

Figure 5: This chondrite-normalized REE diagram of the danburite samples analysed by LA-ICP-MS reveals their general enrichment in light REEs (La to Sm). The three specimens from Tanzania show distinctly higher amounts of heavy REEs (Gd to Lu) than the Burmese samples. All but two of the samples (from Myanmar) show a negative Eu anomaly.

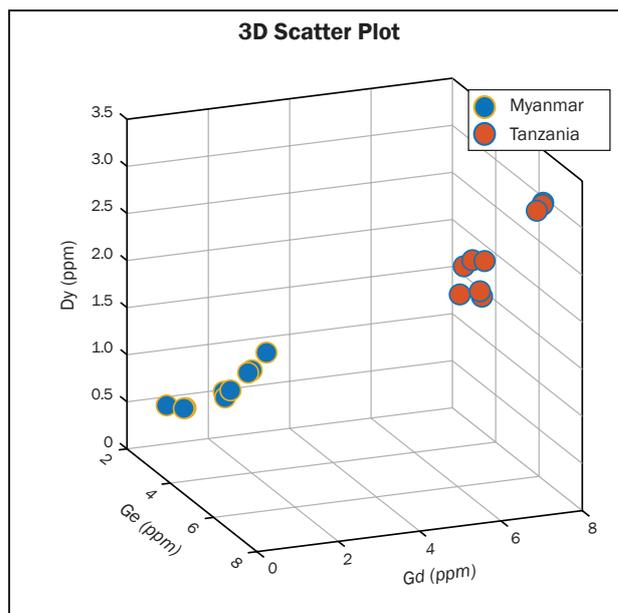


Figure 6: The analysed danburites from Myanmar and Tanzania are clearly distinguished in this three-dimensional scatterplot of germanium, gadolinium and dysprosium.

## References

- Anders E. and Grevesse N., 1989. Abundances of the elements: Meteoritic and solar. *Geochimica et Cosmochimica Acta*, **53**, 197–214, [https://doi.org/10.1016/0016-7037\(89\)90286-x](https://doi.org/10.1016/0016-7037(89)90286-x).
- Chadwick K.M. and Laurs B.M., 2008. Gem News International: Yellow danburite from Tanzania. *Gems & Gemology*, **44**(2), 169–171.
- Guillong M., Meier D.L., Allan M.M., Heinrich C.A. and Yardley B.W.D., 2008. Appendix A6: SILLS, a MatLab-based program for the reduction of laser ablation ICP-MS data of homogeneous materials and inclusions. In P. Sylvester, Ed., *Laser Ablation ICP-MS in the Earth Sciences: Current Practices and Outstanding Issues*. MAC Short Course Vol. 40, Mineralogical Association of Canada, Québec, Canada, 328–333.
- Huong L.T.T., Otter L.M., Macholdt D.S., Foerster M.W., Stoll B., Weis U. and Jochum K.P., 2016. Discrimination of danburite from different deposits by chemical components: A femtosecond LA-ICP-MS study. *35th International Geological Congress*, Cape Town, South Africa, 27 August–4 September, [www.americangeosciences.org/sites/default/files/igc/1423.pdf](http://www.americangeosciences.org/sites/default/files/igc/1423.pdf).
- Weill D.F. and Drake M.J., 1973. Europium anomaly in plagioclase feldspar: Experimental results and semiquantitative model. *Science*, **180**(4090), 1059–1060, <https://doi.org/10.1126/science.180.4090.1059>.

## Yellow Danburite from Namalulu, Tanzania, and Myanmar: Origin of Colour and Its Stability

The origin of the yellow colour in danburite is not fully known. However, some researchers have speculated that it may be due to didymium, a name referring to a mixture of light REEs including praseodymium (Pr) and neodymium (Nd), and sometimes cerium (Ce). These and other REEs can replace  $\text{Ca}^{2+}$ .

When viewed with a desk-model spectroscope, typically no absorption features were observed for yellow danburites from Tanzania and Myanmar

(see preceding Gem Note for sample descriptions). However, in the larger and more intensely coloured samples, a very faint line at approximately 584 nm could be seen. Using a Perkin-Elmer Lambda 950 spectrometer, several weak bands were recorded in the visible region at approximately 525, 567, 577, 584, 732, 744 and 792 nm, as well as two dominant bands in the UV region positioned at approximately 275 and 315 nm (Figure 7).

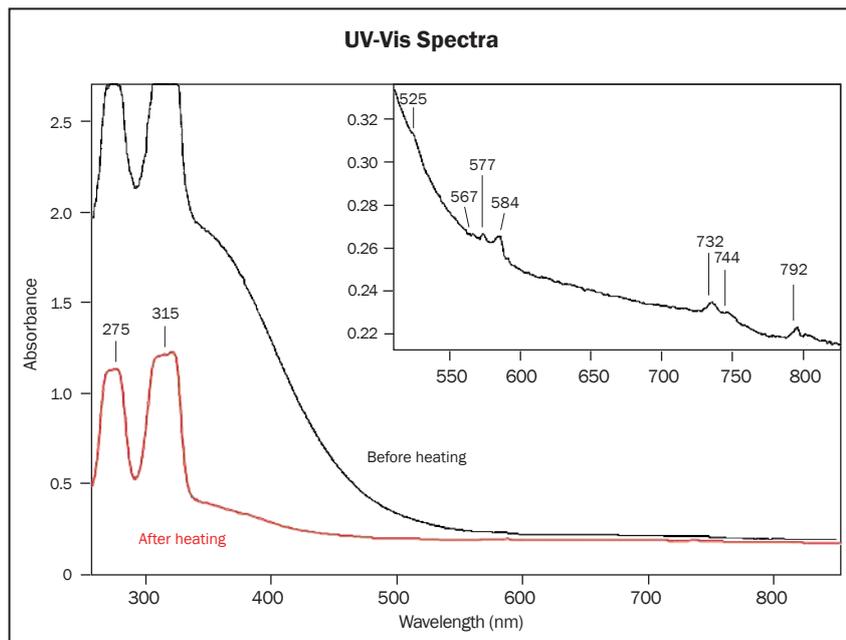


Figure 7: UV-Vis-NIR spectra (5.4 mm path length) are shown for a rough sample of Namalulu danburite, before and after heating. The spectrum before heating shows a general increase in absorption beginning just below 600 nm, as well as two dominant bands in the UV region positioned at approximately 275 and 315 nm. After heating, the yellow sample became colourless with a corresponding decrease in absorption from the visible to the UV region of the spectrum; the bands in the UV region remained unchanged. A series of weak absorption bands positioned at approximately 525, 567, 577, 584, 732, 744 and 792 nm (see inset) appeared to be unaffected by heating.

Although we assume that lanthanides (REE with atomic numbers 57–71) are responsible for the colour of these danburites, we could not find a direct correlation between the yellow colour saturation and the REE concentration in the studied samples from Tanzania and Myanmar. The colour intensity may therefore be linked to variable ratios of the valence states of certain lanthanides (e.g.  $Ce^{2+}$ ,  $Ce^{3+}$ ,  $Ce^{4+}$ ), in addition to their concentration.

To test the colour stability of yellow danburite, one of the authors (CPS) heated one rough sample each from Tanzania (Figure 8a) and Myanmar to 500°C for four hours, and both showed a complete loss of colour (e.g. Figure 8b). The samples were then heated further to 950°C for a period of 24 hours, but they remained colourless. Ultra-

violet-visible-near infrared (UV-Vis-NIR) absorption spectroscopy was performed on the samples before and after heating. In their unheated state, the yellow danburites showed a significant rise in general absorption from roughly 550 nm leading into the UV region of the spectrum (again, see Figure 7). After heating, this absorption was greatly reduced. The mid-infrared spectra (taken with a Thermo Scientific Nicolet 6700 spectrometer) were virtually unaffected by heating, although a band at 3588  $cm^{-1}$  did appear slightly diminished. Additionally, no apparent changes were noted in Raman or photoluminescence spectra (recorded with a Renishaw InVia spectrometer equipped with a 514 nm Ar-ion laser) in the samples after heating.

We did not perform experiments specifically to restore the yellow colour in the danburite

Figure 8: A rough yellow danburite from Namalulu, Tanzania, (a) was heated to 500 °C for four hours, resulting in a complete loss of colour, and the sample remained colourless after further heating to 950 °C for 24 hours (b). For another test, one bead of Namalulu danburite was kept as a reference sample, while another bead was exposed to a tensor lamp for eight hours (c, left and right samples, respectively). After three hours, the bead exposed to the lamp darkened and became more brownish. Photos by Bilal Mahmood (a, b) and C. P. Smith (c).



samples, but exposure of Burmese danburite to X-rays is known to induce a yellow or 'golden' brown colour (Webster, 1953); the stability of the induced colour was not reported.

Gem dealers who have handled danburite from the two localities in Tanzania (Morogoro and Namalulu) have noted a significant difference in their colour stability to sunlight. While the Morogoro material appears stable, Namalulu danburite develops a darker brownish yellow coloration after exposure to sunlight (Werner Radl and Menahem Sevdermish, pers. comm., 2016). To test this, author CPS exposed a yellow danburite from Namalulu to a tensor lamp (positioned 15 cm from the stone) for eight hours and checked hourly for any changes in colour. After approximately three hours, its

colour had become slightly more saturated, yet distinctly more brownish (Figure 8c). After the full eight hours, its colour did not change further. No experiments were performed in an attempt to restore the original coloration, but according to Radl this change in colour is permanent and irreversible under normal conditions of display or wear. He added that mining for the Namalulu danburite has stopped in recent years due to lack of commercial interest as a result of the susceptibility to develop a brownish coloration.

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### Reference

Webster R., 1953. Gemstone luminescence. Part V. *The Gemmologist*, **22**(266), 161–164.

## New Production of Emerald from Ethiopia

Ethiopia has been known as a source of emerald for many years, but recently it produced some high-quality material (see, e.g., Figure 9 and Renfro et al., 2017) and some fine stones were displayed by various dealers during the 2017 Tucson gem shows. One vendor, Mahesh Agarwal (Stone International, Jaipur, India), reportedly obtained approximately 1,000 carats of faceted stones (150–200 pieces) that ranged up to 21.70 ct. The emeralds were cut from selected pieces of a parcel weighing several kilograms that was mined since September 2016 in the Shakiso region of southern Ethiopia. In addition, Agarwal has ob-



Figure 9: These emeralds (total weight 23.60 carats) reportedly were produced recently from Ethiopia and were on display at one of the 2017 Tucson gem shows. Courtesy of Mahesh Agarwal; photo by B. M. Laurs.

Figure 10: A miner searches for emeralds in a narrow shaft in the Kenticha area of Ethiopia. Photo by Dr Klaus Schollenbruch, © Gübelin Gem Lab.



tained ~300 kg of low-to-medium quality rough material. He indicated that the faceted stones were untreated except for light oiling (with mineral oil), as is typically done for coloured stones after they are cut in Jaipur.

According to gem dealer Hussain Rezayee (Rare Gems & Minerals, Los Angeles, California, USA), the recent emerald production took place in the Kenticha area, which is located approximately 40 km south of Shakiso. A series of shallow pits and shafts (up to a few metres deep; e.g. Figure 10) have been dug by about 500 miners in search of emerald. Production from the area