

Magnesium isotope evidence for a recycled origin of cratonic eclogites

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Supplementary Information

The supplementary information includes:

- **Analytical methods**
- **Figures DR1-DR4**
- **Table DR1-DR2**

Analytical Methods

Garnet and clinopyroxene mineral separates were handpicked under a binocular microscope with extra care taken to avoid any alteration products. To evaluate the possible impact of alteration on the mineral Mg isotopic composition, altered garnet and clinopyroxene grains in one low-MgO and one high-MgO eclogite were separated as well. These mineral separates were ultrasonicated for 3 times with each 10 min in 18.2 MΩ water at room temperature before dissolution.

Magnesium isotopic analyses were carried out at the Isotope Laboratory of the University of Arkansas, Fayetteville, USA. Whole rock powders and mineral separates were digested using Optima-grade mixed acid of HF-HNO₃-HCl. After complete dissolution, dried residues were taken up in 1N HNO₃ for ion column chemistry. Detail column chemistry procedures have been reported elsewhere (*e.g.*, Yang et al., 2009; Li et al., 2010; Teng et al., 2010).

Chemical separation and purification of Mg were achieved by cation exchange chromatography with Bio-Rad AG50W-X8 resin in 1N HNO₃ media. At least two in-house standards were processed through column chemistry with each batch of unknown samples. The same column procedure was performed twice in order to purify the Mg. The pure Mg solutions were then dried down, and re-dissolved in 3% HNO₃ in preparation for mass spectrometry.

The Mg isotopic compositions were analyzed by the sample-standard bracketing method using a *Nu* Plasma MC-ICPMS at low resolution mode (Teng and Yang, 2014). At least one well-characterized in-house standard was analyzed during each batch of analysis that contains 10 samples. Ratio measurements of sample solutions were analyzed for >4 times within a session. The long-term precision is better than $\pm 0.07\text{‰}$ (2SD) for the $^{26}\text{Mg}/^{24}\text{Mg}$ ratio. Magnesium isotopic results are reported in the conventional δ notation in per mil relative to DSM-3, $\delta^{26}\text{Mg} = [({}^{26}\text{Mg}/{}^{24}\text{Mg})_{\text{sample}}/({}^{26}\text{Mg}/{}^{24}\text{Mg})_{\text{DSM-3-1}}] \times 1000$. The three in-house standards, Kibourne Hole olivine, Seawater, and San Carlos olivine, yields average $\delta^{26}\text{Mg}$ of $-0.25 \pm 0.02\text{‰}$ (2SD; $n = 20$), $-0.85 \pm 0.04\text{‰}$ (2SD; $n = 4$), and $-0.26 \pm 0.04\text{‰}$ (2SD; $n = 3$), respectively, which are in agreement with previously reported values (*e.g.*, Yang et al., 2009; Foster et al., 2010; Li et al., 2010; Teng et al., 2010, 2015; Ling et al., 2011)

Figures DR1 to DR4

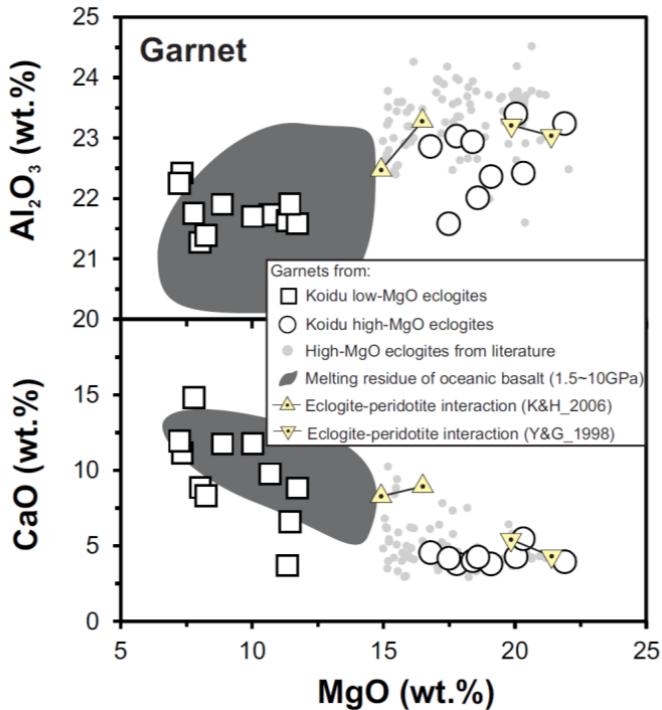


Fig. DR1. Al_2O_3 , CaO and MgO content of garnets. The garnets in Koidu low- MgO eclogites are similar in composition to the residual garnets produced in high-pressure melting experiments on MORBs or gabbros (Yaxley and Green, 1994; Dasgupta et al., 2004; Yaxley and Brey, 2004; Kogiso and Hirschmann, 2006; Hammouda et al., 2009; Kisieva et al., 2012). The garnets in Koidu and other high- MgO eclogites have similar compositions to the eclogitic garnet formed during Mg-Fe exchange between eclogite and peridotite (Yaxley and Green, 1998; Kogiso and Hirschmann, 2006). Data for garnets from Koidu low- and high- MgO eclogites are from Hills and Haggerty (1989). Data for other high- MgO eclogites are from Pyle and Haggerty, (1998), Taylor et al. (2003), Dludla et al. (2006), Heaman et al. (2006), Appleyard et al. (2007), Aulbach et al. (2007), Schmidberger et al. (2007), Smart et al. (2009), Williams et al. (2009), Tappe et al. (2011), and Smit et al. (2014).

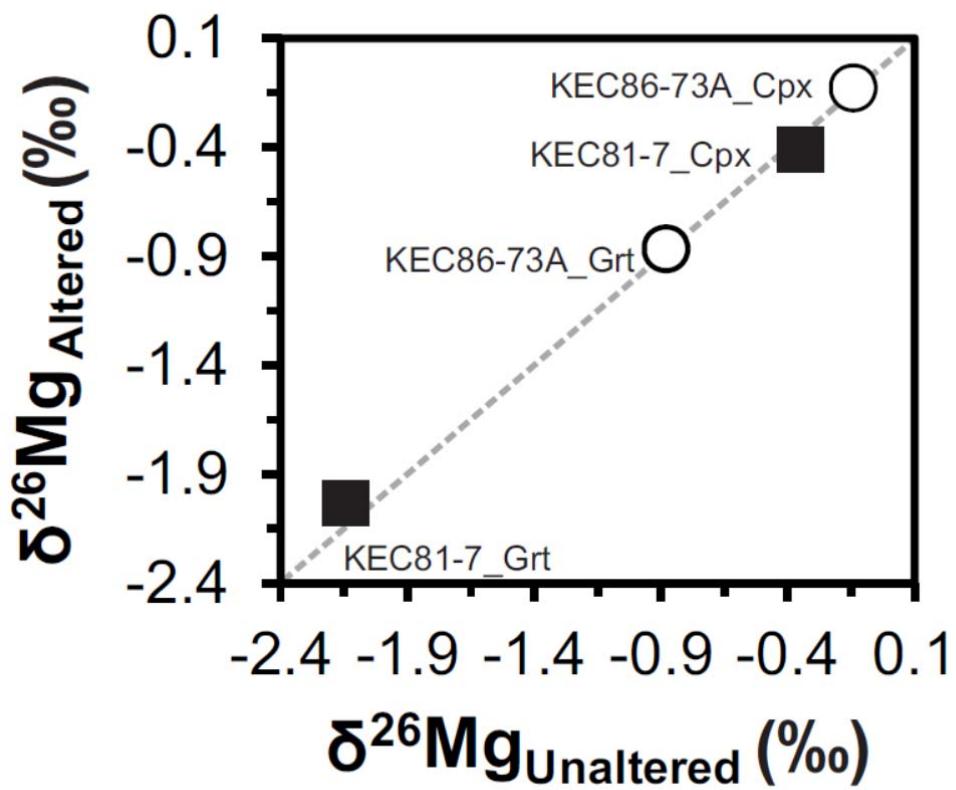


Fig. DR2. A comparison of $\delta^{26}\text{Mg}$ values between altered and unaltered minerals in low-MgO eclogite (square) and high-MgO eclogite (circle). Data from Supplementary Table DR2.

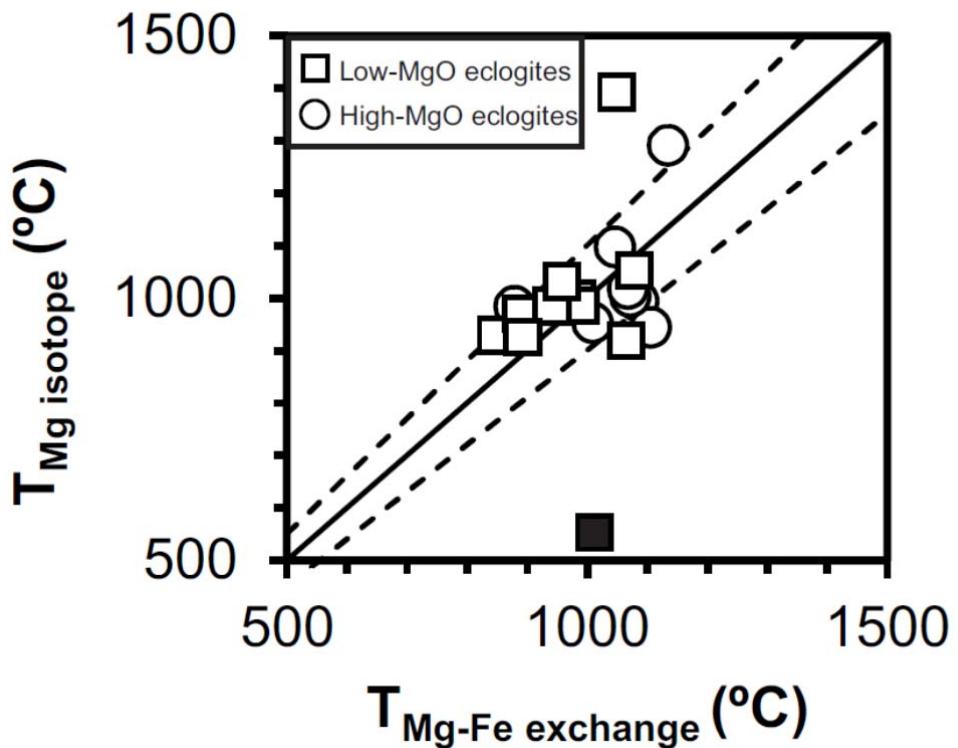


Fig. DR3: A comparison between temperatures calculated using garnet-clinopyroxene Mg-Fe exchange thermometry and Mg isotope thermometry. The garnet-clinopyroxene Mg-Fe exchange temperatures are from Hills and Haggerty (1989), and the garnet-clinopyroxene Mg isotope temperatures are calculated using the equation in Huang et al. (2013). The pressure was assumed to be around 4 GPa. Temperatures calculated using the two methods are within normal mantle temperatures and agree with each other by falling on or near the line of $Y = (1 \pm 0.1) \times X$. Sample KEC81-7 (black filled square) records a Mg isotope temperature that is significantly lower (~ 550 °C at 4 GPa) than normal mantle temperatures.

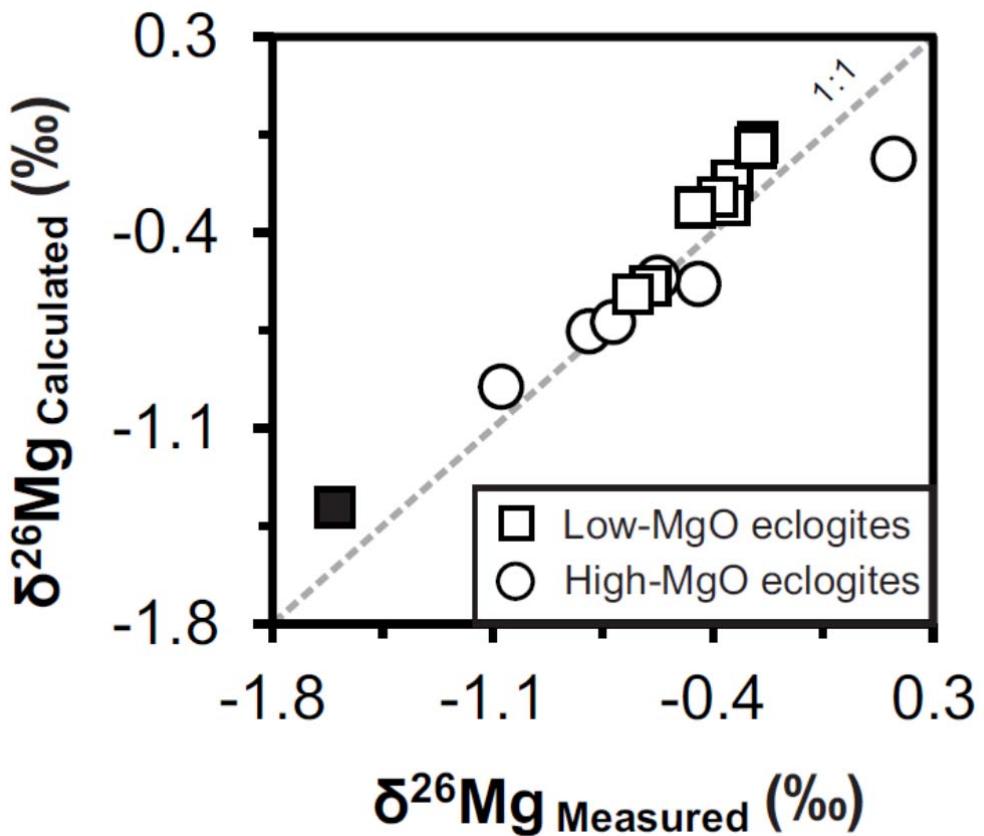


Fig. DR4: A comparison between bulk $\delta^{26}\text{Mg}$ calculated from mineral data ($\delta^{26}\text{Mg}_{\text{Calculated}}$) and bulk $\delta^{26}\text{Mg}$ directly measured from rock powder ($\delta^{26}\text{Mg}_{\text{Measured}}$). The black filled square represents sample KEC81-7. Data from Supplementary Table DR2.

Table DR1. Magnesium isotopic composition of reference materials.

Reference materials	$\delta^{26}\text{Mg}$	2SD	$\delta^{25}\text{Mg}$	2SD
<u><i>San Carlos Olivine</i></u>	-0.26	0.07	-0.12	0.07
Replicate	-0.26	0.08	-0.13	0.06
Replicate	-0.27	0.07	-0.13	0.05
Average	-0.26	0.04	-0.13	0.03
<u><i>Seawater</i></u>	-0.82	0.08	-0.41	0.06
Replicate	-0.87	0.07	-0.45	0.07
Replicate	-0.83	0.09	-0.44	0.09
Replicate	-0.85	0.08	-0.45	0.05
Average	-0.85	0.04	-0.43	0.03
<u><i>Kilbourne Hole Olivine</i></u>	-0.24	0.10	-0.15	0.06
Replicate	-0.26	0.08	-0.12	0.05
Replicate	-0.22	0.08	-0.09	0.05
Duplicate	-0.22	0.08	-0.09	0.05
Duplicate	-0.25	0.08	-0.10	0.05
Duplicate	-0.29	0.07	-0.13	0.07
Duplicate	-0.26	0.08	-0.16	0.07
Duplicate	-0.29	0.07	-0.08	0.06
Duplicate	-0.24	0.07	-0.17	0.06
Duplicate	-0.21	0.07	-0.12	0.06
Duplicate	-0.28	0.07	-0.11	0.07
Duplicate	-0.25	0.07	-0.15	0.05
Duplicate	-0.27	0.06	-0.12	0.05
Duplicate	-0.27	0.06	-0.12	0.06
Duplicate	-0.26	0.05	-0.13	0.03
Duplicate	-0.23	0.05	-0.12	0.06
Duplicate	-0.28	0.06	-0.13	0.08
Duplicate	-0.25	0.08	-0.13	0.06
Duplicate	-0.21	0.07	-0.10	0.04
Duplicate	-0.24	0.08	-0.15	0.04
Average	-0.25	0.02	-0.12	0.01

Note:

Duplicate: repeated measurement of Mg isotopic ratios on the same sample solution.

Replicate: repeated sample dissolution, column chemistry and instrumental analysis.

2SD equals two times the standard deviation of the population of n (n>20) repeat measurements of the standards during an analytical session.

Table DR2. Magnesium isotopic composition of mineral and bulk rock for the Koidu low- and high-MgO eclogites

Sample	Mineral/rock	$\delta^{26}\text{Mg}$	2SD	$\delta^{25}\text{Mg}$	2SD
<i>Low-MgO eclogite</i>					
KEC81-7	Bulk rock	-1.60	0.08	-0.83	0.06
	Grt	-2.13	0.07	-1.08	0.06
	Duplicate	-2.14	0.07	-1.10	0.05
	Replicate	-2.17	0.06	-1.11	0.05
	Average	-2.15	0.04	-1.10	0.03
	Grt*	-2.03	0.07	-1.04	0.05
	Cpx	-0.34	0.08	-0.15	0.05
	Duplicate	-0.36	0.08	-0.17	0.06
	Average	-0.35	0.06	-0.16	0.04
	Cpx*	-0.41	0.07	-0.21	0.05
KEC80-A2	Bulk rock	-	-	-	-
	Grt	-0.56	0.07	-0.30	0.06
	Duplicate	-0.56	0.07	-0.33	0.06
	Average	-0.56	0.05	-0.31	0.04
	Cpx	+0.18	0.06	+0.10	0.03
	Duplicate	+0.18	0.08	+0.09	0.06
	Average	+0.18	0.05	+0.10	0.03
KEC81-3	Bulk rock	-0.34	0.07	-0.18	0.04
	Duplicate	-0.34	0.06	-0.14	0.05
	Average	-0.34	0.05	-0.17	0.03
	Grt	-0.66	0.07	-0.38	0.07
	Cpx	+0.19	0.07	+0.13	0.06
KEC81-4	Bulk rock	-0.35	0.06	-0.16	0.06
	Duplicate	-0.35	0.06	-0.18	0.05
	Average	-0.35	0.05	-0.17	0.04
	Grt	-0.81	0.07	-0.44	0.06
	Duplicate	-0.77	0.06	-0.44	0.07
	Average	-0.79	0.03	-0.44	0.04
	Cpx	+0.05	0.06	+0.01	0.07
	Duplicate	+0.03	0.06	+0.02	0.07
	Average	+0.04	0.05	+0.02	0.05
KEC81-5	Bulk rock	-0.26	0.07	-0.13	0.04
	Grt	-0.54	0.07	-0.34	0.06
	Duplicate	-0.48	0.07	-0.25	0.05
	Average	-0.51	0.05	-0.29	0.04
	Cpx	+0.27	0.06	+0.15	0.03
	Duplicate	+0.29	0.08	+0.14	0.05
	Average	+0.27	0.05	+0.15	0.03
KEC81-8	Bulk rock	-0.26	0.07	-0.10	0.07

		Grt	-0.49	0.07	-0.26	0.07
		Cpx	+0.26	0.07	+0.15	0.06
		Duplicate	+0.29	0.07	+0.16	0.06
		Average	+0.28	0.05	+0.15	0.04
KEC86-6	Bulk rock	-	-	-	-	-
	Grt	-0.48	0.07	-0.16	0.07	
	Cpx	+0.31	0.06	+0.16	0.06	
	Duplicate	+0.25	0.08	+0.14	0.07	
	Replicate	+0.28	0.06	+0.15	0.05	
	Average	+0.28	0.04	+0.15	0.03	
KEC86-13	Bulk rock	-0.39	0.07	-0.22	0.04	
	Grt	-0.76	0.07	-0.40	0.06	
	Duplicate	-0.74	0.07	-0.42	0.05	
	Average	-0.75	0.05	-0.41	0.04	
	Cpx	-0.04	0.05	0.00	0.07	
KEC86-71A	Bulk rock	-0.47	0.07	-0.21	0.04	
	Replicate	-0.45	0.06	-0.25	0.05	
	Average	-0.46	0.05	-0.23	0.03	
	Grt	-0.68	0.07	-0.33	0.06	
	Cpx	+0.16	0.07	+0.06	0.06	
KEC81-10A	Bulk rock	-0.60	0.07	-0.29	0.04	
	Grt	-0.90	0.07	-0.47	0.06	
	Cpx	-0.21	0.07	-0.12	0.06	
KEC81-21	Bulk rock	-0.63	0.08	-0.33	0.04	
	Duplicate	-0.68	0.08	-0.36	0.05	
	Average	-0.66	0.06	-0.34	0.03	
	Grt	-0.83	0.07	-0.41	0.06	
	Cpx	-0.40	0.07	-0.18	0.06	
<i>High-MgO eclogites</i>						
KEC80-B1	Bulk rock	-	-	-	-	-
	Grt	-0.60	0.07	-0.32	0.06	
	Duplicate	-0.67	0.07	-0.37	0.05	
	Average	-0.64	0.05	-0.34	0.04	
	Cpx	+0.13	0.06	+0.07	0.03	
	Duplicate	+0.08	0.08	+0.06	0.05	
	Average	+0.11	0.05	+0.07	0.03	
KEC81-2	Bulk rock	-0.79	0.07	-0.43	0.04	
	Duplicate	-0.80	0.06	-0.39	0.05	
	Average	-0.80	0.05	-0.42	0.03	
	Grt	-1.05	0.07	-0.52	0.06	
	Cpx	-0.41	0.08	-0.19	0.06	
KEC81-11	Bulk rock	-0.45	0.08	-0.24	0.06	
	Grt	-0.78	0.07	-0.38	0.07	
	Cpx	-0.29	0.07	-0.13	0.07	

	Duplicate	-0.26	0.08	-0.13	0.07
	Duplicate	-0.32	0.06	-0.19	0.06
	Average	-0.29	0.04	-0.15	0.04
KEC86-2	Bulk rock	-	-	-	-
	Grt	-0.84	0.07	-0.46	0.07
	Cpx	-0.04	0.06	-0.02	0.06
	Duplicate	-0.09	0.08	-0.08	0.07
	Average	-0.06	0.05	-0.05	0.04
KEC86-8	Bulk rock	-	-	-	-
	Grt	-0.83	0.07	-0.42	0.05
	Cpx	-0.07	0.08	-0.03	0.06
KEC86-15	Bulk rock	+0.17	0.06	+0.06	0.06
	Replicate1	+0.17	0.08	+0.08	0.05
	Replicate2	+0.18	0.07	+0.09	0.06
	Average	+0.17	0.04	+0.08	0.03
	Grt	-0.45	0.07	-0.22	0.06
	Duplicate	-0.48	0.07	-0.26	0.05
	Replicate	-0.47	0.06	-0.24	0.05
	Average	-0.46	0.04	-0.24	0.03
	Cpx	+0.35	0.06	+0.20	0.03
	Duplicate	+0.34	0.08	+0.18	0.06
	Duplicate	+0.41	0.08	+0.22	0.05
	Replicate	+0.33	0.06	+0.19	0.05
	Average	+0.35	0.03	+0.20	0.02
KEC86-60	Bulk rock	-	-	-	-
	Grt	-0.84	0.06	-0.41	0.07
	Replicate	-0.90	0.06	-0.46	0.07
	Average	-0.87	0.05	-0.44	0.05
	Cpx	-0.16	0.06	-0.09	0.07
KEC86-73A	Bulk rock	-0.58	0.08	-0.29	0.04
	Grt	-0.92	0.07	-0.48	0.07
	Duplicate	-0.85	0.07	-0.45	0.07
	Average	-0.88	0.05	-0.47	0.05
	Grt*	-0.87	0.07	-0.47	0.05
	Cpx	-0.13	0.07	-0.08	0.07
	Duplicate	-0.15	0.06	-0.04	0.06
	Average	-0.14	0.05	-0.06	0.04
	Cpx*	-0.13	0.07	-0.06	0.05
KEC86-90	Bulk rock	-1.08	0.07	-0.54	0.04
	Grt	-1.24	0.07	-0.62	0.07
	Duplicate	-1.23	0.06	-0.63	0.05
	Duplicate	-1.17	0.07	-0.61	0.06
	Average	-1.22	0.04	-0.62	0.03
	Cpx	-0.49	0.07	-0.28	0.06

KEC86-107	Bulk rock	-0.72	0.07	-0.34	0.04
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Note:

Grt = garnet; Cpx = clinopyroxene;

“*”altered minerals.

Duplicate: repeated measurement of Mg isotopic ratios on the same sample solution.

Replicate: repeated sample dissolution, column chemistry and instrumental analysis.

2SD equals two times the standard deviation of the population of n (n>20) repeat

measurements of the standards during an analytical session.

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