Water-saturated solidus and second critical endpoint of peridotite determined from liquid texture and chemistry

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Abstract

The melting of peridotite plays a key role in the chemical differentiation of planetary bodies. Water-saturated ('wet') solidus of mantle peridotite defines initial melting temperature of Earth's mantle under water-saturated conditions and the second critical endpoint (SCEP) marks the end of the wet solidus. However, the location of the wet solidus remains an outstanding issue for over 50 years and the position of the SCEP is hotly debated. Published wet solidus shows a difference of 200-600 °C at given pressures, meanwhile, reported SCEP ranges from < 4 to > 6 GPa. Using a large-volume multi-anvil apparatus, we investigated the water-saturated melting behavior of a fertile peridotite (at 3-6 GPa, 950-1200 degC) and obtained well-preserved quenched liquid. Based on the texture and chemistry of the quenched liquid, we successfully determined the wet solidus and the SCEP of peridotite (Fig 1 A). The quenched fluids exhibit fragile fibres at 950 and spherule–fibre mixtures at temperatures above 1000 (Fig 1B). At 3 GPa, the quenched hydrous melt appears as a felt-like mass or as dendritic crystallites and coexist with the quenched fluids (Fig. 1B). We interpreted the presence of spherule–fibre mixtures as an evidence for aqueous fluid above the solidus and fragile fibres as evidence for aqueous fluid below the solidus. Thus, the occurrence of quenched melt and spherule–fibre mixtures indicates that the wet solidus lies between 950 and 1000 at 3 GPa and that 3 GPa is lower than the critical pressure (Pc). The most important textural difference between the run products at 3 GPa and those at other pressures (4 and 6 GPa)o is the presence of aqueous fluids in the former (Fig. 1B) and the absence of which in the latter (Figs. 1C–D).The spherule–fibre mixtures were not found in the 4 and 6 GPa run products. Liquids quenched from 4 and 6 GPa run products are homogeneous (SCF supercritical fluid), suggesting that Pc is lower than 4 GPa. Compositions of the liquids were analysed by EDS. In combine with previous studies, we find that with increasing pressures, the liquid compositions become more deficient in quartz and richer in olivine components. The compositions of silicate melts or SCFs change consistently with respect to pressure: andesitic at 1 GPa, boninite-like at 3 GPa, picritic at 4 GPa, and kimberlite-like at pressures $>$ 5 GPa.

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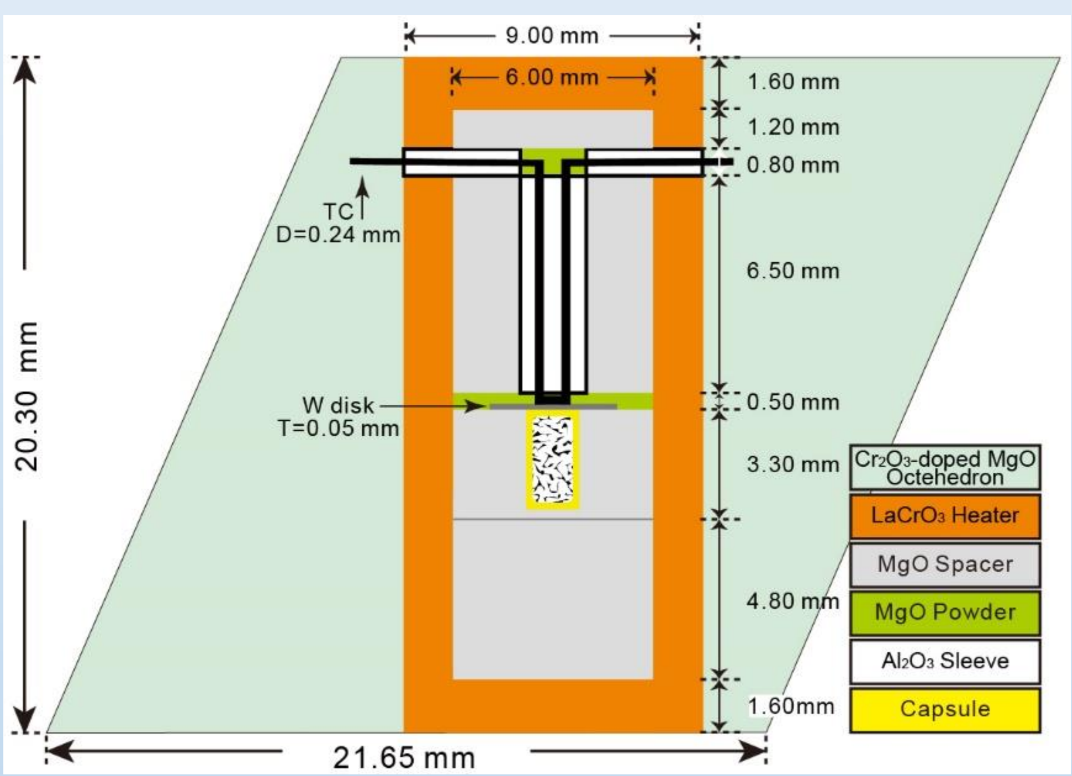
1. Introduction

- Hydrous melting of peridotite is the essential process in magma genesis at subduction zones.
- Water-saturated ('wet') solidus of mantle peridotite defines initial melting temperature of the mantle under water-saturated conditions and the second critical endpoint (SCEP) marks the end of the wet solidus.
- However, published wet solidus shows a difference of 200−600 °C at given pressures, meanwhile, reported SCEP ranges from < 4 to > 6 GPa.

2. High Pressure Experiments

To determine the wet solidus and SCEP, melt and fluid chemistry



KLB-1 + 10 wt% H_2O;

950–1200 °C, 3–6 GPa;

2500 ton Multi-anvils;

Tokyo Institute of Technology

⇩

Guangzhou Institute of Geochemistry

25M (25mm edge length MgO octahedron) with **$LaCrO_3$ furnace**

- Homogeneous temperature distribution (< 20 °C) ;
- Rapid quench rate.
- Isotropic decompression

⇨ (good preservation of delicate fluid textures)

3. Diagnostic Criterions

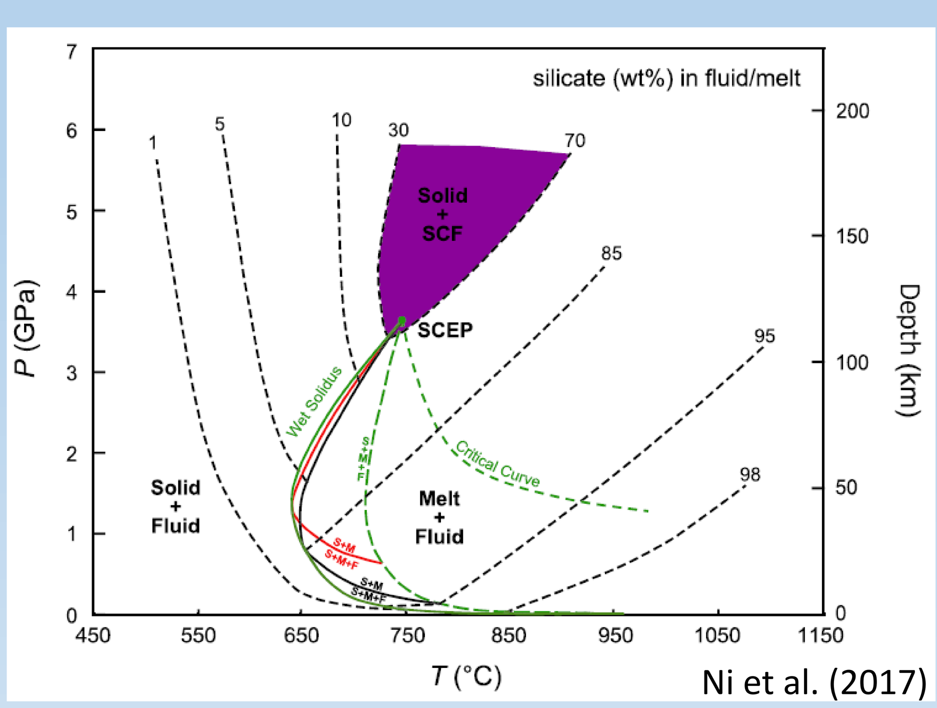
Below P_C

$T<T_{solidus}$, **minerals + fluid**;

$T>T_{solidus}$, **mineral + melt + fluid**

Above P_C

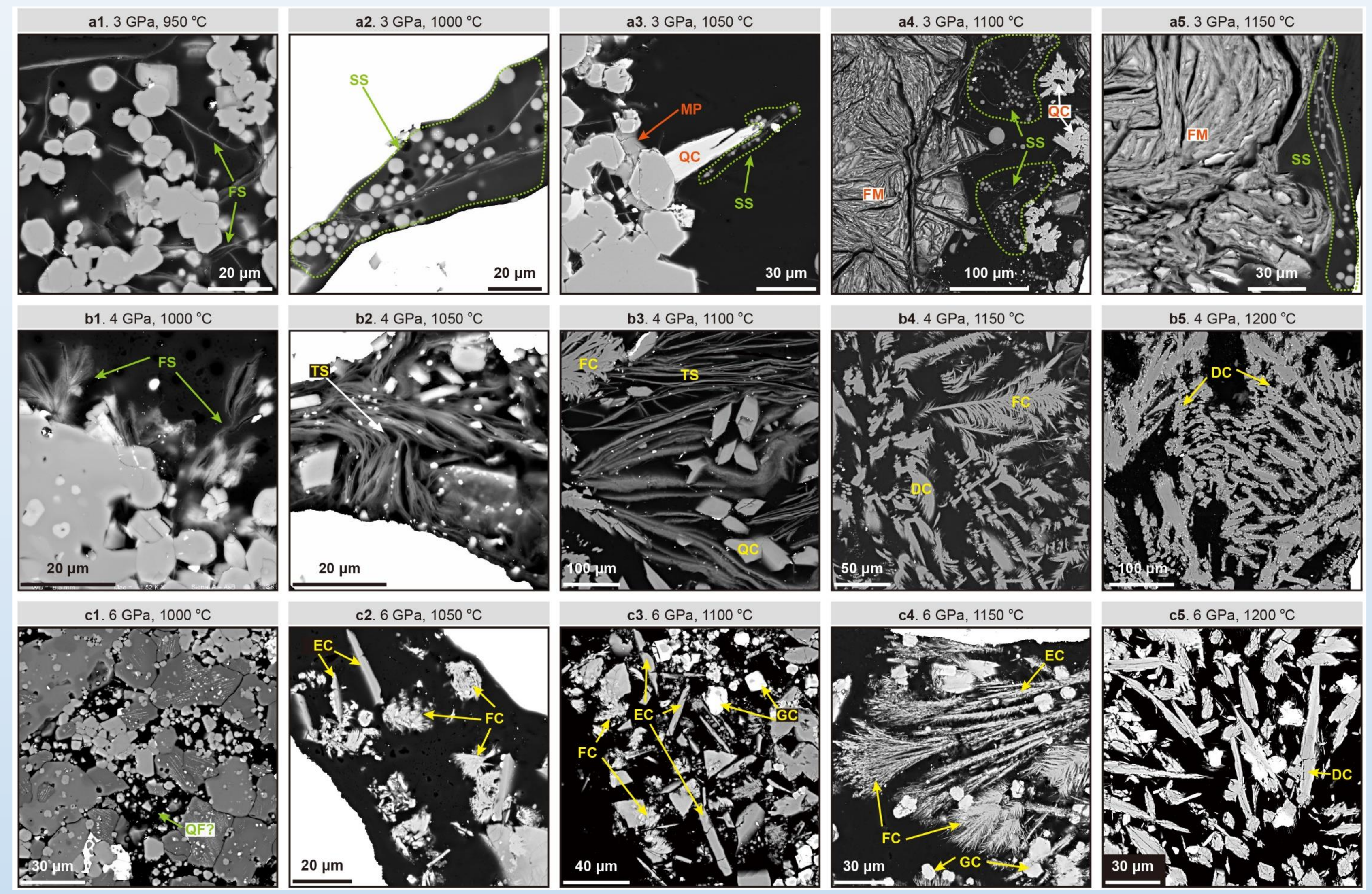
minerals+SCF;



4. Textures of quenched melt and fluid

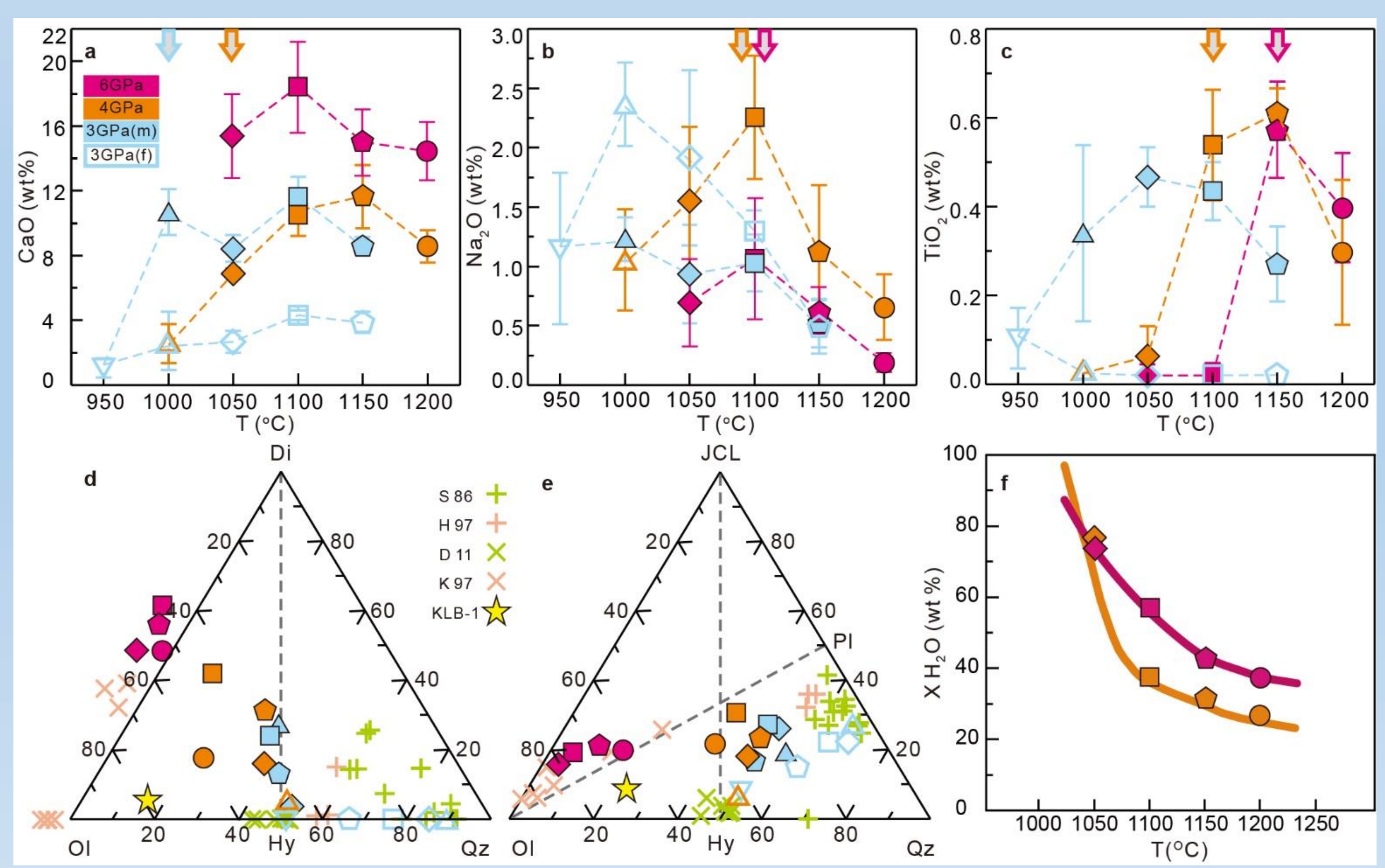
Fluid: $T<T_{solidus}$, fragile sheet (**FS**); $T>T_{solidus}$, sheet + spherule (**SS**);
Melt: melt pocket (**MP**), quenched crystal (**QC**); felt-like masses (**FM**) etc.
SCF: homogeneous phase *Adam et al. (1997, 2014); Mibe et al.(2007,2011)*

We interpreted the (sheet+spherule mixtures) as the quenched fluid above solidus; but Grove & Till (2019) interpreted the sheet and spherule as melt and fluid, respectively. At 3 GPa, coexistence of melt (felt like mass) and fluid (sheet+spherule mixtures) were found.



3 GPa < P_C, **melt** + **fluid**, the wet solidus lies between 950 and 1000 °C;
4 GPa & 6 GPa > P_C, **SCF**, the pseudo-solidus lies between 1000 and 1100 °C;

5. Melt and fluid Chemistry (broad area analysis by EDS)

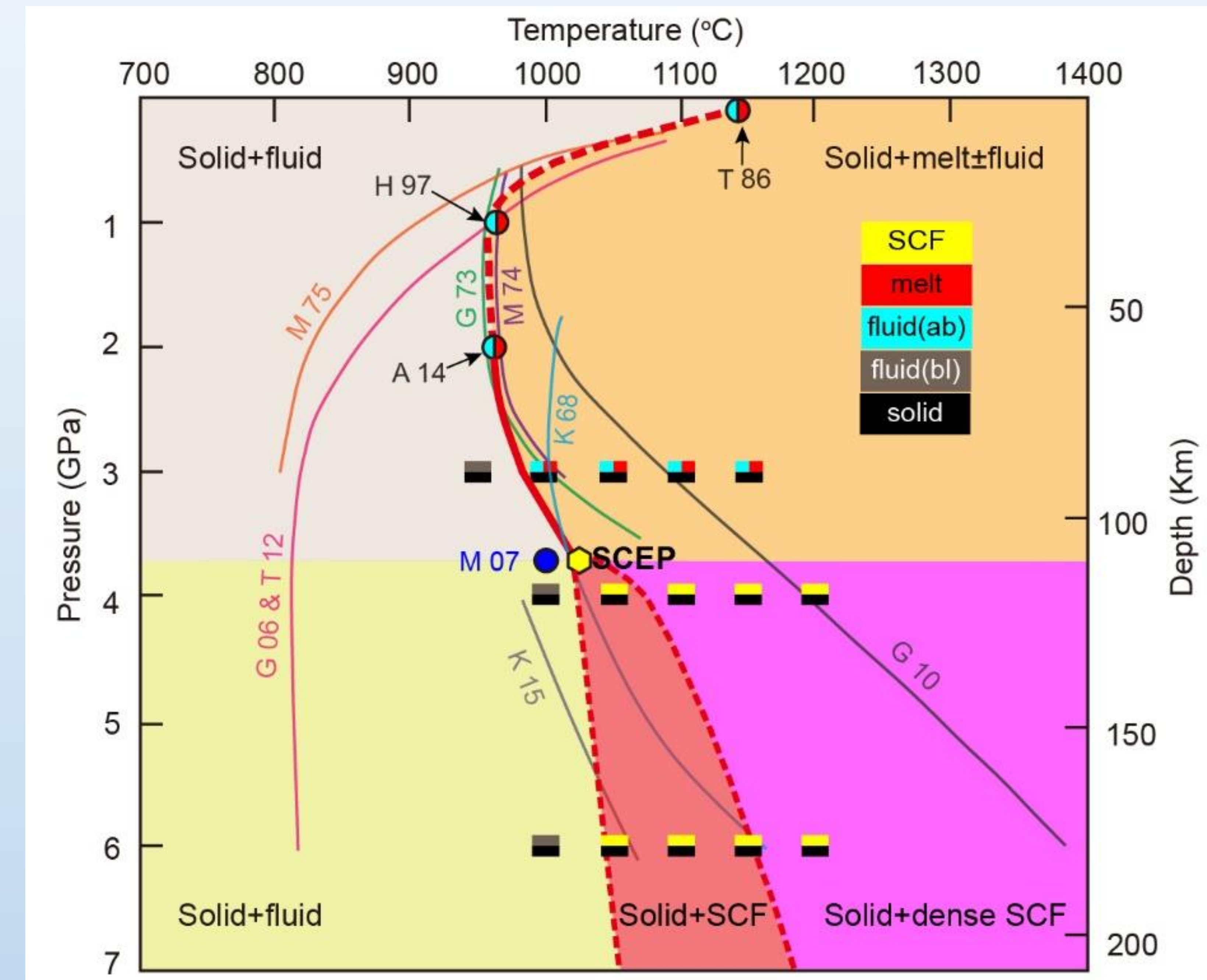


Fluid: Below solidus: **dacitic** at < 2 GPa, **hyperthene** at > 3 Gpa; Above solidus: **dacitic** to **andesitic** at 3 Gpa;

Melt/SCF: **Andesitic** at 1 GPa, **boninite-like** at 3 GPa, **picritic** at 4 GPa, **kimberlite-like** at > 5 Gpa;

Dilute to dense **SCF**: **1050-1100 °C** at 4 GPa, **1100-1150 °C** at 6 GPa;

6. Conclusions



Wet Solidus: 950–1000 °C at 3 GPa; SCEP: 3.8 GPa, 1025±25 °C

7. Implications

- **Magma genesis model in subduction zone;**

(Oral: V53A-03, Friday, 14:10-14:25, Moscone South – 153 – upper Mezz.)

- **Silica enrichment in sub-arc mantle;**

Fluid (below & above the solidus) is capable to cause silica enrichment

- **Formation of ultrabasic magmas in subduction zones;**

Ultramafic magmas can be formed in subduction zones at certain conditions

S86, Schneider and Eggler (1986); **H97**, Hirose (1997); **D11**, Dvir et al. (2011);
K97, Kawamoto and Holloway (1997); **M75**, Mysen and Boettche (1975);
G06, Grove et al. (2006); **T12**, Till et al. (2012); **G 73**, Green (1973); **G10**, Green et al. (2010);
M74, Millhollen et al. (1974); **T86**, Takahashi (1986b); **A14**, Adam et al. (2014);
K68, Kushiro et al. (1968); **M07**, Mibe et al. (2007); **K15**, Kessel et al. (2015);