More Than Blue Almonds

The quarry in Lubiechowa has been attracting mineralogists as well as amateur rock-collectors for years. What undiscovered secrets does it still hold?

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In the now disused quarry in Lubiechowa, in the commune of Świerzawa in Lower Silesia, volcanic deposits of Permian rocks lie exposed on the Łomy hill. These are solidified streams of lava of an intermediate chemical composition, i.e. their silica content by weight varies between 52% and 63%. In the TAS classification of volcanic rocks (based on Total Alkali Silica), they are referred to as basaltic trachyandesite and basaltic andesite. Still, colloquially these visually impressive rocks are called melaphyres, due to their distinctive texture, characterized by the presence of almond-shaped vesicles of various forms and sizes, originally gas bubbles left behind from the degassing of lava spills on the surface of the Earth. As time passed, various mineral phases crystallized within these spaces, creating colorful agates (chalcedony) and tiny geodes filled with calcite, barite and quartz, sometimes in the purple variety known as amethyst. In addition to these almond-like shapes, there are also irregular cracks within the entire rock complex, mainly filled with calcite, often with blue-green hues due to the presence of phyllosilicates.

Minerals present in melaphyre fillings are thought to be of hydrothermal origin. Inflows of hot solutions caused the alteration of the rock mass and the release of elements, which allowed the crystallization of a new generation of mineral phases in the vesicles and fissures. These solutions were rich in carbonate and sulfate ions, which supported the formation of calcite and barite. Such solutions originated from a nearby magma body or infiltrating surface waters, called meteoric waters, whose temperature increased with depth and caused changes within the melaphyres. The significant number of agate bands and the different sizes of crystals within the vesicles clearly suggest that there were many inflows, of varying concentration and chemical composition.

The color of dog-tooth

The main associations of minerals that can be distinguished in such gas-bubble spaces are chalcedony with calcite, celadonite with chlorite, and quartz with calcite and barite. However, this is just a very general classification and mainly applies to vesicles not exceeding 1 cm. In larger ones, the mineralization is much more complex and can combine all kinds of associations.

The most visually attractive minerals found here are light purple quartz (SiO_2), known as amethyst, and chalcedony (SiO_2), whose colorful bands form agates. The most common colors of chalcedony are white, gray and pink; rarely light blue.

The second most frequently occurring mineral is calcite ($CaCO_3$). Its crystals predominantly fill the central part of a vesicle; sporadically, in a several-centimeter geodes it forms crystals in the shape of scalenohedron, otherwise known as a "dog-tooth Spar". The calcites from this site exhibit many different colors, from white to dark gray; there are also pink ones. The latter, when exposed to ultraviolet radiation at the 254nm wavelength, display the well-known phenomenon of pink fluorescence, probably associated with doping of manganese in their structure.

Phyllosilicates are almost as common as quartz, chalcedony or calcite in this hydrotermal association. They occur nearly always together in the vesicles as two main groups: chlorites and micas. Minerals of the chlorite group do not form crystals visible to the unaided eye; rather, they resemble a dense black or sometimes brown-green mass. They usually fill vesicles smaller than 1 cm or form a thin layer within calcite.

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Further reading:

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Michalik M. (1991). *Morphology of celadonite aggregates in melaphyres froxm Lubiechowa (North-Sedetic Depression)*. Mineralogia Polonica, Vol. 22, Nr 1, 51–62.

Manecki A. (2015). *Agaty i krzemienie, geneza piękna – pięknogenezy* [Agates and Flints, the Genesis of Beauty]. AGH. Uczelniane Wydawnictwa Naukowo-Dydaktyczne, Kraków, 80, 98, 134–135, 430–431.

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The best known mica group mineral that occurs in Lubiechowa is blue-green celadonite K(Mg, Fe^{2+})Fe^{3+} $Si_4O_{10}(OH)_2$. It occurs here in the form of tiny scales, usually noticeable only under optical or electron microscope. Celadonite crystals form complexes of laths arranged radially or clusters of very fine crystallites dispersed within calcite or chalcedony.

Titanic scrutiny

In order to determine the chemical composition of these mineral phases, in my research I employed the method of micro-area analysis, using a Cameca SX-100 electron probe microanalyzer at the Electron Micro-Probe Laboratory of the Inter-Institute Laboratory of Microanalysis of Minerals and Synthetic Substances, Faculty of Geology, University of Warsaw. The presence of certain minerals previously known and described in the literature was confirmed, including quartz, calcite, barite and celadonite, as well as a phase macroscopically resembling minerals of the chlorite group.

Supplementary X-ray diffraction studies showed that the composition of minerals of the chlorite group is more complicated. We are dealing here with silicates with a complicated mixture of layers, made up of at least three mineral phases, indistinguishable in electron microscope imagery. Thus, the electron microprobe technique does not allow their exact chemical composition to be determined, as the obtained results represent the totalized chemistry of several mineral phases.

Due to the relatively simple composition of elements making up quartz and calcite, I focused on the exact determination of the chemical composition of the celadonite. I carried out over 80 analyzes of this mineral, converting the resulting percentages (expressed as oxides of a given element) into the positions of the given element in the crystal lattice.

In 15 analyses, the results showed that the aluminum content was higher in relation to iron. After calculations, this value turned out to be significant to such an extent that some of the analyzed crystals should have been classified not as celadonite K(Mg, Fe^{2+})$Fe^{3+}Si_4O_{10}(OH)_2$, but as its aluminum-enriched equivalent, namely aluminoceladonite K(Mg, Fe^{2+})$AlSi_4O_{10}(OH)_2$. This phase has not previously been described in any publication on minerals from melaphyre fillings from Lubiechowa. Its largest accumulations are found in rock fissures, in association with calcite, although it is also present in melaphyre vesicles.

Moreover, monazite-(Ce) (cerium) and accompanying titanium oxides were found in several places within the aggregate of aluminoceladonite crystals. Monazite group minerals are commonly used for rock dating, due to their increased content of uranium and thorium. The occurrence of these minerals within a hydrothermal mineralization may in the future allow its exact age to be determined.

Overall, my work in applying the analysis using the microprobe has allowed aluminoceladonite to be distinguished from celadonite, phases which are indistinguishable micro- and macroscopically. Further research into the rock material may indicate the age of this mineralization. As it has turned out, the Lubiechowa site – frequently visited by both scientists and aficionados of mineralogical showpieces alike – still affords new discoveries and abounds with new research opportunities. The quarry is just one of many mineralogical sites in Lower Silesia. Who knows what the others might be concealing? ■

A gray-brown basaltic andesite with a large number of mineral-filled vesicles.