

# Melting of a Primitive Martian Mantle at 1-2 GPa

Max Collinet<sup>1</sup>, Etienne Médard<sup>2</sup>, Jacqueline Vander Auwera<sup>1</sup> and Bernard Charlier<sup>3</sup>

<sup>1</sup>Département de Géologie, Université de Liège - F.R.S.-FNRS, Belgium - [mcollinet@ulg.ac.be](mailto:mcollinet@ulg.ac.be);

<sup>2</sup>Laboratoire Magmas et Volcans, Université Blaise Pascal - CNRS - IRD, Clermont-Ferrand, France;

<sup>3</sup>Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute Of Technology, Cambridge, MA, USA.



## 1. Introduction

The surface of Mars is covered with basalts produced by partial melting of the planetary interior.

The compositional variability reflects primarily the composition of mantle sources and the pressure-temperature conditions at which melting occurs.

Model compositions of the bulk silicate Mars (i.e. the primitive Martian mantle) have been proposed based on physical constraints and correlations between element ratios from Martian meteorites and chondrites [1,2].

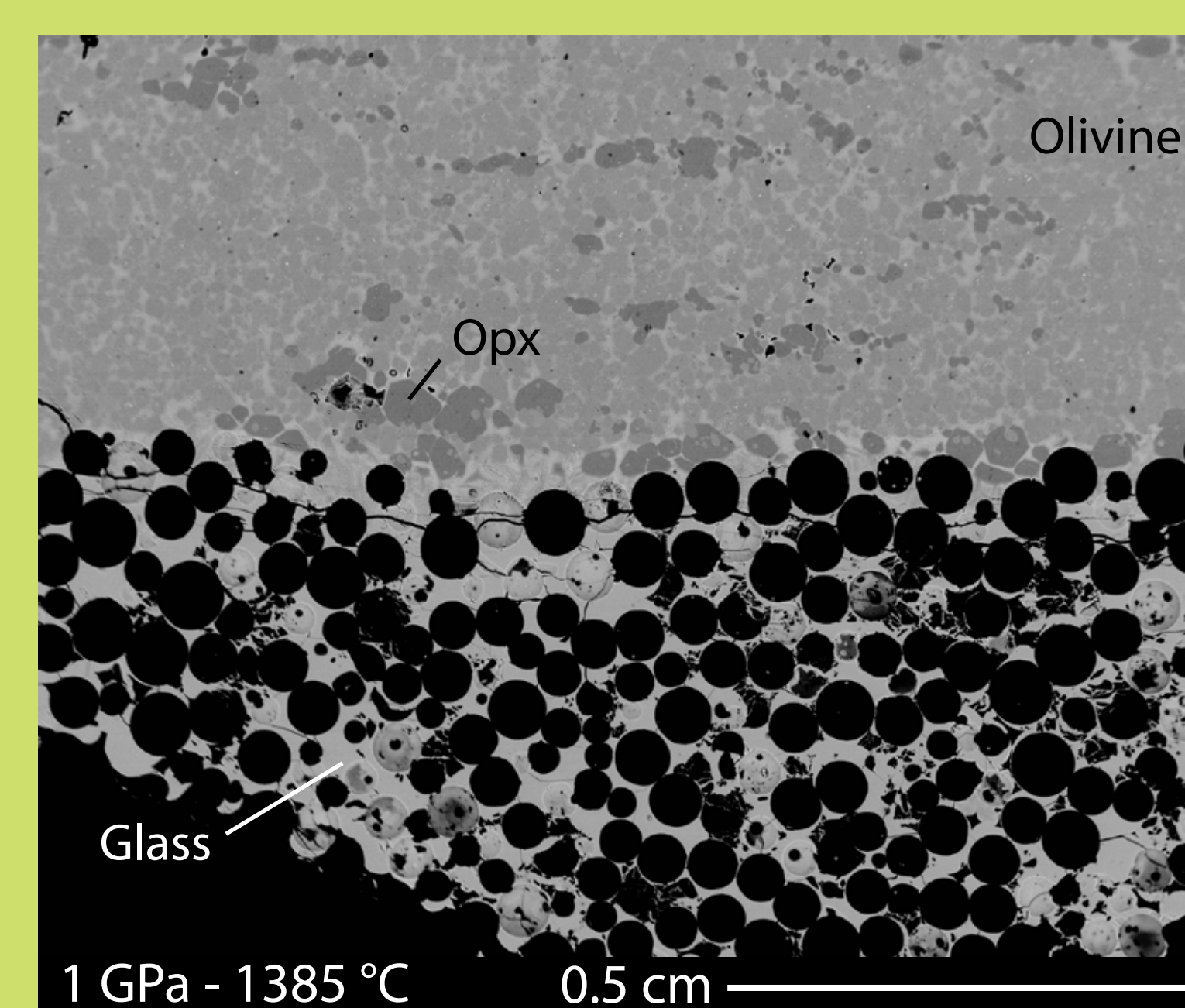
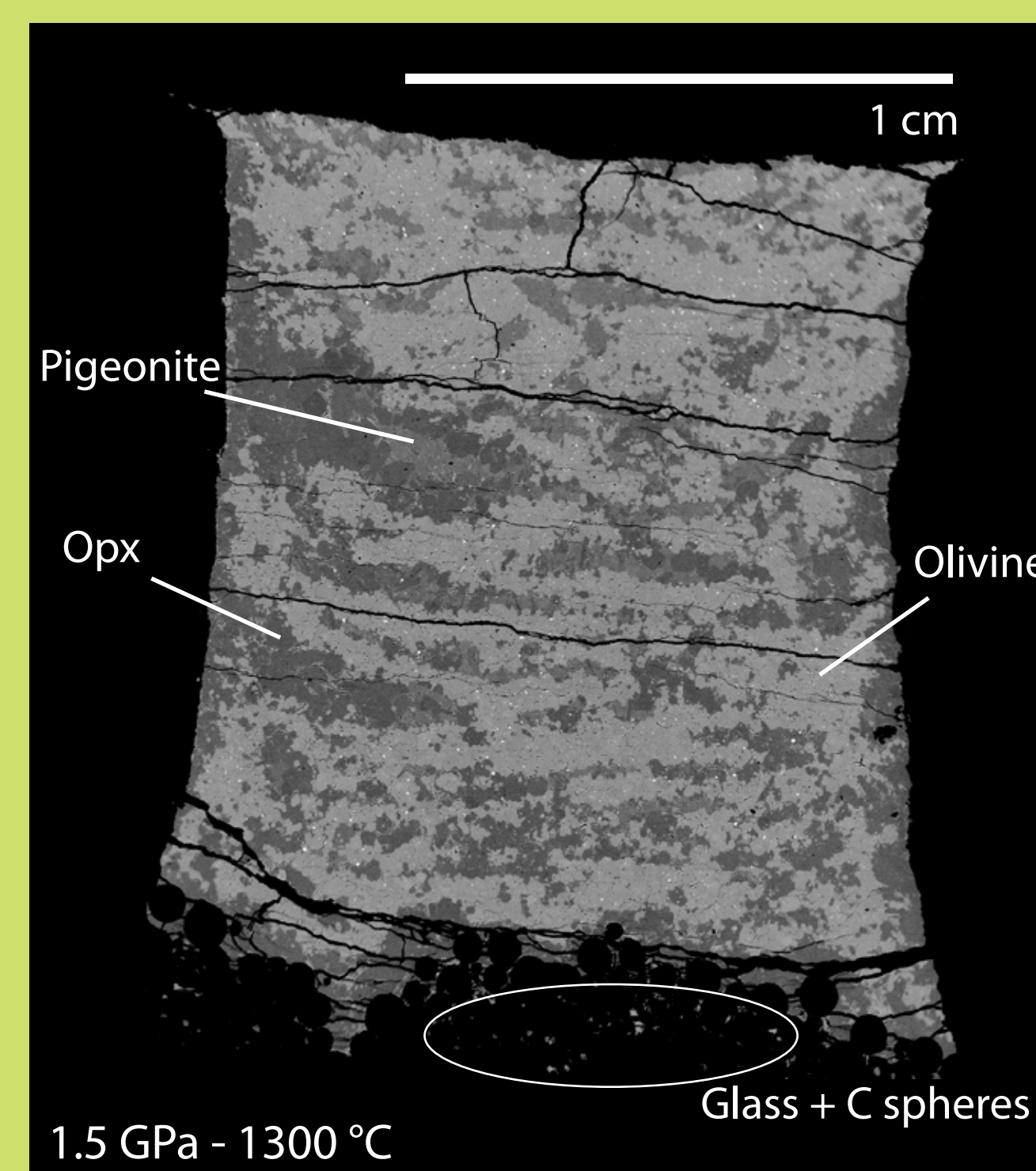
We use the Dreibus and Wänke [1] composition to perform melting experiments at 1-2 GPa (from 5 to 50% melt fractions).

Experimental melts are compared to Martian rocks in order to discuss their origin.

### Bulk silicate planets

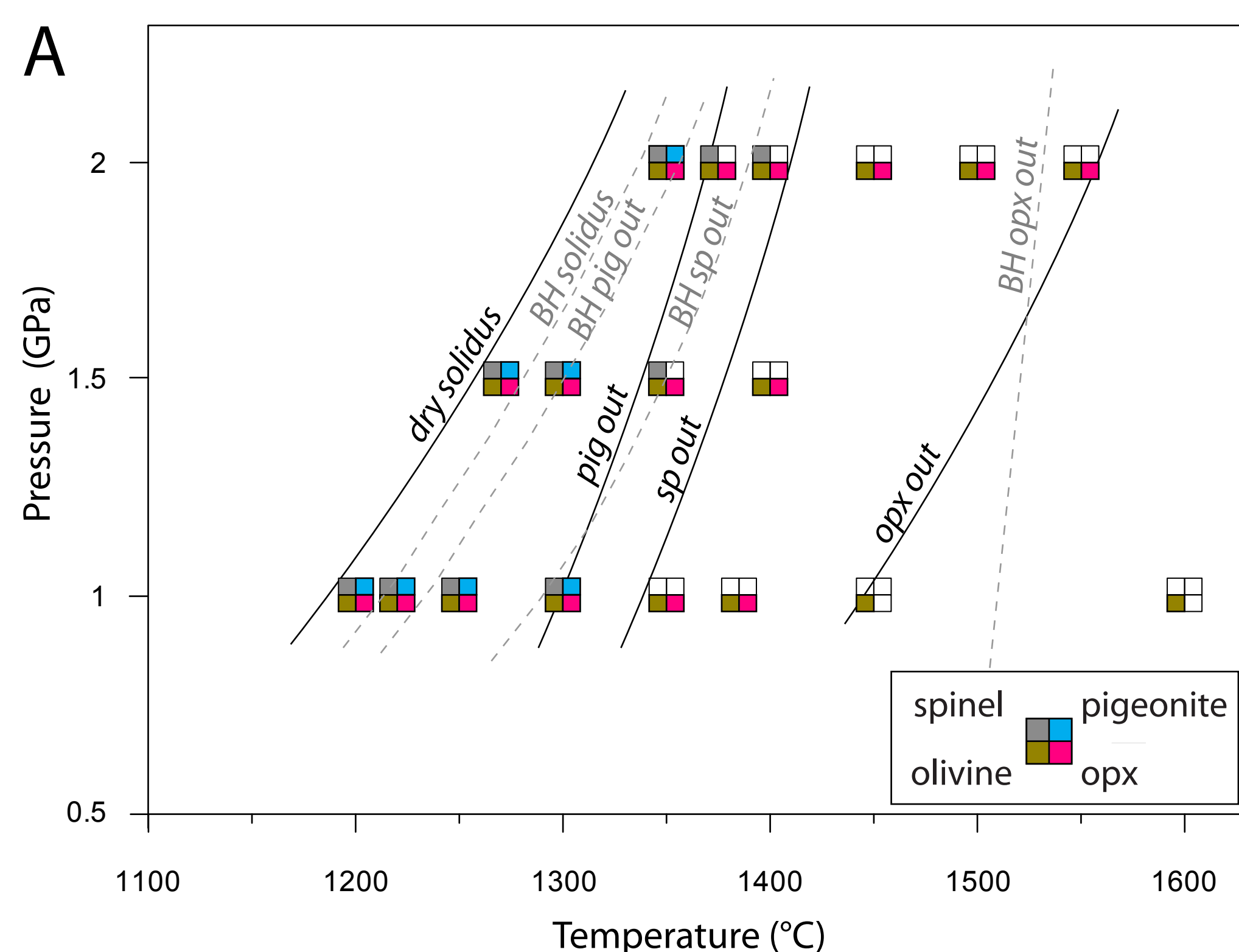
	Earth	Mars DW
SiO <sub>2</sub>	45.95	44.38
TiO <sub>2</sub>	0.23	0.13
Al <sub>2</sub> O <sub>3</sub>	4.2	3.02
Cr <sub>2</sub> O <sub>3</sub>	0.44	0.76
FeO	7.58	17.90
MnO	0.13	0.46
MgO	36.85	30.21
CaO	3.54	2.44
Na <sub>2</sub> O	0.39	0.50
K <sub>2</sub> O	0.03	0.04
P <sub>2</sub> O <sub>5</sub>	0.015	0.16

**Table 1** Composition of bulk silicate Mars, DW [1], the starting material, compared to bulk silicate earth [10].



**Fig. 1** BSE images of experimental charges

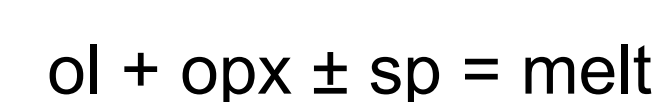
## 3. Phase Equilibria



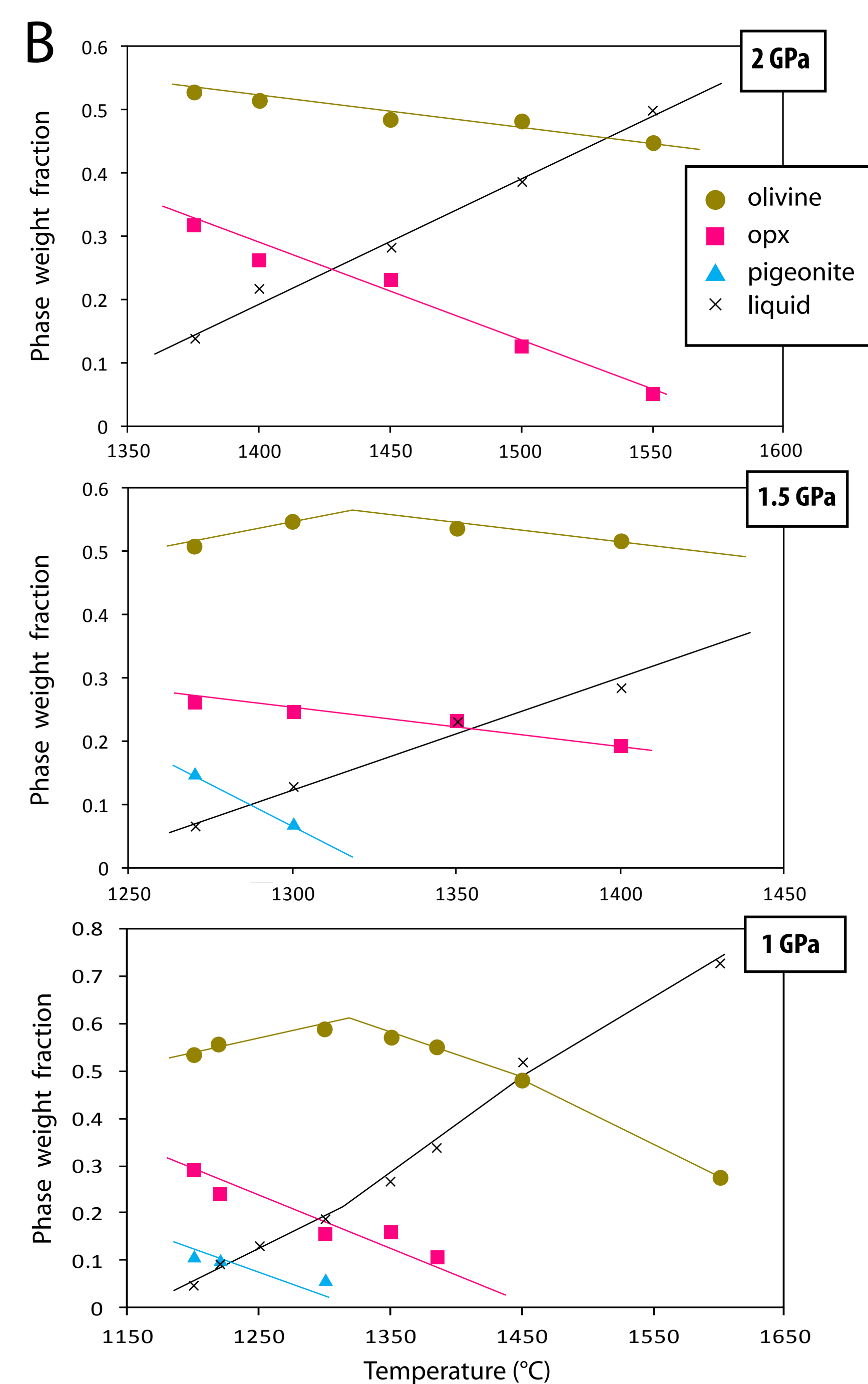
**Fig 2.** [A] Pressure-temperature phase diagram (this work). Bertka and Holloway [3] diagram is represented by dotted lines (melts only analyzed at 1.5 GPa). [B] Phase proportions calculated by mass balances.

Melting first proceeds through a peritectic reaction:  
 $opx + pig + sp = ol + melt$   
 with the CaO content of pigeonite decreasing progressively from 12 to 4 wt%.

After disappearance of pigeonite, melting occurs following an eutectic reaction:



Solidus temperatures are lowered by 30°C compared BH [3] and result from the addition of K<sub>2</sub>O in our starting material.



## 2. Experimental Approach

- Starting Material: synthetic equivalent of the Dreibus and Wänke [1] composition (table 1).
- Piston-cylinder apparatus / Pt-Graphite capsules
- Pressure range: 1.0, 1.5 and 2.0 GPa (depth: 80-170 km)
- Liquid extraction techniques (prevent modification of melts by crystal growth during the quench):
  - Vitreous carbon spheres traps (1 and 1.5 GPa)
  - Micro-fractures in graphite capsules (2 GPa)
- Analysis of run products: Cameca SX100 Electron Probe Microanalyser

## 4. Melt compositions and Implications for the Origin of Martian Rocks

Experimental melts:

Liquids produced by low degrees of melting at 1 GPa are considerably richer in SiO<sub>2</sub> than most Martian rocks. This results from depolymerization of silicate melts and decrease of SiO<sub>2</sub> activity coefficient by alkalis at low pressure [4]. SiO<sub>2</sub> decreases with pressure due to shifting of the ol-opx cotectic.

The maximum FeO content (20%) is the same at every pressure investigated but is reached after <20%, 25-30 and 40% of melting at 2, 1.5 and 1 GPa, respectively.

The maximum CaO content in liquids (9%) and the beginning of the "CaO/Al<sub>2</sub>O<sub>3</sub> plateau" coincide with the disappearance of pigeonite.

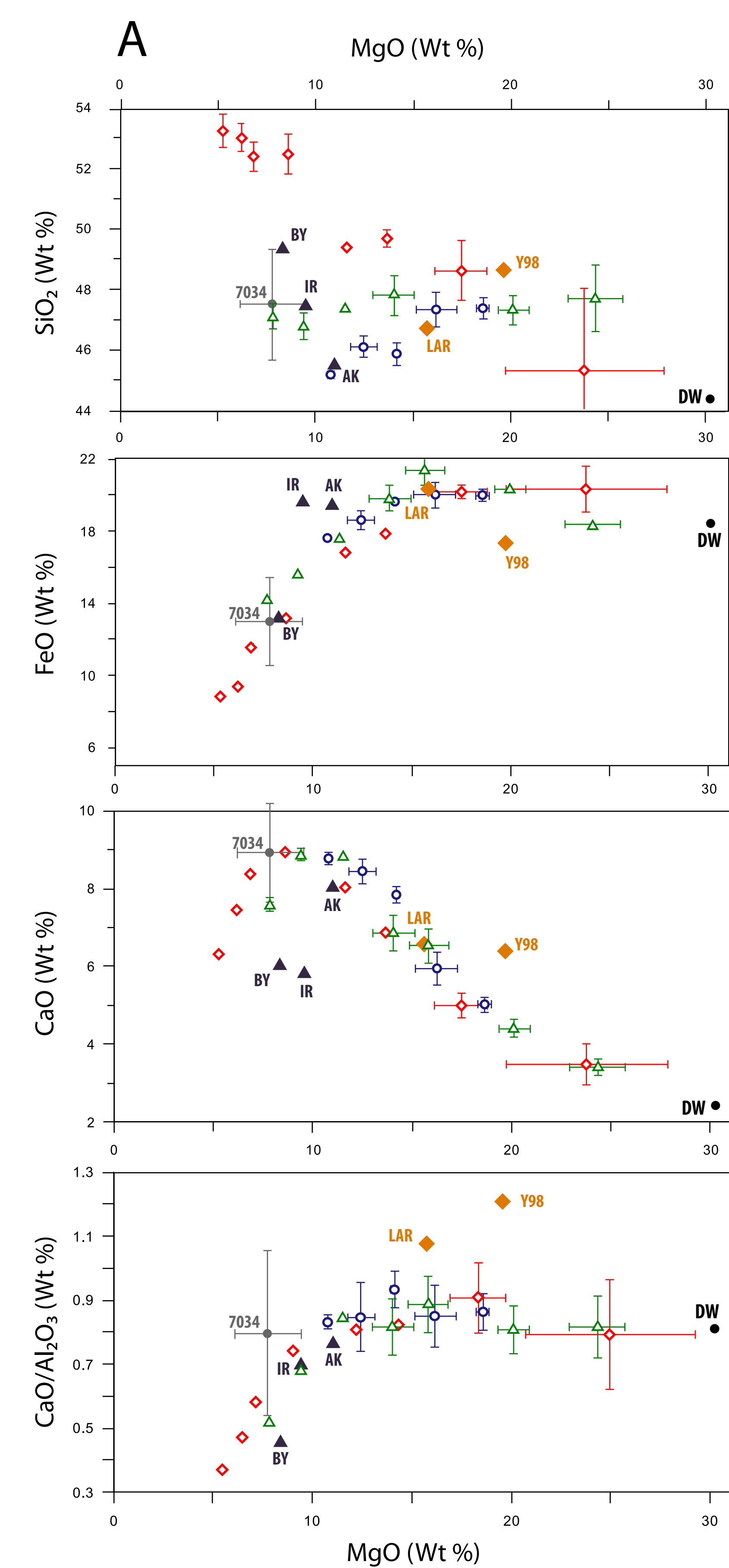
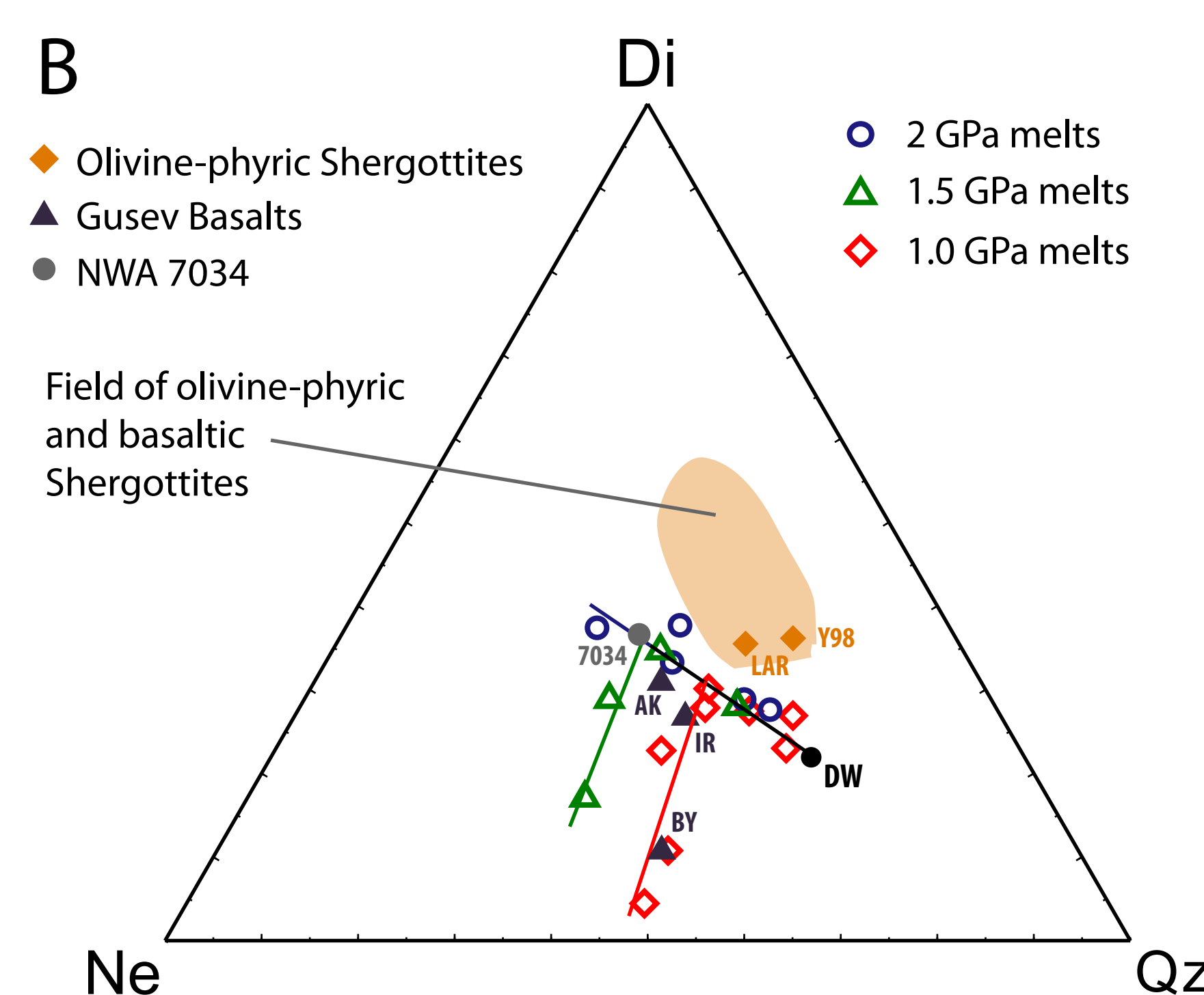
Comparisons with Martian basalts:

**Adirondack class** basalts always plot in experimental trends. Their SiO<sub>2</sub> contents are best reproduced by melting of the primitive Martian mantle around 2 GPa.

The new atypical **NWA 7034** meteorite [5] is also in the range of experimental melts and could derive from a DW-like primitive Martian mantle.

**Shergottites** present a depletion in Al which is probably inherited from their source.

The low FeO content of depleted shergottites (e.g. **Yamato 980459**) suggest that their source is also poorer in FeO compared to the DW mantle.



**Fig 3.** [A] Variation diagrams of experimental melts and Martian rocks. Points > 15% MgO at 1.5 GPa are from [3] [B] Projection from Ol of the Ne-Di-Qz-Ol system [6] DW = Dreibus and Wänke (starting material) [1]; LAR = Larkman Nunatak 06319 [7]; Y98 = Yamato 980459 [8]; AK = Adirondack class; IR = Irvine; BY = Backstay [9]; 7034 = Northwest Africa 7034 [5].

## 5. Conclusion

Some Martian basalts (Gusev basalts, NWA 7034) are close to the composition of experimental melts and could thus result from equilibrium melting of the primitive Martian mantle at low to medium pressure (< 2 GPa).

However, the chemical variability of Martian rocks exceeds the one of our melts. Shergottites probably derive from a different mantle source. Basaltic shergottites have been likely affected by fractional crystallization, another process which could have been of significant importance for the formation of the crust.

## References

- [1] Dreibus G. and Wanke H. (1985) Meteoritics, 20, 367-381.
- [2] Khan A. and Connolly J. A. D. (2008) JGR, 113, E07003.
- [3] Bertka C. M. and Holloway J. R. (1994) Contrib. Mineral. Petr., 115, 313-322 and 323-338.
- [4] Hirschmann M. M. et al. (1998) Geochim. Cosmochim. Ac., 62, 883-902.
- [5] Agee et al. (2013) Science, 339, 780-785.
- [6] Sorbadere F. et al. (2013) J. Pet., 54, 215-233.
- [7] Basu Sarbadhikari A. et al. (2009) Geochim. Cosmochim. Ac., 73, 2190-2214.
- [8] Misawa K. (2004) Antarct. Meteorite Res., 17, 1-12.
- [9] Schmidt M. E. and McCoy T. J. (2009) EPSL, 296, 67-77.
- [10] Wanke H. and Dreibus G. (1988) Phil. Trans. R. Soc. A, 325, 545-557.