

# Raman and optical spectroscopic investigation of gem-quality smoky quartz crystals



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## ABSTRACT

Rough samples and cut stones of smoky quartz from the Slovak Ore Mts. and the Tribeč Mts. were investigated by Raman and optical spectroscopy, electron microprobe and standard gemological techniques. Raman spectra of both cut stones and polished slices comply with already published data on quartz with the most prominent bands at around 463, 205 and 128 cm<sup>-1</sup>. The samples contain two-phase H<sub>2</sub>O-CO<sub>2</sub> fluid inclusions aligned in crystallographically defined planes and also freely scattered. Optical spectra showed high absorption at violet-to-green region on [AlO<sub>4</sub>]<sup>4-</sup> group color centers and perceived brown color results from strong green-to-orange transmission with addition of red. Exposition time to natural irradiation also influences the color tone, hue and saturation. Gemological research on this material has confirmed that it is very suitable for jewelry. Our applied methodology and results documents advantages of Raman and optical spectroscopy in the research of smoky quartz as a gemstone.

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## 1. Introduction

Smoky quartz is a very popular gem variety of quartz. Occurrences of this quartz variety in the Alpine veins are widespread throughout the Alps and Carpathians in the Central Europe. A smoky quartz from this kind of mineralization is well-known and can be used for jewelry purposes. The gem-quality smoky quartz has been produced and mined mainly in Brazil [1–3], USA [4–6], Australia [7], Madagascar [8–12], Namibia [13], Russia [14,15], Scotland [16], Switzerland [17] and Austria [18]. In Slovakia many varieties of quartz including microcrystalline, cryptocrystalline and amorphous phases occur. The smoky quartz was first described from the Slovak Ore Mts. by Zipser [19] from the surroundings of Hnúšťa-Klenovec, Kokava nad Rimavicou and Lehota nad Rimavicou area. Nice smoky quartz occurred in the recesses of forest roads and streams next to Korimovo near Kokava nad Rimavicou. Smoky quartz is present in the Železná brána area near Klenovec but also at the Kohút Hill near Revúca. Its staining approaches morion. The variety of dark smoky quartz to morion

can be found near Detva (crystals more than 10 cm long) and they also occur in Kriváň-Píla railway tunnel. Smoky crystals were described in the Pod Zvonickou locality in the valley of Ábelová. Druses of the smoky quartz crystals up to 10 cm were also found in granitic rocks 3 km north of the village Zlatno near Zlaté Moravce in the Tribeč Mts [20].

The crystals have a trigonal or ditrigonal prismatic shape; they are usually well terminated, often doubly terminated. In some localities, e.g. the Kohút Hill near Revúca, overgrowth of smoky quartz exceeding 20 cm in length with weight more than 15 kg occurs. Their color saturation is moderate to strong; clarity of the crystals is transparent, semi-transparent to translucent. Typically they range from 3 to 10 cm long and 1–4 cm in diameter.

The aim of the study focuses on the application of Raman and optical absorption spectroscopy in the mineralogical and gemological research of quartz on the example of the smoky quartz variety. Raman spectroscopy was used for identification of quartz and structural settings. It was also used for determination of inclusions. Optical spectroscopy was used to determine the light absorption in the UV and visible regions of the electromagnetic spectra. Additionally, chemical composition was established by electron microprobe. Gemological properties of cut gemstones were also determined by standard gemological methods.

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Fig. 1. Location of smoky quartz occurrences in Slovakia.

## 2. Location of samples and geological settings

Studied smoky quartz was found in several localities; Detvianska Huta (DH), Látky (LA), Čierny Balog–Tlstý Javor (TJ), Revúca–the Kohút Hill (KR) in the Slovak Ore Mountains and Zlatno (ZL) in the Tribeč Mountains (Fig. 1).

The Slovak Ore Mountains can be geologically divided to western Veporic and eastern Gemeric Unit. Studied occurrences are entirely located in the Veporic Unit. This tectonic unit consists of three major, southdipping, thick-skinned basement imbricates that originated by Cretaceous crustal stacking in the Central Western Carpathians. All rocks in the Veporic Unit are affected by intense Alpine tectonometamorphic reworking which records a complete Cretaceous orogenic cycle, progressing from a deep burial to exhumation within rear parts of the developing Western Carpathian orogenic wedge [21]. The Veporic basement is composed of various metamorphic and magmatic rocks partly preserving the Variscan nappe structure. A structural complex consists of mica schists and gneisses, migmatites and amphibolites [22].

The formation of Alpine-type veins in the Veporic Unit is closely related to extensional metamorphic processes occurring during the Alpine metamorphism [23,24]. The Alpine metamorphism of the Veporic crystalline basement has regional extension with an indication of a crystalline rock diaphoresis to form the quartz-albite-chlorite-sericite-epidote and clinozoisite mineral assemblage at 400–450 °C and pressure of 600–700 MPa [25], or the adular-quartz-albite-chlorite-tourmaline-rutile association characteristic of metamorphic greenschist facies [24]. A tectonic position of fissures and nature of fluids distinguishes two stages of a cracks formation during the Alpine tectonometamorphic cycle [23]. The earlier fissures are characterized by the smoky quartz occurrences in Veporic granitoids [24].

Zlatno locality is situated in the south of the Tribeč Mts. which is the westernmost protrusion of the internal zone of the Carpathian core-mountains in Slovakia. Its pre-Alpine fundament is built by Variscan granitoids. The Tribeč Mts. is divided into Zobor part with Tatric and Fatric Units, Tribeč part with Tatric Unit, and Rázdiel part formed by complexes of Tatric, Fatric, Veporic and Hronic Unit [26]. Tribeč and Zobor massifs consist of granitoid rocks with Mesozoic

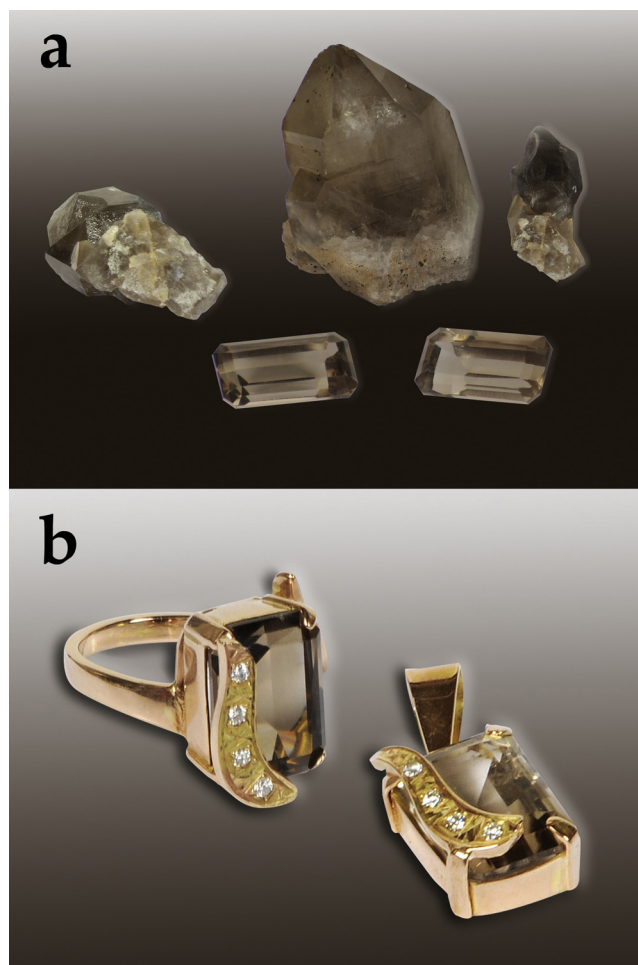


Fig. 2. Smoky quartz in Slovakia. (a) It mostly occurs in form of isolated crystals (sample from Látky is 10 cm in length) but also in druses of euhedral quartz (Revúca–the Kohút Hill, size of sample 4 cm). These specimens provide material suitable for cut stones (5.35 ct and 5.30 ct). (b) Smoky quartz cut stones from Čierny Balog–Tlstý Javor and Revúca–the Kohút Hill were mounted to the jewelry and set with diamonds.

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