

Case Study on an Emerald Bead: Is it from the ancient mines in Egypt or not? 這是否古埃及礦產的祖母綠？

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瑞士珠寶研究院收到一顆200.845cts水滴型已打磨的祖母綠珠子及三件小晶體碎片，要求原產地檢證，據客戶轉述賣方稱該批祖母綠是來自古埃及南部的礦產。筆者通過傳統及高階的檢測方法，論述其與古埃及產的祖母綠之比較及異同，並總結其是否產自古埃及的祖母綠礦床。

The Swiss Gemmological Institute SSEF received a drop-shaped, polished and drilled emerald of 200.845 cts (in the following sample A), together with three small crystal fragments (in the following samples B1-B3) for investigation and origin determination (Fig. 1). According to the client, these stones were sold as emeralds originating from the ancient emerald deposits in upper Egypt.



Fig. 1 The samples investigated for this study. On the right the 200 cts polished and drilled specimen (A), and on the left three small beryl fragments (B1–B3), all reportedly from the ancient emerald mines in Egypt.
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The specimens provided were tested at the SSEF laboratory using classical gemmological methods (refractometer, polariscope, ultraviolet lamps, hydrostatic balance) and the microscope (inclusion study). In addition, the stones were chemically analysed with a Thermofisher Quant’X ED-XRF system. The following results and observations on these samples are compared with data and descriptions found in gemmological and mineralogical literature.

Historic emerald mines in Egypt



Fig. 2 The ancient emerald mines are located near the small community of Marsa Alam in the Sikait-Zubara region.
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The emerald mines in upper Egypt have been known since ancient times and represented one of the most important sources of emeralds for many centuries during the ancient Egypt, Greek, Roman and Byzantine periods, together with the mines in the Habachtal in Austria (Jennings et al. 1993, Shaw et al. 1999, Giuliani et al. 2000).

Located at remote sites such as Zabara, Sikheit, Nugrus, and Umm Kabu in the rugged coastal hills near the small community of Marsa Alam (Fig. 2) on the Red Sea (Jennings et al. 1993), these ancient mines, also known as the “Emerald mines of Cleopatra”, were abandoned many centuries ago with only very episodic and unsuccessful mining activities taking place since then (Jennings et al. 1993). Although a major source of emeralds (according to the literature) in ancient times, only relatively few specimens are known today, mostly in archaeological museums. A number of specimens have

been analysed mineralogically and gemmologically and are reported in literature (Jennings et al. 1993, Guiliani et al. 1998, Abdalla & Mohamed 1999, Shaw & Bunbury 2003, Aurisicchio et al. 2005).

Results of the investigated specimens for this study

Although said to be from the same geographic source, the polished emerald (sample A) is very different in appearance from the three rough crystal fragments (samples B1-B3). Sample A is quite transparent (semi-transparent based on the SSEF terminology), whereas the three small fragments (B1-B3) are completely opaque with a light greenish white colour. These fragments are distinctly altered in their chemical and mineralogical composition, mostly with clay mineral components replacing the original green beryl. Due to this fact, a comparison of the chemical data between the polished and rough samples is neither feasible nor reasonable.

Microscopic examination of the polished sample A revealed many fractures, filled with a slightly brownish (aged) oil to modify its clarity. Apart from this, the sample contains basal fluid-platelets, arranged in “patchy” layers throughout the emerald (Fig. 3). Furthermore, the sample contains irregular to partly rectangular two-phase fluid inclusions. Microscopically, no biotite could be observed.



Fig. 3 Semi-transparent emerald (specimen A) showing basal fluid-platelets, arranged in “patchy” layers throughout the emerald and brownish (aged) oil in fissures.
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Due to the shape of sample A, we could only determine an approximate refractive index (RI) of 1.57 (spot reading); but no birefringence could be measured. The specific gravity (SG) of sample A is 2.71. The sample shows no reaction under the long wave ultraviolet light (365 nm) except a distinct yellow fluorescence along the numerous fractures, due to the oil filling in the fissures.

The chemical analysis of sample A shows iron (0.17 wt% Fe_2O_3) dominating over chromium (0.034 wt% Cr_2O_3) with only negligible traces of vanadium (< 0.006 wt% V_2O_5). Caesium is present in traces (0.036 wt% Cs_2O), whereas magnesium and sodium are below detection limits (ca. 0.5 wt% for MgO and 1.5 wt% for Na_2O) using our EDXRF setup. Comparing our analyses with chemical data of ancient Egyptian emerald reported in literature (Table 1) reveals a marked difference, especially with the distinctly lower Na, Mg and Fe concentrations in our studied sample (A).

Comparison of the analysed results and literature

Based on the observed and analysed data, we can conclude that sample A is distinctly different from Egyptian emeralds as described in literature. The following arguments underline this:

Emeralds from Egypt showing a “good” transparency are rarely larger than a few carats (Jennings et al. 1993). The investigated sample A shows an impressive size of approximately 200 cts, which by far surpasses any mentioned ancient emerald of this quality. Documented large emeralds from Egypt are very often nearly opaque and full of inclusions and fractures (Grundemann et al. 1993, Jennings et al. 1993, Aurisicchio et al. 2005). These stones often also show distinct colour zoning (with a distinct green zone at the surface and a very light green internal zone (Grundemann et al. 1993), a feature not observed in the polished sample A. They are generally cut in hexagonal shapes, actually often just representing slightly polished emerald crystals. This is very much in contrast to the drop-shaped polished sample A (with the c-axis actually perpendicular to the largest dimension!), which requires a distinctly larger original crystal to cut out such a volume.

In sample A, inclusions described from Egyptian emeralds such as quartz, biotite, brownish oxidised amphibole needles, and growth tubes, partially filled with brownish Fe-hydroxide (Jennings et al. 1993) could not be observed, but basal fluid-platelets, arranged in “patchy” layers throughout the emerald, were similar to emeralds from Brazil and other sources.

The chemical data of emeralds from “schist-type” emerald deposits, forming during regional metamorphism is quite uniform (Grundmann et al. 1993), regardless of their geographic provenance (e.g. South Africa, Zambia, Austria, Brazil, Egypt). Thus the chemistry of these emeralds is rather unspecific: generally iron distinctly dominates Cr, and they often contain distinct amounts of Mg and Na. Based on the chemical data on sample A, no specific geographic origin can be deduced, but an Egyptian origin is very unlikely (see Table 1).

Table 1: Comparison of chemical data of emerald specimen A with literature data of Egyptian emerald

	specimen A		Em1A	Em1B	Em2	Em3A	SE-1	SE-2	KE-1R	KE-1
	this study		Shaw et al. 2003				Abdalla et al. 1999			
	1st meas.	2nd meas.								
Na₂O	b.d.	b.d.	1.79	1.99	1.80	2.04	1.50	1.73	1.48	1.62
MgO	b.d.	b.d.	2.22	2.80	2.33	2.54	2.28	2.75	2.23	2.59
Al₂O₃	19.340	19.770	14.99	13.90	15.06	14.65	14.42	12.87	13.90	13.40
SiO₂	64.840	64.750	64.74	64.52	65.12	65.22	64.80	64.29	64.63	64.48
Cl	0.046	0.026	0	0.02	0	0				
K₂O	0.081	0.056	0.01	0.04	0	0	0.02	0.03	0.02	0.04
CaO	0.066	0.040	0.01	0.13	0.01	0.01	0.02	0.04		
Sc₂O₃	0.342	0.030								
TiO₂	0	0	0.02	0.01	0.02	0.01			0.01	
V₂O₃	0.010	0.006								
Cr₂O₃	0.012	0.034	0.08	0.21	0.13	0.29	0.08	0.15	0.12	0.13
MnO	0	0.045	0	0.01	0	0	0.02	0.02		0.01
Fe₂O₃	0.202	0.169	0.57	0.87	0.50	0.44	0.42	1.07	0.81	1.33
NiO	0	0.001	0.01	0	0.02	0				
CuO	0.001	0.002								
ZnO	0.015	0.021								
Ga₂O₃	0.004	0.002								
Rb₂O	0.003	0.001								
Cs₂O	0.032	0.036								
BeO	13 [*]	13 [*]					13.00	13.30		13.00
H₂O	2 [*]	2 [*]					2.43	2.40		2.31
total	100.000	100.000					99.00	98.70		98.90

* BeO and H₂O fixed values based on stoichiometry

Comparison of chemical data of emerald specimen A with literature data of Egyptian emerald. The analysed data of sample A clearly differs from the reported data of Egyptian emeralds, especially having distinctly lower Na, Mg and Fe concentrations.

Sample A shows an approximate RI (spot reading) of 1.57 and an SG of 2.71. Both measured values are well in-line with Mg and Na-poor emeralds. They are however distinctly lower than the values reported for emeralds from Egypt with RI generally above 1.58 and SG at 2.75 (Jennings et al. 1993 and references therein). Although the approximate RI value is only indicative, it is noticeable that the combination of both values is distinctly lower than the reported data from Egyptian emeralds.

Conclusions

Sample A shows no evident consistency in size and appearance with documented emeralds from Egypt. It also lacks a great number of inclusions, described in Egyptian emeralds. The chemical data and physical properties such as RI and SG are also not consistent with reported data.

Based on these findings, we can be almost certain that sample A did not originate from one of the ancient Egyptian mining sites. Based on the present data, the material probably originated from emerald mines either in Africa (e.g. Nigeria) or South-America (Brazil).

Although it is not possible for us to give a conclusive opinion on the origin of the small fragments (B1-B3) due to their advanced mineralogical transformation (see also Krzemnicki 2011), they –at least visually– show the closest resemblance to ancient Egyptian emeralds, and thus such a provenance might be possible.

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翡翠的定義 Definition of Fei Cui

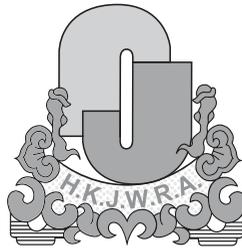
GB/T 23885-2009 2009-06-01發佈 2010-03-01實施

中華人民共和國國家標準

主要由硬玉或由硬玉及其他鈉質、鈉鈣質輝石(鈉鉻輝石, 綠輝石)組成的、具工藝價值的礦物集合體, 可含少量角閃石、長石、鉻鐵礦等礦物。

National Standard, People's Republic of China

"Fei Cui" is mainly composed of jadeite or composition of jadeite jade and other sodium and sodium-calcium pyroxene (kosmochlor, omphacite) mineral aggregates with arts & crafts value; may contain minor amounts of amphibole, feldspar and chromite, etc. (translation)



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