AN ANCIENT EGYPTIAN COMMEMORATIVE SCARAB CARVED IN ROCK: NON-DESTRUCTIVE MINERAL IDENTIFICATION BY RAMAN MICROSCOPY

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Abstract: This contribution reports on the Raman Microscopic (RM) characterisation of crystals in the unknown rock type in which an ancient Egyptian commemorative scarab was carved. The orthopyroxene species enstatite is identified, and it seems to be the dominant mineral species.

An ancient Egyptian commemorative scarab, most probably from the Amenhotep III dynasty (*circa* 1390-1352 BC), and presently belonging to the private collection of Mr. Danièl Foury, is imaged in Fig. 1 where it can be observed that the flat surface is beautifully inscribed by hieroglyphics. The other side is very smooth and humped. It resembles a beetle, as do all Egyptian scarabs (*e.g.* [1]). This very delicately engraved rock, 10.5 x 6.6 x 3.4 cm in size, dense and hard, and variably light-green to beige to grey-brown in colour, constituted a precious artefact ideal for a completely non-destructive Raman microscopic determination of the nature of the rock by means of identifying its constituent minerals (*cf.* [2]). This artefact is just small enough to be placed under a standard microscope such that it was not necessary to employ mobile Raman microscopy.

Fig.1a (bottom edge) Fig. 1b (the whole) Fig.1c. (top right)
Photographs of this scarab by D.C. Smith (1a) and D. Foury (1b & 1c, reproduced with permission)

The first problem, as anticipated, was the usual patina on archaeological artefacts that obscures observation of the microtexture of the rock (*cf.* [2]) such that it is difficult to distinguish if it is a very fine–grained rock (most probable, *cf.* jade) or a monocrystal with mineral inclusions (possible). Raman analysis was made with no preparation other than a quick wipe with an ethanol-impregnated tissue to remove recent pollution from handling or packaging. The second problem, also anticipated, was a strong fluorescence with the green 514.5 nm laser. Very weak Raman intensity was noted in spectral zones (below 700 cm^{-1}, and above 1000 cm^{-1}) where pyroxenes $\{XYSi_2O_6\}$ give characteristic bands [3-5]. Subsequently analysis was made with a red 647.0 nm laser; this still caused fluorescence and an irregular baseline, but the signal to noise ratio was better. The spectral zones reproduced in Fig. 2 (spectrum n° IHCP18) were obtained by two successive subtractions of oblique straight lines in order not to affect the local spectral details.

The seven main Raman bands obtained at several points from this scarab occur at 240, 338, 381 (weak), 660 (shoulder), 679, 1012 and 1031 cm^{-1}. These correspond to a *Pbca* orthopyroxene rather than to a *C2/c* $(Ca,Mg,Fe)^{2+}$ clinopyroxene, because of (a) a *stronger* band around 235 cm^{-1}, (b) the *absence* of a band around 355 cm^{-1}, (c) the central *doublet* (T-O-T vibration) at 679 cm^{-1} with a *shoulder* on the *lower* wavenumber side, (d) the presence of *two* bands between 1000-1035 cm^{-1}, and (e) the *positions* of the 338, 679 and 1031 cm^{-1} bands. Other clinopyroxenes such as jadeite, the key mineral species of Burmese and Mesoamerican jade [6], also do not fit.

Most natural orthopyroxenes lie close to the binary join enstatite $\{MgMgSi_2O_6\}$ - ferrosilite $\{Fe^{2+}Fe^{2+}Si_2O_6\}$ and their chemical compositions are often described by their number *mg* = $Mg/(Mg+Fe^{2+})$. Comparison with the Raman spectra from various orthopyroxenes with *mg* between 85 & 95 [3-5] reveals that this scarab has a physical structure and a chemical composition which may be described as an orthopyroxene with *mg* = 90 ± 5. However this ignores the role of Ca, which commonly rises to 5 cation % of $(Ca+Mg+Fe+Mn+Ni)^{2+}$, and of possible $(Mn,Al,Fe,Cr)^{3+}$, which cause slight variations in Raman band positions (*cf.* Fig. 2 where an Mg-rich orthopyroxene from Norway is superposed). It is thus deduced with confidence that the mineral composition may be described as 90 % enstatite + 10 % ferrosilite ± 10 mol. % of other components.

Following recent official IMA terminology, the proper mineral species name is enstatite, but older names like "bronzite" (*mg* = 70-87.5) and "hypersthene" (*mg* = 50-70) are widely mentioned in the geological literature. An apparently exhaustive list of materials in which ancient Egyptian jewellery was carved [1] includes names of rocks, mineral groups, species, varieties and “common names”, but none correspond to orthopyroxene. "Hypersthene" has however been mentioned for some Egyptian scarabs in the archaeological literature [7], but how this was proved, argued or just guessed is not explicit. It is difficult to distinguish orthopyroxene from various other mineral species without RM or a *destructive* geological/chemical analytical method. Apart from Fe-oxide, it is not yet clear what other minerals are present in this scarab; if it is confirmed that enstatite is dominant, then the proper rock name would be “enstatitite” or “orthopyroxenite”, regardless whether it was of igneous or metamorphic origin, and this is a relatively rare rock type (*cf.* jade).

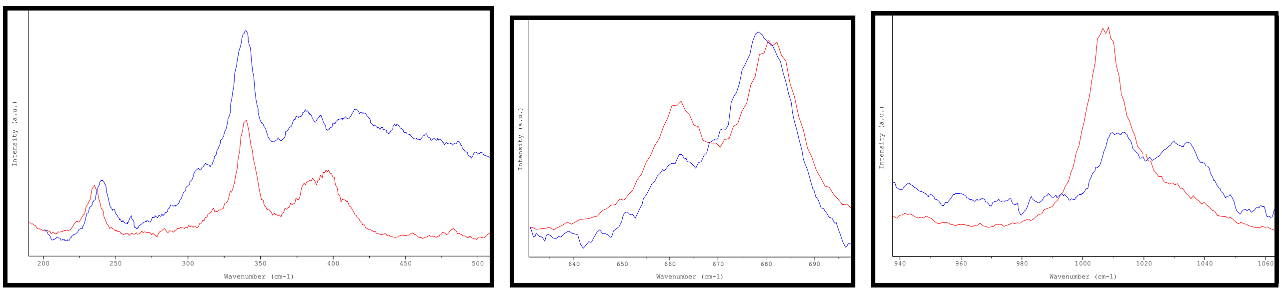

Fig. 2. 2a (200-500 cm^{-1}) 2b (630-700 cm^{-1}) 2c (940-1060 cm^{-1})
Raman spectrum of this scarab (*blue*) obtained with a 647.0 nm laser; Norwegian enstatite (*red*).

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