, metallic mineral grains (most probably magnetite) are present, up to 2 mm in size, distributed in a linear layout forming echelons (Fig. 6). It is interesting to note that ultrapotassic volcanic rock dikes in this locality also contain jasper veins, but of quite different appearance, with characteristic greenish colour (Fig. 5 d), demonstrating the dependence of the resulting gemstone habit on the local geologic setting and host-rock type.

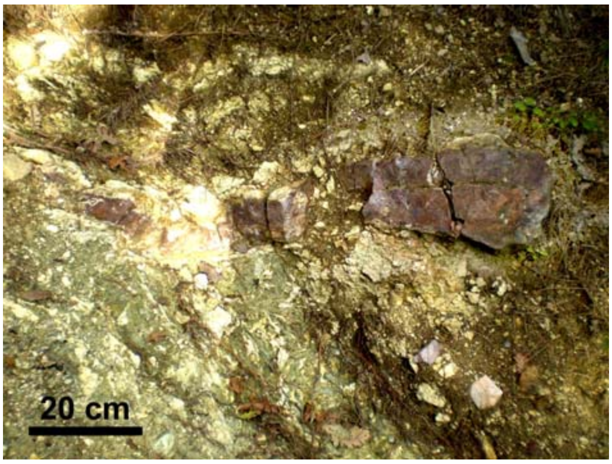

Fig. 4. Jasper vein *in situ*, a rare site.

Pejčić et al. [1, 2] estimated the inferred resources of jasper to be 3370 t in C_2 category. According to the geoeconomic classification of deposit types [14], this deposit belongs to the 4th category – deposits with complicated geologic structure, extreme changeability of geologic characteristics and irregular distribution of mineral raw material where detailed exploration aiming at specifying the proved reserves (A and B category) is not economically feasible.

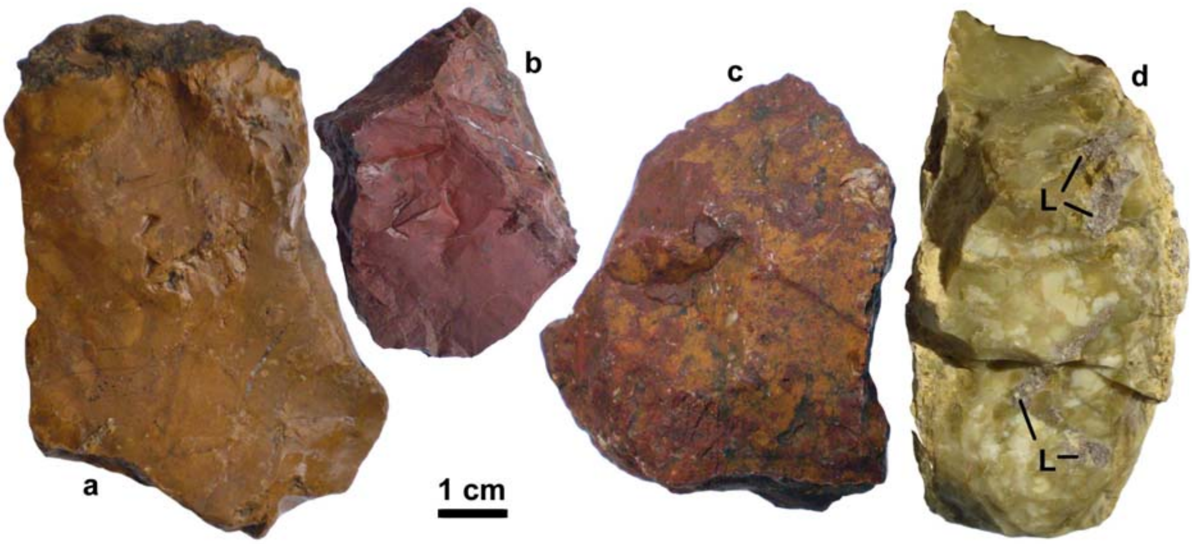

Fig. 5. Jasper varieties:
a. buff-brown; **b.** dark red; **c.** mottled; **d.** jasper from the ultrapotassic rock (L – host rock fragments).

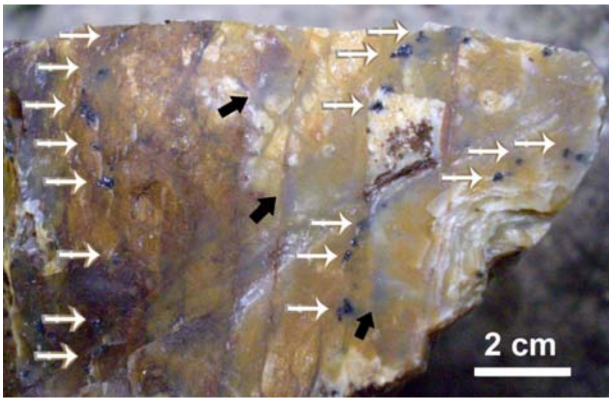

Fig. 6. Metallic mineral grains in echelon disposition (white arrows) and chalcedony zones (black arrows).

Chalcedony is present in three forms:

A) as colourless chalcedony amygdules in magnesite, formed through the segregation of the Mg-carbonate and silica fractions within the gel (Fig. 7 a);

B) as slightly coloured and semi-transparent chalcedony zones within the jasper veins, formed at the same time, through the segregation of the gel zones with greater (jasper) or smaller (chalcedony) percent of the colouring agent – mostly iron oxide-hydroxides (Fig. 6, black arrows); and

C) as separate veins and veinlets, forming stockworks in jasper, magnesite and hydrothermally altered serpentinite (Fig. 7 b, c).

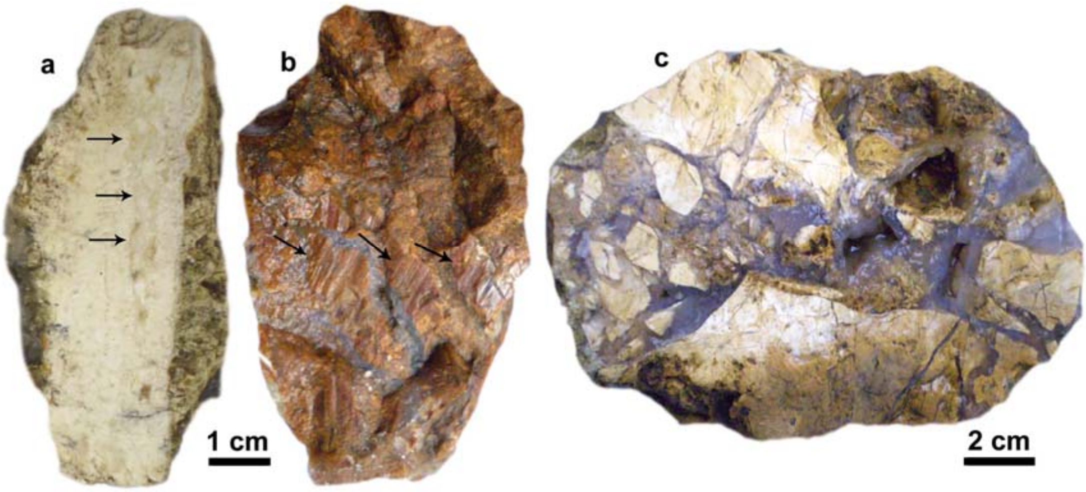

Fig. 7. Chalcedony varieties: **a.** chalcedony amygdules (arrows) in magnesite vein; **b.** chalcedony veins in jasper (a slickenside cast in the first-formed jasper from the host serpentinite (arrows) is visibly broken apart before the formation of the chalcedony veins); **c.** brecciated magnesite veined with chalcedony

A-type chalcedony forms minute amygdules, up to 1–2 mm thick, within the magnesite veins. It is translucent to transparent, but in such small aggregates this is barely visible. It can be used as a gemstone only together with the magnesite vein, and this chalcedony part is what enables the use of magnesite as a gemstone, giving it hardness, workability and durability it wouldn't have possessed by itself.

B-type chalcedony is an integral part of jasper veins, differing from the jasper variety only by its slightly increased translucency. It can be used as a gemstone only together with the entire jasper pieces because these chalcedony zones are up to few millimetres thick.

C-type chalcedony is a separate gemstone type, formed in a separate phase of hydrothermal activity. It is noted that between the jasper phase and the chalcedony phase, there has been an intense tectonic activity, crushing both magnesite (Fig. **7 c**) and jasper veins (Fig. **7 b**), but also opening up the new circulation paths through the serpentinite as a host-rock. Thus, chalcedony veins can be from few millimetres thick to 7 cm thick. Most often, veins are up to 2–3 cm thick. Veinlets form stockworks. Thickened vein parts can include very small altered serpentinite pieces and are reminiscent of moss agate. Chalcedony amygdules can form geodes with quartz crystals in the centre, pointing to the gradual transition into a solution and crystallization in the closed system (Fig. 8 a). Where silica gel has formed in an open system, in crevices with open circulation, chalcedony aggregates have visible botryoidal surfaces (Fig. 8 b).

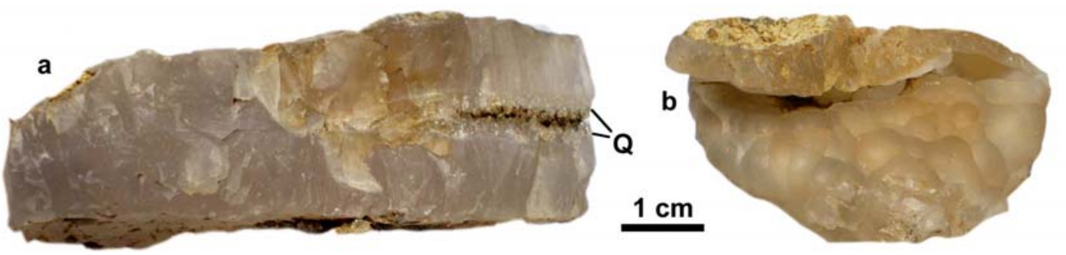

Fig. 8. Chalcedony geodes: **a.** chalcedony vein with quartz crystals in the central geode (Q); **b.** chalcedony geode with botryoidal surface.

Quartz is present as small, densely packed crystals filling up the central parts of chalcedony geodes (Fig. 8 a). Their size can be from barely visible up to 2.5 cm long, the latter being very rare. Most often they reach only 2–3 mm in length. Such quartz mineralizations, forming drusy encrustations on chalcedony aggregate surfaces, are not considered a gemstone *per se*, because they can not be used, i.e. processed separately from the chalcedony base.

Magnesite veins (Fig. 7 a, c) appear in a narrow transition zone between the intensely silicified serpentinite and hydrothermally unaltered serpentinite. They seem to have formed as a first product of hydrothermal activity. Vein thickness varies from few millimetres to several centimetres, most often 1–4 cm. Veins have a NW dip with 80º dip angle. When magnesite is penetrated by chalcedony, it is regarded a gemstone because it assumes the satisfying hardness. Magnesite colour slightly varies from white to yellowish. Fresh-open magnesite veins are white in colour, while prolonged exposure to the sun causes the colour to change into yellow. When magnesite veins contain rounded green serpentinite lithic fragments, its colour and fabric become more decorative.

EXPERIMENTAL USE AS A GEMSTONE

Testing of physical properties

Samples of brown jasper and chalcedony were tested according to the Serbian standards (SRPS) for determination of their physical properties (Table 1) which are important for possibility of their use as a gemstone.

T a b l e 1.

The results of physical properties testing.

Property	Units	Method SRPS	Jasper	Chalcedony
Apparent density	g/cm^3	B.B8.032	2.460	2.470
Real density	g/cm^3	B.B8.032	2.705	2.675
Porosity	%	B.B8.032	9.06	7.67
Water absorption	%	B.B8.010	0.85	1.70
Mohs hardness	–	–	6.5 – 7	6.5 – 7

Experimental processing

The usual processing type for this type of mineralizations is tumbling in a mass production or manual rounding on an abrasive wheel. The resulting shapes are baroque pieces and cabochons, respectively, used for setting into various types of jewellery pieces – pendants, bracelets, necklaces etc. Smaller parts are usually turned into so-called chips pieces, and used as beads. The evaluation of a gemstone raw material and its suitability for jewellery production is best given after the experimental processing into cabochons or other gem types. The results of the experimental processing of the raw material from Gaj-Lazine locality are presented in Fig. 9.

Fig. 9. Baroque gems obtained by the experimental processing of various gemstone types from Gaj-Lazine deposit:
a. red jasper with agate amygdules;
b. buff-brown jasper with chalcedony veins;
c. "moss" chalcedony;
d. chalcedony vein.

GENETIC ASPECT

Gaj-Lazine deposit is of hydrothermal origin. In deposit type division by Lefebure et al. [15], it belongs to Hydrothermal silica veins ("IO7") type and Hydrothermal jasper veins ("Q05") type. Almost all the other silica gemstone deposits found in the Vardar zone of central Serbia are of the same type. They are, together with near-by talc-magnesite ("M07") and chrysotile-asbestos ("M06") deposits Stragari, Vučkovica, Brđani, Nevade and many others across Vardar zone of Serbia [16], part of the same magmatic-hydrothermal complex generic process, connected to Neogene calc-alkaline magmatic activity in the supra-subduction zone and situated in the listwenitized serpentinite of the obducted Vardar zone ophiolitic sequence of late Mesozoic age [3].

Geologic setting on the regional scale is the stage of the complex geotectonic evolution of the Vardar zone [17]. In the closure of the Tethys Ocean through collision and thrusting of ophiolite sequence, the environment tectonically permeable for circulation of hydrothermal fluids was formed. Tertiary syncollisional to postcollisional magmatic activity of the Vardar zone, predominantly of calc-alkaline character, as a consequence of subduction processes occurred during the extensional phases. However, as extensional phases within the predominantly collisional setting were short-lived, huge portions of molten magma did not reach the field surface. In this setting were formed hidden plutons which caused hydrothermal activity in the overlying rock formations.

Ore controls are the open spaces and other permeable zones open to silica-bearing solutions. Serpentine-hosted veins are associated with major faults related to crustal extension which control the ascent of hydrothermal fluids to suitable sites for silica deposition, in this case most probably due to changes in pressure, temperature and to neutralization of the colloid electrical charge.

Most authors exploring hydrothermal silica agree on the fact that relations between crypto- to microcrystalline silica (chalcedony) and crystalline silica (quartz) precipitated from hydrothermal solutions depend on relations of silica saturation, temperature and pressure ([18] and references therein). As each silica vein has different shares of the present gemstone types, it is evident that an intensely fractured serpentinite of the ophiolite sequence provides an extremely changeable host environment, where some veins formed within the closed system and the other within an open one.

The presence of ultrapotassic dikes, which are also a host to hydrothermal silica veins, enables at least a relative determination of mineralization age. According to Cvetković et al. [13], the age of the closest ultrapotassic rocks occurrence is 31.87 ± 1.23 Ma (minette of Rudnik volcanic complex which is situated some 15 km to the west). Since these also contain hydrothermal silica veins, it can be assumed that the age of hydrothermal activity, and therefore silica mineralization, is under 30 Ma. A proposed mechanism of formation of Gaj-Lazine deposit includes a hidden pluton, needed to initiate the hydrothermal circulation in this area. Such pluton presence was hypothesized to be present between the Rudnik Mt. and Stragari area, and confirmed through drillings within the Rudnik Pb-Zn mine. The isotopic age of this pluton of 23 Ma [19] fits perfectly a given hypothesis. Quartzlatite dykes present both in Rudnik Mt. and Stragari area have formed within the same magmatic phase as this pluton.

Tentative genetic model based on field-observed and here presented data presumes three main phases of formation:

a. magnesite, formed from the gel, together with silica in the form of chalcedony;

b. jasper, both buff-brown and red (including mottled red-buff); and

c. chalcedony, with equant crystalline quartz.

Mutual relations between magnesite and jasper are still not clear enough, since we haven't observed their direct contact in this deposit until now. Microscopic analysis shall be done for this purpose

DISCUSSION AND CONCLUSION

The variety of the gemstone types in this locality and also the patency due to a deep erosional level of this deposit make it the most interesting locality in central Serbia for examination of the genetic processes and establishing the genetic model, not only for this particular deposit, but also for all the conjugate deposits in the Vardar zone ophiolitic sequence of central Serbia: Ugljarevac, Ramaća, Dobrača, Vučkovica, Boblija, Srezojevci, Sirča, Teočin and others.

In order to establish the mutual relations of the various silica types and magnesite and their order of formation with more precision, further lab examinations of the representative samples shall be performed.

Economic potentiality of this deposit regarding silica gemstones, especially jasper and chalcedony is significant, due to their satisfying quality and their presence as thickened veins and amygdules. Jasper colour span is narrow, but its inferred reserves are quite enough for exploitation. Chalcedony appears as thickened veins more rarely than jasper. Its appearance as skeletal stockworks is more often and this type of mineralization can not be used for jewellery making. The form of quartz present in this occurrence is not regarded as gemstone because it can not be separately processed. When processed together with chalcedony base, it is market-named "drusy quartz". It is usually fancy-coloured (colouring of the chalcedony base) and given the metallic sheen (quartz crystals are sprayed with patented metal mixtures).

Jasper and chalcedony samples from Gaj-Lazine have the average values of density, porosity, water absorption and Mohs hardness for this type of material.

Experimental processing has shown that the resulting baroque pieces have quite satisfying quality, however, due to the regular occurrence of hidden cracks in all silica gemstone types formed from gel (as are chalcedony and jasper), it is necessary to perform the visual inspection and hand-picking of pieces suitable for processing to avoid the losses caused by the processing of unsuitable raw material.

Significant amounts of jasper and its quality give a potential economic value to this locality, although jasper is generally considered a lower value gemstone named "semi-precious" or "ornamental". Other present gemstone types (colourless chalcedony, quartz and silicified magnesite) have lower economic importance due to their less abundant presence.

REFERENCES

[1] Pejčić M., Seke L.: Report on explorations of opal and other semi-precious gemstones in Ramaća environs during 1981, *Fond Instituta za istraživanje mineralnih sirovina*, p. 38 (1982).

[2] Pejčić M., Seke L., Milenković M.: Report on explorations of semi-precious gemstones in Ramaća environs during 1983*, Fond Instituta za istraživanje mineralnih sirovina*, 1984, p. 36.

[3] Marčeta L.: *Geological characteristics of gemstone occurrences in Šumadija district*, Unpublished Magisterium thesis, Faculty of Mining and Geology, 2005, p. 109.

[4] Vukašinović S.: *Anomalous geomagnetic field and geology of the Republic of Serbia*, Geoinstitut, 2005, p.126.

[5] Robertson A., Karamata S., Šarić K.: Overview of ophiolites and related units in the Late Plaeozoic–Early Cenozoic magmatic and tectonic development of Tethys in the northern part of the Balkan region. *Lithos*, **108**, 1–4, pp. 1–36 (2009).

[6] Cvetković V., Knežević V., Pécskay Z.: Tertiary igneous formations of the Dinarides, Vardar zone and adjacent regions: from recognition to petrogenetic implications. In: *Geology and Metallogeny of the Dinarides and the Vardar zone*. The Academy of Sciences and Arts of the Republic of Srpska, Banja Luka–Serbian Sarajevo, 2000, p. 245–252.

[7] Antonović A., Vasković N.: Occurrences of listwenitization in the central part of the Balkan Peninsula (Bosnia, Serbia, Macedonia, Greece). *Radovi Geoinstituta*, **27**, pp. 303–331 (1992).

[8] Protić D., Tomić V., Timotijević S.: Geochemical significance of serpentinite in formation of thermal waters of Gornja Trepča (environs of Čačak, Serbia). *Geološki anali Balkanskog poluostrva*, **62**, pp. 367–374 (1998).

[9] Yee, N., Phoenix, V. R., Konhauser, K. O., Benning, L. G. and Ferris, F. G.: The effect of cyanobacteria on silica precipitation at neutral pH: implications for bacterial silicification in geothermal hot springs. *Chemical Geology*, **199**, pp. 83–90 (2003).

[10] Potapov V. V.: Formation of solid deposits of amorphous silica in a flow of hydrothermal solution. *Glass Physics and Chemistry*, **30**, 1, pp. 82–89 (2004).

[11] Fallic A. E., Ilić M., Russel M. J.: A stable isotope study of the magnesite deposits associated with the Alpine-type ultamafic rocks of Yugoslavia. *Economic Geology*, **86**, pp. 847–861 (1991).

[12] Işik, E. Ö., Osamu, M., Fazli, Ç.: Genesis of hydrothermal stock-work type magnesite deposits associated with ophiolite complexes in the Kütahya-Eskişehir region, Turkey. *Neues Jahrbuch für Mineralogie – Abhandlungen*, **181**, 2, pp. 191–205 (2005).

[13] Cvetković V., Prelević D., Downes H., Jovanović M., Vaselli O., Pécskay Z.: Origin and geodynamic significance of Tertiary postcollisional basaltic magmatism in Serbia (central Balkan Peninsula). *Lithos*, **73**, pp. 161–186 (2004).

[14] Ilić M.: *Methods of exploration of non-metallic mineral resources,* Mining and geology faculty, Belgrade University, 2003, p. 250.

[15] Lefebure, D. V., Alldrick, D. J. and Simandl, G. J.: Mineral Deposit Profile Tables – Listed by Deposit Group and Lithological Affinities. B. C. Ministry of Energy, Mines and Petroleum Resources, Open File, 1995–8.

[16] Janković S.: *Ore deposits of Serbia*, Republički društveni fond za geološka istraživanja, 1990, p. 760.

[17] Schefer S., Cvetković V., Fügenschuh B., Kounov A., Ovtcharova M., Schaltegger U. and Schmid S.: Cenozoic granitoids in the Dinarides of southern Serbia: age of intrusion, isotope geochemistry, exhumation history and significance for the geodynamic evolution of the Balkan Peninsula. *International Journal of Earth Sciences*, **100**, pp 1181–1206 (2011).

[18] Kurešević L., Dević S.: Gemstone silica veins in Kremenjača volcanic rocks (Serbia). *Geologica Macedonica*, **28**. 1, 33–38 (2014).

[19] Cvetković V.: Volcanologic, geochronometric and petrochemical study of Rudnik volcanic-plutonic massif, Unpublished study, Faculty of Mining and Geology, 2009, p. 48.

Р е з и м е

СИЛИКАТНИ ЖИЦИ ВО ЛОКАЛИТЕТОТ ГАЈ-ЛАЗИНЕ (ЦЕНТРАЛНА СРБИЈА) КАКО СКАПОЦЕН КАМЕН

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Клучни зборови: бесценет камен; силикатни жици; јаспис; калцедон, вардарска зона

Наоѓалиштето на бесценет камен Гај-Лазине се наоѓа во централна Србија, 3,5 km југоисточно од Страгари. Доминантен тип на бесценет камен се непровидниот калцедон–јаспис и безбоен калцедон. Споредно се присутни кристален кварц и карбонатни минерали. Сите тие се појавуваат како единични жици, а почесто кака сложени штокверци, кои ги заполнуваат пукнатините во серпентинитот од офиолитската секвенција на вардарската зона. Генетските процеси на оваа појава се поврзани со неогената калко-алкална магматска активност во вардарската зона и со хидротермалната активност предизвикана од неа. Економското значење на ова наоѓалиште на бесценет камен е високо за јасписот и калцедонот, но мало за другите присутни видови бесценети камења, поради нивната мала застапеност.