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# GEOLOGY OF GEMSTONE DEPOSIT UGLJAREVAC (CENTRAL SERBIA) AND CONTRIBUTIONS TO GENETIC MODEL

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A b s t r a c t: Silica gemstone deposit Ugljarevac is situated within the ophiolite sequence of the Vardar zone central deep fault. Genetic processes of this deposit are connected to the Neogene calc-alkaline magmatic activity of the Vardar zone and hydrothermal activity triggered by it. Based on surface occurrences of listwenitized serpentinite containing silica mineralization, it can be inferred that the ore body is an elongated oval stock. Within the stock of hydrothermally altered serpentinite, the gemstone mineralization occurs as veins, stockworks and irregular bodies. Present gemstone types include chalcedony varieties (jasper, colourless and greenish chalcedony, carnelian and sard) and opal (opalized serpentinite). Homogenous pieces are very rare. Most often, various types of silica are intimately intermixed and combined. The mineralization has formed in two distinct hydrothermal phases, apparently in close time succession. Jasper and coloured chalcedony (and rare magnesite) are the products of the first phase of hydrothermal activity, while the colourless chalcedony is formed in the second phase. Newly discovered type of silica vein with central-symmetrical parallel banding gives new contributions to a genetic model, proving the precipitation process and its products are unpredictably changeable, heterogeneous and depending on the evolution of the local environment physico-chemical conditions, notably the contents of impurities and system's openness degree.

**Key words**: gemstone; silica veins; jasper; chalcedony; central Serbia

## INTRODUCTION

Silica gemstone deposit Ugljarevac is situated within the ophiolite sequence of the central deep fault of the Vardar zone. It is one of the eight thus far discovered of the same type within the serpentinite belt more or less continually trending from Stragari in the north to Vučkovica in the south. Deposit formation process is connected to hydrothermal activity accompanying the magmatic activity in this area [1].

The deposit is situated 4.5 km SSE from Stragari, near the road Stragari–Bare–Kragujevac (Figure 1). The area of listwenitized serpentinite containing gemstone mineralization is around 1 km long, trending north-south. A small portion has been examined, since the mineralization is under a thick soil layer covered with forest.

Previous paper [2] includes the results of the petrochemical characterization of the gemstone types as part of possibility of use assessment.


**Fig. 1.** Geographical map of Ugljarevac locality. Inset – position in Serbia

## GEOLOGICAL SETTING

Gemstone deposit is situated within the serpentinized masses of the Vardar ocean floor ultramafic rocks, obducted upon its closure. These masses have tectonic contacts (Figure 2) with Upper Cretaceous sediments (Turonian-Senonian) of the facies designated in Brković et al. [3] as "Jarmenovac development" to the west. To the east, they have tectonic contacts with various sediments of Cretaceous age (mostly Barremian-Aptian and Turonian-Senonian) designated in [3] as "Stragari development"; and with diabase-chert formation of Jurassic age. The tectonic setting of this locality is very complicated due to intense fracturing and thrusting during the closure of the Vardar ocean. Gemstone bodies have been formed by circulation of hydrothermal fluids through intricate tectonic lines within serpentinite mass, since these were the most favourable circulatory conduits for hydrothermal fluids.

The area of listwenitized serpentinite containning gemstone mineralization is around 1 km long, trending north-south, most probably as an elongated oval stock [4] (Figure 3). Within this ore body, the mineralization is present as veins, stockworks and irregular bodies. These can be observed at the field surface, where erosion has cut into the forested area. All veins and irregular bodies are fractured due to continual tectonic movements.

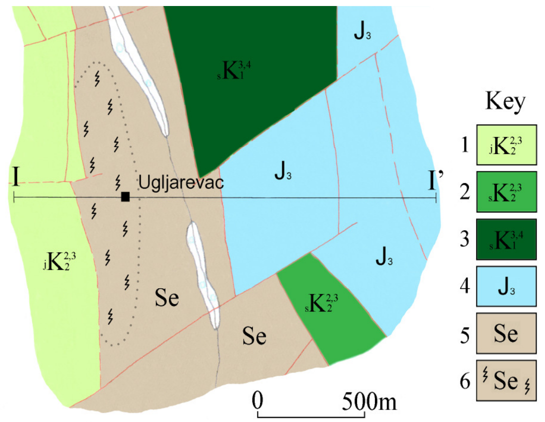


**Fig. 2.** Geologic map of deposit area.
Key: **1.** limestone of Turonian-Senonian age ("Jarmenovac development"), **2.** alevrolite, marly limestone of Turonian-Senonian age ("Stragari development"), **3.** sandstone, alevrolite, limestone of Barremian-Aptian age ("Stragari development"), **4.** Jurassic diabase-chert formation, **5.** serpentinite, **6.** listwenitized serpentinite; according to [5], modified

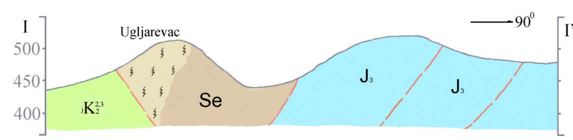


**Fig. 3.** Geologic profile (I-I' from Figure 2).
Key and horizontal scale as in Figure 2. Vertical scale doubled for discernment

## GEMSTONE VARIETIES

Gemstone types present in the deposit are predominantly of silica composition: chalcedony varieties (jasper, colourless and greenish chalcedony, sard and carnelian) and opal. Mineralogically homogenous specimens are rare, if not completely absent. Various types of silica are intermixed (jasper and colourless chalcedony, jasper and opal, opal and colourless chalcedony) as veins, veinlets, stockworks, irregular bodies and even breccias. Magnesite is quite rare, compared to other deposits of this type in the area (e.g. [6]). Mentioned gemstone bodies represent infillings of tectonic lines (fractures, joints, slickensides) within the altered serpentinite mass transformed into opalized, silicified, carbonated, argillaceous mass via hydrothermal activity. It is composed of antigorite, chrysotile, calcite, dolomite, magnesite, silica, clay (montmorillonite type) and oxidized metallic minerals. Majority of silica gemstone veins dip 50 to 75° toward SE.

Opal in this deposit, as in all the other deposits of this type in Stragari-Vučkovica belt, is represented by plain opal, formed by opalization of serpentinite [7]. It forms silica veins' walls. At the field surface, it appears as cracked chunks impregnated with chalcedony and limonite veins, most often green in colour (Figure 4). Pieces range from few cm to 10 cm in size. More rare are pieces buff, brown, off-white or red in colour. Material found deeper under surface is less cracked, appearing as lenses and veins up to 50 cm thick. Opal reserves of $C_2$ class are estimated to 500 t [4]. Technical properties of this material enable its use for very limited range production of decorative items due to cracking.

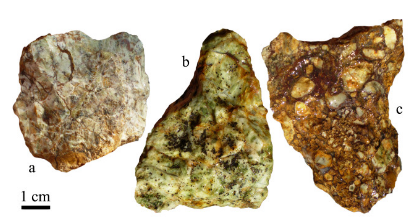


**Fig. 4.** Types of opal:
**a.** off-white to buff; **b.** green; **c.** opal breccia

Chalcedony appears at the field surface as small pieces and lower under surface as composite veins 1–10 cm thick and stockworks pervading the opalized serpentinite zones. Chalcedony mass appearance is very changeable regarding colour and translucency (Figure 5). The zones of colourless, white, red, grey, pink and greenish silica mass interchange gradually and also with zones of opaque silica (jasper). Manganese oxide dendritic aggregates are sometimes present in it.

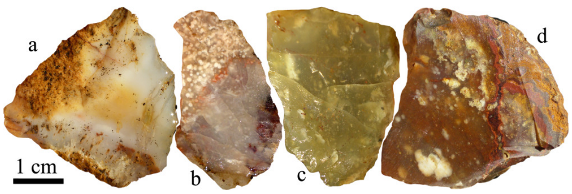


**Fig. 5.** Types of first-phase chalcedony:
**a.** varicoloured, semi-translucent; **b.** varicoloured with a macroscopically visible spherulitic zone; **c.** greenish; **d.** reddish semi-translucent

The second phase chalcedony most often appears as tiny colourless veinlets in the first-phase varieties (in jasper, Figure 7b, or first-phase chalcedony, Figure 5a, right edge) or in opal. It also forms individual veins up to few cm thick, with or without a central void and botryoidal free surfaces (Figure 6). These veins sometimes form agate (Fig. 6c). Central void of a geode is often lined with druses of tiny quartz crystals.

As a gemstone, this material is considered of high quality, containing rare cracks and with excellent visual characteristics. Quality of the raw material enables for simple mechanical processing into various cab forms, beads and decorative items, with high-gloss finish.

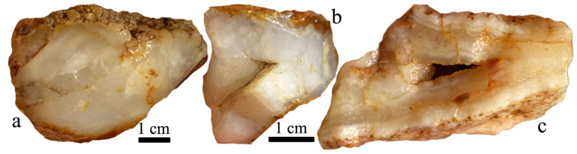


**Fig. 6.** Types of colourless chalcedony veins:
**a**. homogeneous vein; **b.** vein with the central void; **c.** agate

Chalcedony reserves of $C_2$ class are estimated to 5000 t [4], however, this amount also includes reserves of jasper, since the cited authors did not differentiate chalcedony and jasper as separate gemstone types.

Jasper, an opaque variety of chalcedony, appears at the field surface as pieces up to 20 cm long, and lower under surface as veins 2–20 cm thick pervaded by the second-phase chalcedony veinlets. Jasper veins often "evolve" into lenses in fractured, opalized and argilized serpentinite host rock. Colour ranges from buff to brown and almost black, and red to burgundy (Figure 7).


**Fig. 7.** Types of jasper:
**a.** burgundy-white with Liesegang rings; **b.** buff-brown; **c.** red-burgundy; **d.** burgundy with agate lenses

As a gemstone, this material is considered to be of favourable quality, although cracks are sometimes present. Sound pieces enable for simple mechanical processing into various cab forms, beads and decorative items, with high-gloss finish.

## EXPERIMENTAL SECTION

The results of the performed XRD, XRF and microscopic laboratory examinations serve as a valuable aid in defining the genetic process.

### *Microscopic examinations*

Microscopic examinations and photomicrograph capturing are performed in stone and aggregate laboratory of the Institute for Materials Testing in Belgrade. These are two-fold. The first part is performed on stereo-microscope type ZEISS Stemi 2000-C with digital camera AxioCam ERc 5s (Figures 8, 9, 10B). The second part of microscopic analyses is performed on microscopic thin sections with polarizing microscope Ernst Leitz, model RP 48 (Figures 11–16).

Figure 8 shows the second-phase colourless chalcedony infilling the cracks within the buff-brown jasper in two perpendicular directions. Figure 9 shows the typical view of the peripheral parts of a jasper vein. Jasper silica mass has pervaded the joint walls ("m" in Figure 9), made up of opalized serpentinite, now greenish opal ("OS" in Figure 9). Jasper vein that formed has been fractured due to the regional tectonic movements (observed in upper right part of the figure). As in Figure 8, the second-phase colourless chalcedony (Ch) pervaded the jasper parts and the spaces generated between the opalized walls and the jasper vein (lower parts of the Figure 9). Figures 8 and 9 show two adjacent parts of the same jasper vein, few centimetres apart.

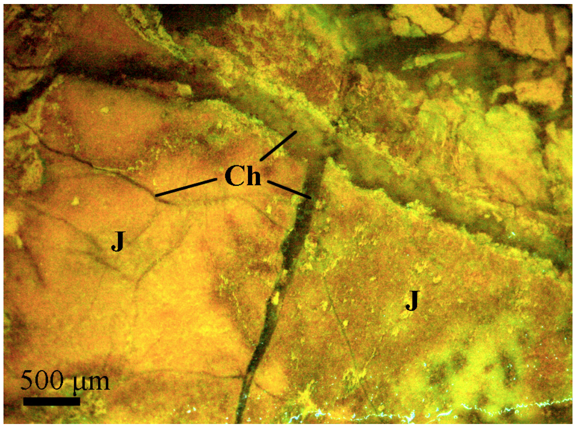


**Fig. 8.** Jasper pervaded by second-phase chalcedony veinlets (Key: J – jasper, Ch – chalcedony)

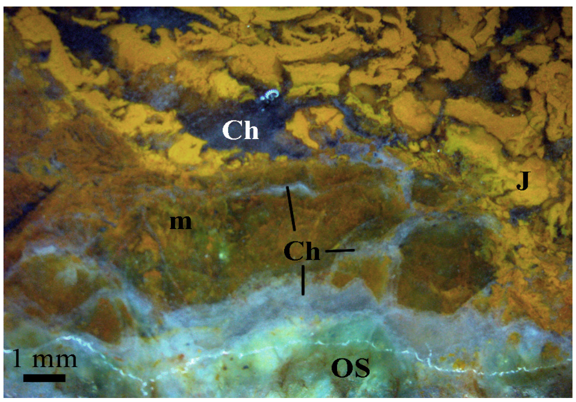


**Fig. 9.** Peripheral part of the jasper vein (Key: J – jasper, Ch – chalcedony, OS – opalized serpentinite, m – intimately intermixed zones of jasper, chalcedony and opalized serpentinite)

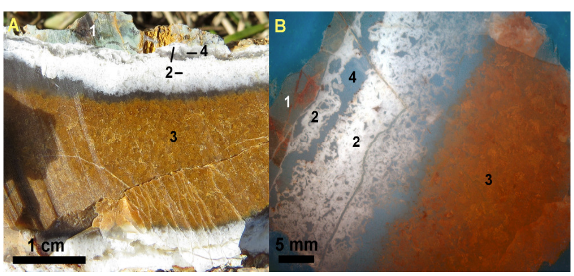


**Fig. 10.** Sample of the examined silica vein. A. macroview. B. binocular microscope view of the thin section of A (blue base pad is used for better discernment). Key: **1**. opalized serpentinite host rock; **2.** chalcedony with white magnesite zone; **3.** chalcedony with Fe-oxihydroxide; **4.** slightly younger chalcedony veinlet

Figure 10 shows the complex silica vein with symmetrical zoning. This type of vein has been discovered for the first time in 2016. The central part of the vein is made up of brown jasper, 12–23 mm thick. Toward the vein boundaries, both directions, it is interchanged by a thin interbed of colourless chalcedony (1–4 mm, up to 6 mm where white layer is absent) and then white chalcedony (1–5 mm, including a thin colourless chalcedony veinlet) at the peripheral part of the vein. Microscopic examination of this vein is performed, aiming to define the differences between the three silica varieties – buff-brown jasper, colourless silica and white silica and contribute to shaping the genetic model of this deposit type.

Properties of the raw material reflected through the discovered vein, important for shaping the genetic model: the vein and all of its parts have been formed penecontemporaneous, i.e. contemporaneous, save the thin chalcedony veinlet ("4" in Figure 10), which has been injected somewhat later, into still unsolidified silica mass. The vein consists of subparallel bands, all of which are composed of silica, containing different impurities. Bands trend through the vein approximately parallel and central-symmetrical in regard to the walls of the fracture that the silica fluid has filled.

In Figure 10, zone "1" is the opalized host rock (serpentinite). Relicts of the original minerals can be only assumed, since it is completely permeated and replaced by silica (Figures 11 and 12). Metasomatic processes of the primary, i.e. secondary rock (the first being hartzburgite, the latter serpentinite formed via its regional weathering) due to hydrothermal fluid activity have been described in [7]. This zone makes up the fracture walls filled by silica vein.

Zone marked "2" is the nearest to the host rock wall. It is made up of chalcedony clouded by variable content of cryptocrystalline magnesite. Chalcedony appears as very small fibres (i.e. tiny quartz crystals stacked along c-axes), with length up to 0.02 mm. No typical spherulites can be observed. Small, irregular chalcedony aggregates carry cryptocrystalline magnesite accumulations of irregular form along the common rim. Magnesite is macroscopically pure white in colour. Chalcedony aggregates carrying magnesite are visibly segregated in regard to more pure chalcedony aggregates, which are macroscopically not clouded by magnesite (in Figure 10, compare the white zone "2" and the colourless chalcedony zone in transitional zone from "2" into "3"). Harmonious transition from "2" into "3" (Figures 13 and 14) demonstrates the contemporaneous formation.

As there is segregation of chalcedony with magnesite in zone "2", so is there segregation of chalcedony clouded by impurities of iron-oxihydroxides (limonite, hydrated hematite) into the zone "3". Macroscopically, this silica type is named jasper. Its buff-brown colour is typical for all deposits of this same type in central Serbia [1]. Under polarizing microscope, this zone appears similar to zone "2", except that here iron-oxihydroxides give the typical reddish-brown hue under parallel polarizers (Figure 13). Chalcedony fibres are predominantly very small, reaching the length of maximum 0.02 mm (Figure 14). Ferruginous matter is fine-grained, forming small aggregations of irregularly shaped particles. Former examinations [4] have shown the primary minerals that gave oxihydroxides through oxidation process to be pyrite and marcasite, however, their relics have not been found in this specimen.

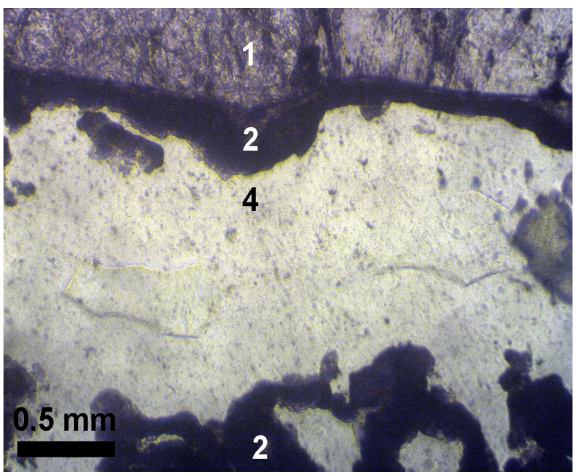


**Fig. 11.** Photomicrograph of the vein part including serpentinite **(1),** magnesite-rich chalcedony zone **(2)** and younger chalcedony veinlet **(4)**. Parallel polarizers

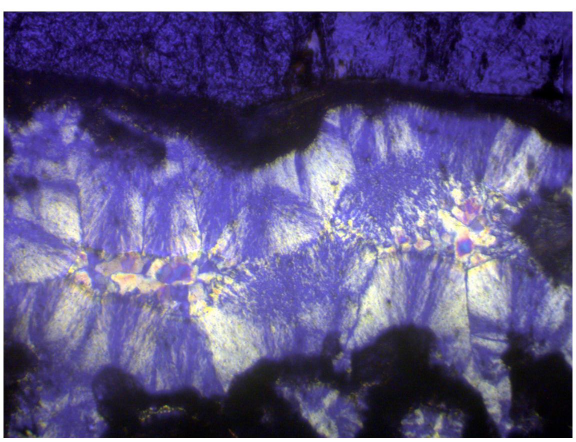

**Fig. 12.** Photomicrograph, same as Figure 11. Crossed polarizers

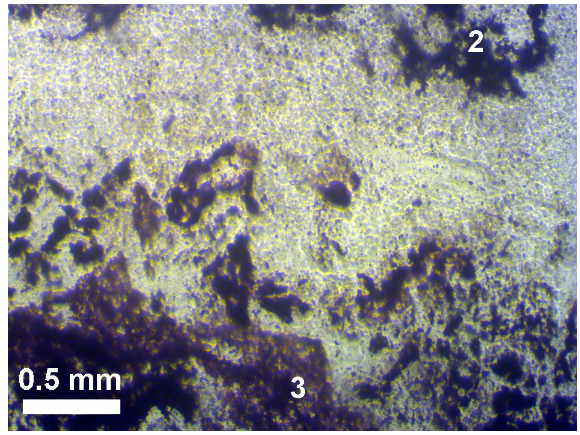


**Fig. 13.** Photomicrograph of the vein part including Mg-rich chalcedony **(2),** Fe-rich chalcedony **(3)** and a transitional zone of purer chalcedony between them. Parallel polarizers.

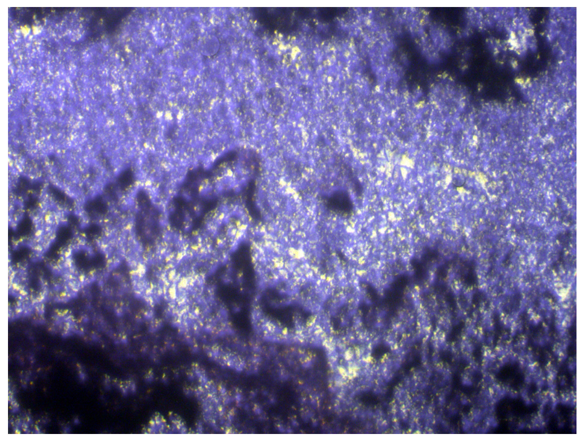

**Fig. 14.** Photomicrograph, same as in Figure 13. Crossed polarizers.

Into the magnesite-rich zone (2), a tiny veinlet of colourless chalcedony has been intruded with a certain delay ("4" in Figures 10, 11, 12). Veinlet is made up of chalcedony with longer fibres forming radially-divergent bundles or aggregates, i.e. spherulites and half-spherulites seeded on magnesite aggregates (Figure 12). As the degree of silica oversaturation in the colloid and content of impurities such as iron decrease, the longer chalcedony fibres form [8]. Here chalcedony fibres' length reaches maximum 0.1 mm. Spherulitic cross can be clearly observed (Figure 15). With aid of $\lambda$-compensator, we have determined this to be the length-fast chalcedony (Figure 16).

Within the zone "4", the process of fluid evolution is completed by colloid recurrence to solution [9]. This is testified by formation of the granular quartz at the end of precipitation process, lining the walls of cavities – tiny geodes within the chalcedony veinlet "4" (such as those shown in Figure 12, centre left and centre right). These cavities can also be formed by gel shrinking during solidification process.

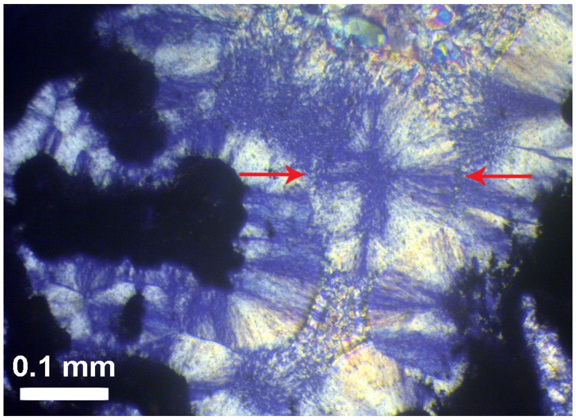


**Fig. 15.** Photomicrograph of chalcedony veinlet ("4" in Figures 10, 11, 12) with a visible chalcedony spherulite (arrows) showing a typical spherulitic cross. Crossed polarizers.

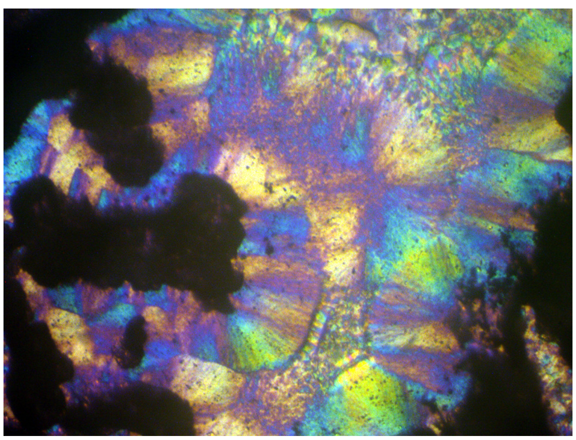

**Fig. 16.** Photomicrograph, same as Figure 15, under λ-compensator, revealing chalcedony type to be length-fast. Crossed polarizers

*Energy-dispersive X-ray fluorescent analysis*

XRF analysis is performed in the laboratory for binders, chemistry and mortar of the Institute for Materials Testing in Belgrade. Operating conditions: spectrometer Oxford ED 2000 with Ag target anode, Si(Li) detector and SMART digital pulse processor, excitation time 200 s, resolution 170–185 eV, voltage 5–50 kV. The sample of greenish chalcedony along with the colourless chalcedony is analyzed, aiming to establish the contents of possible colouring sources in the first-mentioned. Presence of the greenish chalcedony with characteristic olive-green hue has been noticed in only one other deposit of the same type in this area (Dobrača; [1]), forming veins whose connection to other silica gemstone varieties still isn't established due to its rarity, however, its potentiality for jewellery production is much higher than other varieties. The results of the XRF analysis are presented in Table 1.

Table 1

*Results of XRF analysis of two chalcedony types.*

| Substance | Contents in colourless chalcedony | Contents in greenish chalcedony | Substance | Contents in colourless chalcedony | Contents in greenish chalcedony |
|---|---|---|---|---|---|
| $Na_2O$ | 935 ppm | 0.00 wt% | S | 896 ppm | 844 ppm |
| MgO | 653 ppm | 916 ppm | Cl | 25 ppm | 24 ppm |
| $Al_2O_3$ | 0.00 wt% | 0.00 wt% | Tl | 6 ppm | 0.08 ppm |
| $SiO_2$ | 94.83 wt% | 94.56 wt% | V | 64 ppm | 126 ppm |
| $P_2O_5$ | 0.25 wt% | 0.32 wt% | Cr | 0.25 wt% | 0.28 wt% |
| $K_2O$ | 205 ppm | 381 ppm | Co | 373 ppm | 394 ppm |
| CaO | 0.34 wt% | 0.40 wt% | Ni | 113 ppm | 89 ppm |
| $TiO_2$ | 0.00 wt% | 28 ppm | Cu | 95 ppm | 94 ppm |
| MnO | 230 ppm | 247 ppm | Zn | 28 ppm | 0.00 wt% |
| $Fe_2O_3$ | 2.87 wt% | 2.43 wt% | Ga | 12 ppm | 0.00 wt% |
| $H_2O$ | 0.77 wt% | 0.94 wt% | Ge | 0.00 wt% | 12 ppm |
| $CO_2$ | 0.28 wt% | 0.71 wt% | As | 9 ppm | 0.00 wt% |
| Pb | 45 ppm | 0.00 wt% | Se | 2 ppm | 7 ppm |
| Bi | 29 ppm | 8 ppm | Br | 15 ppm | 2 ppm |
| Th | 1 ppm | 15 ppm | Rb | 7 ppm | 10 ppm |
| U | 15 ppm | 12 ppm | Sr | 0.5 ppm | 0.00 wt% |
| Nb | 1 ppm | 3 ppm | Ta | 0.00 wt% | 44 ppm |
| Mo | 3 ppm | 4 ppm | W | 5 ppm | 0.00 wt% |
| Ag | 83 ppm | 76 ppm | Hf | 206 ppm | 196 ppm |
| Cd | 0.00 wt% | 5 ppm | Cs | 10 ppm | 6 ppm |
| I | 0.00 wt% | 7 ppm | Ba | 0.00 wt% | 0.00 wt% |
| Sn | 0.00 wt% | 3 ppm | La | 13 ppm | 16 ppm |
| Sb | 10 ppm | 0.00 wt% | Ce | 8 ppm | 0.00 wt% |
| Te | 6 ppm | 0.00 wt% | Pr | 0.00 wt% | 52 ppm |

**Notes:** contents of Y, Zr, Hg, In, I, Nd are not shown – for both samples they are 0.00 wt%. The total iron content is automatically recalculated and presented as $Fe_2O_3$

*X-ray diffraction analysis*

XRD analysis is performed in laboratory of the Institute for Technical Sciences of the Serbian

Academy of Science and Art in Vinča. Patterns are collected using a Philips PW 1050 powder diffractometer with Ni-filtered CuKα radiation (α = 1.5406 Å) and a scintillation detector. Measurements were done at room temperature over the $2\theta$ range from 10º to 70º, with a scanning step width 0.05° and counting time of 3 s per step. Peak matching done via Match! Crystal impact software.

Three samples have been examined – the sample assumed to be silicified magnesite made up of tiny globules; sample of red jasper and a sample of brown jasper, in order to define the percent and relationship between magnesite and silica in the first-mentioned, and, if possible, to determine the presence of Fe-minerals yielding the colouring in the latter two. Results are presented in Figures 17, 18 and 19.

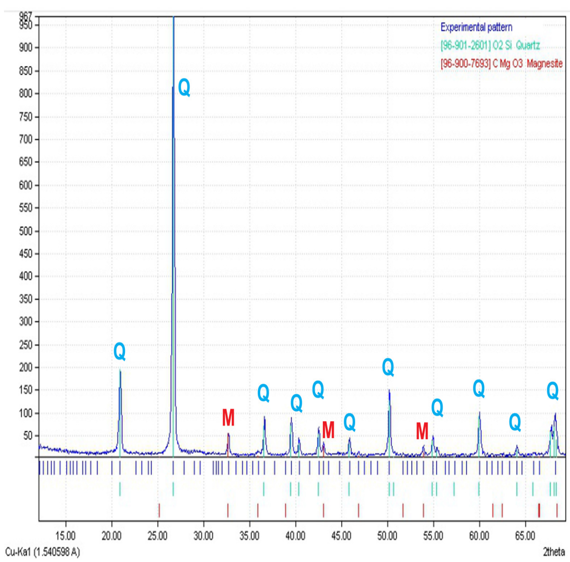


**Fig. 17.** Result of XRD analysis of the sample macroscopically labeled as silicified magnesite (Key: Q – quartz, M – magnesite)

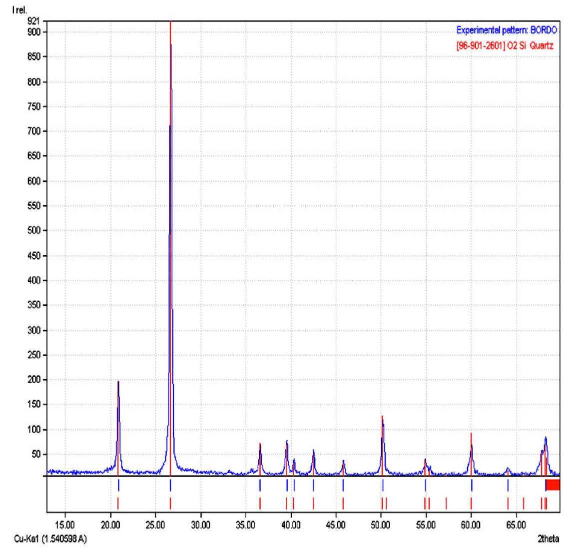


**Fig. 18.** Result of XRD analysis of the red jasper. All peaks belong to quartz

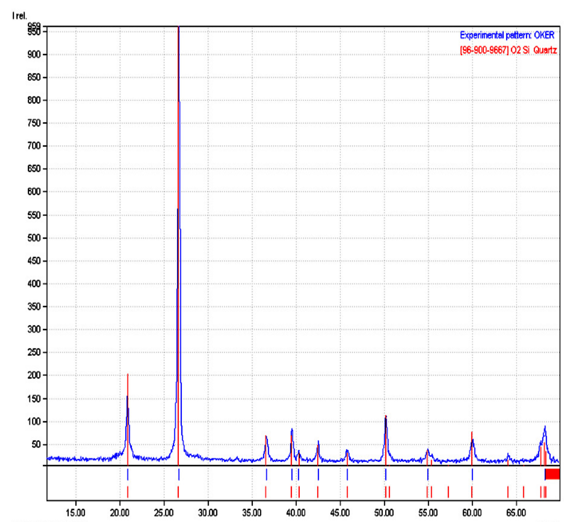


**Fig. 19.** Result of XRD analysis of the brown jasper. All peaks belong to quartz

## GENETIC PROCESS

Genetic process has been described in [1, 7, 6] and, for this specific deposit, in [2]. The deposit is of hydrothermal origin. In deposit type division by Lefebure et al. [10], it belongs to hydrothermal silica veins ("IO7") type and hydrothermal jasper veins ("Q05") type. They are, together with many others across Vardar zone of Serbia [11], 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 [1]. Geologic setting on the regional scale is the stage of the complex geotectonic evolution of the Vardar zone [12].

As magmatic and hydrothermal activities have been multi-phase, along with the hydrothermal opalization, listwenitization and limonitization of serpentinite, jasper and chalcedony have been precipitated in two main phases: first-phase jasper, some magnesite and varicoloured chalcedony, and second-phase colourless chalcedony with central void surfaces lined with equant quartz druses. Since the processes of gel drying and solidification of magnesite and jasper haven't been completed before they were impregnated with the second phase silica (colourless chalcedony veinlets), it can be concluded that the first phase has been followed by a second phase after a relatively short break in hydrothermal circulation activity, most probably caused by the intermittent tectonic activity.

Fluids in both hydrothermal phases have used the same tectonic structures as conduits, and thus, the veins of jasper and chalcedony are most often intermixed. Tectonic activity between the two precipitation phases has caused the cracking of the semi-solidified jasper silica gel (and these cracks have served as spaces for the precipitation of second-phase silica) and also some "rolling" and "rounding" in jasper precipitates, which can also be observed in opal bodies. Liesegang rings macroscopically observed in some samples (Figure 7a) macroscopically testify of the colloid nature of the generic fluid and primary precipitation of silica from a gel/sol, as an amorphous matter.

## DISCUSSION AND CONCLUSION

Results of XRF analyses show that the colourless chalcedony has higher contents of $Na_2O$ and Pb compared to the greenish chalcedony, and the lower contents of MgO, $K_2O$, $TiO_2$, carbonates, V, Cr and Co. These differences give a direction in the further examination of the colour source.

XRD analyses have shown that the sample macroscopically labeled as silicified magnesite has been labeled correctly. Content of $SiO_2$ in the sample is dominant (88.1 %) over magnesite $MgCO_3$ content (11.9 %). Brown and red jasper samples have shown 100% presence of quartz (Figures 18 and 19).

Field examination of the Ugljarevac silica gemstone deposit has shown that the ore body shape can not be determined with high precision due to heavy forestation and a thick soil layer formed from the partly to completely hydrothermally altered serpentinite. The mineralization can be observed in rare places where flood torrents have carved relatively deep gullies. Gemstone silica appears in veins and irregular bodies ranging from below 1 cm to over 7 cm in thickness, and most often 3 to 5 cm. All veins except some rare second-phase chalcedony veins are composite, containing different silica gemstone varieties. Monochromatic silica is rare, with exception of the second-phase chalcedony.

Reserves can only be estimated as category $C_2$, and the gemstone vein characteristics and type (colour, variety) are unpredictably heterogeneous – there are no two pieces of silica mass alike. Based on all examinations, gemstone types jasper and chalcedony can be successfully used for production of decorative items and further geological exploration works in this location would be beneficial.

In regard to genetic model for this deposit type, silica-carbonate hydrothermal veins formed in serpentinite, Potapov et al. [9] propose that silica enters the solution as molecules of silicic acid $H_4SiO_4$ via leaching of host rock alumosilicate minerals by hydrothermal fluids at the depth of 1.0–3.5 km, temperature 250–350ºC and pressure 4.0–20.0 MPa. Ascending through the joint-pore systems in the host rock, temperature and pressure decrease, causing the solution to become oversaturated in respect to amorphous silica. Monomeric silicic acid in water solution is unstable, and silica acid molecules commence to polymerize at the temperature 120–150ºC, forming colloid-sized particles of hydrated silica $nSiO_2 \cdot mH_2O$. Polymerization of silica acid molecules causes concentration of SiOH silanol groups along polymer rims, which dissociate with detachment of $H^+$ and silica polymers particle surface becomes negatively charged, attracting positively charged impurities. Cations or their hydrated polycation complexes get sorbed by negatively charged silica polymers particle surfaces, causing neutralization.

Taking into account evidence both from here observed material and papers cited, we propose that:

– When the ascending solution reaches near-surface field zones, temperature and pressure decrease further, while contemporaneously with polymerization into colloid particles, the fluid encounters metal cations generated in the weathering processes of the original ultramafic rock and its transformation into serpentinite. Potapov et al. [9] also proved that cations, whether they be $Mg^{2+}$ or $Fe^{3+}$, cause silica coagulation and precipitation. Encounter with these cations causes neutralization and precipitation of silica particles, including the impurities present.

– Colloidal particles of hydrated metal cations or their macrocomplexes as flakes (as observed in jasper zones) are sorbed by the negatively charged surface of colloidal silica particles. This is the cause for aggregation of $MgCO_3$ and Fe-oxihydroxides along chalcedony aggregate rims.

– As in the near-by deposit Gaj-Lazine of the same genetic type [13], here it was found that jasper and magnesite have co-precipitated in the same phase of hydrothermal activity. It is a confirmation that in all examined deposits of this genetic type in central Serbia, the order of phases of formation and mineral precipitation are generally the same, with differences in silica varieties stemming from varying contents and mutual relationships of silica, magnesia and Fe-oxihydroxides, which are extremely changeable even in singular localities, and locally impacted by changes in physico-chemical properties of the environment.

– As observed by Lee [8], the smaller chalcedony particles carry more impurities. This is observed also in our examination, both in magnesite- and Fe-rich bands. Vein parts and a veinlet with longer chalcedony bundles are more pure regarding the impurities content, which can be observed both macroscopically and microscopically. This is also valid for the second-phase chalcedony veins.

– Formation of the examined vein in a closed system would enable the gradual evolution of the fluid and a relatively slow solidification. This is the reason for segregation due to cohesive forces which macroscopically resulted in central-symmetrical, parallel-banded appearance. Parental hydrothermal fluid rich in $CO_2$ leached the host serpentinite until it became supersaturated in silica, turned into a colloid, and, after precipitation of excess silica along with impurities, has evolved back into a solution, from which the grainy quartz precipitated.

– The host rock has a significant role in determination of the silica variety to be formed. World agate deposits are known to have formed within volcanic rocks, while here examined deposits are formed exclusively in serpentinite host rock. One so far found deposit of this age, formed due to the same cycle of hydrothermal activity, but in the volcanic host rock [14] contains completely different set of silica varieties, including agate. The abundance of impurities in serpentinite host rock can cause the fast transformation of the molecular solution into a colloid, and, either by ageing of the gel or colloid neutralization due to sorption of cations, chaotic formation of the heterogeneous silica masses.

– Tectonic movements were active throughout the entire genetic cycle in this type of deposits in central Serbia. Untempered tectonic activity continued through the long time span, as testified not only in crack-and-heal fabric evidence in all these deposits, only of somewhat decreased intensity during the formation process of these veins, but also by formation of numerous Neogene lacustrine basins in the entire region [15]. Correlation with deposition of related sediments could aid dating of formation of this deposit type in central Serbia.

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## Р е з и м е

## ГЕОЛОШКИ КАРАКТЕРИСТИКИ НА НАОЃАЛИШТЕТО НА СКАПОЦЕНИ КАМЕЊА УГЉАРЕВАЦ (ЦЕНТРАЛНА СРБИЈА) И ПРИДОНЕС ЗА ГЕНЕТСКИ МОДЕЛ

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**Клучни зборови:** скапоцен камен; силика-жици; јаспис; калцедон; централна Србија

Наоѓалиштето на силикатни скапоцени камења Угљаревац се наоѓа во офиолитската серија на централниот длабок расед 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. Врз основа на површинската појава на лиственизиран серпентинит кој содржи минерализиран силициум диоксид, може да се заклучи дека рудното тело има издолжен овален облик. Во ова тело на хидротермално променет серпентинит, минерализираниот скапоцен камен се појавува во вид на жици, штоквери и неправилни тела. Постојните скашоцени камења претставуваат варијетети на калцедон (јаспис, безбоен калцедон, зеленикав калцедон, карнеол и сардер) и опал (опализиран серпентинит). Хомогени парчиња се многу ретки. Многу често одделните видови силика се меѓусебно тесно измешани и комбинирани.

Минерализацијата е се одвивала во две одделни хидротермални фази, очигледно со кратки временски растојанија. Јасписот и обоениот калцедон (и реткиот магнезит) се настанати во првата фаза на хидротермалната активност, додека безбојниот калцедон е формиран во втората фаза. Новооткриениот вид на силициумска жица со централно-симетрични паралелни ленти придонесува за генетски модел, докажувајќи дека процесот на преципитацијата и нејзини производи е непредвидливо променлив, хетероген и зависи од развојот на физичко-хемиските услови на локалната средина, особено од содржината на нечистотии и степенот на отвореноста на системот.