NOTES & NEW TECHNIQUES

YELLOW SCAPOLITE FROM IHOSY, MADAGASCAR

Margherita Superchi, Federico Pezzotta, Elena Gambini, and Emanuela Castaman

Attractive yellow to light greenish yellow gem scapolites have been mined from a skarn deposit near the town of Ihosy, in southern Madagascar, since the late 1990s. Chemical analysis indicates that the scapolites have a mostly meionite content, with lesser amounts of marialite and a small percentage of silvialite. These results are agreeable with the RI measurements and IR spectra. Inclusions were identified as diopside, garnet (andradite-grossular), and mica (probably phlogopite), consistent with the minerals accompanying scapolite in Ihosy skarns. The samples' UV fluorescence appears to be distinctive from that of commercially available scapolites from other localities.

Scapolite is a silicate mineral that occurs in crystals often characterized by good transparency, significant size, and a wide variety of colors: greenish yellow, yellow, pink, purple, dark pinkish purple, and violet. Colorless crystals also exist. Despite its relatively low hardness (Mohs 6), it has interest as a collector's gem. The most important localities for gem-quality scapolite are Afghanistan (Badakhshan), China (Xinjiang-Uygur Autonomous Region), Myanmar (Mogok), Pakistan, Sri Lanka, Tajikistan, Kenya, Madagascar, Mozambique, Tanzania, and Brazil.

The scapolite group consists of two main end members: marialite ($Na_4[Al_3Si_9O_{24}]Cl$) and meionite ($Ca_4[Al_6Si_6O_{24}]CO_3$). Intermediate compositions in the solid-solution series are named after the closest end member (Deer et al., 1992). Meionite (Me) possesses higher RI and SG values than marialite. The meionite end member has refractive indices of n_o = 1.600 and n_e = 1.564, and an SG of 2.78; the marialite end member has RIs of n_o = 1.539 and n_e = 1.531 and an SG of 2.50 (Deer et al., 1992). A third end member of the group, silvialite, is characterized by an SO_4 anionic group ($Ca_4[Al_6Si_6O_{24}]SO_4$; Teertstra et al., 1999); however, silvialite has not been considered in previous gemological studies of gem scapolite.

It has not yet been systematically established whether the different colors of scapolite correspond to different compositions. Likewise, it is also unclear if properties such as RI and SG are related to specific colors. However, Couper (1991), reporting on a study of scapolite from Myanmar, noted that violet-to-pink samples plotted in the marialite field, and yellow and colorless samples fell in the meionite field. Because of the uncertainties concerning minerals of this group, a better knowledge is needed of the composition of gem-quality scapolites and the methods for their identification.

This study characterizes yellow scapolite from the Ihosy deposit in Madagascar, and investigates the suitability of previously established methods for calculating scapolite composition so it can be properly identified.

BACKGROUND

Yellow gem scapolite has been known from Madagascar since the beginning of the 20th century (Lacroix, 1922). In the past, production was sporadic and large gem crystals were rare. In the late 1990s, however, a new discovery was made about 35 km south of the town of Ihosy, in veins associated with skarn rocks typical of southern Madagascar (Martelat et al., 1997). The high-grade gneiss host

---

See end of article for About the Authors and Acknowledgments.
GEMS & GEMOLOGY, Vol. 46, No. 4, pp. 274–279.

Figure 1. The largest of these rough scapolites from Ihosy weighs about 10 g and measures 2.7 cm in diameter. A standard penlight is shown for scale. Photo by F. Pezzotta.

rocks contain a network of narrow granular scapolite veins associated with calcite, apatite, diopside, and minor spinel.

Local miners equipped with hand tools have worked the veins close to the surface in partially weathered horizons, and in fresh rock to a depth of a few meters. In 2007, occasional finds of good-quality scapolite caused them to work the deposits more actively, and there was a significant increase in production. The material showed an attractive yellow color (figure 1), and several kilograms of gem-quality rough—including clean, well-formed crystals up to 90 g—began to reach the local market. The faceted scapolites usually range from 4 to 12 ct, with some pieces as large as 30 ct (e.g., figure 2).

MATERIALS AND METHODS

Five cut stones (4.14–7.50 ct) and 16 pieces of rough (0.74–2.15 g) scapolite were analyzed (figure 3). Samples were selected from a large parcel of rough purchased from local miners in Ihosy by author FP. The studied samples are representative of the quality range produced from this locality. The five faceted stones were cut in Antsirabe (Madagascar) by a local

Figure 2. These faceted scapolites from Ihosy weigh 22.5 ct (left) and 29.7 ct (right). Courtesy of Giovanni Bossi and Riccardo Caprilli, respectively; photos by Roberto Appiani.

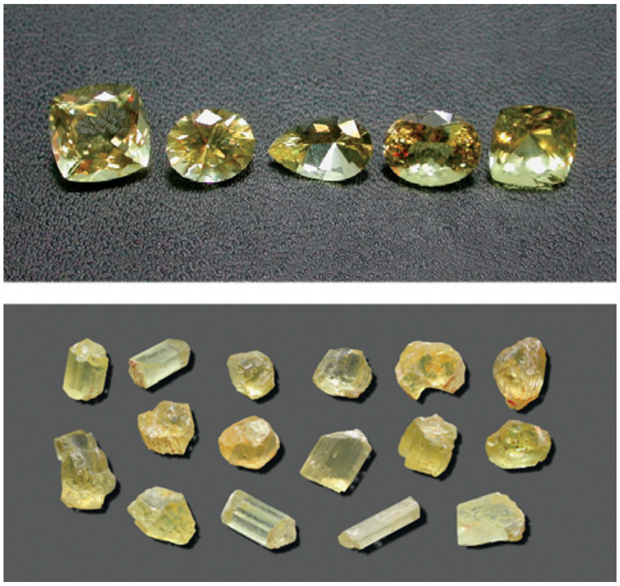


Figure 3. These five faceted scapolites (4.14–7.50 ct) and 16 rough crystals (0.74–2.15 g) from Ihosy were studied for this report. Photos by E. Castaman.

gem cutter; they were examined by standard gemological methods to determine their refractive indices, hydrostatic specific gravity, and microscopic features (using 20×–60× magnification). Long-wave (365 nm) and short-wave (254 nm) ultraviolet fluorescence was observed using a standard UV lamp.

Semiquantitative analyses of all 21 samples were performed with energy-dispersive X-ray fluorescence (EDXRF) spectroscopy using a Philips 9100 instrument operated with a voltage of 35 kV and a current of 100 μA. We also performed quantitative analyses of two representative pieces of rough (S2-P and S4-P), which were mounted in resin and polished, using a Cameca SX50 wavelength-dispersive spectroscopy (WDS) electron microprobe with an accelerating voltage of 15 kV and a current of 15 nA. Minerals used as standards for each element were apatite (F), albite (Na), olivine (Mg), corundum (Al), wollastonite (Si, Ca), sphalerite (S), vanadinite (Cl), orthoclase (K), synthetic $MnTiO_3$ (Ti, Mn), hematite (Fe), and celestite (Sr).

TABLE 1. Properties of five cut scapolites from Ihosy, Madagascar.[a]

Sample	Weight (ct)	RI (n_e–n_o)	SG	Me (%)[b]
1	4.13	1.555–1.575	2.68	60.0
2	4.32	1.555–1.580	2.71	64.9
3	5.70	1.554–1.581	2.72	64.9
4	7.23	1.555–1.581	2.72	65.9
5	7.50	1.552–1.574	2.68	56.0

[a] *All samples fluoresced pale yellow to long-wave UV radiation and strong purplish red to short-wave UV.*

[b] *Calculated from refractive indices following the formula reported in Deer et al. (1992).*

Infrared absorption spectroscopy of the scapolite was performed, but the spectra were not useful because the thickness of the whole samples resulted in total saturation in the 1600–400 cm^{-1} region (obscuring the diagnostic area for scapolite at 610.4 cm^{-1}). Accordingly, we used the KBr disc method on powder from one of the pieces of rough, and analyzed it with a Jasco FTIR 410 spectrometer (64 scans and a resolution of 4 cm^{-1}).

NEED TO KNOW

- Gem scapolite is a solid-solution series consisting of two main end members, marialite and meionite, and a third end member, silvialite.
- RI, SG, and IR spectral features vary with chemical composition.
- Gem-quality yellow scapolite has been produced sporadically from the Ihosy area since the late 1990s.
- Unlike most other gem scapolite, which is primarily marialite, Ihosy scapolite is mostly meionite with lesser marialite and minor silvialite components.

The few inclusions we observed in both the rough and faceted samples were analyzed by Raman spectroscopy (Renishaw 1000 instrument equipped with a 514 nm laser). One surface-reaching inclusion was analyzed by electron microprobe.

RESULTS AND DISCUSSION

The samples were yellow to light greenish yellow (Munsell 10Y 9/4 to 10Y 9/6), with moderate light yellow to light yellow-green pleochroism. Standard gemological data for the five cut stones are reported in table 1. The refractive indices were n_o= 1.574–1.581 and n_e=1.552–1.555, with a birefringence of 0.022–0.027; the SG ranged from 2.68 to 2.72. These values are consistent with meionite-dominant scapolites (Deer et al., 1992). All the samples fluoresced pale yellow to long-wave UV radiation and strong purplish red to short-wave UV. The fluorescence of Ihosy scapolite is similar only to that of the rare crystals found in Switzerland (table 2).

Semiquantitative EDXRF data from all samples suggested a limited compositional range. Therefore, we believe the two rough pieces chosen for quantitative WDS electron microprobe analysis (table 3) are representative for all these samples. The data revealed they were mainly meionite (54.7–62.0%) with lesser marialite (29.9–37.8%) and minor silvialite components (7.5–8.1%; see also figure 4). The chemical composition had significant influence on the physical properties of the gem material.

Ulbrich (1973), Arem (1987), and Deer et al. (1992) related scapolite's refractive indices to its meionite content. Their methodology for calculating composition from RI values does not take into account the silvialite component (a rather new addition to the scapolite group). Moreover, Deer et al. (1992) pointed out the uncertainty of the method for specimens containing relatively large amounts of K, S, or Cl, and suggested a typical error of ±6.5% in the Me value. Nevertheless, in view of the rather consistent and relatively low silvialite component of our samples, we applied the method proposed by Deer et al. (1992), represented by the equation $(n_e+n_o)/2 = 1.5346 + 0.000507(\text{Me}\%)$. The results, shown in table 1, indicate a meionite content of 56.0–65.9%, assuming a two-component composition. These results are in good agreement with the microprobe data obtained from the two crystals. Moreover, the SG values of the samples generally agreed with their meionite content, per Deer et al. (1992).

Wehrenberg (1971) proposed an indirect method for

TABLE 2. UV fluorescence of yellow scapolite from various geographic origins.

Locality	UV fluorescence	
	Long-wave (365 nm)	Short-wave (254 nm)
Madagascar[a]	Pale yellow	Strong purplish red
Tanzania[a]	Pale purple	Strong purple
Tanzania[b]	Strong yellow	Strong yellow
Myanmar[a,b]	Pale yellow to orange	Moderate yellow-orange to pink
Brazil (Espirito Santo)[a]	Inert to pale "lilac"-pink	Strong red to purple
Switzerland (Lake Tremorgio)[a]	Pale yellow	Strong purplish red

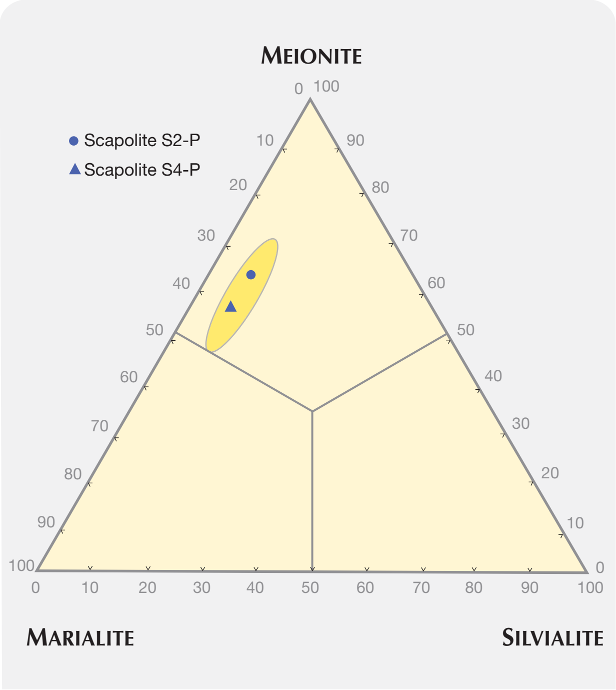
[a] Samples from the Natural History Museum of Milan.
[b] Data from Arem (1987).

TABLE 3. Quantitative electron microprobe analyses of two rough scapolite samples from Ihosy, Madagascar.

Oxide (wt.%)	S2-P[a]	S4-P[b]
SiO_2	44.71	49.29
TiO_2	0.01	0.01
Al_2O_3	26.83	25.77
Fe_2O_3	0.06	0.04
MnO	0.01	0.01
MgO	0.03	0.02
CaO	16.24	14.41
Na_2O	3.82	4.95
K_2O	0.66	0.80
SO_3	0.71	0.70
Cl	1.24	1.86
F	0.01	0.02
Total	94.34	97.88
Calculated components (%)[c]		
Meionite	62.0	54.7
Marialite	29.9	37.8
Silvialite	8.1	7.5

[a] Average of 16 point analyses.
[b] Average of 18 point analyses.
[c] Calculated using Mincalc software; CO_2 used for the meionite component was calculated to obtain the best stoichiometry.

Figure 4. This ternary diagram shows the composition of the two scapolite samples analyzed by electron microprobe. The oval field illustrates the compositional variation (from EDXRF semiquantitative analyses) of all 21 samples.



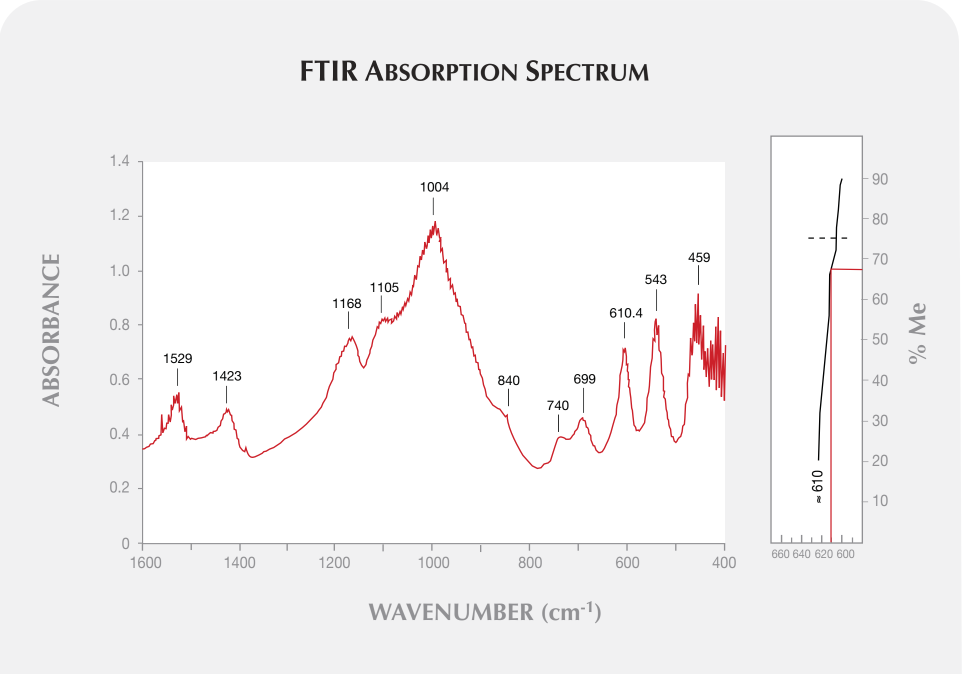


Figure 5. The FTIR spectrum on the left and the diagram on the right (after Wehrenberg, 1971) illustrate the correlation between the absorption peak at 610.4 cm^{-1} and Me content.

determining meionite content based on the position of the IR band located at ~610 cm^{-1}, which is directly related to meionite content in scapolites containing 20–90% Me. Sample S2-P's diagnostic peak was centered at 610.4 cm^{-1}, which corresponds to 67% ± 5% meionite (figure 5). This is somewhat similar to the 62.0% Me obtained by microprobe analysis if we consider that the latter value was calculated for a three-component system (i.e., accounting for silvialite, in addition to marialite and meionite). On the same sample, the refractive indices obtained on a polished area before mounting in epoxy correlated to 62.9% Me.

Inclusions were rare in all samples, and most consisted of hollow channels, probably related to growth structures that were affected by late-stage corrosion. The few mineral inclusions observed in the samples (e.g., figure 6) were identified by Raman spectroscopy as garnet (andradite-grossular), mica (very likely phlogopite, the most abundant mica in the host rock), and calcic pyroxene. Microprobe analysis of the (surface-reaching) pyroxene identified it as diopside. All of these inclusions correspond with minerals present in the skarn host rocks at the Ihosy deposit.

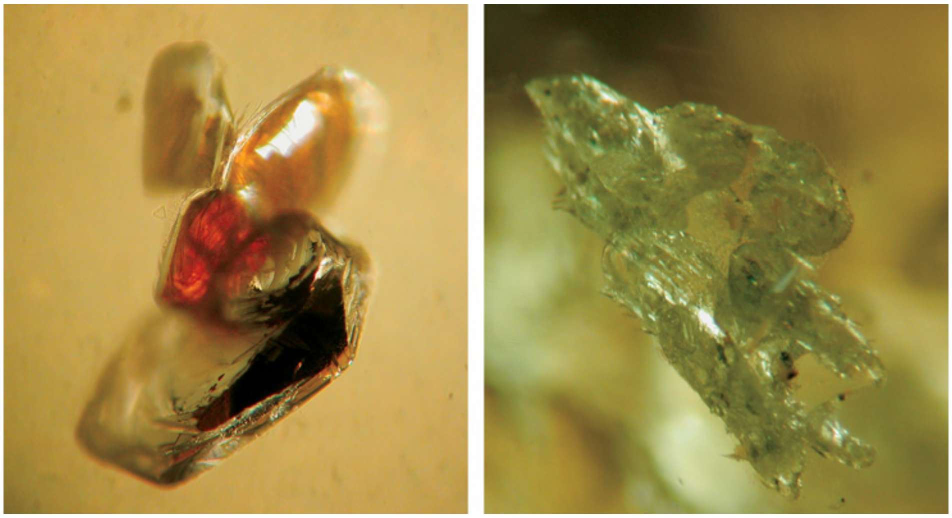


Figure 6. Microscopic examination revealed inclusions of tabular hexagonal mica and brownish orange garnet (left), as well as diopside (right). Photomicrographs by E. Castaman; fields of view 0.5 mm (left) and 0.8 mm (right).

CONCLUSIONS

Various analytical techniques allowed us to establish the meionite-dominant composition of Ihosy scapolites, in the approximate range of 55–65% Me. The results obtained from different samples using the three methods applied (electron microprobe, RI, and FTIR) were generally in good agreement. Moreover, the electron microprobe analyses showed the silvialite content of the Ihosy scapolite was ~8%. To our knowledge, this is the first gemological study in which the silvialite content of scapolite has been reported. We have yet to make compositional comparisons with scapolites from other sources. Nevertheless, it is interesting to note that these scapolites fell in the meionite field, while the majority of commercial gem scapolite from other localities are marialite (see, e.g., Graziani and Gübelin, 1981 [Tanzania]; Peili, 1992 [China]; Kammerling et al., 1995 [Tajikistan]; Gomes et al., 2004 [Mozambique]; Zwaan, 1996 [Sri Lanka]; and McClure et al., 2005 [Afghanistan]).

Although only limited mining for Ihosy scapolite is being conducted, there is strong potential for future production from this deposit.

ABOUT THE AUTHORS

Margherita Superchi is scientific gemological consultant, and Elena Gambini and Emanuela Castaman are staff members, at the Gemmological Centre of the Milan Chamber of Commerce (CISGEM), Milan, Italy. Federico Pezzotta (fpezzotta@yahoo.com) is mineral curator of the Natural History Museum of Milan, Italy.

ACKNOWLEDGMENTS

The authors thank Antonello Donini and Andrea Marzola of CISGEM for their help in collecting and analyzing the data. We also thank Alessandro Guastoni of the University of Padua for the electron microprobe analyses and Alberto Paleari of the University of Milan-Bicocca for helpful discussions. This study is based in part on the diploma thesis of Barbara Gorini (2006).

REFERENCES

Arem J.E. (1987) *Color Encyclopedia of Gemstones*, 2nd ed. Van Nostrand Reinhold, New York, pp. 166–167.

Couper A.G. (1991) Colour as a guide to the composition of scapolite from Burma. *Journal of Gemmology*, Vol. 22, No. 5, pp. 259–263.

Deer W.A., Howie R.A., Zussman J. (1992) *An Introduction to the Rock-Forming Minerals*. Longman Scientific & Technical, London, 696 pp.

Gomes C.L., Quinn E.P., Koivula J.I. (2004) Gem News International: Scapolite from Mozambique. *G&G*, Vol. 40, No. 2, pp. 172–173.

Gorini B. (2006) Caratterizzazione della scapolite di Ihosy, Madagascar. Unpublished B.S. thesis, Università degli Studi di Milano-Bicocca, 128 pp.

Graziani G., Gübelin E. (1981) Observations on some scapolites of central Tanzania. *Journal of Gemmology*, Vol. 17, No. 6, pp. 395–405.

Kammerling R.C., Koivula J.I., Johnson M.L., Alitsch E. (1995) Purple scapolite from Tajikistan. *G&G*, Vol. 31, No. 3, pp. 211–212.

Lacroix A. (1922) *Minéralogie de Madagascar*, Vol. 1–3. A. Challamel, Paris.

Martelat J.E., Nicollet C., Lardeaux J.M., Vidal G., Rakotondrazafy R. (1997) Lithospheric tectonic structures developed under high-grade metamorphism in the southern part of Madagascar. *Geodinamica Acta*, Vol. 10, pp. 94–114.

McClure S.F., Rossman G.R., Shigley J.E. (2005) Gem News International: Tenebrescent scapolite from Afghanistan. *G&G*, Vol. 41, No. 3, pp. 269–271.

Peili Z. (1992) Gem-quality scapolite from Sinjiang region, west China. *Australian Gemmologist*, Vol. 18, No. 4, pp. 115–117.

Teertstra D.K., Schindler M., Sherriff B.L., Hawthorne F.C. (1999) Silvialite, a new sulfate-dominant member of the scapolite group. *Mineralogical Magazine*, Vol. 63, pp. 321–329.

Ulbrich H. (1973) Crystallographic data and refractive indices of scapolites. *American Mineralogist*, Vol. 58, pp. 81–92.

Wehrenberg J.P. (1971) The infrared absorption spectra of scapolite. *American Mineralogist*, Vol. 56, pp. 1639–1654.

Zwaan P.C. (1996) Enstatite, cordierite, kornerupine, and scapolite with unusual properties from Embilipitiya, Sri Lanka. *G&G*, Vol. 32, No. 4, pp. 262–269.