A splendid rock, a little bit of history...

LUXULLIANITE

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Fig. 1 - Mausoleum of the Duke of Wellington (St. Paul's Cathedral, London).
© Wikipedia.

As the season draws to a close, there are places where entertainment is essential. These are the cemeteries.

Fig. 2 - Arthur Wellesley, 1st Duke of Wellington (1769-1852).

A burst of sunlight in these sad places warms the heart. We must admit that if the statuary can become expressive, a happy choice of “tombstones” iridescent our eyes moistened with memories. Stone masons prefer hard, unalterable rock to mossy limestone. Thus the pale winter sun is reflected in the iridescence of labradorite, a feldspar that shimmers with a thousand lights. But granit is often chosen. Although there are many varieties, some are very rare. This is the case with the tombs of the “Great Men”, whose rock has the same strength as that which characterized the recumbent figure. Let us choose the mausoleum of Arthur Wellesley, 1st Duke of Wellington (1769-1852). Remember that this nobleman of Irish origin famously defeated Napoleon at Waterloo (1815). His physical strength and unyielding will earned him the nickname “Iron Duke”. His tomb was carved from an exceptional granit from the South of England.

GRANIT

Granit is a magmatic plutonic rock with a granular texture, characterized by its constituent minerals: quartz, micas (biotite or muscovite), potassium feldspars (orthoclase) and plagioclase.

Fig. 3 - Slice of Luxullianite with orthose and tourmaline crystals (Wikipedia).

Granit and its associated rocks form the bulk of the planet's continental crust. Granit is the result of the slow, deep cooling of large masses of intrusive magma, which most often form plutons. These plutons currently surface thanks to erosion, which has stripped away the overlying rocks.

Fig. 4 – Saint Austell granit complex (Cornwall) © Wikipedia.

Fig. 5 – Raw luxullianite, with orthose and tourmaline crystals.
Photo by Kevin Walsh.

These acidic magmas (i.e. relatively rich in silica) are the result of the partial melting of the continental earth's crust. In total, there are now more than 500 different colors of granite.

LUXULLIANITE

Luxullianite, on the other hand, is a very rare type of granite. Its name is taken from the village of Luxulyan in Cornwall (UK). Luxullianite is made up of orthoclase and quartz phenocrysts embedded in a matrix of quartz, alkali feldspar, brown mica and cassiterite. This combination contains numerous fibrous aggregates of tourmaline. But at first glance this rock appears to be made up of two components, a tabular pink-salmon feldspar and black tourmalines.

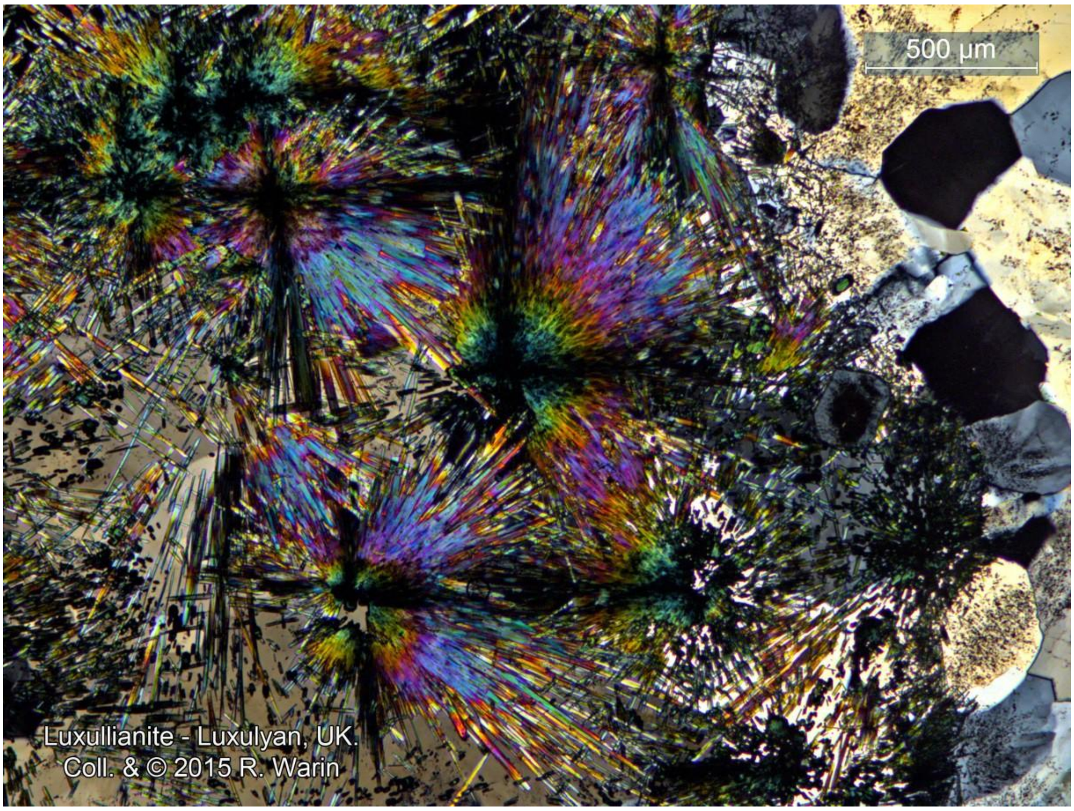


Fig. 7 – Thin section of Luxullianite – Luxulyan, Cornwall Coll. & © R. Warin.

Luxullianite belongs to the St Austell granite complex, whose fractional crystallization generated pegmatitic fluids rich in boron and fluorine. This St Austell complex was formed approximately 280 million years ago by the partial melting of the lower continental crust during Variscan orogeny. The Luxulyan quarry is a large cavity currently filled with water.
The site is now classified as an SSSI (site of special scientific interest) and is therefore normally inaccessible.

METASOMATISM

The metasomatism associated with the batholith has chemically transformed the original granite. **Metasomatism** is an extreme case of metamorphism. This process modifies the overall chemical composition of the rocks due to the addition of new chemical elements, in particular boron in this case, accompanied by the expulsion of other elements. The term **batholith** (from the Greek "bathos": depth and "lithos": rock) refers to a mass of intrusive igneous rocks (also called pluton or plutonic rocks). This massif does not respect the lines of force of the surrounding rocks. There is thus a strong discordance in the nature of the rocks between the intrusion and the surrounding environment.

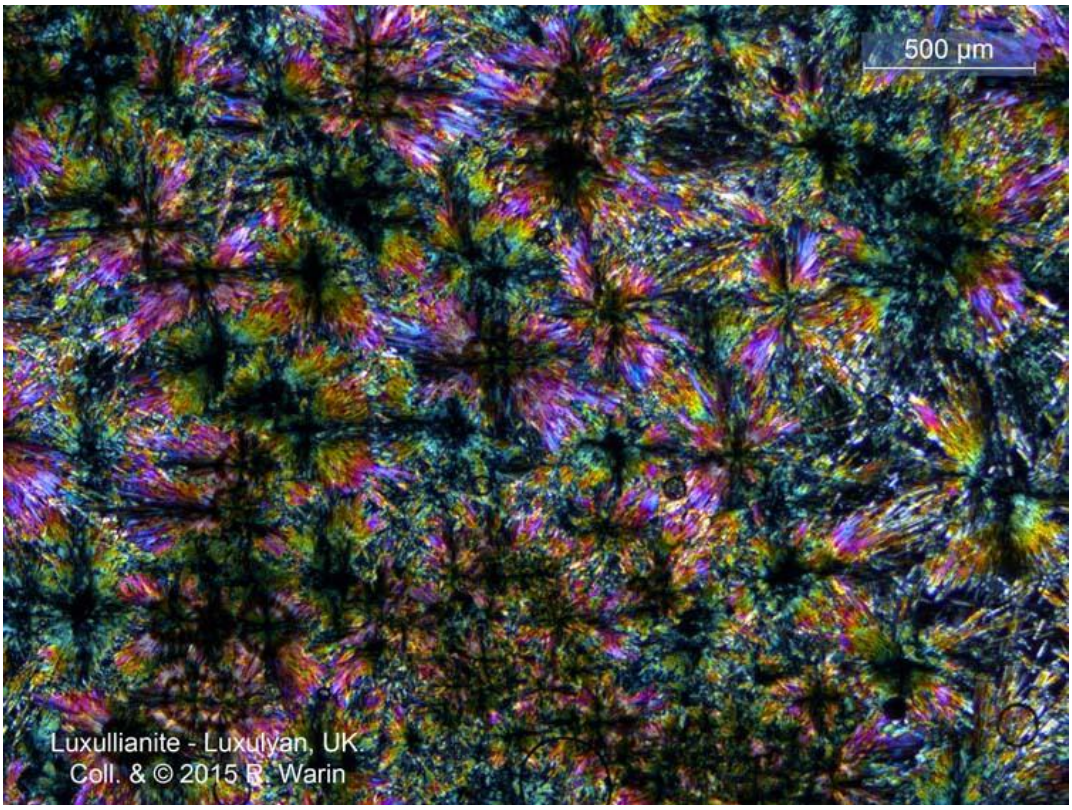


Fig. 8 – Luxullianite – Aggregate of acicular tourmaline spherulites. © R.Warin.

In these drastic conditions of temperature and pressure, the hydrothermal fluids transport ions in solutions that disrupt the initial chemical equilibrium and induce chemical reactions to give new mineral species of metasomatic origin. The circulation of these fluids thus transports ions and molecules such as CO_2, the anions Cl^-, F^-, $(BO3)^{3-}$ (or borates), metal cations and many other elements. The metasomatism of the Cornish granites produces deposits of tourmaline and greisen (feldspar-free granites strongly altered into various minerals typical of pegmatites). There is a close correlation between the intrusion of igneous rocks from the batholith and contact metamorphism with the surrounding local rocks thanks to the circulation of hydrothermal fluids, the composition of which also plays a role. The resulting mineralogy is thus variable and depends on the nature of the batholith or pluton, the nature of the surrounding rocks, the composition of the hydrothermal fluids and even the possible presence of meteoric water.

TOURMALINIZATION

Following the introduction of boron (a competitive element of silicon), tourmalinization, is a process by which previously existing minerals are replaced wholly or in part by tourmaline. In this chemical process caused by the addition of boron and fluorine, metasomatic replacement of micas and feldspars takes place to form tourmaline. This process is so widespread in the granites of Cornwall that it can go so far as to form a rock containing only quartz and tourmaline.

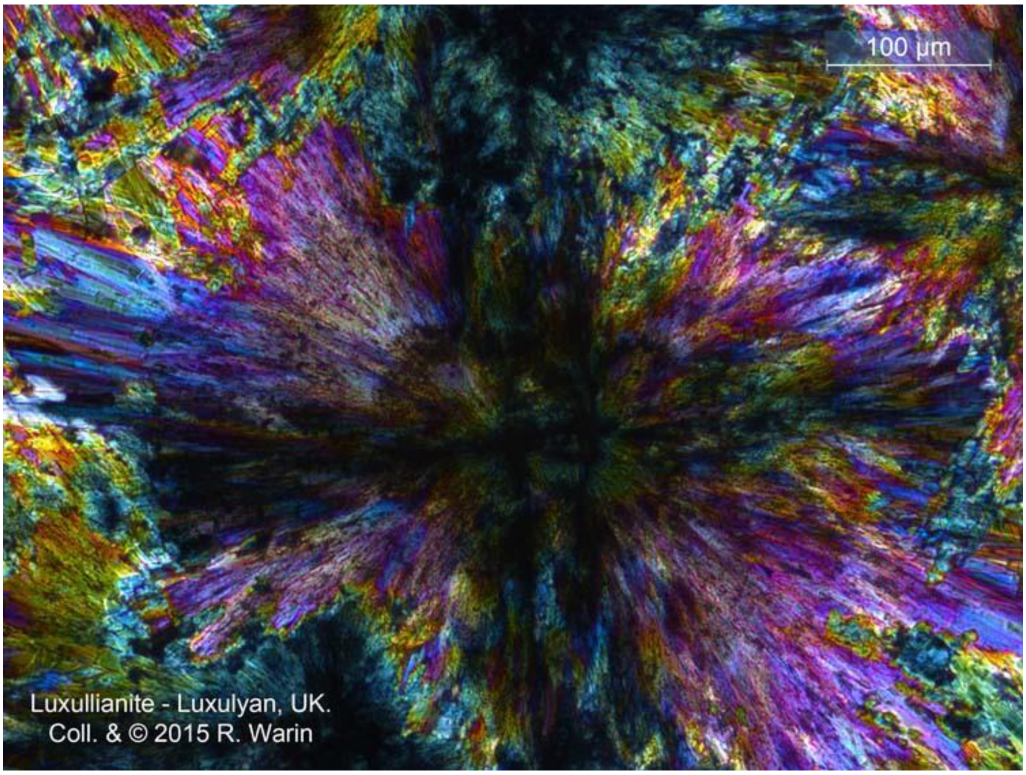


Fig. 9 – Luxullianite – Extinction cross correlated with 2 or 3 contiguous acicular tourmaline spherulites. Coll. & © R. Warin.

Fig. 10 - Quarter of a tourmaline spherulite in Luxullianite. Magnification 400X - Field of view: 0.3 mm. Coll. & © R. Warin.

The majority of tourmalines are black, but elbaite is also present. Numerous colors exist depending on the presence of trace elements or the variation of the major elements. Several localities have yielded varieties of red-pink tourmaline, but they have become exceptional, having been highly sought after by collectors.

THIN SECTIONS OF LUXULLIANITE

This rock from Luxulyan could only produce superb thin sections, surprising in more ways than one. This granite, which has undergone deep metasomatism, shows orthose phenocrystals and spherulites of fiber-rayed tourmaline. The birefringence of the tourmaline (~0.03) produces second-order colors under cross-polarized light. The aesthetic effect is surprising. I would like to thank John Kashuba (Eng.) (Oregon) for giving me one of these TS and thus enabling me to describe it. Many thanks, John.

But there is also an optical phenomenon rarely observed in petrology, the presence of extinction crosses correlated with the existence of these spherulites. The position of these crosses (the Maltese crosses) is independent of the rotation of the microscope platin, which clearly proves their exceptional nature.

It was Jacques Rocchia (PhD in Geology, Volcanology – France) who explained it to me, recalling the writings of former Masters, Roubault in this case. Here is his report:

> *“It is a granite that dates back to the Variscan (Hercynian) orogeny of England, characterized by a rather particular crystallogenesis which gives these spherulites with needles polarizing in the second order and showing these enigmatic crosses independent of the rotation of the stage which therefore remain oriented in the same way while the needles (fibers) show - in rotation - what we call a rolling extinction. These are not the black crosses that can be seen in converging light after removing the microscope eyepiece.”*
>
> *It is important not to confuse this black cross with a phenomenon sometimes observable in parallel light, when certain minerals appear in very fine needles (sometimes in fibers so thin that they can be indiscernible), grouped in such a way as to give rise to a kind of globule or spherulite, arranged in a radiated manner around its center. If the fibers in question are extinguished lengthwise, we therefore have a black cross more or less blurred in parallel light (black) since the fibers having the direction of the reticle threads are extinguished and, on the contrary, those directed at 45° present their maximum illumination. When the preparation is rotated, the cross naturally remains oriented in the same way, with new fibers extinguishing as those that were extinguished begin to polarize again.*
>
> *Extract from Roubault (1963).*

COMMENTS

The legends of the photos of the various thin sections (TS) of Luxullianite deserve comment. The first is figure 7. It shows a mixed part with, on the left, an aggregate of tourmaline spherulites whose sections give these radiating stars in analyzed polarized light (or crossed at 90°). To the right of the view is a range of quartz grains of arenite texture.

Figure 8 highlights a range of tourmaline spherulites. These small spherical aggregates are contiguous, and each well-individualized spherulite shows an extinction cross similar to a Maltese cross. All these crosses are oriented in the same way, regardless of the actual orientation of each spherulite, which is arbitrary.

Figure 9 isolates an aggregate, which is, however, split in two, as shown by the double Maltese cross. The field of view is 0.6 mm. This gives an idea of the smallness of these spherulites.

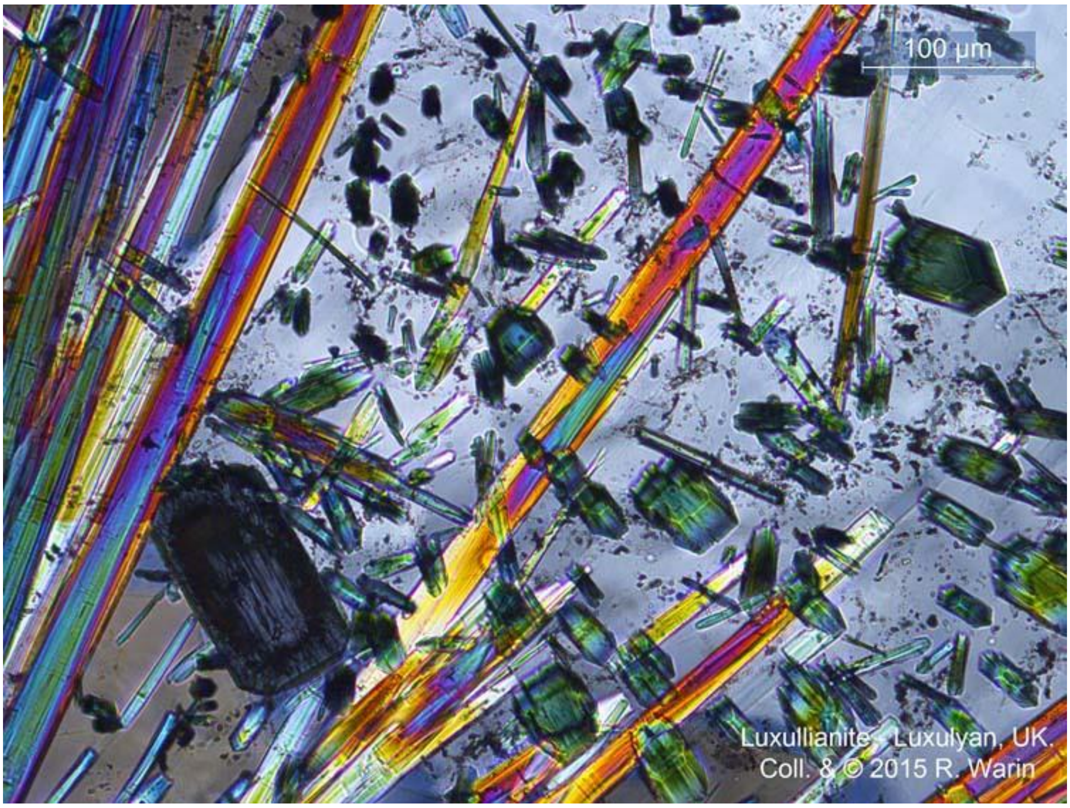


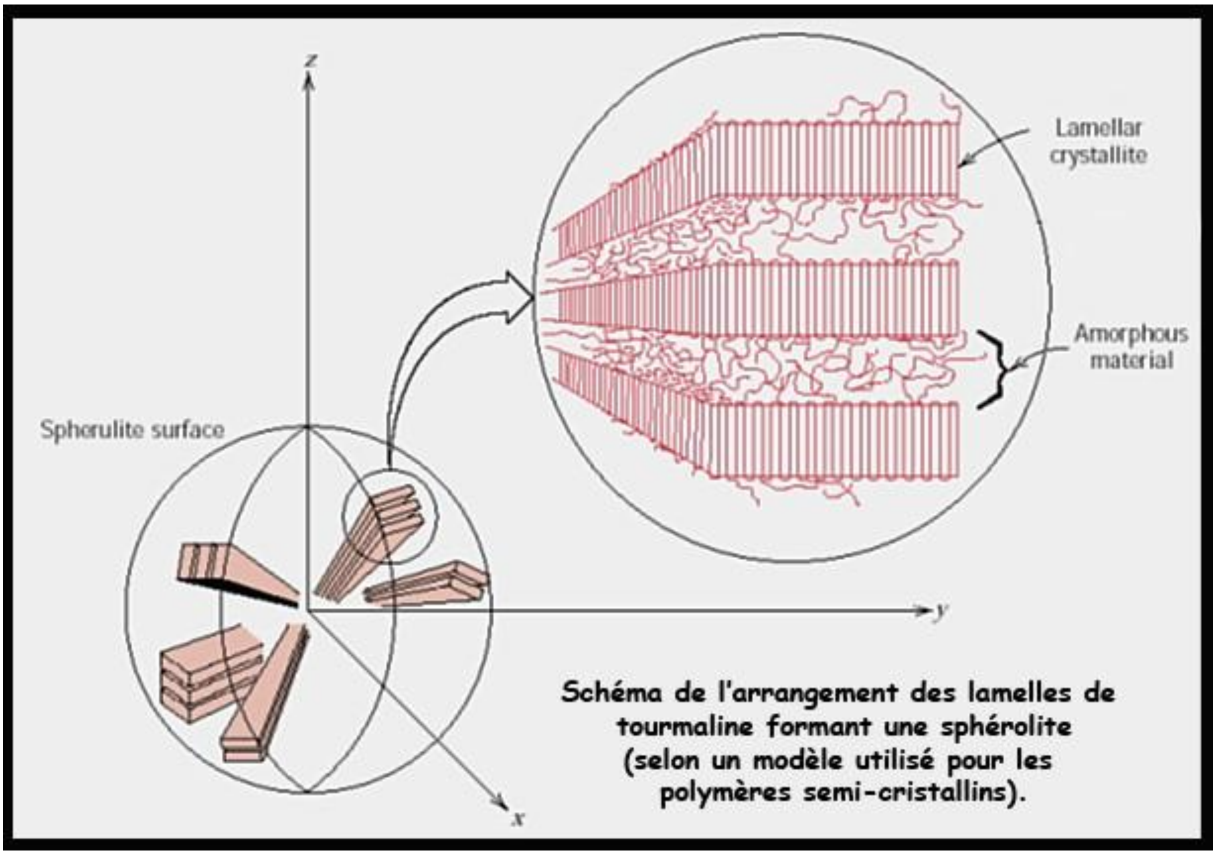
Fig. 11 – Luxullianite – Next to the tourmaline fibers, there are idiomorphic tourmaline crystals embedded in feldspar. Coll. & © R. Warin.

Thanks to their very small dimensions, these tourmaline spherulites have given rise to an optical phenomenon rarely observed in petrology, the appearance of extinction crosses initiated by these tiny spherulites. These crosses are independent of the rotation of the microscope platin, i.e. their orientation is constant and unique for all the spherulites. This phenomenon is clearly distinct from the undulating variations appearing on rotation of the microscope platin, which may have been induced by shocks deforming the crystal lattices (shocked rocks).
An unanalyzed light view of the thin section (natural colors) shows transparent greenish tourmaline crystals (Fig. 14).

Figure 10 shows only a quarter of a spherulite. This choice eliminates any extinction zone of the Maltese cross. The width of the field is very small, only 0.3 mm. Magnification : 400 X.

Figure 11 shows an interesting area in that it demonstrates that late crystallization has left some non-acicular and even idiomorphic, stocky-shaped tourmaline microcrystals. Their dimensions vary between a few dozen microns and up to a hundred microns (1 micron = 1µm = 10^{-6} m or 0.000 001 meters). These microcrystals show their different poles, as the bases terminating the prisms are not symmetrical. This pyramidal hemihedral nature of elbaite allows the microcrystals to be identified.

STRUCTURE OF A SPHEROLITH



These small spherical aggregates are the result of a dispersion of very fine needles or lamellae arranged radially from a center. The diagram in Figure 12 gives an idea of this fibrous-radiated geometry. I borrowed and slightly modified an explicit diagram found in crystallography studies of semi-crystalline polymers.

The thin layers of tourmaline are separated by a few microns by the rock matrix, which is essentially made up of feldspar. This matrix is an amorphous material.

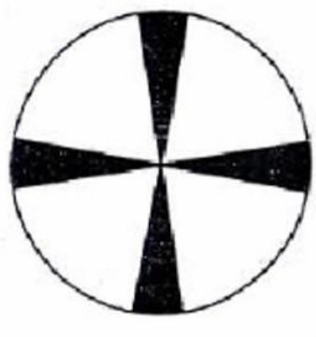


Fig. 13 – Malta Cross of spherulite.

Spherulite is therefore represented by a sphere containing these tourmaline fibers separated by an amorphous phase.

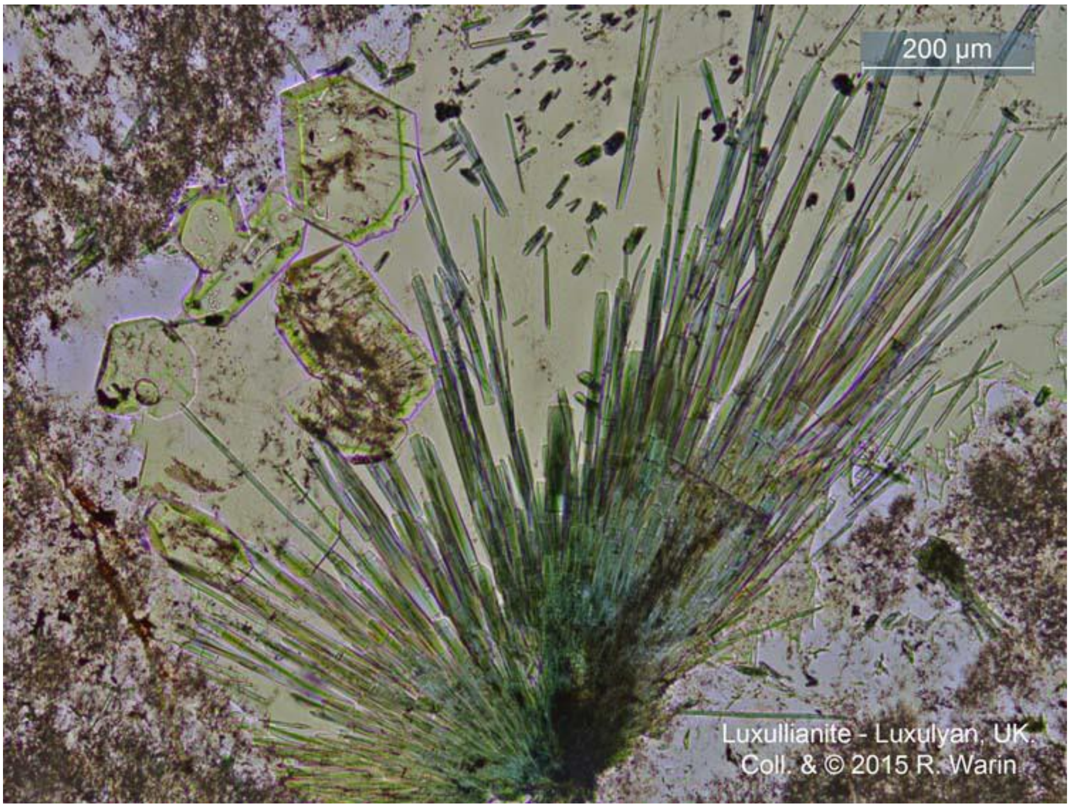


Fig. 14 – Luxullianite – Light not analyzed. © Coll. & © R. Warin.

CONCLUSION

A small piece of well-chosen rock can tell a beautiful story, combining historical notions with advanced geochemical considerations. One can only admire the Ancient Geologists who knew how to make stones speak with means as gentle as a microscope. The last figure (Fig. 14) shows what this rock looks like in natural light, not analyzed by a second polarizer. The colors here are therefore natural, whereas polarized light crossed at 90° produces hues that are a function of several factors, in particular the nature of the mineral through its birefringence.

References

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