

Interesting Muscovite Specimens from Pakistan: Epitaxial Incrustation and Pseudomorphism after Beryl

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本文描述一系列從巴基斯坦西北部出產的白雲母樣本，有助於理解地質學及寶石學的定向連生及假晶象概念。

Abstract:

The present article describes an interesting series of muscovite specimens, which were found recently in a pegmatite in NW-Pakistan. Based on the hexagonal outline of the specimens and genetic considerations, it is assumed that they represent epitaxial by-products grown on previously present beryl columns that were later replaced by a pseudomorph of mostly fine-grained sericite. Although not gemstones, these specimens are useful aids to understanding the concepts of epitaxy and pseudomorphism in mineralogy and gemmology.

Introduction:

Recently, the Swiss Gemmological Institute SSEF received a number of mineral samples (Fig. 1), which were said to originate from a pegmatite outcrop in the North West Territories of Pakistan, close to the Afghanistan border (the Hindu Kush).



Fig. 1 The samples analysed for this study. Ranging in size from approximately 24 to 33 mm in diameter. The specimens show a marked hexagonal outline formed by an incrustation of small tabular crystals.
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The Hindu Kush, the western branch of the Himalayas, the mountain range which extends about 1000 km between northern Pakistan and central Afghanistan in the West, is well known for numerous findings of attractive mineral specimens and gemstones (Bariand & Poullen 1978, Kazni et al. 1985, Blauwet et al. 1997, Blauwet 2004). Many pegmatite-type deposits related to granitoid intrusion bodies are known within this mountain range, which formed as a consequence of the collision of the Indian

plate with the Eurasian continental plate during the Cenozoic period, with the main mountain building activity being 65-35 million years (ma) ago (Gansser 1966, Yin & Harrison 2000, Yin 2006). Minerals and gemstones from these pegmatites are widespread in the market and include beryls (mostly aquamarine and morganite), topaz, spodumene (kunzite and hiddenite), and tourmalines.

The reason, that these samples caught our interest was the presence of a very attractive incrustation of shiny white tabby crystals, which obviously represent a secondary mineral formation grown epitaxially on a primary mineral phase. The original mineral has been replaced by new mineral phases forming a pseudomorph during a late stage of retrograde mineral formation (Deer et al. 1996).

Definitions:

Epitaxy and Pseudomorphism

The term epitaxy describes the oriented ongrowth of a crystal on another crystal. The epitaxial growth is controlled by a congruence of the crystal structures of the involved minerals. In nature, this ongrowth often occurs with two different mineral phases (e.g. rutile grown epitaxially on hematite crystals), but is also known between crystals of the same variety (e.g. rutile grown epitaxially with each other forming a dense triangular pattern called "sagenite") (Okrusch & Matthes 2010).

A pseudomorph is a mineral (or finegrained mineral mixture), which does not show its own mineral habit defined by its crystal structure, but is present in the shape of

another mineral which it has usually replaced during a mineral alteration. Typical examples are Fe-hydroxides pseudomorph after pyrite and quartz after calcite or fluorite. In case of an incrustation as is the case in the described specimens, the term "perimorphism" may also be used (Putnis et al. 2005, Putnis 2009, Okrusch & Matthes 2010).

Samples and Methods:

The seven specimens analysed for this study range from 7.70 – 48 ct in weight. Their size is about 24 to 33 mm in diameter. They had already been cut in slices from at least two original specimens when we received the samples, thus enabling us to see the interior part of the samples.

All specimens are characterised by a distinct six-sided outline (see Fig. 1), formed by an incrustation of white crystals on a previously existing hexagonal crystal. The incrustation shows distinct shiny reflections on the main pinacoid faces of the ongrown crystals. The interior of the samples is either hollow or filled with a fine-grained powdery mineral-filling. (Fig. 2a).



Fig. 2 Three different specimens, showing a partially hollow interior (a), the columnar stacked arrangement of the incrustation at the side (b) and the oriented pattern of the incrustation at the top, consisting of white tabular crystals (c).

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The incrustation consists of stacked tabular crystals, forming long columnar piles parallel to the hexagonal "prisms" (visually somehow resembling basalt columns; see Fig. 2b). Similar stacking is often encountered with sheet silicates such as mica. From above, not only the monoclinic outline of the tabular crystals is evident, but also the well oriented arrangement of this incrustation (see Fig. 2c). Part of the specimens also show a few randomly oriented white crystals grown on the surface, which have been identified (by Raman microspectrometry) as albitic feldspar (see Fig. 3).



Fig. 3 White tabular albitic grown randomly on top of the incrustation.
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The chemical composition of the samples was analysed by energy dispersive X-ray fluorescence (EDXRF), using a Tracor Spectrace spectrometer with a series of excitation energies of 8, 10, 15 and 25 kV to cover the detection-range from sodium to the heavy elements. To gain qualitative access to light elements such as beryllium and lithium, the samples were analysed with laser induced plasma spectroscopy (LIPS), using an Ocean Optics setup and a Quantel

Q-switched Nd-YAG nanosecond laser at 266 nm wavelength.

Furthermore the samples were analysed with a Renishaw Raman microspectrometer, using a 514 nm argon laser.

Results:

Based on chemical data and vibrational spectra (Raman), the incrustation was identified as muscovite, the potassium-rich member of the mica mineral group. The mica group consists of further members such as lepidolite (Li-bearing), phlogopite (Mg-bearing) and biotite (Fe-bearing) to name just a few. The group is characterised by extensive miscibility in their chemical composition. Due to the rugged surface of the incrustation, no quantitative EDXRF data could be obtained, however Si, K and Al as main constituents with minor Fe were readily detected. With LIPS, distinct amounts of lithium (emission at 670.8 nm), cesium (852.2 nm), sodium (doublet at 589 nm), magnesium (279.6 nm), and traces of beryllium (313.1 nm), barium (455 nm), and strontium (407 nm) were also found. Qualitative chemical analyses on the fine grained matrix within the hexagonal incrustation revealed a very similar chemical composition compared to the incrustation.

Discussion:

These specimens are interpreted as being the result of alteration processes during a late stage of mineral formation. After a primary growth of prismatic beryl (most probably aquamarine, based on the habit of the samples and the abundance of this beryl variety in this region), the crystal was covered epitaxially by a dense and oriented pattern of muscovite mica, preserving

the hexagonal and columnar shape of the original beryl crystal (Fig. 4a and b). The very precise hexagonal inner outline of the specimens clearly indicates that these muscovites grew epitaxially (oriented) on the still existing beryl and thus did not replace the beryl at this stage. The mineral muscovite is very common in pegmatites and is often found together and even grown on beryl (Blauwet 2004; see photos in ExtraLapis). The presence of Li (and Be, Sr, Ba and Cs) as is found in the incrustation is characteristic for a pegmatitic formation (Deer et al, 1996).



Fig. 4 An aquamarine crystal as a model to demonstrate its resemblance to the six-sided columnar muscovite incrustation which is interpreted as having grown epitaxially on a previously present beryl crystal prior to a pseudomorphic replacement process.

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At a later stage, a pseudomorph of a fine-grained mineral mixture replaced the primary beryl. Based on the chemical data and literature, we presume that this fine-grained matrix consists mostly of "sericite", a fine-grained variety of muscovite, and clay minerals such as kaolinite. Similar replacements of Al-rich primary pegmatitic minerals such as beryl, tourmaline, topaz, kyanite, and spodumene, which have reacted with late low-temperature fluids, are well-known in literature (Cerny 1968, Deer et al. 1996, Markl & Schuhmacher 1997). Finally, part of the fine grained filling was washed out by meteoric waters, leaving part of the specimens as hollowed muscovite incrustations.

Although not gem materials, these specimens are very attractive. First because of the shiny reflections on the oriented pattern of the muscovite incrustation, and second, because they unveil, beautifully, a very interesting aspect of mineral formation/alteration dynamics in a pegmatite exposed to late low-temperature fluid reactions.

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