

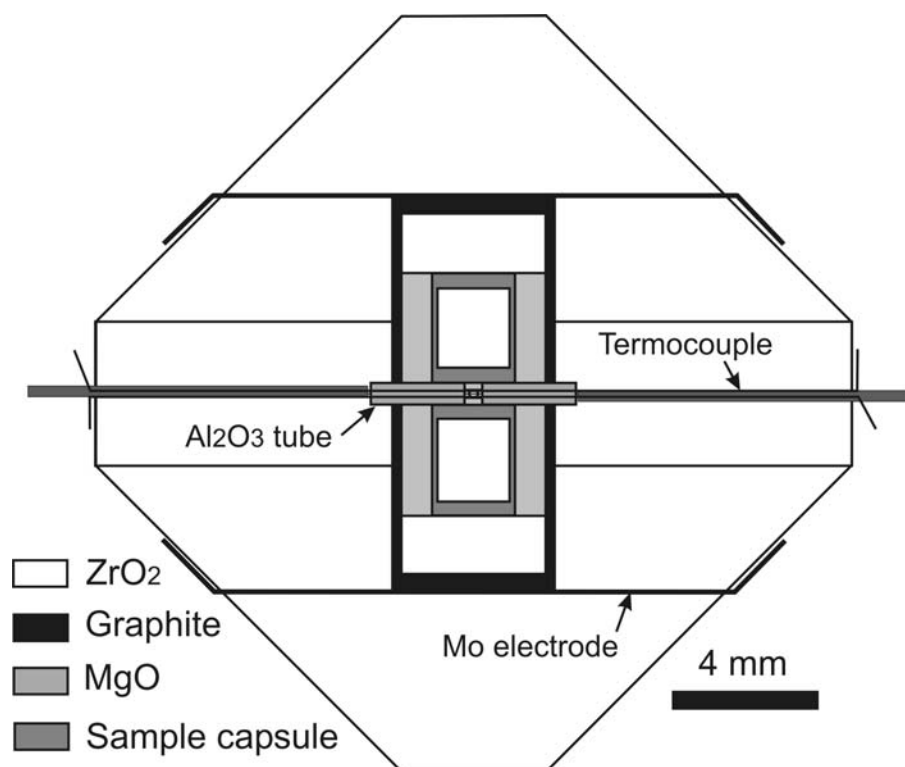
## Supplemental information for

## The Solidus of Alkaline Carbonatite in the Deep Mantle

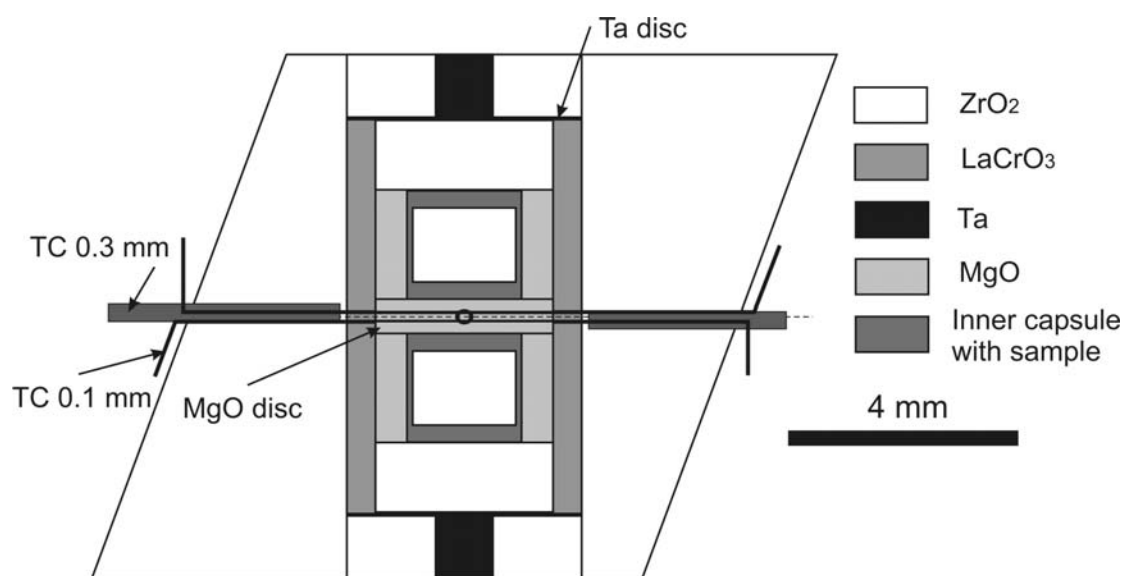
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### EXPERIMENTAL METHODS

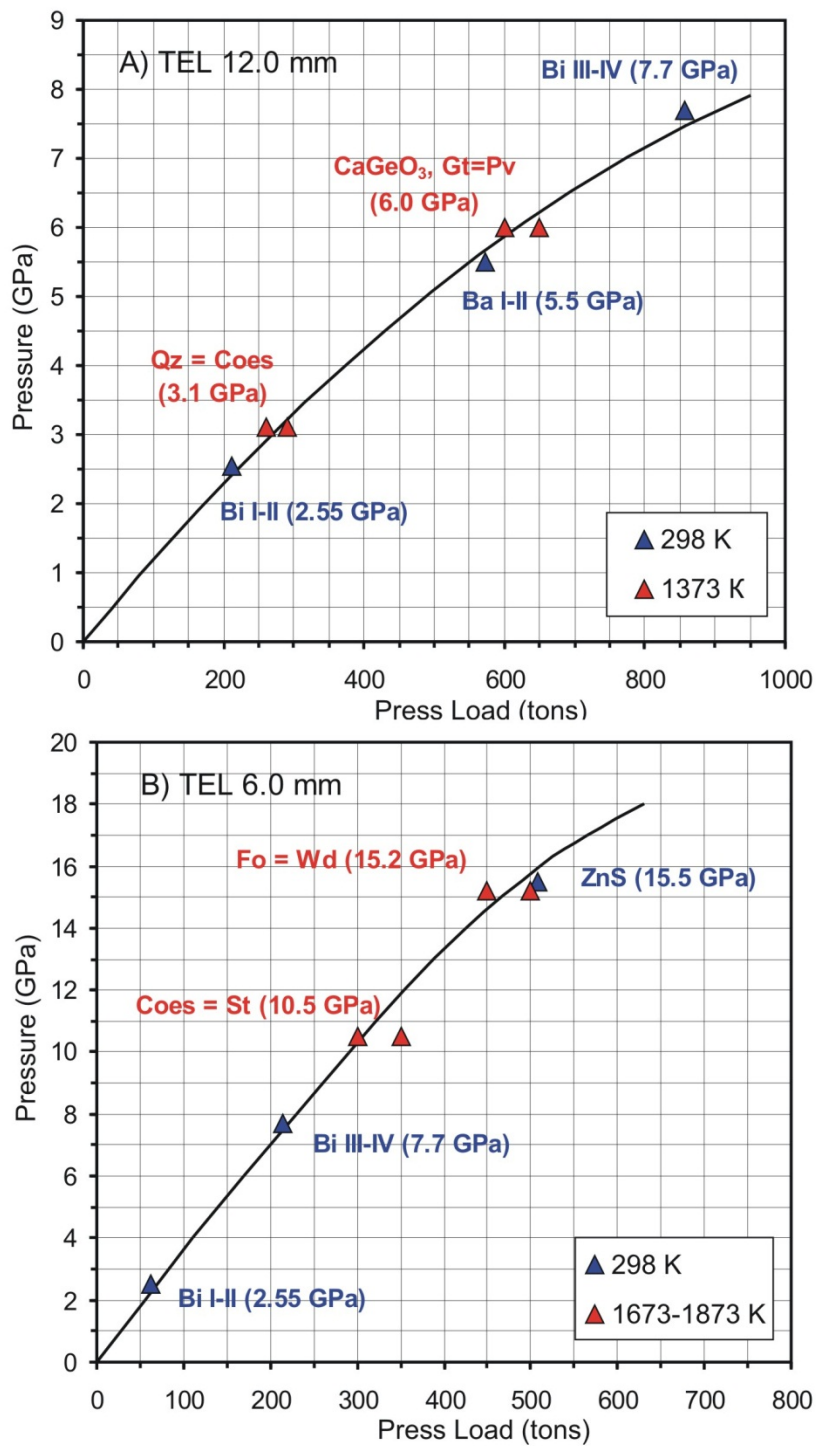
The starting materials for the experiments (Table S1) were oxide and carbonate mixtures. Si and Fe were added as  $\text{SiO}_2$  and  $\text{FeO}$  and Mg, Ca, Na, and K were added as carbonates. High pressure experiments were performed using a Kawai-type 1500 and 3000 ton multianvil apparatuses at Tohoku University. The truncated edge lengths (TEL) of the tungsten carbide anvils were 12.0 (3.0-6.5 GPa), 6.0-5.0 (10-16 GPa), and 3.5 mm (21 GPa and one experiment at 15 GPa). The experimental cells contained two charges: one with the Na-carbonatite composition and the other with a K-carbonatite composition, sealed in  $\text{Au}_{75}\text{Pd}_{25}$  capsules. Semi-sintered zirconia was used as the pressure medium and a cylindrical  $\text{LaCrO}_3$ -heater was used as the heating element (except experiments at 3.0 and 6.5 GPa, where graphite furnaces were used). A MgO insulator was placed between the capsule and heater. Temperature was measured with a  $\text{W}_{97}\text{Re}_3$ – $\text{W}_{75}\text{Re}_{25}$  thermocouple located at the center of the furnace. The lateral and vertical temperature variations across the charge do not exceed 50 °C as confirmed by a series of temperature gradient experiments using two-pyroxene thermometry (Litasov and Ohtani, 2009a). The cell assemblage design and pressure calibration for TEL 12 mm and 6.0 mm is shown in Figs. DR1-DR3 and those for 3.5 mm were reported previously (Litasov and Ohtani, 2009b). The pressure uncertainty was determined to be within 1 GPa. After samples were returned to ambient conditions, the capsules were cut down the middle, mounted into epoxy, and polished under petroleum benzene to preserve water-soluble alkali carbonates. Repeated vacuum impregnation with low viscosity epoxy resin was applied to minimize polishing damage of the quenched materials. Mineral and melt compositions were measured by JEOL Superprobe JXA-8800L electron probe microanalyser at the Tohoku University using an acceleration voltage of 15 kV and a beam current of 1-10 nA. Natural olivine, clinopyroxene, dolomite, magnesite, calcite, feldspar, and basalt glasses were used as analytical standards. We also prepared internal standards of alkali carbonates with compositions of  $\text{Na}_2\text{Ca}(\text{CO}_3)_2$  and  $\text{K}_2\text{Mg}(\text{CO}_3)_2$ . To ensure accuracy and precision of analytical data, standard minerals of known compositions were analyzed in each probe session as secondary standards. Back-scattered electron images of the samples were obtained using JEOL JXA-5410 scanning electron microscope.



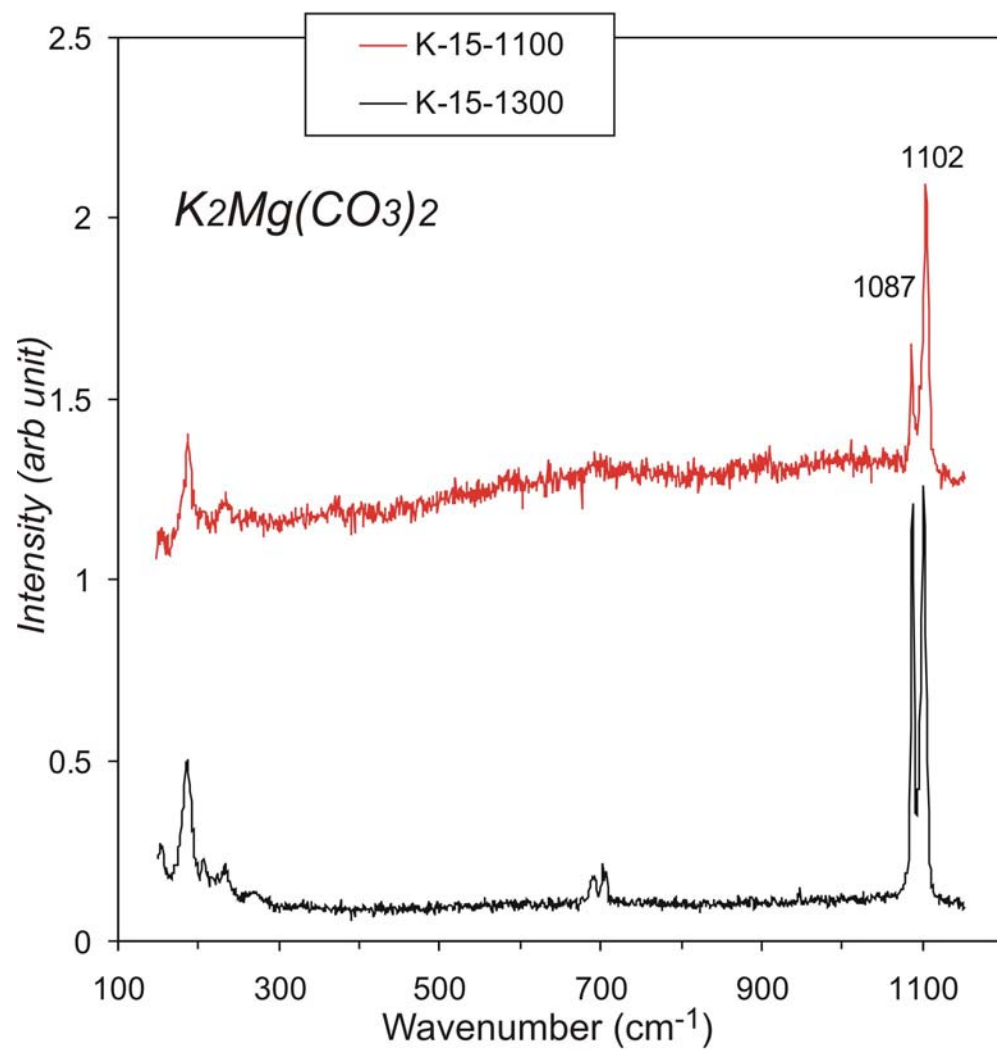
**Figure DR1.** Cell assembly configuration for TEL 12.0 mm (experiments at 3 and 6.5 GPa).



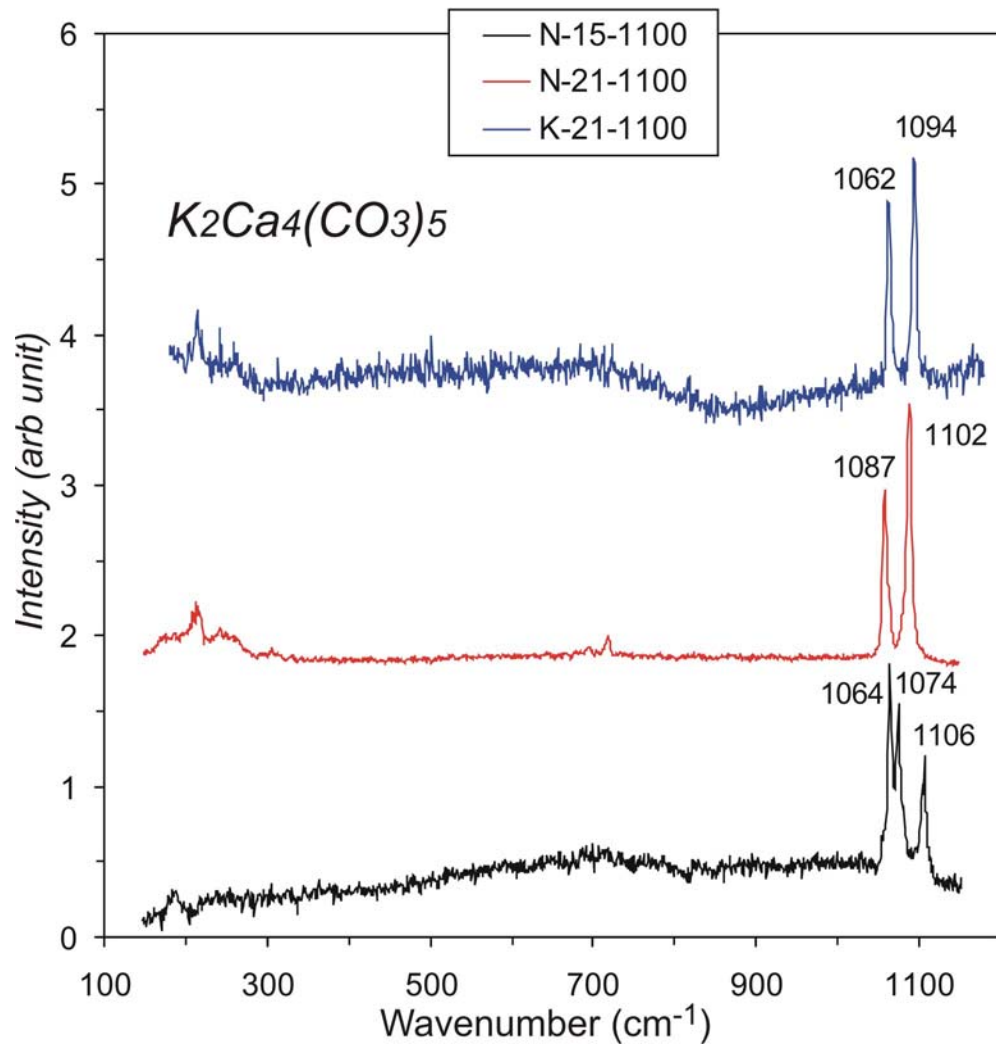
**Figure DR2.** Cell assembly configuration for TEL 6.0 mm (experiments at 10.5 and 15.5 GPa).



**Figure DR3.** Pressure calibration curves for ZrO<sub>2</sub> high-pressure cells (TEL 12.0 and 6.0 mm). Qz – quartz, Coes – coesite, St – stishovite, Gt – garnet, Pv – perovskite, Fo – forsterite, Wd – wadsleyite.



**Figure DR4.** Raman spectra of  $K_2Mg(CO_3)_2$  phase. Sample number includes system (K- K-carbonatite, N –Na-carbonatite), pressure in GPa and temperature in  $^{\circ}C$ .



**Figure DR5.** Raman spectra of  $(K,Na)_2Ca_4(CO_3)_5$  phase. Sample number includes system (K- K-carbonatite, N –Na-carbonatite), pressure in GPa and temperature in  $^{\circ}C$ .

**Table DR1.** Starting compositions of Na- and K-carbonatite compared with partial melts from carbonated peridotite and eclogite.

	1	2	3	4	5	6	7	8	9	10
SiO <sub>2</sub>	4.0	4.0	3.17	2.57	12.73	6.39	10.24	8.16	1.15	2.62
TiO <sub>2</sub>	---	---	0.52	0.72	1.05	1.04	0.60	0.69	0.29	0.10
Al <sub>2</sub> O <sub>3</sub>	---	---	2.10	0.38	3.48	1.53	2.20	1.56	0.16	0.11
Cr <sub>2</sub> O <sub>3</sub>	---	---	0.24	---	0.21	---	0.32	0.08	---	0.05
FeO	4.0	4.0	4.96	4.54	5.52	5.99	4.02	4.07	13.74	4.13
MnO	---	---	---	0.16	---	---	---	---	0.08	0.21
MgO	14.0	20.2	15.17	15.12	16.79	15.24	16.26	13.93	14.03	16.53
CaO	27.0	20.2	22.59	21.60	18.63	21.40	20.46	21.91	26.06	20.10
Na <sub>2</sub> O	7.0	2.0	5.40	4.93	4.44	5.01	0.40	2.10	2.76	3.28
K <sub>2</sub> O	2.0	7.0	0.38	7.01	2.13	2.20	4.04	5.35	1.00	7.52
P <sub>2</sub> O <sub>5</sub>	---	---	0.52	---	0.41	0.74	0.44	---	---	---
CO <sub>2</sub>	42.0	42.6	---	40.31	34.60	---	41.00	---	40.70	40.80
H <sub>2</sub> O	---	---	---	2.66	0.85	---	2.12	---	---	---
Total	100.0	100.0	55.1	100.0	100.0	59.5	100.0	57.9	100.0	95.5

1 – Na-carbonatite, this work.

2 – K-carbonatite, this work.

3 – Carbonatite melt in equilibrium with amphibole peridotite at 2.5-3.0 GPa and 1000°C (Wallace and Green, 1988).

4 – Carbonatite melt in equilibrium with phlogopite peridotite at 3 GPa and 1100°C (Thibault et al., 1992).

5 and 6 – Starting composition of Na-bearing carbonated system and its partial melt at 2.5 GPa and 1200°C from (Sweeney, 1994), respectively.

7 and 8 – Same for K-bearing carbonated system, melt at 3.4 GPa and 1100°C, respectively (Sweeney, 1994).

9 – 10% partial melt of carbonated eclogite at 8.5 GPa and 1280°C (Dasgupta et al., 2004).

10 – composition of low degree (~5%) partial melt of carbonated peridotite doped with Na<sub>2</sub>O (0.4 wt.%) and K<sub>2</sub>O (0.3 wt.%) at 20 GPa and 1400°C (K. Litasov, unpubl. data). This melt contain also near 4.5 wt.% trace elements.

The CO<sub>2</sub> contents are not shown for compositions, which contain also unknown amount of H<sub>2</sub>O.

**Table DR2.** Representative average compositions of the quenched melts from experiments in the Na- and K-carbonatite systems (wt%).

Sample	Mode	SiO <sub>2</sub>	FeO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	CO <sub>2</sub>	Total
Na-carbonatite									
N-3-900	0.46	0.55	3.45	10.93	23.39	13.21	3.58	44.0	99.1
N-3-1100	0.85	2.64	3.79	13.56	26.12	7.84	2.31	43.7	100.0
N-6.5-900	0.08	0.27	3.59	13.64	13.96	17.24	8.58	42.7	100.0
N-6.5-1100	0.33	1.71	3.24	7.17	25.30	14.32	3.74	44.0	99.5
N-10-1200	0.22	0.42	2.06	6.27	32.70	11.31	5.32	41.9	100.0
N-10-1400	0.71	3.71	3.40	8.25	31.87	8.39	2.55	41.8	100.0
N-15.5-1200	0.08	0.51	3.12	5.50	19.13	18.89	9.57	41.0	97.7
N-15.5-1400	0.64	3.03	3.73	7.90	30.53	10.29	3.06	41.5	100.0
N-21-1200	0.23	1.55	4.22	6.50	27.22	12.87	3.88	43.7	99.9
N-21-1300	0.51	1.48	3.75	7.12	30.05	10.83	3.05	43.7	100.0
N-21-1450	0.82	1.74	3.81	9.19	32.43	7.84	2.61	42.4	100.0
K-carbonatite									
K-3-900	0.34	0.67	4.92	12.44	15.30	4.64	20.09	41.9	100.0
K-3-1100	0.82	2.20	3.61	16.44	22.53	2.37	8.45	44.4	100.0
K-6.5-900	0.10	0.07	2.42	6.54	17.32	11.89	21.62	40.1	100.0
K-6.5-1100	0.44	1.64	2.59	7.90	23.82	4.25	15.79	41.7	97.7
K-10-1200	0.20	2.34	2.55	6.31	26.11	5.25	15.73	41.7	100.0
K-10-1400	0.83	3.17	3.73	17.25	23.05	2.14	8.47	42.2	100.0
K-15.5-1200	0.14	1.02	2.72	6.56	27.17	8.15	12.01	42.4	100.0
K-15.5-1400	0.79	2.97	3.76	15.74	23.50	2.41	8.72	42.9	100.0
K-21-1200	0.14	0.61	4.15	7.10	31.78	6.86	7.98	41.5	100.0
K-21-1300	0.39	0.57	4.53	9.80	28.77	3.94	9.00	43.4	100.0
K-21-1450	0.68	2.15	3.12	12.03	28.62	2.89	9.84	41.4	100.0

Sample number includes pressure in GPa and temperature in °C. The standard deviation of the analyses does not exceed 10% in 10-20 points of defocused beam scans. The CO<sub>2</sub> contents were calculated from electron microprobe totals or as 1 atomic unit of carbon per 3 oxygen (corresponding to maximum possible CO<sub>3</sub><sup>2-</sup> content in the melt). Modal melt fraction was calculated from mass-balance. The compositions of all melts and solid phases will be reported in a full-size manuscript.

## References for Supplemental Information

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