BASTNÄSITE-(CE) AND PARISITE-(CE) FROM MT. MALOSA, MALAWI

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Large crystals of the rare-earth carbonates bastnäsite-(Ce) and parisite-(Ce) have been collected from alkaline pegmatites at Malawi's Mt. Malosa, where they occur associated with aegirine, microcline, and several other unusual accessory minerals. Only small portions of some crystals are suitable for cutting into attractive gems, because most of the material is opaque or heavily fractured. This report presents the gemological and chemical properties of Mt. Malosa bastnäsite-(Ce) and parisite-(Ce) gemstones. This area shows good potential for future production of these rare-earth carbonates, although cut stones will continue to be rare.

Bastnäsite-(Ce), which has the chemical formula (Ce,*RE*)(CO_3)(F,OH), and parisite-(Ce), or Ca(Ce,*RE*)$_2$(CO_3)$_3$(F,OH)$_2$, are cerium-dominant rare-earth (*RE*) carbonates. Although they very rarely form as crystals large and clean enough for faceting, one locality in Pakistan (Zagi or Zegi Mountain) has produced bastnäsite-(Ce) that has been faceted into stones up to 20 ct (Johnson, 1999; Obodda and Leavens, 2004). Gem-quality parisite-(Ce) has been reported very rarely, usually associated with Colombian emeralds such as those from Muzo (Henn et al., 1992). In fact, the mineral is named in honor of J. I. Paris, one of the first managers of the Muzo mine (Palache et al., 1963). This note reports on bastnäsite-(Ce) and parisite-(Ce) from Malawi's Mt. Malosa, where these minerals occur as well-formed crystals that locally may contain clear, gem-quality portions (e.g., figure 1). One of the authors (AG) visited the deposit in 2002 for research purposes, and has documented the geology and mineralogy of the area in other publications (e.g., Guastoni et al., 2007, 2009).

See end of article for About the Authors and Acknowledgments.
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LOCATION AND ACCESS

The Zomba-Malosa massif is located in southern Malawi, ~250 km southeast of the capital city of Lilongwe (figure 2). Pegmatites containing bastnäsite-(Ce) and parisite-(Ce) are located close to the summit of Mt. Malosa (elevation ~2,000 m) and along the slopes flanking the Zomba-Malosa massif. The steep terrain makes mining dangerous and restricts accessibility in the area (figures 3 and 4). Lake Valley Minerals Ltd. (Lilongwe) is sponsoring and training local farmers in mining techniques, and assisting them with obtaining nonexclusive licenses for commercially recovering mineral specimens from this deposit.

GEOLOGIC SETTING

The pear-shaped Zomba-Malosa pluton (again, see figure 2) is composed of a central core of syenite and an outer ring of peralkaline granite (Bloomfield, 1965). This suite was emplaced ~113 ± 4 million years ago (Eby et al., 1995), and belongs to the Chilwa alkaline belt, which includes several smaller Cretaceous plutons outcropping along the East African rift (Woolley, 1987). The bastnäsite-(Ce) and parisite-(Ce) crystals are hosted by miarolitic alkaline pegmatites and are associated with albite, aegirine, arfvedsonite, Ce-bearing pyrochlore, fluorite, hingganite-(Y), microcline, several Nb-Ta-Y oxides and Be-Na-Y-Zr-Ba-silicates, the niobophyl-

Figure 1. Some gem-quality portions can be seen in this 2 cm parisite-(Ce) crystal from Mt. Malosa, which is sitting on a matrix of aegirine. Courtesy of the Natural History Museum of Milan, catalog no. 37800; photo by R. Appiani.

lite-astrophyllite mineral series, quartz, synchysite-(Ce), xenotime-(Y), and zircon (e.g., Guastoni et al., 2007). For the most part, these pegmatites outcrop within the central syenite portion of the Malosa intrusion, and they often contain large miarolitic cavities of decimeter-to-meter dimensions that are lined with the aforementioned minerals and RE-carbonates.

DESCRIPTION OF THE CRYSTALS

Bastnäsite-(Ce) and parisite-(Ce) from Mt. Malosa form prismatic or barrel-shaped crystals up to 20 cm long. The bastnäsite-(Ce) crystals are brownish orange and interlayered with opaque yellow-brown parisite-(Ce). The parisite-(Ce) crystals are fractured (again, see figure 1) and commonly consist of an inner transparent brownish orange core that is surrounded by an opaque crust composed of yellow-brown bastnäsite-(Ce) + rhabdophane-(Ce) + cerianite. However, the parisite-(Ce) crystals may be completely replaced by goethite + microcline. A detailed description of the mineralogy of these two carbonates is provided by Guastoni et al. (2009).

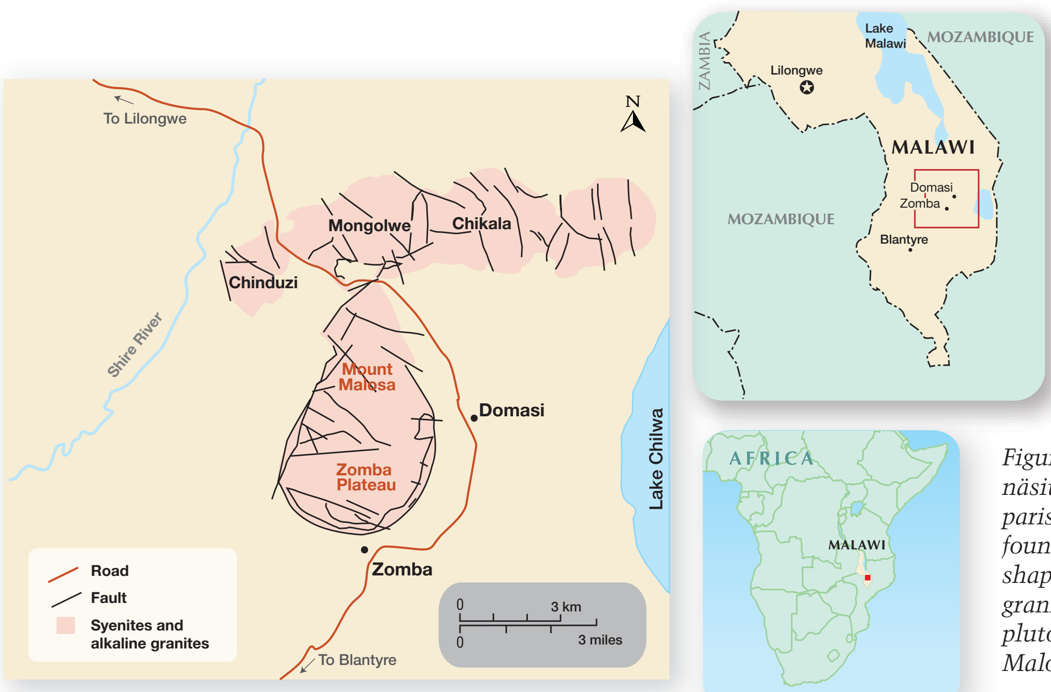

Figure 2. Bastnäsite-(Ce) and parisite-(Ce) are found in the pear-shaped syenitic-granitic alkaline pluton at Mt. Malosa.

Figure 3. The pegmatite mining area is located within steep terrain, as seen here from the summit of Mt. Malosa. Photo by A. Guastoni.

MATERIALS AND METHODS

We studied four faceted samples of bastnäsite-(Ce) and one faceted parisite-(Ce), all from Mt. Malosa (see table 1 and figure 5), from the gem collection of the Natural History Museum of Milan. All five samples were characterized by standard gemological methods and Raman spectroscopy at GIA in New York. Chemical analyses were performed at the University of Padua.

Color appearance was assessed in a Macbeth Judge II light box and in incandescent light. We determined specific gravity hydrostatically, and measured refractive indices using a standard gemological refractometer. Fluorescence was tested using standard long- and short-wave UV lamps, and internal features were observed with a gemological binocular microscope. Ultraviolet-visible–near infrared (UV-Vis-NIR) absorption spectra were observed with a double-beam spectrophotometer. Raman spectra were collected with a Renishaw inVia microspectrometer.

Chemical data were obtained from two rough samples (nos. 79815 and 79819) before they were faceted. Electron microprobe analyses were performed using a Cameca Camebax SX 50 instrument with wavelength-dispersive spectrometers (16–18 spot analyses per sample). The F^- and OH^- contents were measured with a CE-Instruments EA 1110 automatic CHNS elemental analyzer, and CO_2 content was obtained with thermogravimetric profiles (Guastoni et al., 2009).

Figure 4. Small tunnels follow miarolitic cavities in the alkaline pegmatites on Mt. Malosa. Photo by A. Guastoni.

NEED TO KNOW

- Bastnäsite-(Ce) and parisite-(Ce) are cerium-dominant rare-earth carbonates.
- Both minerals are mined from alkaline pegmatites in Malawi, but very rarely in gem quality.
- As gems, both have a similar brownish orange color, but they are easily separated by their standard gem properties.

RESULTS AND DISCUSSION

Visual Appearance and Physical Properties. These properties are summarized in table 1. The faceted bastnäsite-(Ce) and parisite-(Ce) samples generally resembled one another, with face-up colors ranging from slightly brownish orange to very slightly brownish yellowish orange; they appeared slightly more brownish when examined with incandescent vs. daylight-equivalent illumination. The RI values for bastnäsite-(Ce) were n_o = 1.718–1.719 and n_e = over the limits of the refractometer (>~1.81); the parisite-(Ce) had RIs of n_o = 1.669 and n_e = 1.769. Both RE-carbonates were uniaxial positive and strongly birefringent. The SG of bastnäsite-(Ce) ranged from 5.05 to 5.23; Guastoni et al. (2009) found that this variability is related to the abundance of lanthanides, particularly

TABLE 1. Gemological properties for the Malawi bastnäsite-(Ce) and parisite-(Ce) samples studied.

Sample no.	Species	Weight (ct)	Color	Refractive index		Specific gravity	Raman vibrational bands (cm^{-1})
				n_o	n_e		
79815	Bastnäsite-(Ce)	1.55	Slightly brownish orange	1.718	>1.81	5.13	3588, 1743, 1442, 1097, 352, 259, 166
79816	Bastnäsite-(Ce)	0.82	Slightly brownish orange	1.719	>1.81	5.05	3598, 1743, 1441, 1097, 737, 349, 259, 166
79817	Bastnäsite-(Ce)	0.79	Slightly brownish orange	1.719	>1.81	5.23	3586, 1742, 1431, 1097, 738, 353, 260
79818	Bastnäsite-(Ce)	0.34	Very slightly brownish yellowish orange	1.719	>1.81	5.07	3586, 1743, 1433, 1097, 738, 353, 260
79819	Parisite-(Ce)	0.22	Very slightly brownish yellowish orange	1.669	1.769	3.79	1740, 1567, 1431, triplet at 1101/1093/1083, 741, 398, 269

the ratio Ce/(Y+La+Pr+Nd+Sm). The SG of the parisite-(Ce) was measured at 3.79. All the samples were inert to both long- and short-wave UV radiation. All samples showed "rare-earth" spectral features, consistent with descriptions by Johnson (1999) and Massi (2007). The hardness of bastnäsite-(Ce) and parisite-(Ce) are reported to be 4–4.5 and 4.5, respectively (Gaines et al., 1997).

Our bastnäsite-(Ce) samples showed properties comparable to those in gems from Pakistan reported by Johnson (1999) and Massi (2007). Our single parasite-(Ce) sample had similar RI values to those reported for two samples from Muzo (Fryer, 1982), but our SG of 3.79 was markedly different from the 4.18 value measured for the Colombian sample.

Internal Features. Microscopy revealed the presence of numerous "fingerprints" and fractures in all samples (e.g., figure 6). The fingerprints in the bastnäsite-(Ce) gemstones were composed of multiphase inclusions, frequently displaying a large gas bubble and in some cases a very minute transparent solid phase. The fingerprints in the parisite-(Ce) sample were composed of finer two-phase (fluid-gas) inclusions.

None of our bastnäsite-(Ce) samples contained the needle-like inclusions that are common in material from Pakistan, which were identified as astrophyllite by Niedermayr (2001).

Figure 5. These samples (from left to right, 79818, –16, –15, –17, and –19; see table 1) were examined for this study. The faceted round stone on the right is parisite-(Ce), and the other four stones are bastnäsite-(Ce). Photo by J. Liao.

Raman Spectra and Chemical Composition. Figures 7 and 8 show the Raman spectra of the bastnäsite-(Ce) and parisite-(Ce) samples, respectively. The main feature of the bastnäsite-(Ce) spectra (which were quite similar for the four samples studied) is the intense vibrational band at ~1097 cm^{-1}, which is consistent with symmetric CO_3 stretching. Further characteristic bands were recorded at approximately

Figure 6. These "fingerprints" in bastnäsite-(Ce) are composed of two- and three-phase inclusions. Photomicrographs by D. Kondo; image widths 2.1 (left) and 1.1 mm (right).

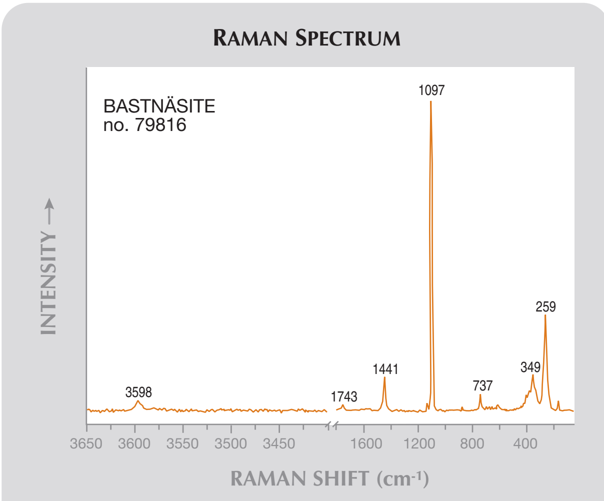

Figure 7. The Raman spectrum for bastnäsite-(Ce) displays the most intense vibrational band at ~1097 cm⁻¹.

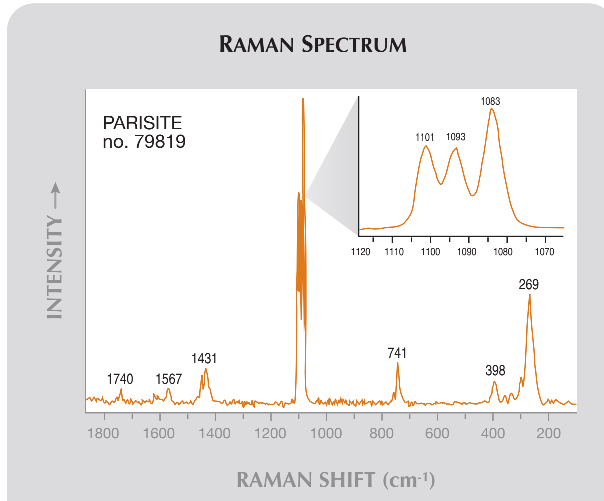

Figure 8. The Raman spectrum for parisite-(Ce) displays the strongest vibrational band at 1083 cm⁻¹.

259 cm^{-1} [translational lattice mode T(Ce,CO_3)], 737 cm^{-1} (symmetric CO_3 deformation), and 1441 cm^{-1} (asymmetric CO_3 stretching; see Gunasekaran et al., 2006). In addition, a clear band at ~3600–3585 cm^{-1} can be assigned to OH^- (Guastoni et al., 2009). The Raman spectrum of the parisite-(Ce) sample recorded a main vibrational band at 1083 cm^{-1}, similar to bastnäsite-(Ce). However, the inset in figure 8 clearly shows a marked split of the band at three slightly different wavenumber values (1101, 1093, and 1083 cm^{-1}), which is due to different crystal structure features.

Representative electron microprobe analyses of bastnäsite-(Ce) and parisite-(Ce) are presented in table 2. The bastnäsite-(Ce) samples were rather homogeneous in composition, and the parisite showed a similar makeup—except for a significantly higher Ca content, as expected from the chemical formula. The minor Sm and traces of Ca in our bastnäsite-(Ce) samples have not been reported in the material from Pakistan (e.g., Johnson, 1999).

TABLE 2. Chemical composition of bastnäsite-(Ce) and parisite-(Ce) from Mt. Malosa, Malawi.

Oxide (wt.%)	Bastnäsite-(Ce) (no. 79815)	Parisite-(Ce) (no. 79819)
CaO	nd[a]–0.2	9.3–9.8
Y_2O_3	0.2–0.6	0.5–1.1
La_2O_3	17.2–20.5	14.8–17.0
Ce_2O_3	34.4–36.9	30.4–32.3
Pr_2O_3	3.1–3.6	2.5–3.5
Nd_2O_3	8.8–9.5	7.8–8.9
Sm_2O_3	1.6–2.1	1.3–1.7
CO_2	20.9–21.2	23.9–24.7
F	6.5–7.2	5.6–6.3
H_2O	0.7–0.9	0.3–0.6
Total	99.6–99.8	99.7–99.9

[a] *nd = not detected*

Identification. Bastnäsite-(Ce) and parisite-(Ce) from Malawi can be easily separated by their RI and SG values, as well as by Raman analysis and chemical composition. Parcels of bastnäsite-(Ce) from Pakistan have been mixed with similar-colored grossular and sphene, but these can be easily separated by their standard gemological properties (Blauwet and Hyršl, 2001), as well as their rare-earth spectral features observable with a spectroscope or spectrophotometer.

CONCLUSION

Bastnäsite-(Ce) and parisite-(Ce) are rare accessory minerals from alkaline pegmatites at Mt. Malosa, and only small portions of these materials are suitable for faceting. Parisite-(Ce) gemstones are particularly rare, because most of the rough is opaque or heavily fractured. Although production of both minerals is still less than 20 grams per year, the deposit appears to be extensive. Most faceted RE-carbonates are sold to private collectors because they are too soft to be set in jewelry.

ABOUT THE AUTHORS

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