**Figure 14:** These violet-to-purple and reddish brown-to-pink spinels were mined from the Kuran wa Munjan District in Badakhshan Province, Afghanistan. The faceted stones at the bottom weigh 0.47–1.23 ct. Photo by S. Hänsel.

## Update on Purple Spinel from Afghanistan

Afghanistan is known for high-quality emerald, ruby and lapis lazuli, as well as spinel. Pink-to-red spinel has been mined from the Badakhshan region of eastern Afghanistan, close to the famous mines of Kuh-i-Lal, Tajikistan, since ancient times (Hughes 1994). Starting in early 2017, attractive purple spinels from Badakhshan entered the markets in Thailand and the USA (Boehm 2017). Recently, one of the authors (SH) purchased 450 g of small-sized rough violet-to-purple spinel from a Pakistani dealer, who reported that it came from the Zo Valley in the Kuran wa Munjan District of southern Badakhshan. Several others who buy rough gems from that area confirmed this locality. Surprisingly, 90% of the rough material showed not only lamellar growth lines but also complex twinning in several directions (e.g. Figure 14, centre), and only a few pieces had the classic octahedral shape that is typical of spinels from some other primary deposits.

After cutting some of the rough spinel, author SH selected eight faceted violet-to-purple gems (0.47–1.23 ct; Figure 14, bottom row) for standard gemmological testing. In addition, windows were polished on several of the remaining rough samples. The gemmological properties were typical for natural spinel: RI = 1.715 (± 0.001) and SG = 3.53 (± 0.05). Most stones were inert to both long- and short-wave UV radiation, although some clean ones showed a slightly greenish reaction to long-wave UV. All of them exhibited a strong pink reaction when viewed with the Chelsea Colour Filter.

Microscopic observation revealed mineral inclusions consisting of rutile (Figure 15a–c), apatite (Figure 15d) and zircon (Figure 15e). Clusters of mica (Figure 15f) were also present in some stones and resembled those documented in Afghan purple spinel by Boehm (2017). The identity of all of these inclusions was confirmed by Raman micro-spectroscopy using a Renishaw inVia instrument.

Additional testing of 11 violet-to-purple rough and faceted samples was done at The Gem and Jewelry Institute of Thailand (GIT). Ultraviolet-visible (UV-Vis) spectroscopy performed with a PerkinElmer Lambda 1050 spectrophotometer revealed absorption features at 372, 386, 458 and 555 nm (Figure 16) related to iron. The absorption at 458 nm is due to $Fe^{3+}$, while those at 372, 386 and 555 nm are due to $Fe^{2+}$ (D'Ippolito *et al.* 2015); together they create transmission windows

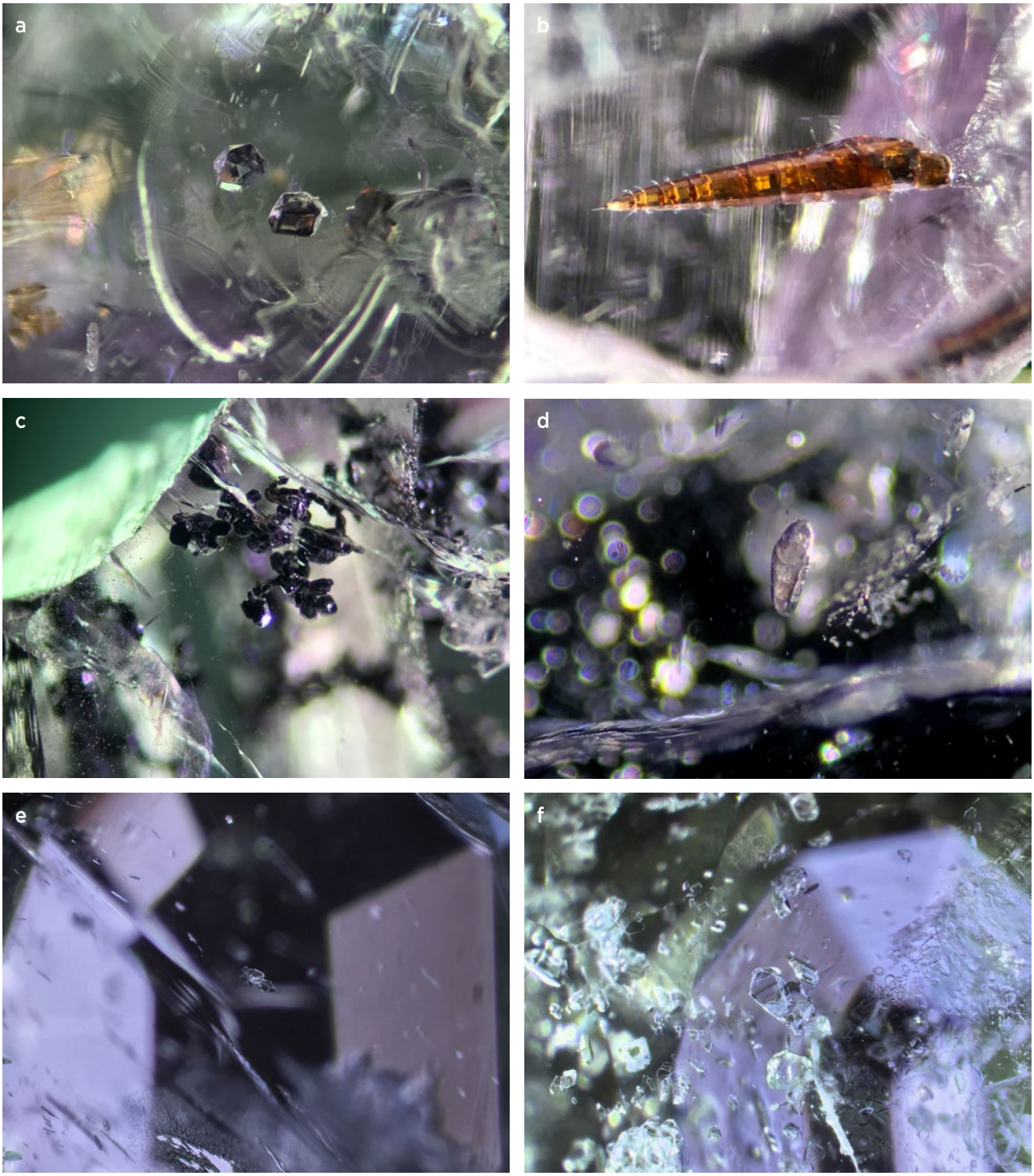


**Figure 15:** Mineral inclusions in the spinels consist of rutile (**a**–**c**), apatite (**d**), zircon (**e**) and mica (**f**). Photomicrographs by S. Hänsel in darkfield illumination; magnified approximately 90×.

in the red and blue regions that are responsible for the purple colouration.

Chemical analysis of these 11 samples was performed at GIT by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) using a Thermo Scientific iCAP RQ ICP-MS coupled to a New Wave Research NWR213 laser ablation unit. Iron was by far the most abundant trace element (average 10,170 ppm), consistent with the absorption features recorded in the UV-Vis spectrum. Also present were traces of Zn, Ga, Mn, Ti, Ni, V, Be, Li, Co, Cr and Cu (Table I). All of these elements have been documented previously in gem spinels from various deposits (cf. Peretti *et al.* 2015).

The seller of these purple spinels indicated that such material is more commonly appearing in the local markets of Afghanistan and Pakistan, often mixed with

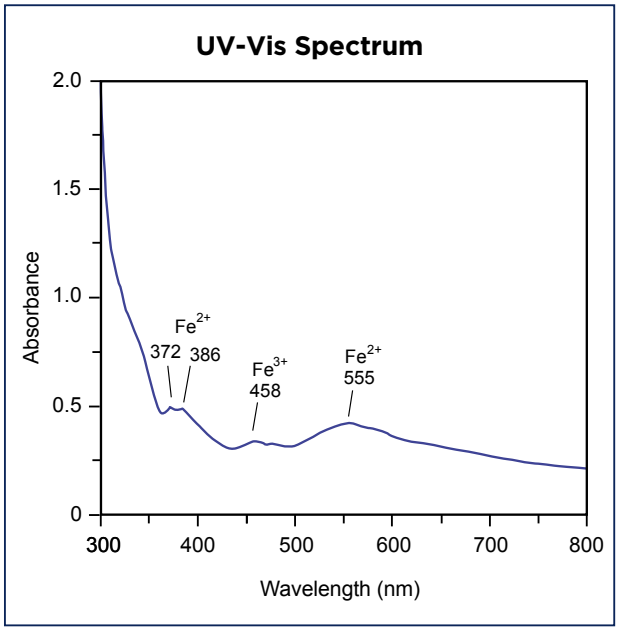


**Figure 16:** This representative UV-Vis spectrum of a purple spinel from Afghanistan (about 3.0 mm path length) shows absorption peaks related to $Fe^{2+}$ and $Fe^{3+}$.

purplish pink spinel. Both colour varieties are said to originate from mines in the Kuran wa Munjan District. The carrot-shaped crystal form of the rutile inclusions documented here is not commonly encountered in spinels from other deposits and may provide a good indicator for Badakhshan material.

*Sebastian Hänsel FGA*
*International Colored Gemstone Laboratory*
*Bangkok, Thailand*

*Thanapong Lhuaamporn (lthanapong@git.or.th),*
*Montira Seneewong-Na-Ayutthaya and*
*Cheewaporn Suphan*
*GIT Gem Testing Laboratory*
*Bangkok, Thailand*

**Table I:** Trace-element concentrations in violet-to-purple spinels from Afghanistan, as determined by LA-ICP-MS.

| Element | Average (ppm) | Range (ppm) |
|---|---|---|
| Li | 23.3 | 8.60–39.7 |
| Be | 26.2 | 12.7–53.0 |
| Ti | 83.5 | 69.4–99.9 |
| V | 28.0 | 17.3–39.5 |
| Cr | 1.04 | <0.36–3.60 |
| Mn | 243 | 196–287 |
| Fe | 10170 | 8720–12210 |
| Co | 8.91 | 5.49–15.2 |
| Ni | 39.7 | 18.9–59.3 |
| Cu | 0.23 | <0.03–4.37 |
| Zn | 1160 | 420–2510 |
| Ga | 329 | 185–526 |

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# DIAMONDS

## Treated Greenish Yellow Diamond with Brown Radiation Stains

The Swiss Gemmological Institute SSEF recently analysed a treated greenish yellow diamond showing evidence of artificial irradiation and annealing (Figure 17). This 1.07 ct cushion-shaped stone exhibited very strong greenish yellow fluorescence under long-wave UV radiation (with slightly less intensity under short-wave UV). The greenish yellow fluorescence was visible even in normal daylight.

Infrared spectroscopy (Figure 18) revealed that it was type IaAB, and contained approximately 64 ppm nitrogen as A centres and 135 ppm nitrogen as B centres (based on absorption coefficients given in Boyd *et al.* 1994, 1995), as well as platelets and hydrogen-related defects. In addition, two clear absorption lines at 5163 and 4934 $cm^{-1}$ indicated the presence of H1c and H1b centres, respectively (Figure 18, inset).