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The dependence of emeralds and chromaquamarines colours on chemical elements

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Beryls, that are found in Zambia, Tanzania and Australia, are characterized by particularly beautiful greenish blue hues with a bright pleochroism. These minerals contain a small amount of chromium and vanadium, however, they are relatively rich in iron which determines a bluish colour and provides pleochroism. The author distinguished a new variety that is called *chromaquamarine*. Chromium or vanadium impart a green colour in emerald, divalent iron imparts a light blue colour for aquamarine and all three previously mentioned chemical elements impart a bluish colour with a greenish hue for chromaquamarine.

Key words: chromaquamarine, emerald, aquamarine, beryl

INTRODUCTION

Beryl mineral $Be_3Al_2[Si_6O_{18}]$ may be of various colours. According to the colour and chemical composition beryl is divided into varieties. Emeralds (Fig. 1) are beryls that contain green chromium and vanadium, beryls containing iron may be of several colours: light blue – aquamarine (Fig. 2), greenish – green beryl (Fig. 3), yellow hues – heliodor (Fig. 4), and golden beryl (Fig. 5); redish and orange beryls rich in manganese are bixbites (red beryl) (Fig. 6) and morganites (Fig. 7); goshenite beryl is called a colourless beryl which does not contain chromofores; colourless beryls which have only vanadium chromofores are called vanadium beryls. A blue and yellow mineral of the beryl group with scandium is called bazzite [1], and a light blue mineral with sodium, magnesium and water is called stoppaniite [2]. In 2002, in Madagascar and Afghanistan a new deep purplish pink mineral of the beryl group, pezzottaite [3, 4], was discovered. It was named after the name of Italian explorer Dr. Federico Pezzotta. This mineral is enriched with cesium and lithium. The author, having researched bluish beryls with chromium from Zambia, Tanzania and Australia, identified a new variety of beryls – chromaquamarines (Fig. 8) [5–9].

In Zambia, the *Kafubu* (Fig. 9) accumulation, beryls occur in biotite phlogopite schist, in Australian the *Poona* (Fig. 10)

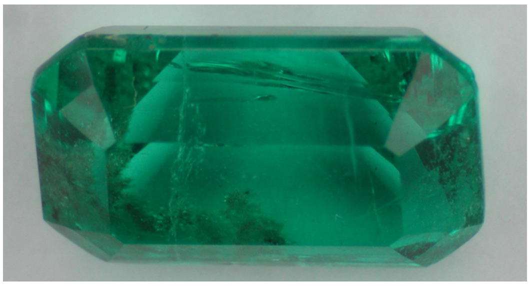

Fig. 1. Emerald. Picture by A. Kleišmantas

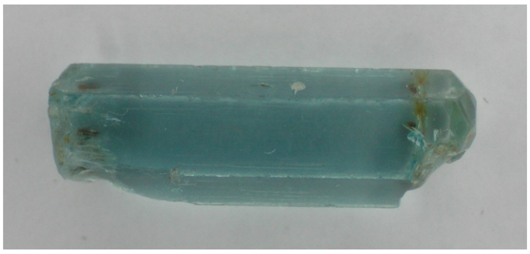

Fig. 2. Aquamarine. Picture by A. Kleišmantas

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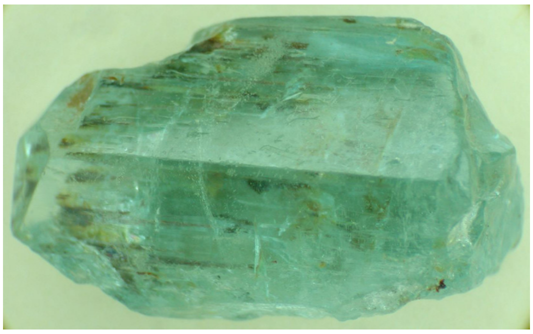


Fig. 3. Green Beryl. Picture by A. Kleišmantas

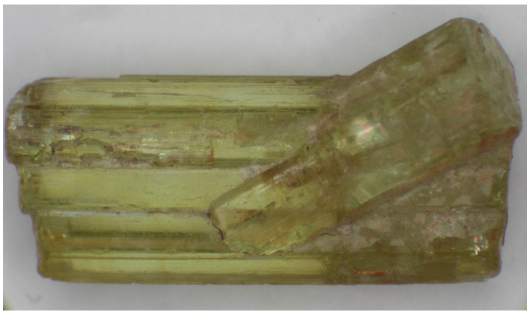


Fig. 4. Heliodor. Picture by A. Kleišmantas

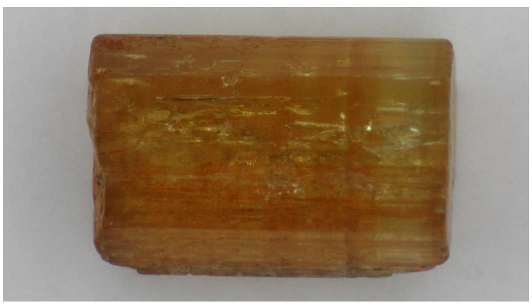


Fig. 5. Golden beryl. Picture by A. Kleišmantas

Fig. 6. Bixbite (Red Beryl). Picture by A. Kleišmantas

Fig. 7. Morganite. Picture by A. Kleišmantas

Fig. 8. Chromaquamarines. Picture by A. Kleišmantas

Fig. 9. Location of the *Kafubu* emeralds and chromaquamarines area in Zambia

Fig. 10. Location of the *Poona* emeralds and chromaquamarines area in Australia

Fig. 11. Location of the emeralds and chromaquamarines area near *Manyara* and *Eaysi Lakes* in Tanzania

accumulation of these minerals resides in biotite and changed hornblende schist [10, 11, 12] and in Tanzania, near *Manyara* and *Eyasi Lakes* (Fig. 11) in the Mbula district, where minerals occur in mica schist in aggregates along contact zones between biotite-actinolite schist and pegmatites [2], and in biotite-actinolite lens residing in alluvial deposits. In these accumulations chromaquamarine is found together with emeralds as the chemical composition of chromaquamarine variety is similar to that of emerald. However, parts of beryls found in Zambia, Australia, and Tanzania are characterized by beautiful greenish blue hues with a bright pleochroism. These minerals contain a small amount of chromium and vanadium but they have a considerably big amount of iron, which determines a blue colour and provides pleochroism.

MATERIALS AND METHODS

While examining beryls, the following researches have been used: chemical composition has been determined, colour description according to the CSG (Colored Stones Grading) GIA system has been performed.

The amount of chemical elements was researched for 23 bluish and green beryls: 4 chromaquamarines from Tanzania and 5 emeralds from alluvial deposits near *Manyara Lake*, 1 chromaquamarine from alluvial deposits near *Eyasi Lake*, 6 emeralds and 4 chromaquamarines from Zambia (*Kafubu*), and 1 chromaquamarine and 2 emeralds from Australia (*Poona*).

Concentration of chemical elements Cr^{3+}, Mn^{n+}, V^{3+}, Fe^{n+} in samples from Tanzania has been determined with the help of an inductively coupled plasma optical emission spectrometer OPTIMA 7000 DV (PerkinElmer). The samples were dissolved in a mixture of HCl (1 part), HF (6 parts) and HNO_3 (2 parts) acids by means of sample preparation equipment MULTIWAVE 300 (Anton Parr). Multielemental standard solutions were prepared from monoelemental standard solutions. When measuring chemical elements, Cr 267.716 nm, Mn 257.610 nm, V 292.464 nm and Fe 259.939 nm analitical peaks were used. Gas flows: plasma – 15 L/min, auxiliary – 0.2 L/min, sprayer – 0.6 L/min. Capacity is 1 300 W, a sprayer with intersecting flows was used. Concentration of chemical elements in Zambian and Australian minerals has been researched by a scanning electron microscope JXA-50A electron probe microanalyzer. Hue, tone and saturation description of beryl minerals was performed according to the (CSG) GIA[#] system when using GIA GemSet.

Describing colour

Hue is the basic impression of colour that we notice immediately, the component that gives it its "family" name, like red, green, or yellow. It is due principally to the selective absorption of certain wave-lengths of light by the object; the blend of the remaining wavelengths produces the body colour we see. For greater accuracy, the GIA GemSet's 324 samples cover each of the 31 hues for many combinations of tone and saturation. Basic hue names are the familiar red, orange, yellow, green, blue, violet, and purple. We modify these to indicate where other hues lie, using terms like bluish, greenish, or orangy, plus the modifiers slightly and strongly. Thus, a hue that is predominantly blue with a hint of green is very slightly greenish blue.

Tone is the lightness or darkness of a colour sensation. We divide tone into 11 steps from colourless or white through increasingly darker grays to black. We use 7 of those steps (tones 2 through 8) in grading tone in transparent beryl minerals. The word terms that correspond to the tone samples in the Demonstration Set describe the lightness or darkness of the colour the eye perceives at each tone level.

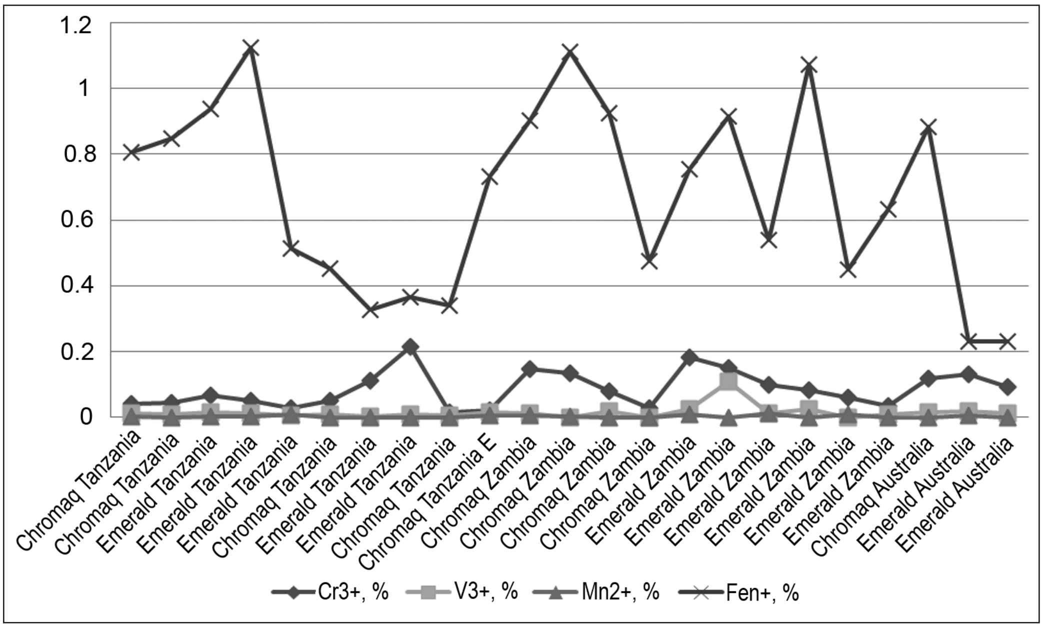
Saturation is the strength, purity, or intensity of the hue present in colour sensation. Saturation is assessed on a seven-level (0 though 6). The corresponding word terms, from neutral to vivid, describe the relative purity of hue the eye perceives at each saturation level [13].

RESULTS AND DISCISSION

Chromofores of bluish and green beryl varieties have been determined in Tanzania near *Manyara* and *Eyasi Lakes*, in Zambia and Australia near *Kafubu* and *Poona* accumulations; colour description was given according to the (CSG) GIA system. Chromaquamarine and emerald colour dependence on the chemical composition has been presented.

The investigated bluish and greenish beryls have Cr^{3+} (0.017–0.214%) and V^{3+} (0–0.11%) (Scheme 1), which is typical for emeralds. However, after having made colour description according to the (CSG) GIA system, it was determined that some beryls have a bright blue colour. It has been found that it is *chromaquamarine* which is different from aquamarine, green beryl and emerald. The chemical composition of this variety is similar to that of emeralds

[#] Visual colour description after gemmological CSG (Colored Stone Grading) GIA (American Gemological Institute of America) system.

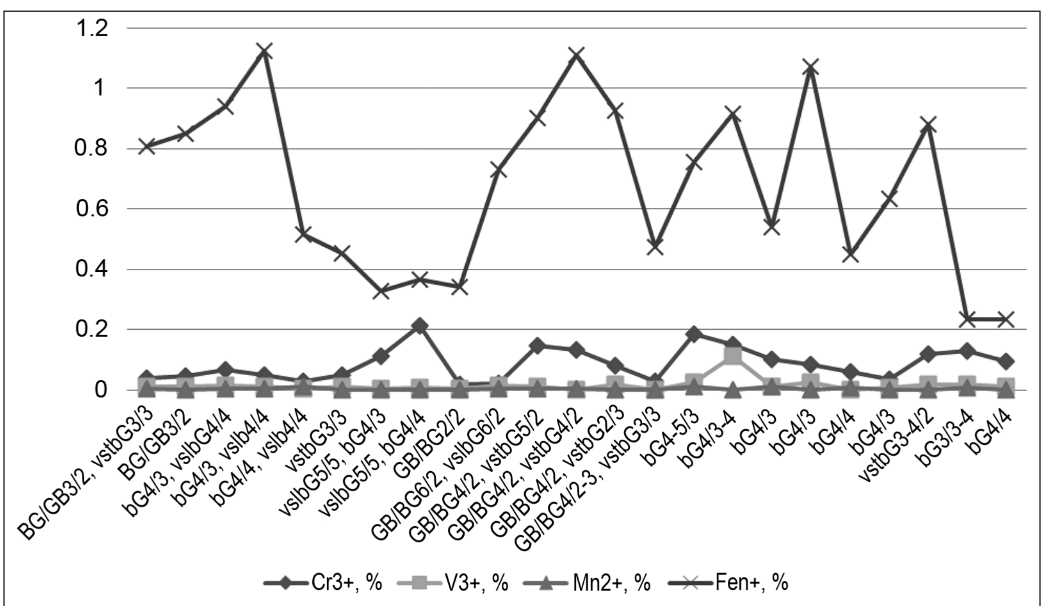


Scheme 1. The composition of chromaquamarines and emeralds (Chromaq – chromaquamarine; Tanzania – Tanzania Manyara Lake; Tanzania E. – Tanzania Eaysi Lake)

but in chromaquamarines the amount of Fe^{n+} (0.34–1.11%) (Scheme 1) is significantly higher than Cr^{3+} (0.017–0.146%) or V^{3+} (0–0.018%). Mn^{n+} (0–0.011%) has been found in the researched beryls. This amount is quite small but it can affect pleochroism. According to the (CSG) GIA system, used by gemmologists, chromaquamarine is of Green-Blue or Blue-Green (GB/BG) hue which corresponds to aquamarine hue and very strongly bluish Green (vstbG), corresponding to the colour of green beryl. However, they contain chromium and do not belong to iron-bearing beryls but are valued as emeralds. Fe^{2+} which is in the channel of crystal lattice provides the mineral a bluish colour [14].

According to Viana and other authors' [14] research, bigger amount of Fe^{2+} should be in chromaquamarine's channel than in the octaedro of crystal lattice. Having compared chromaquamarines from Tanzania, Zambia and Australia, it can be noticed that in the Tanzanian minerals the amount of Cr^{3+} (0.017–0.050%) is smaller than in Zambian Cr^{3+} (0.027–0.146%) and Australian Cr^{3+} (0.118%) beryls; the amount of V^{3+} was determined respectively: 0.005–0.014%, 0–0.018% and 0.017%. However, having compared the amount of Fe^{n+} in these mines, the result is the following: 0.340–0.855%, 0.475–1.11% and 0.882%. Hence, it was established that the amounts of iron are similar and they determine a blue colour for this particular variety.

Chromaquamarine variety differs from aquamarine and green beryl by not only the composition of chromophores but also by the colour saturation and tone [8]. It was established that chromaquamarines are darker and more intense than aquamarines and green beryls. These colour characteristics are provided by Cr^{3+}. The researched minerals have Green-Blue or Blue-Green (GB/BG) (Scheme 2) hue, which is specific



Scheme 2. The composition and colour of chromaquamarines and emeralds according to (CSG) GIA colour description system

to aquamarines. Due to their inherent pleochroism, some of them have another hue specific to beryls or emeralds that is very strongly bluish Green (vstbG) or very slightly bluish Green (vslbG). However, they are not attributed to emeralds as they have a very light saturation (3) and light tone (3).

Two explored chromaquamarines from Tanzania and one from Australia do not have pleochroism and are very light corresponding to the GB/BG and vstbG 3–4/2 hues. They are very similar to aquamarines but due to Cr^{3+} they are attributed to chromaquamarines.

These unusual Blue-Green emeralds noted for their pleochroism and found in Zambia accumulations (*Miku-Kafubu*) have been mentioned in the article of [15, 16]. When synthesizing emeralds in Russia, some blue emeralds were unexpectedly synthesized too and this led to a series of questions for scientists. However, neither natural nor synthetic minerals were distinguished into a separate variety.

The researched Tanzanian emeralds have a bright pleochroism. The amounts of Cr^{3+}, V^{3+}, Mn^{n+} and Fe^{n+} in them correspond to (0.027–0.214%), (0.004–0.014%), (0.001–0.002%) and (0.326–1.125%). Due to a relatively large amount of Fe^{n+}, the researched emeralds have two hues: bluish Green (bG) and very slightly bluish Green (vslbG). The amounts of Cr^{3+}, V^{3+}, Mn^{n+} and Fe^{n+} in Zambian and Australian emeralds correspond to (0.034–0.183% and 0.094–0.13%), (0.001–0.11% and 0.011–0.019%), (0–0.011% and 0–0.007%) and (0.540–1.072% and 0.232%). Zambian and Australian emeralds are characterized by one bluish Green (bG) hue. It was also Fe^{n+} that provided these minerals with a slightly blue colour.

CONCLUSIONS

It has been found that Zambian, Tanzanian and Australian beryls, that contain a small amount of chromium (0.017–0.146%) and vanadium (0–0.018%), but have a relatively huge amount of iron (0.34–1.11%), are distinguished by their bluish colour. Due to the mentioned chemical composition and a bluish hue, a new variety of beryls, called chromaquamarines, has been identified.

It has been determined that according to the (CSG) GIA colour description system, chromaquamarines are characterized by Green-Blue or Blue-Green (GB/BG), very strongly bluish Green (vstbG) and very slightly bluish Green (vslbG) hues, and emeralds: bluish Green (bG) and very slightly bluish Green (vslbG) hues. The majority of chromaquamarines has pleochroism and hues specific for both aquamarines and emeralds.

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References

1. R. V. Gaines, H. C. W. Skinner, E. E. Foord, B. Mason, A. Rosenzweig, V. T. King, *Dana's New Mineralogy*, John Wiley and Sons, 1819 (1997).
2. D. Belakovskij, A. U. Falster, *Beryl and Its Color Varieties*, Lapis International LLC, East Hampton, CT, 113 (2005).
3. B. M. Laurs, W. B. Simmons, G. R. Rossman, et al., *Gems Gemol.*, **39(4)**, 284 (2003).
4. W. B. Simmons, A. U. Falster, S. F. McClure, E. P. Quinn, G. F. Rossman, F. C. Hawthorne, B. M. Laurs, *Gems Gemol.*, **39**, 50 (2003).
5. A. Kleišmantas, *Geologijos akiračiai*, **3**, 14 (1998). In Lithuanian.
6. A. Kleišmantas, G. Skridlaitė, *Geologija,* **48**, 15 (2004). In Lithuanian.
7. A. Kleišmantas, *Gems Gemol.,* **42**, 137 (2006).
8. A. Kleišmantas, *Gemstones Market*, **2**, 90 (2007).
9. A. Kleišmantas, A. Selskis, *Proceedings of the 31th IGC Congress Arusha, Tanzania*, 26 (2009).
10. U. Henn, *Gemmologie*, **44(4)**, 62 (1995).
11. R. V. Karanth, *Gems and Gem Industry in India*, Geological Society of India, Bangalore, 405 (2000).
12. G. Giuliani, C. France-Lanord, P. Coget, et al., *Min. Dep*., **33**, 513 (1998).
13. *Colored Stone Grading. Colored Stone Grading Course Lab Manual*, The Gemological Institute of America (Y/YE), 56 (1994).
14. R. R. Viana, G. M. Da Costa, E. De Grave, H. Jord-Evangelista, W. B. Stern, *Phys. Chem. Miner.*, **29**, 78 (2002).
15. K. Schmetzer, *Gemmol.*, **17(7)**, 443 (1981).
16. K. Schmetzer, H. Bank, *Gemmol.*, **21**, 145 (1988).

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SMARAGDŲ IR CHROMAKVAMARINŲ SPALVOS PRIKLAUSOMYBĖ NUO CHEMINIŲ ELEMENTŲ

Santrauka

Zambijoje, Tanzanijoje ir Australijoje randami berilai pasižymi itin gražiais žalsvai melsvais atspalviais su ryškiu pleochroizmu. Šie mineralai turi nedidelį kiekį chromo ir vanadžio, tačiau santykinai didelį kiekį geležies, kuri lemia melsvą spalvą bei suteikia pleochroizmą. Tai nauja autoriaus išskirta atmaina – chromakvamarinas. Smaragdui žalią spalvą suteikia chromas ir vanadis, akvamarinui žydrą spalvą – dvivalentė geležis, o chromakvamarinui melsvą spalvą su žalsvu atspalviu – šie trys paminėti cheminiai elementai.