

The composition of Chicxulub Allanite

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Allanite is a REE-rich epidote group mineral with complex compositional variability (e.g., [1–2]), which makes it a challenging target for electron microprobe analysis. To add to the challenge, we chose to characterize the composition of allanite crystals in granitoid rocks that experienced shock pressures of 12–17 GPa in the peak ring of the 66 Ma old, 200 km-Ø K-Pg Chicxulub impact structure [2]. Our drill core samples were recovered by International Ocean Discovery Program (IODP) Expedition 364 [4–5].

Using Arizona State's JEOL JXA-8530F electron microprobe, we surveyed petrographic thin sections of 15 samples from the 584.7 m thick Lower Peak Ring section [5]. We characterized allanite grains and their petrographic settings with back-scattered electron images and energy-dispersive spectrometry. Utilizing wave-length-dispersive spectrometry, 20 kV accelerating voltage, 20 nA beam current and beam diameters of 1 to 5 µm, and peak-overlap corrections for X-ray lines of V, Sm, Gd, and Eu with Ti, Ce, Ce and Pr, respectively, we determined the concentrations of up to 29 elements (Ti, Si, Zr, Th, U, Al, V, La, Ce, Nd, Pr, Sm, Gd, Dy, Er, Eu, Y, P, Nb, Ba, Mg, Fe, Ca, Mn, Sr, Zn, Na, Cl, and F) in selected allanite grains. We evaluated the stoichiometry based on 12.5 oxygen-atoms, including an estimate for Fe²⁺ and Fe³⁺ and H₂O content, following the scheme devised by [2].

Allanite occurs in granitoid rocks throughout the 584.7 m thick Lower Peak Ring section. However, we identified large, ~50 to 1000 µm grains only between ~779 and ~1221 mbsf (meters below sea floor). These allanite-(Ce) grains are typically associated with epidote and some of them are transected by veins of epidote. Alteration features include cellular voids, the crystallization of thorite (ThSiO₄), and replacement with spherulitic to acicular REE hydroxyl/halogen carbonates, likely bastnäsite [(Ce,La)(CO₃)F], parisite [Ca(Ce,La)₂(CO₃)₃F₂], and/or synchysite [Ca(Ce,La)(CO₃)₂F], that are only a few µm in size; the fine-grained, spherulitic shapes of these REE carbonates may indicate growth due to rapid heating to relatively high temperatures >200 °C under hydrothermal conditions because slower approach to supersaturation produces euhedral crystal shapes in Nd-hydroxyl carbonate [6].

Well-preserved allanite-(Ce) grains are euhedral and composed of domains with modest ThO₂ concentrations <~1 wt% that are stoichiometric allanite (Table 1). However, most allanite-(Ce) grains are compositionally zoned and domains with ThO₂ > ~1.30 wt% tend to be non-stoichiometric and metamict (Figure 1). MgO shows a moderately negative correlation with ThO₂ (R²=0.46), while FeO and Fe₂O₃ show weak negative correlations with ThO₂ (R²=0.29 and 0.25, respectively). While their alteration is variable and apparently increased if they are located close to impact melt-rich sections in the drill core, we found that overall, the major and minor element concentrations of large, well-preserved allanite-(Ce) grains in the lower peak ring have grossly similar compositions.[7].

References:

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Table 1. Representative electron microprobe analyses of Chicxulub allanite.

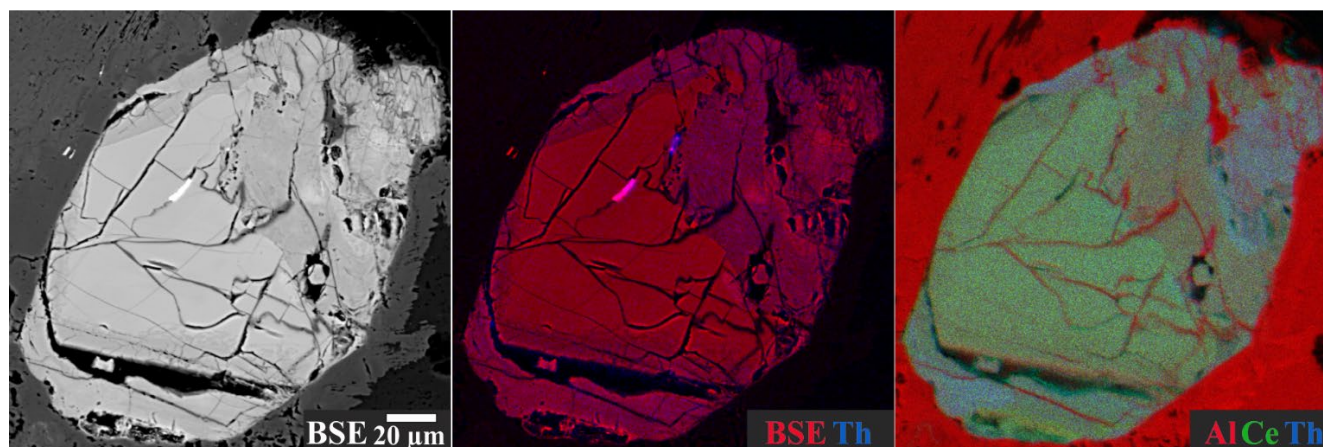
Drill core sample [†]	SiO ₂	TiO ₂	ThO ₂	Al ₂ O ₃	La ₂ O ₃	Ce ₂ O ₃	Pr ₂ O ₃	Nd ₂ O ₃	Sm ₂ O ₃	Gd ₂ O ₃	Dy ₂ O ₃	Er ₂ O ₃	Eu ₂ O ₃	FeO*	Fe ₂ O ₃ *
C247_1159.99	31.7	0.79	1.56	12.62	7.24	9.10	0.50	1.28	<0.05	0.20	0.23	<0.05	<0.05	7.64	6.49
C247_1159.99	30.8	0.87	2.47	12.26	5.51	9.10	0.66	1.95	<0.05	0.15	0.33	0.06	0.08	7.96	5.34
C247_1159.99	31.3	0.57	2.21	14.13	4.84	8.39	0.78	2.07	0.09	0.14	0.14	<0.05	<0.05	6.42	7.90
C247_1159.99	31.7	1.13	0.53	14.05	5.19	10.25	0.93	3.16	0.27	0.22	0.16	0.13	<0.05	8.01	8.33
C247_1159.99	31.6	1.82	0.27	13.34	5.09	9.99	0.95	3.01	0.20	0.26	0.21	0.09	<0.05	8.24	7.68
C116_805.2	31.1	0.85	2.79	13.17	4.92	8.66	0.72	1.92	0.09	0.16	0.40	<0.05	0.06	6.96	6.15
C116_805.2	32.3	0.61	1.28	16.04	5.50	8.83	0.78	2.52	0.09	0.16	0.17	0.07	<0.05	7.30	7.05
C266_1221.125	31.5	0.54	2.30	13.71	4.05	8.78	0.92	3.38	0.37	0.27	0.30	<0.05	0.09	8.11	6.27
C266_1221.125	30.8	0.58	1.32	14.09	5.62	8.92	0.74	2.42	0.09	0.17	0.19	<0.05	0.07	6.92	8.95

[†]sample depth in meters-below-sea-floor (mbsf); *calculated from charge-balancing after stoichiometry had been calculated based on 12.5 O-atoms;

Table 1. Continued.

MgO	CaO	MnO	SrO	V ₂ O ₅	Na ₂ O	Cl	H ₂ O*	Totals	T (Si+Al)	M1 (Ti+ Al+FeIII)	M2 (Al)	M3 (FeII+Mn+ V+Mg+FeIII)	A1 (Ca+Na)	A2 (REE+ Th+Ca)
0.58	13.45	0.55	0.16	<0.05	0.04	0.07	1.51	95.7	3.108	0.999	1.000	0.758	1.118	1.000
0.38	13.02	0.83	0.16	<0.05	0.04	0.07	1.46	93.5	3.115	0.937	1.000	0.803	1.121	1.000
0.43	14.37	0.31	<0.08	<0.05	0.06	0.10	1.52	95.7	3.049	1.000	1.000	0.839	1.133	1.000
0.85	12.92	0.40	<0.08	0.12	<0.03	<0.01	1.59	100.0	3.000	1.000	1.000	0.996	0.993	1.000
0.93	12.91	0.40	<0.08	0.06	<0.03	<0.02	1.58	98.6	3.000	1.000	1.000	0.995	1.004	1.000
0.29	13.08	1.10	0.43	0.08	0.22	0.43	1.40	95.0	3.085	1.000	1.000	0.783	1.133	1.000
0.73	13.32	0.35	0.09	<0.05	0.12	0.13	1.58	99.0	3.008	1.000	1.000	0.994	0.997	1.000
0.47	11.90	0.68	0.21	0.07	0.35	0.42	1.42	96.1	3.091	1.000	1.000	0.883	1.027	1.000
0.46	12.81	0.38	0.32	<0.05	0.13	0.34	1.46	96.8	3.000	1.000	1.000	0.952	1.047	1.000

Figure 1. Back-scattered electron image (BSE) and X-ray maps of allanite grain C247_1159.99 A36.



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