

## Electronic Supplementary Material description

**Table EA1.** Analytical settings used for EPMA analysis of monazite and xenotime.

Element	Line (mnz/xtm)	Standard	Crystal	Peak (s) (mnz/xtm)	Background (s) (mnz/xtm)
<b>P</b>	K $\alpha$ /K $\alpha$	apatite	PET	30/30	30/30
<b>Al</b>	K $\alpha$ /K $\alpha$	plagioclase	TAP	30/30	30/30
<b>Si</b>	K $\alpha$ /K $\alpha$	almandine	TAP	30/30	30/30
<b>Ca</b>	K $\alpha$ /K $\alpha$	plagioclase	PET	30/30	30/30
<b>Y</b>	L $\alpha$ /L $\alpha$	YPO <sub>4</sub>	PET	60/75	30/30
<b>La</b>	L $\alpha$ /L $\alpha$	LaPO <sub>4</sub>	LIF	75/60	50/30
<b>Ce</b>	L $\alpha$ /L $\alpha$	CePO <sub>4</sub>	LIF	75/60	50/30
<b>Pr</b>	L $\beta$ /L $\beta$	PrPO <sub>4</sub>	LIF	60/60	30/30
<b>Nd</b>	L $\beta$ /L $\beta$	NdPO <sub>4</sub>	LIF	75/60	50/30
<b>Sm</b>	L $\beta$ /L $\beta$	SmPO <sub>4</sub>	LIF	60/60	30/30
<b>Eu</b>	L $\beta$ /L $\beta$	EuPO <sub>4</sub>	LIF	60/60	30/30
<b>Gd</b>	L $\beta$ /L $\alpha$	GdPO <sub>4</sub>	LIF	60/60	30/30
<b>Tb</b>	L $\alpha$ /L $\alpha$	TbPO <sub>4</sub>	LIF	60/60	30/30
<b>Dy</b>	L $\beta$ /L $\beta$	DyPO <sub>4</sub>	LIF	60/75	30/50
<b>Ho</b>	L $\beta$ /L $\beta$	HoPO <sub>4</sub>	LIF	60/60	30/30
<b>Er</b>	L $\beta$ /L $\beta$	ErPO <sub>4</sub>	LIF	60/75	30/50
<b>Tm</b>	L $\alpha$ /L $\alpha$	TmPO <sub>4</sub>	LIF	60/60	30/30
<b>Yb</b>	L $\alpha$ /L $\alpha$	YbPO <sub>4</sub>	LIF	60/75	30/50
<b>Lu</b>	L $\beta$ /L $\beta$	LuPO <sub>4</sub>	LIF	60/60	30/30
<b>Pb</b>	M $\beta$ /M $\beta$	Crocoite (PbCrO <sub>4</sub> )	PET	100/100	100/100
<b>Th</b>	Ma/M $\alpha$	Th-metal	PET	100/100	100/100
<b>U</b>	M $\beta$ /M $\beta$	U-metal	PET	100/100	100/100
<b>Fe</b>	K $\alpha$ /K $\alpha$	almandine	LIF	30/30	30/30

Correction applied for P-K $\alpha$  due to interference with Gd.

Correction applied for Eu-L $\beta$  due to interference with Dy-L $\alpha$ .

Tm is monazite in not reported because of an interference on Tm-L $\alpha$  by Sm-L $\gamma$  that could not be corrected for.

**Table EA2.** Analytical settings used for EPMA analysis of allanite, clinozoisite, and REE-fluorocarbonates.

Element	Line	Standard	Crystal	Peak (s)	Background (s)
Ca	K $\alpha$	plagioclase	PET	30	15
Si	K $\alpha$	plagioclase	TAP	30	15
Al	K $\alpha$	plagioclase	TAP	30	15
Fe	K $\alpha$	almandine	LIF	30	15
Mg	K $\alpha$	diopside	TAP	30	15
Mn	K $\alpha$	rhodonite	LIF	30	15
Ti	K $\alpha$	rutile	LIF	30	15
La	L $\alpha$	LaPO <sub>4</sub>	LIF	60	30
Ce	L $\alpha$	CePO <sub>4</sub>	LIF	60	30
Nd	L $\beta$	NdPO <sub>4</sub>	LIF	60	30
Pr	L $\beta$	PrPO <sub>4</sub>	LIF	60	30
Sm	L $\beta$	SmPO <sub>4</sub>	LIF	60	30
Gd	L $\beta$	GdPO <sub>4</sub>	LIF	60	30
Y	L $\alpha$	YPO <sub>4</sub>	PET	60	30
Th	M $\alpha$	Th-metal	PET	50	50
U	M $\beta$	U-metal	PET	50	50
F	K $\alpha$	fluorite	TAP	40	20
Cl	K $\alpha$	tugtupite	PET	40	20

**Table EA3.** Summary of monazite EPMA data.

(in attached spreadsheet)

**Table EA4.** Summary of monazite LA-ICP-MS data.

(in attached spreadsheet)

**Table EA5.** Summary of xenotime EPMA data.

(in attached spreadsheet)

**Table EA6.** Summary of xenotime LA-ICP-MS data.

(in attached spreadsheet)

**Table EA7.** Summary of allanite, clinozoisite and REE-fluorocarbonate EPMA data.

(in attached spreadsheet)

**Table EA8.** Summary of allanite, clinozoisite and REE-fluorocarbonate LA-ICP-MS data.

(in attached spreadsheet)

**Table Monazite\_all.** All monazite EPMA and LA-ICP-MS data.

(in attached spreadsheet)

**Table Xenotime\_all.** All xenotime EPMA and LA-ICP-MS data.

(in attached spreadsheet)

**Table Allanite\_clinozoisite\_all.** All allanite and clinozoisite EPMA and LA-ICP-MS data.

(in attached spreadsheet)

**Table REEfluorocarbonates\_all.** All REE-fluorocarbonate EPMA and LA-ICP-MS data.

(in attached spreadsheet)

**Figure EA1.** Ta vs. Ho concentrations in monazite and xenotime from LA-ICP-MS showing the interference effects, see text below.

**Figure EA2.** Hf vs Dy concentrations in monazite and xenotime from LA-ICP-MS showing the interference effects on Hf in monazite, see text below.

**Figure EA3.** W vs Er concentrations in monazite and xenotime from LA-ICP-MS showing a limited interference effect on W, see text below.

**Figure EA4.** Additional photomicrographs showing the significant replacement of primary monazite in Djupedal. Note especially the continuation of the twin lamellae in the altered monazite crystals, which we consider clear evidence that fluorapatite replaced monazite and not the other way around.

### **Comparison between LA-ICP-MS and EPMA data for the analyzed REE minerals:**

For monazite and xenotime, the concentrations of the major REE are within 10 to 20% of the values determined by EPMA. Larger deviations, up to 50%, are shown for REE with concentrations below about 1 wt%, and especially for Lu. Concentrations of Th, U, Si, and Ca are somewhat variable and show the largest deviations from the EPMA data below 0.25-0.5 wt%, but show good agreement above 1 wt%. For allanite, the measured LREE+Y concentrations are up to 40% lower than those measured by EPMA, likely an effect of the standardization relative to Al using the GSE-1G standard. However, the REE concentrations obtained from LA-ICP-MS analysis of allanite were invariably used for calculation of normalized ratios or patterns. The major elements are within 20%.

### **Discussion on the potential interferences on $^{181}\text{Ta}$ , $^{178}\text{Hf}$ , and $^{182}\text{W}$ in monazite and xenotime during LA-ICP-MS analysis:**

**Monazite:** For Ta, most of the analyses display a positive trend with increasing Ho concentrations (Fig. EA1), which we interpret to be an analytical artifact due to interference of  $^{181}\text{Ta}$  by  $^{165}\text{Ho}^{16}\text{O}$ . However, a deviation from this trend is shown by two samples, independent from the measured oxide production rates (the ratio  $^{248}\text{ThO}/^{232}\text{Th}$  is measured daily during the tuning process to monitor the oxide production in our setup). These two samples are represented by the BMS-hosted monazite-(Ce) and fluorapatite-associated monazite-(Ce) in Djupedal. For these, we consider the presence of Ta real, although the calculated concentrations may be slightly higher than the true ones. For the other measured samples, Ta has been excluded and is listed as not available (n.a.) in the tables in the Electronic Supplementary Material. Hafnium, which may be affected by the interference of  $^{162}\text{Dy}^{16}\text{O}$  and  $^{162}\text{Er}^{16}\text{O}$  on  $^{178}\text{Hf}$ , shows the same trend (Fig. EA2). Thus, only BMS-hosted monazite-(Ce) and fluorapatite-associated monazite-(Ce) in Djupedal actually contain Hf. For the other measured samples, Hf has been excluded and is listed as not available in the tables

in the Electronic Supplementary Material. In contrast, W does not show the same trends (Fig. EA3), and the interference of  $^{166}\text{Er}^{16}\text{O}$  on  $^{182}\text{W}$  in monazite-(Ce) probably only contributes less than 1 ppm to the calculated concentrations. Therefore, the much higher W contents in late-type monazite-(Ce) are significant.

**Xenotime:** Since xenotime-(Y) preferentially incorporates the HREE, interferences by HREE on Hf, Ta, and W may be larger than for monazite-(Ce). For Ta, which displays low concentrations, the same trend as for monazite-(Ce) is observed (Fig. EA1). Thus, only BMS-hosted xenotime-(Y) and fluorapatite-associated xenotime-(Y) from Djupedal probably contain Ta. For the other samples, the Ta has been excluded in the tables in the Electronic Supplementary Material. In contrast to monazite-(Ce), Hf in xenotime-(Y) does not show a good correlation with Dy (Fig. EA2), but shows a good correlation with Zr (Fig. 11C). Thus, the Hf concentrations in xenotime-(Y) are significant, and potential effects from the oxide interference are minor. Likewise, high W concentrations in xenotime-(Y) are not correlated with higher Er (Fig. EA3, Electronic Supplementary Material), and the potential interference probably accounts only for a maximum of few ppm of the calculated W concentrations.