

Table S1. Melt and fluid inclusion data of carbonatite complexes of the Central Asian province (Russian Siberia and South Mongolia)

Carbonatite complex	Carbonatite / silicate rock	Host mineral	Type of inclusion	Thom. inclusion, °C	P, MPa	Total salt concentration, wt. %	Daughter-phases and inclusions composition*	Mineral assemblages
Western Transbaikalia** Khaluta	Shonkinite, alkaline syenite	Titanite Clinopyroxene K-feldspar	Melt Silicate, and salt-silicate	780-800 Immiscibility	---	95 - 97	Cpx, Kfs, Phl, Cal, Anh, Ba-Clt, mss, CO ₂ ; Ab, Ba-Clt	Potash feldspar, aegerine-diopside and amphiboles, phlogopite, apatite, titanite, albite, calcite, celestine, and zircon and allanite
Yuzhnoe	Carbonatites REE	Magnetite Bastnaesite-(Ce) Fluorite	Melt carbonate-sulphate Brine-melt Crystal-fluid	> 480 - 520 360 - 470 110 - 165	280-300 < 250	> 80 60 - 74 (54-68 – sulphates) 43 – 56 -< 15	Cal, Str, alkaline (Na-Ca) carbonates and Ba-Clt; Anh, Ba-Clt, Thn, Acn, and Att; Na-K-carbonates; Na-Sr sulfates, Na ± Ca carbonates and chlorides CO ₂ -H ₂	Calcite, fluorite, bastnaesite-(Ce), biotite Barite, fluorite, calcite, celestite
Arshan	Carbonatites REE-Ba-Sr	Fluorite	Brine-melt Multiphase and two-phase	420-560 90-150	---	50-67 (46-55 – sulphates) 12-14	Na ± Ca ± Sr sulfates and Na-Sr carbonates CO ₂ ± N ₂ ± H ₂	Calcite, barytocelestite, and fluorite Calcite, bastnaesite-(Ce), fluorite
Ulan-Ude (Portovoe)	Carbonatites F-REE	Bastnaesite-(Ce) Fluorite	Brine-melt Crystal-fluid (primary and pseudo-secondary)	>> 490 - 520 440-520 370-400 135 - 250	> 310	> 65 52 - 62.5 (54-68 – sulphates) 38 – 42 14.5 - 16	Ten, Glb, REE-, and Na-Ca-carbonates; Ca-Na-REE carbonates, Na-Sr sulfates and chlorides, CO ₂ (L); Chlorides and hydrocarbonates of Na, K, and Ca, and CO ₂ ± N ₂ ± H ₂	Fluorite, bastnaesite-(Ce), monazite-(Ce), albite, and K-feldspar, zircon, Nb-rutile, ilmenite; glaukophane, plumbogummite, monazite-(Ce), corkite. Fluorite, bastnaesite-(Ce), calcite, siderite

			Fluid gas-liq					
Central Tuva carbonatites***	Ankerite- calcite (first phase of carbonatite intrusions)	Quartz	Melt carbonate	790-820	>> 350	97 - 99	Ank, Cal, CO ₂	Calcite, ankerite, phlogopite, fluorapatite, Ti-magnetite, quartz, and muscovite
		Apatite, phlogopite	Melt Silicate- carbonate	>> 500		Silicates - 50- 70 vol.%; carbonates – 30-50 vol.%	Silicate phase (Phl?): Si, Al, Ca, Na, K, Fe, Mg, Ti, O, Cl, OH Ank: Ca, Fe, Mg, Sr, CO ₂	
		Fluorite	Brine-melt	620-650	340 –350	~ 87.5-95 Carbonates – 10-50; chlorides - 40- 75	HI, Syl, Cal, Ank, CO ₂ (L)	
Karasug***			Brine-melt	610-650		> 80	Ca, Na, K, Mg, Fe, Ba, Sr - silicates, carbonates, chlorides, fluorides, sulphates and bastnaesite	Calcite, fluorapatite, Ti- magnetite, quartz, muscovite, fluorite, monazite-(Ce), bastnaesite-(Ce)
Ulatai-Choza								
Karasug***	Siderite Fe-F- REE (second phase)	Quartz	Brine-melt	580-640	290-330	87 – 92 NaCl - 45-48 KCl - 32-30	HI, Syl, Sd, Anh, ancylite-Ce Fe-copiapite-CO ₂ (L)	Siderite, calcite, fluorite, quartz, barite, Ba- celestite, bastnaesite- (Ce), fluorapatite, muscovite, and magnetite
Ulatai-Choza***		Fluorite		>> 500	320-350	Siderite 10-15 75 – 77 NaCl - 42-47 KCl - 28-30	HI, Syl, Sd, Bsn-(Ce), Silicates, Brt-Clt - CO ₂ (L)	

Karasug	Siderite	Quartz, fluorite	Crystal- fluid (primary and pseudo- secondary)	420-480	200-250	40 – 60 KCl - 30-45 NaCl - 10-15 Sulphates - 2-5	Hl, Syl, Anh, Br ₂ -Cl ₂ , Thn, Bst-(Ce) -CO ₂ (L)	Siderite, calcite, dolomite, fluorite, quartz, barite, Ba- celestite, bastnaesite- (Ce), parisite-(Ce), synshysite-(Ce), xenotime-(Y), fluorapatite, strontianite, and sericite
Ulatai-Choza	Ankerite- calcite, siderite	Fluorite quartz		300-380	180-230	30 – 40 NaCl - 10-25 KCl - 30-15		
	Ankerite- calcite	Quartz	Multiphase and two- phase	250-300	50-75	15 - 30 NaCl –eq.	H ₂ O- NaCl/KCl - CO ₂ (G/L)	Quartz, calcite, fluorite, etc.
Mushugai- Khudag complex****	Magnetite- apatite rocks****	Fluorapatite	Melt****	830-850	320-340	89 – 97	Na-Amp, Anh, Br ₂ - Cl ₂ , Mn ₂ -(Ce), Hem - CO ₂ (L)	Magnetite, fluorapatite, ilmenite, phlogopite
			Brine- melt****	500-580				
			Crystal- fluid	400-380 250-150	---	45 – 60 10 - 20	Hl/Syl, Anh, Br ₂ -Cl ₂ , Mn ₂ -(Ce), Hem - CO ₂ (L)	Monazite-Ce, celestite, rutile, quartz, fluellite, fluorite, barite, gypsum, and phosphosiderite
	Calcite-fluorite rocks	Fluorite****	Brine-melt	500-530	---	52 - 64	Hl/Syl, Ank, Br ₂ -Cl ₂ , Thn, Cal, Mag, Bst- (Ce), Sgn -CO ₂ (L)	Magnetite, calcite, apatite, fluorite, barite, celestite
	Late-stage quartz- carbonate- celestite- fluorite rocks	Fluorite	Crystal- fluid	470-390 295-250	----	38 – 46 13.9 – 6.5	Hl/Syl, Cal, Bst-(ce), Br ₂ -Cl ₂ , Anh, - CO ₂ (L) Hl/Syl, Cal, Bst-(ce), Br ₂ -Cl ₂ , Anh, Str, P- Sid - CO ₂ ±H ₂	Quartz, fluorite, calcite, barite, celestite, pyrolusite, bastnaesite- (Ce), monazite-(Ce), ilmenite, rutile, siderite and phosphosiderite

Notes: T_m – melting temperature of the salt component; T_{hom} - homogenisation temperature of inclusion; cr. ph - crystalline phase; "---" - parameter is not detected, * - the composition of the crystalline phase indicated by Raman spectroscopy and SEM-EPMA analyses; ** - our previous [50-52,54,56] and present data; *** - our previous [40] and present data. **** - our previous [49,59] and present data. Abbreviations of mineral phases according to [55].

Table S2. LA-ICP MS elemental concentrations in the brine-melt inclusions in the carbonatites of the Central Asian province

Province Areal	Central Tuva				Western Transbaikalia		Mushugai-Khudak complex	
Complexes	Ulatai-Choza*	Karasug*		Ulatai-Choza	Yuzhnoe	Ulan-Ude		
Type of carbonatite	Ankerite-calcite	Fe-F-REE Siderite			REE Calcite	F-REE Carbonatites	Magnetite-apatite rocks	Calcite-fluorite rocks
Mineral Element	Quartz	Quartz	Fluorite	Quartz	Fluorite		Fluorapatite	Fluorite
Na, wt%	7.5 - 15	17 – 18	13.4 – 13.6	5 – 10	15 – 20	10 – 22	10 – 15	10 – 22
K, wt%	8.1 - 12.2	14 - 15	5.4 – 7.1	12 – 15	10 - 15	10 - 12	5 - 10	10 - 12
Fe, wt%	0.25 - 6	5 - 6	3.6	6.2 - 7.8	5.2 – 10.1	8.2 – 15.6	10.2 – 15.5	9.9 – 10.4
Mn, wt%	0.13 – 1.1	0.65 – 1.1	0.045 – 0.3	0.48 – 1.1	0.5 – 1.5	0.5 – 1.1	0.5 – 1.5	0.5 – 1.2
Ca, wt%	12.7 – 15.6	0.01–0.32	0.013 – 0.1	0.8 – 1.2	10.5 – 25	15 – 20	5 – 10	15 – 20
Sr, wt%	---	0.28 – 0.7	0.43 – 2.7	0.88 – 2.66	5.5 – 12.1	5.5 – 12.1	5 – 16.2	12.5 – 15.1
Ba, wt%	---	0.2 – 0.8	0.01 – 1.2	0.32 – 1.18	1.3 – 2.65	0.3 – 0.65	0.5 – 0.55	0.5 – 0.65
La, ppm	4-5	30 - 60	460–1400	380 – 1565	2540 - 6550	3040 - 8550	2540 - 5650	3050 - 9550
Ce, ppm	880-1100	15 – 70	2200 - 4700	2548 – 3988	3280 – 9520	4250 – 10520	4550 – 7500	4450 – 9550
Nd, ppm	---	20 - 30	450 - 4450	305 – 2680	3520 – 7500	4020 – 7800	3020 – 5500	4050 – 8800
Y, ppm	---	0.15 - 6	---	250 – 1520	580 – 1050	550 – 1020	250 – 520	580 – 1050
Th, ppm	---	0.3 - 28	0.2–0.6	0.5 – 10	0.5 - 10	0.5 - 50	0.5 - 10	0.5 - 30
U, ppm	---	2.5 - 35	10-35	10 - 30	10 - 50	10 - 50	10 - 20	10 - 25

* - our previous data [40] and present data. The LA-ICP MS method was used to analyze 38 inclusions from the Central Tuva region, 27 inclusions from the West Transbaikalia region, and 36 inclusions from the rocks of the Mushugai-Khudak carbonatite complex.