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PRELIMINARY INVESTIGATIONS OF INCLUSIONS IN SOME TOPAZ CRYSTALS FROM VOLODARSK-VOLYNSKI MASSIF (WESTERN UKRAINE)

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Abstract: The aim of this paper is the gemmological and microthermometric studies of colour types of topazes (colourless, light pink and blue) from pegmatites of the Volodarsk-Volynski massif (Western Ukraine). These topaz crystals are characterized by the presence of numerous solid and fluid inclusions, mainly of a secondary origin as well as the abundance of micropores. The solid inclusions include mainly albite, tourmaline, Fe-bearing mineral phases and probably organic matter. Among the groups of fluid inclusions, secondary two-phase (liquid-vapour) inclusions distinctly dominate over sparse inclusions of a primary origin. The measured values of temperature homogenization (T_h) for selected primary and secondary fluid inclusion assemblages ranges from 350-380°C and 322°C, respectively. Topaz from Volodarsk-Volynski Massif crystallized during hydrothermal stage in medium temperature conditions. The presence of different secondary and pseudosecondary fluid inclusions together with the traces of necking down processes, point that after the crystallization the topaz was also affected by mechanical, thermal and metasomatic processes.

Keywords: topaz, Volodarsk-Volynski, inclusion, homogenization temperature

1. Introduction

Topaz is a gem, which is commonly associated with acid igneous rocks of granite type and pegmatites, as well as pneumometasomatic and hydrothermal veins (e.g. tin-bearing greisens). Commonly it coexists with tourmaline, chrysoberyl, cassiterite, muscovite, fluorite, beryl and quartz (Abdel-Rehim, 1999). Important sources of topaz crystals are found in Brazil, the USA, Mexico, Russia, Pakistan, Madagascar and Australia. In Europe the finest topaz crystals are found in Volodarsk-Volynski, a village near Novograd-Volynski by the river Irsha (western Ukraine), a.k.a. "a stony heart of Ukraine". It is a centre of many precious gems as beryl, topaz, "rock crystal", labradorite and many others. Though this area is better known for gem-quality and interestingly etched yellow-green beryls, the topaz crystals of various colours are considered to be among the most beautiful in the world.

Four topaz samples from Volodarsk-Volynski massif (VVM) were the subject of gemmological studies. The crystals have been investigated by standard optical microscope, scanning electron microscopy (SEM) with backscattered electron (BSE) observations. The main aim of this work was to determine the complex characteristics of the topaz samples coming from VVM. More attention was paid to the presence of solid and fluid inclusions within the crystals.

Ukrainian topaz's promotion has been limited since the majority of papers concerning mainly geology and mineralogy of Volodarsk-Volynski massif, have been published in Russian or Ukrainian. Hence the authors of this paper hope the results of the gemmological studies of the topaz from western Ukraine contribute to the discussion on topaz group.

2. Geological setting

The VVM is the largest block of the anorthosite-rapakivi-granite Korosten Pluton, which is situated at the north-western part of the Ukrainian Shield. The extensive overview of the geology and geochronology of the Korosten complex was presented by Bogdanova et al. (2004). The VVM covers an area of ca. 1250 km^2 that makes up about

10% of the pluton. It is mainly composed of leucocratic large-grained gabbro-anorthosites in which anorthosites occur in the form of local bodies. Gabbro-norites, diabases, and ultrabasic rocks are present only in the periphery of the massif (Kravchenko, 2005).

The VVM was formed during two magmatic episodes at 1789.1 ± 2.0 Ma and between 1761 − 1758 Ma. Rapakivi granites constitute a more abundant group of rocks within the Korosten Pluton surrounding the VVM. Their emplacement took place 1767.4 ± 2.2 Ma ago (Amelin et al., 1994). In the western part of the massif at the contact zone of rapakivi granites with mafic rocks, miarolitic pegmatites occur abundantly. The Volodarsk-Volynski pegmatites are restricted to 0.3 to 1.5 km wide and 22 km long zone of the intrusion. They exhibit diverse mineral content and structures which are probably connected with their neighbour various basic and acid rocks (Koshil at al., 1991). Over 90 minerals, with gem-quality crystals as beryl, topaz, smoky quartz, amethyst, citrine and many others were identified in the miarolitic pegmatites of Volodarsk-Volynski massif.

Topaz forms usually prismatic crystals, of light blue, brownish-yellow and light pink colour. The crystals could appear from transparent to opaque. The presence of various mineral soild inclusions (e.g. fluorite, mica, columbite, albite, quartz) together with numerous fissures within the topaz crystals, is responsible for its non-transparent character (Koshil et al., 1991). Most of the topaz crystals show also etching effects. The Volodarsk-Volynski topaz can reach considerable sizes; the largest one weights 117 kg.

3. Analytical methods

Investigations of four differently coloured varieties of gem-quality topaz (T1, T2, T3, T4; see Table 1 and Figure 1) were carried out at the laboratories of the Department of Mineralogy, Petrography and Geochemistry and the Department of Economy and Mining Geology, Faculty of Geology, Geophysics and Environment Protection, AGH–University of Science and Technology in Kracow, Poland. All the samples were studied macroscopically. Standard optical examinations were carried out with an Olympus BX 51 polarizing microscope. The gemmological determinations of internal features, optical characteristics and luminescence under short- and long-wave radiation were carried out using Schneider equipment. Backscattered Electron (BSE) observations were performed on polished sections coated with carbon using a FEI Quanta 200 FEG scanning electron microscope with an EDS detector. The system was operated with 15 kV accelerating voltage and high – vacuum mode. Fluid inclusion analyses were carried out on double polished wafers (0.2 mm thick). Microthermometric measurements were conducted using a Linkam THMSG600 Geology Heating and Freezing Stage mounted on NIKON ECLIPSE E600 microscope. The measurements were carried out with the rate of 1 °C/min and with accuracy of 0.1 °C. The heating rate was 10°C/min and when approaching Th it was lowered to 0.5°C/min. T1 topaz sample was chosen for detailed fluid inclusion analyses.

4. Results

Specific gravity measured of all the 4 samples range from 3.3 to 3.5 g/cm^3. All crystals contain numerous inclusions of different kinds which affect their transparency. Some internal defects are visible with the naked eye. In T2 and T3 topaz crystals two kinds of solid inclusions were macroscopically observed, i.e. tiny, light creamy - feldspars and bigger, brown coloured - probably Fe-bearing minerals. In T1 topaz some aggregates of mineral crystals with characteristic prismatic or acicular habit can be found. Under immersion-

Table 1. Description and gemmological characteristics of topaz crystals from Volodarsk-Volynski Massif (western Ukraine).

Sample No./Parameter	**T-1**	**T-2**	**T-3**	**T-4**
Linear dimensions [length X width X height] (mm)	44 x 25	25 x 30	32 x 24	22 x 8
Colour	pale pink	colourless	blue	blue
Luminescence	Not observed	Not observed	Not observed	pale blue
Refractive Indexes	1.60-1.64	1.60-1.64	1.61-1.62	1.61-1.63
Pleochroism	Not observed	Not observed	pale blue- greenish	pale blue- greenish
Optical character	+	+	+	+
Specific gravity[g/cm^3]	3,51 zł	3,49 zł	3,30 zł	3,53 zł

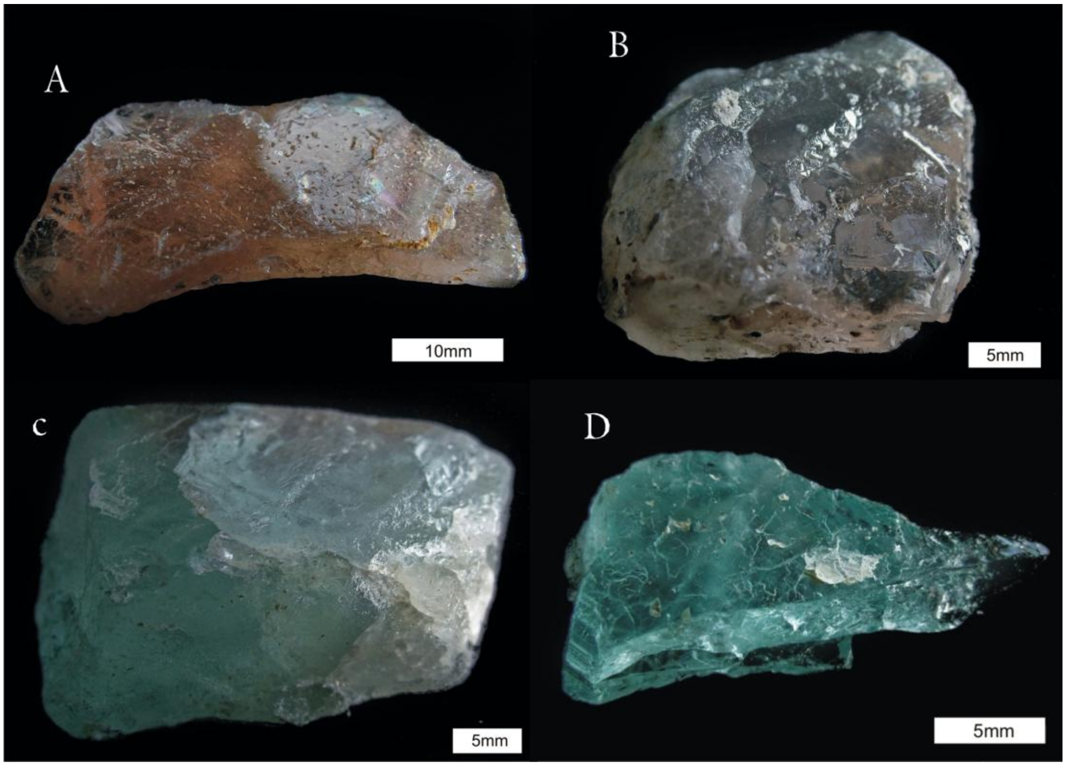

Fig. 1. Colour varieties of topaz crystals from Volodarsk-Volynski Massif (Ukraine); A-pale pink sample T1, B-colourless sample T2, C- blue sample T3, D-blue sample T4.

scope numerous fluid inclusions and growth zones can be identified within the topaz crystals. Under SW and LW UV -light only T4 crystal presents pale blue luminescence. The results cited above are summarized in the table 1.

T1 topaz crystal is rich in fluid inclusions assemblages (FIA) with sizes from 1 μm to 1 mm. Fluid inclusions studies revealed the presence of numerous inclusions of secondary and probably pseudosecondary origin as well as some relatively rare primary fluid inclusions. The distinction of pseudosecondary from secondary fluid inclusions seems difficult in this sample. Additionally, tiny primary inclusions with sizes from 1 to 3 μm are present sporadically within the T1 topaz from VVM (Fig. 2a). Fluid-inclusion's study also revealed the presence of oval in shape, two-phase liquid-vapor (L-V) inclusions with about 10% gas by volume at room temperature.

Moreover, secondary inclusions of the T1 sample, form diversified aggregates (Figs. 2b and c). The smaller oval inclusions are concentrated along craks' planes. Among them there are also bigger more elongated inclusions. The largest inclusions (up to 1mm in length) are usually oval and have characteristic "tails". They are most probably the oldest secondary fluid inclusions, identified within the topaz crystals, which had been changed in necking-down process.

The secondary inclusions are usually two-phase and exhibit a variable proportion of vapour to liquid (V/L). However, vapour phase prevails in most of them (Fig. 2c). Some fluid inclusions are composed mainly of gas (90% per volume) and only 10 wt% of liquid.

The scarcity of primary inclusions together with their small sizes, are both responsible for the difficulties in observation of the phases changes during heating. In order to avoid the effects of stretching, necking, and leaking, two groups of primary fluid inclusions (i.e. I-FIA and II-FIA) with consistent L/V ratios (Ermakov 1972; Roedder 1984, Goldstein and Reynolds 1994) from T1 topaz crystal were chosen for Th measurements. The group of inclusions I-FIA showing < 15% gas by volume at room temperature included eight inclusions with <10 μm in size. The homogenization temperatures revealed Ths from 362 to 380°C for I FIA. The II-FIA consisted of three tiny and spherically-shaped inclusions with <10 μm in size (Fig. 2a) with < 15% gas by volume too. The measured homogenization temperatures (T_h) range from 380 to 385°C for II FIA.

For microthermometric measurements were chosen

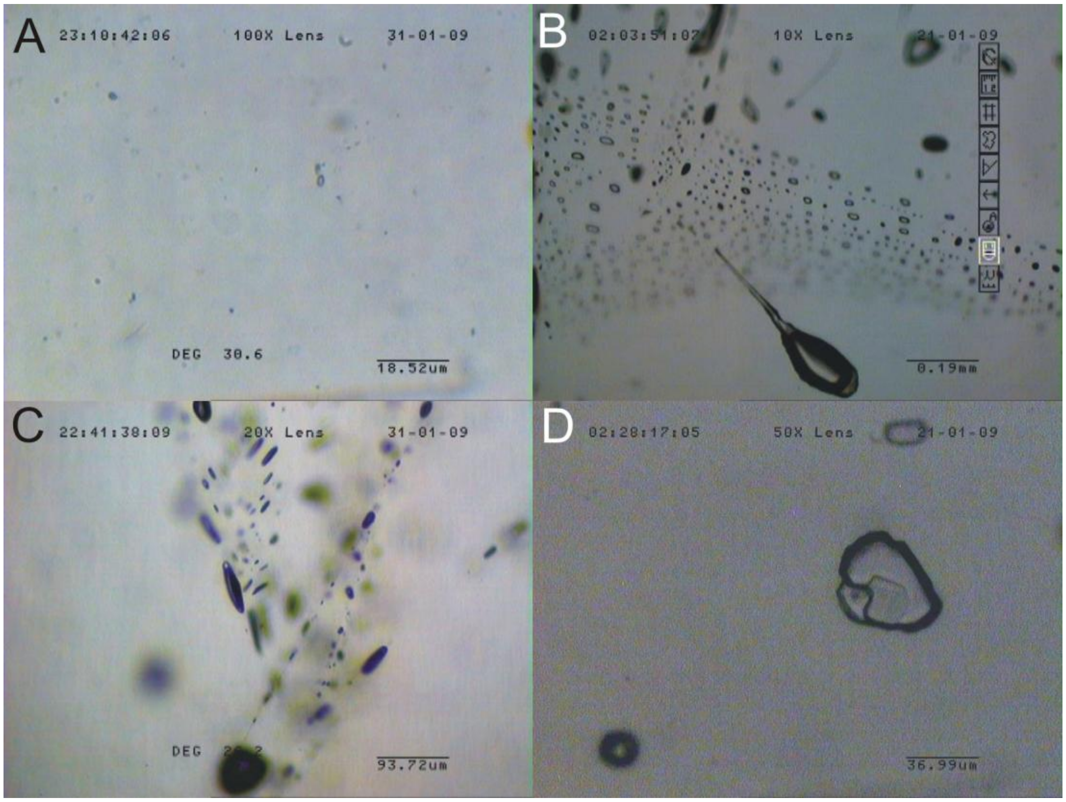

Fig. 2. A- Primary fluid inclusions in T1 topaz sample. B- Abundance of secondary fluid inclusions in T1 topaz sample. C- Fluid inclusions assemblage of secondary origin with the predominance of gas over liquid in T1 topaz sample D- Fluid inclusion with a daughter mineral in T1 topaz sample.

only the groups of secondary inclusion with sizes below 20 μm and which showing consistent L/V ratios (ca. 10% gas phase per volume). The determination of homogenization temperature for these inclusions can be an evidence for their sealing off before phase separation (Goldstein and Reynolds, 1994). Homogenization temperatures measurements revealed constant Th 322 °C for all analysed fluid inclusions.

The T1 topaz from VVM contains also single secondary inclusions with some daughter minerals. The cubic habit of this mineral suggests the possible presence of halite (Fig. 2d). All solid mineral phases occurring in this sample were identified with SEM-EDS. In homogeneous structure of topaz with crystallites from 40-50 μm in length, some micropores and rare mineral phases can be observed. Sodium plagioclase belongs to the most numerous inclusions (Fig. 3). Albite form tabular crystals with ca. 600 μm in length. Very tiny (1 μm long) Ce-bearing phases occur subordinately. In T2 topaz, black and long crystals with characteristic acicular or prismatic habit were observed (Fig. 4), being probably tourmaline. Gübelin and Koivula (1997) had already observed some tourmaline crystals within topaz matrix. Some inclusions filled with a black-brown mineral phase are irregularly scattered in the crystals. This mineral is an iron-rich phase. However, it is very probably that organic substance also appears in these solid aggregates. This could also be the potential cause of its pale blue luminescence under UV radiation.

5. Discussion and Conclusion

Detailed microscopic observations in one sample revealed the occurrence of plentiful secondary fluid inclusions with subordinate primary inclusions. Its secondary fluid inclusions with sizes from 10 μm to 1 mm usually form intersecting inclusion assemblages (FIA). Its fluid-inclusion petrography revealed mainly the presence of two-phase liquid-vapour (L-V) inclusions. Occasionally these inclusions show changeable L/V ratios, i.e. some of them are vapour - rich phase (ca. 90% gas by volume).

Microthermometric measurements on the T1 sample suggest that it was formed during the final pegmatite's crystallization in 362-385 ºC. Then it was probably affected by mechanical, thermal and metasomatic processes. The predominance of gas over liquid phase and variable L/V ratios in secondary inclusions of the topaz indicates that the environment of fluid entrapment could probably had been changed from homegenic to heterogenic, with much amounts of gases. The values of homogenization temperatures measured for secondary and primary inclusions assemblages, which are approximate to each other, suggest that some cracks present in the topaz could be formed during crystallization of the mineral under hydrothermal conditions. However, studies on a bigger number of samples should be done in order to prove the results.

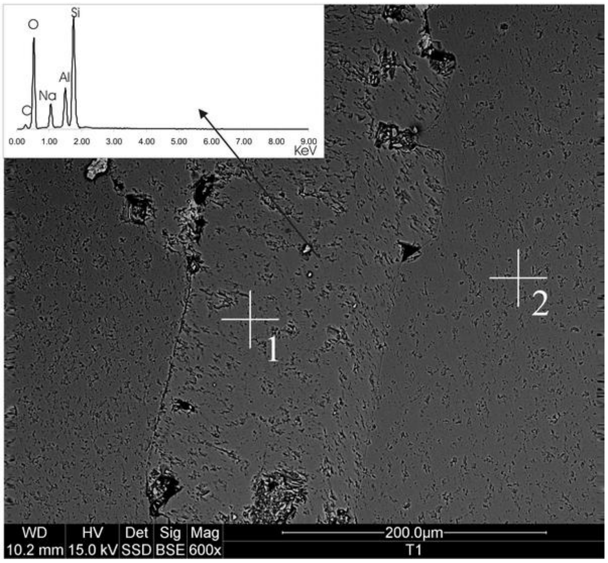

Fig. 3. Solid inclusion of albite (point no 1) in T1 topaz sample (point no 2), BSE image. In the inset is the chemical analysis diagram.

Solid inclusions of albite, tourmaline, Fe-bearing phases were identified within the four topaz crystals from VVM examined during this study. In one crystal potential evidence of organic matter's presence is observed. However, more studies should be done with other methods (e.g. Raman spectrometer), in order to verify this.

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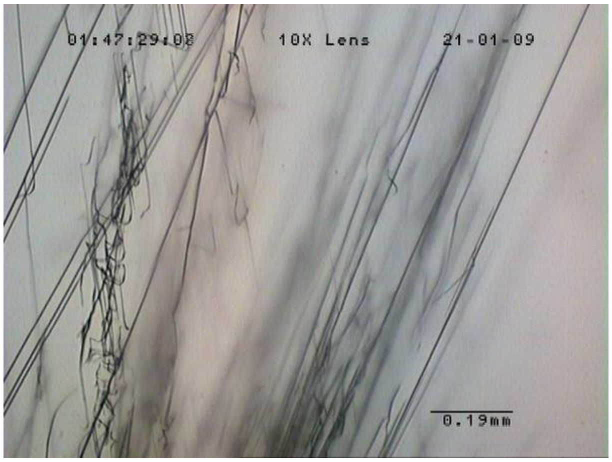

Fig. 4. Solid inclusions (probably of tourmaline) in T2 topaz.

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