The abundance and role of Indiginous lunar volatiles

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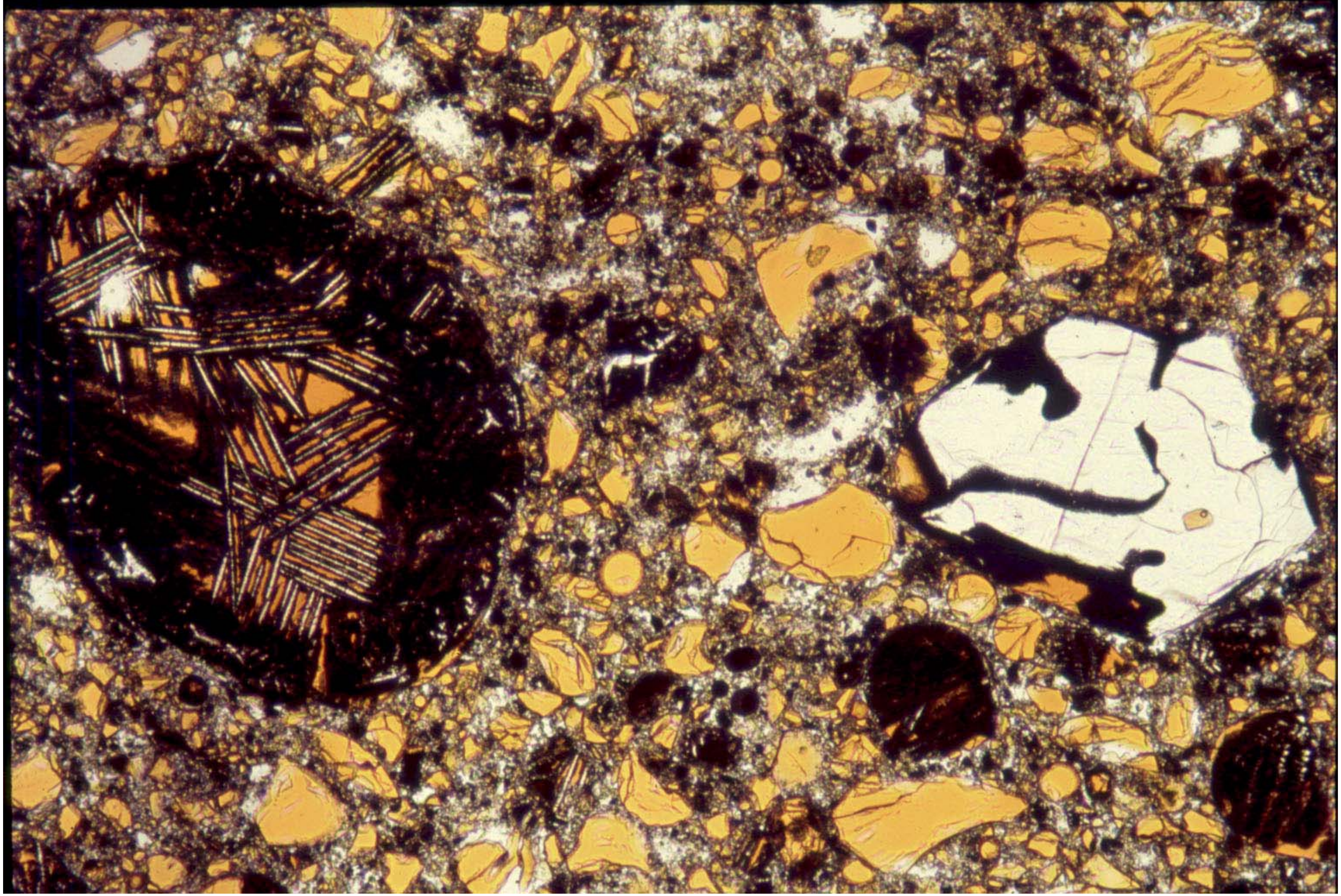
15016
Vesicular Olivine basalt

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

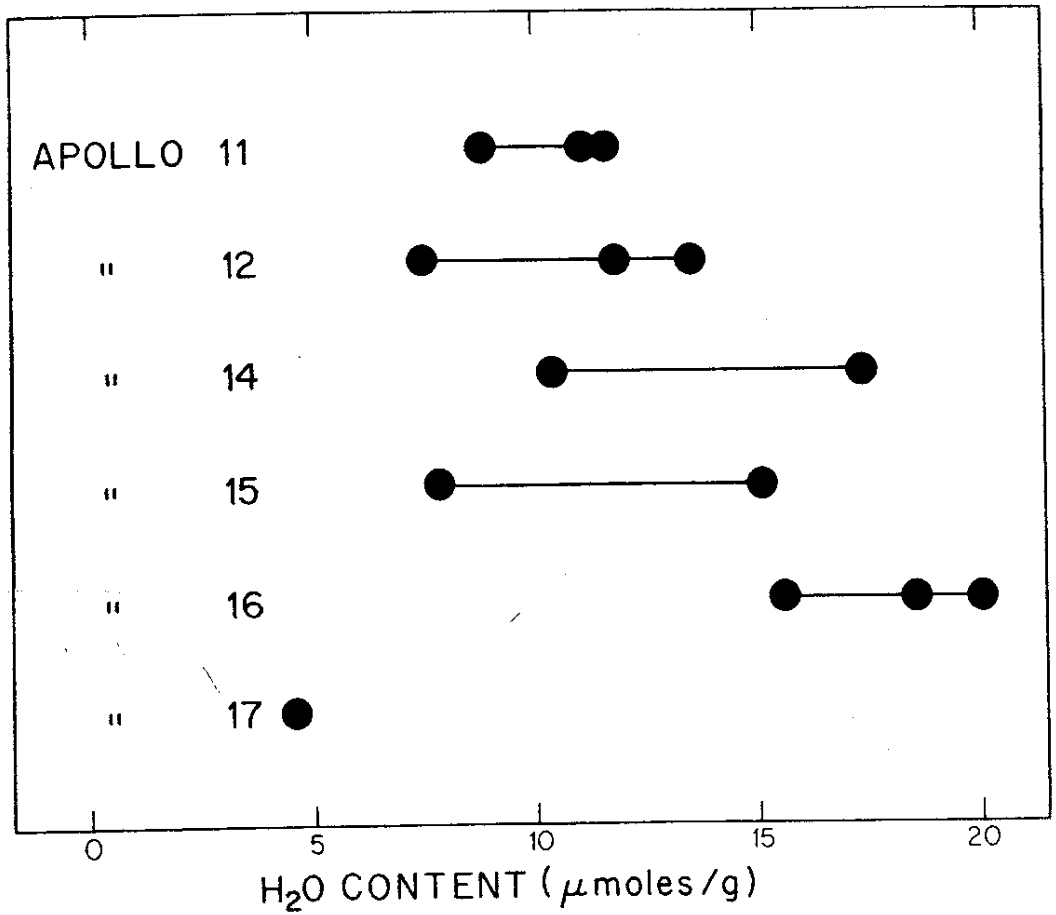


74002 PTS with 0.8 mm olivine containing a glassy M.I.
Volatiles in M.I. glass, in glass spheres, and as coatings on sphere surfaces.
Indigenous gas contains B, C, N, F, Na, S, Cl, Ar, Cu, Zn, Ga, Ge, Se, and other volatile metals (Epstein and Taylor, 1973; Meyer et al., 1975).

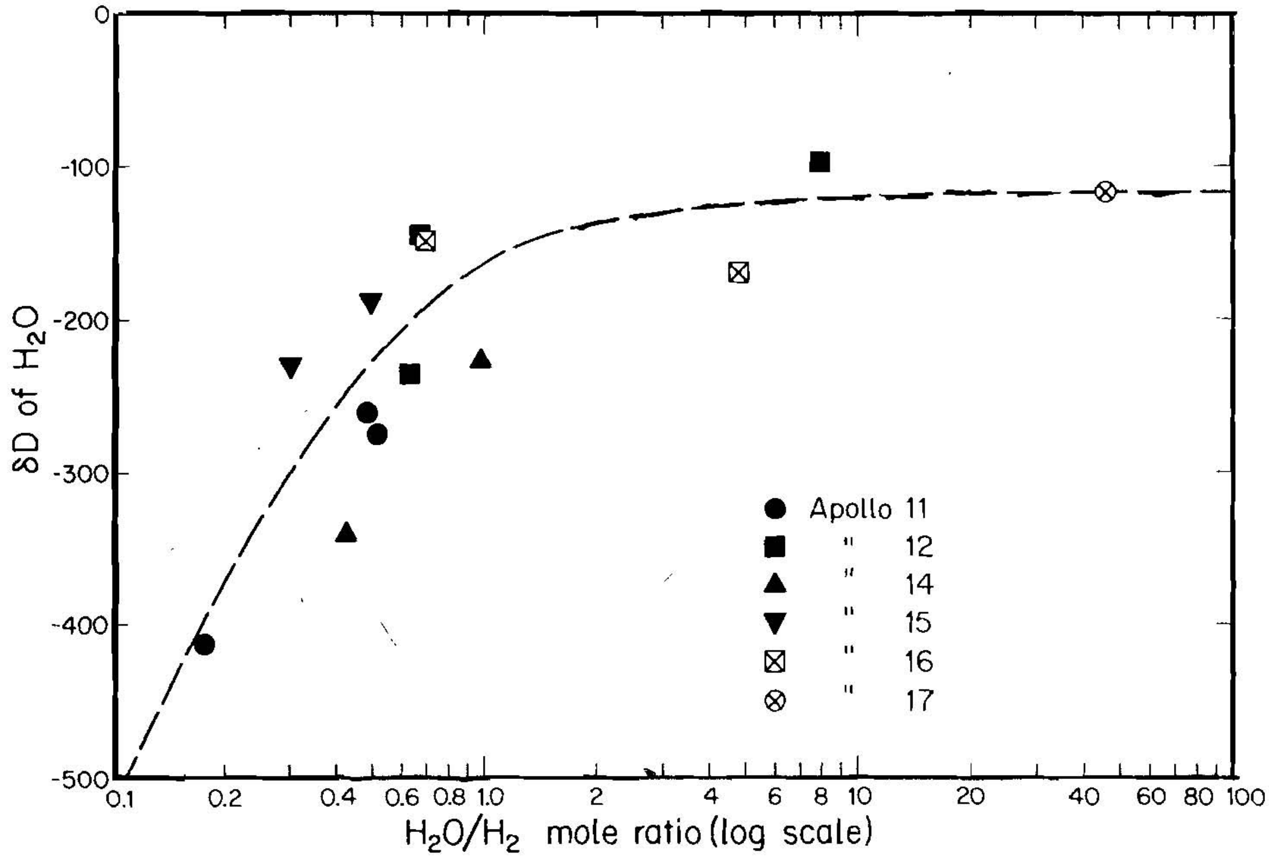
Sources and Processes affecting abundances

- Three possible sources for the lunar volatiles:
  - (1) primary magmatic gases
  - (2) late stage impact material,
  - (3) solar wind implantation of H, C, N etc.

- Several mechanisms for remobilization/modification
  - (1) Post magmatic volatile transport
  - (2) Transport induced by impacts
  - (3) Loss of light elements to space



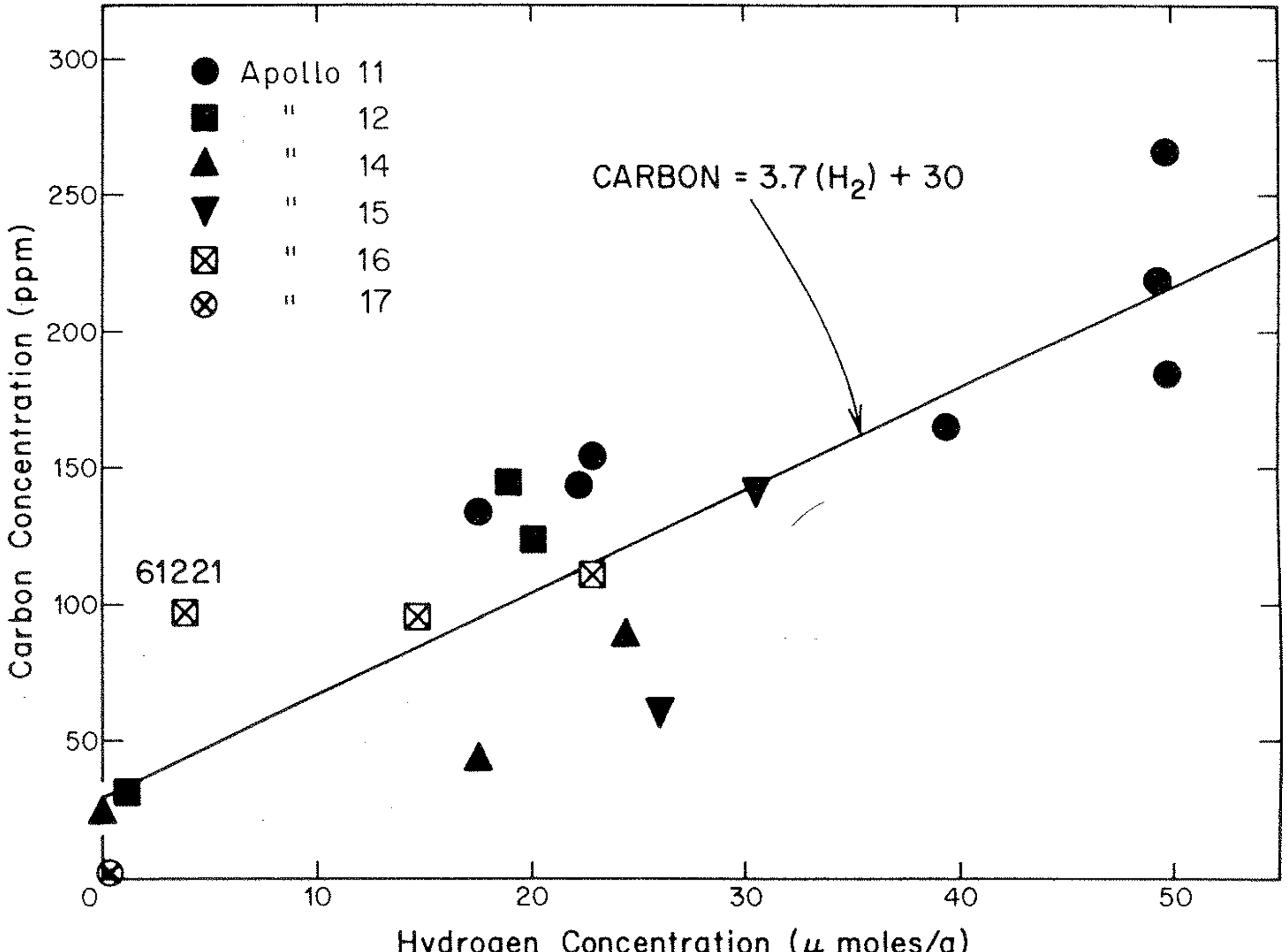
From Epstein and Taylor,1973



Relationship between δD of "lunar water" and H_2O/H_2 of lunar soils. A-17 sample is 74220 orange volcanic glass, and having the max H_2O/H_2, is interpreted to be essentially free of solar implanted H_2.

(From Epstein and Taylor, 1973)

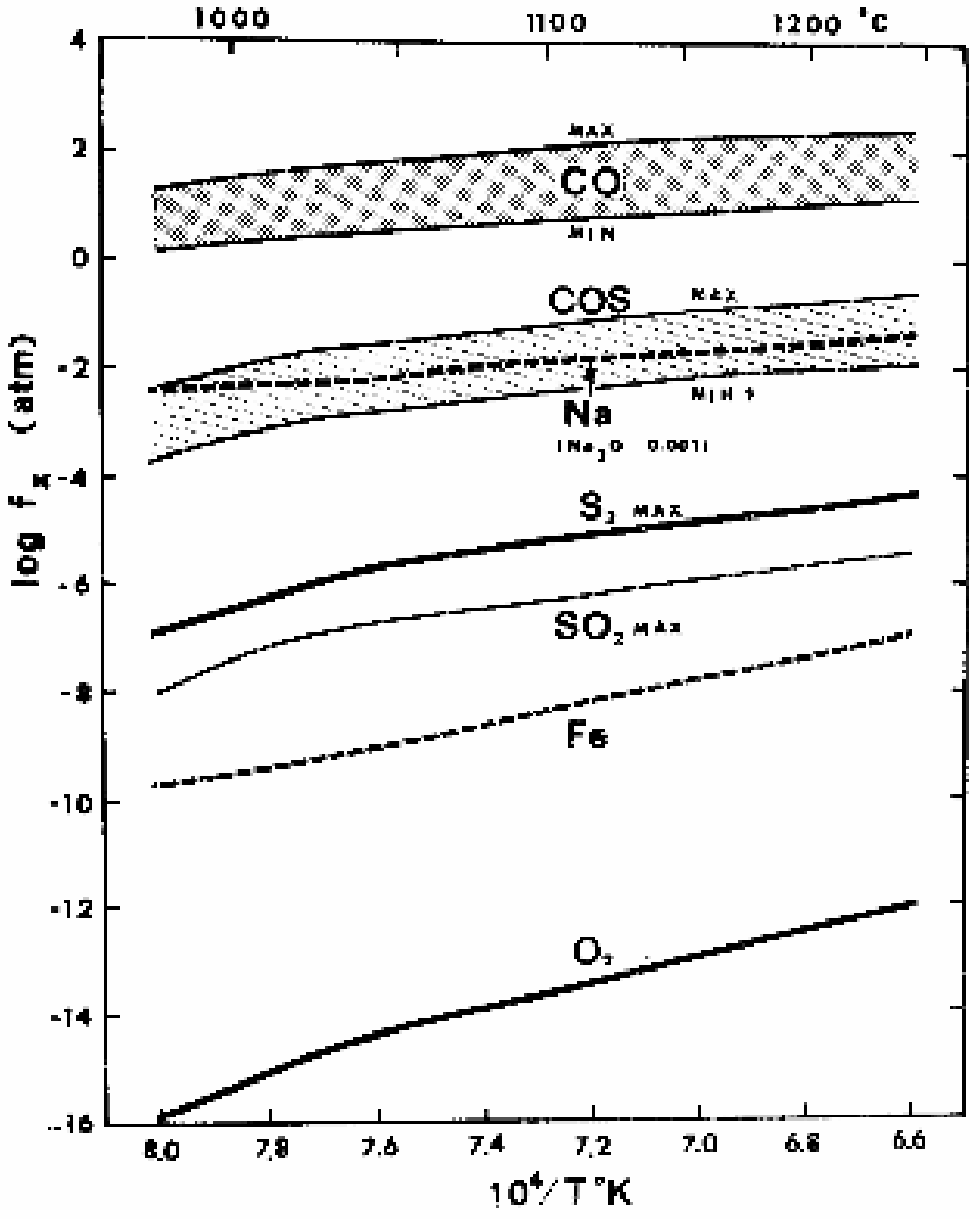
Carbon
(ppm)



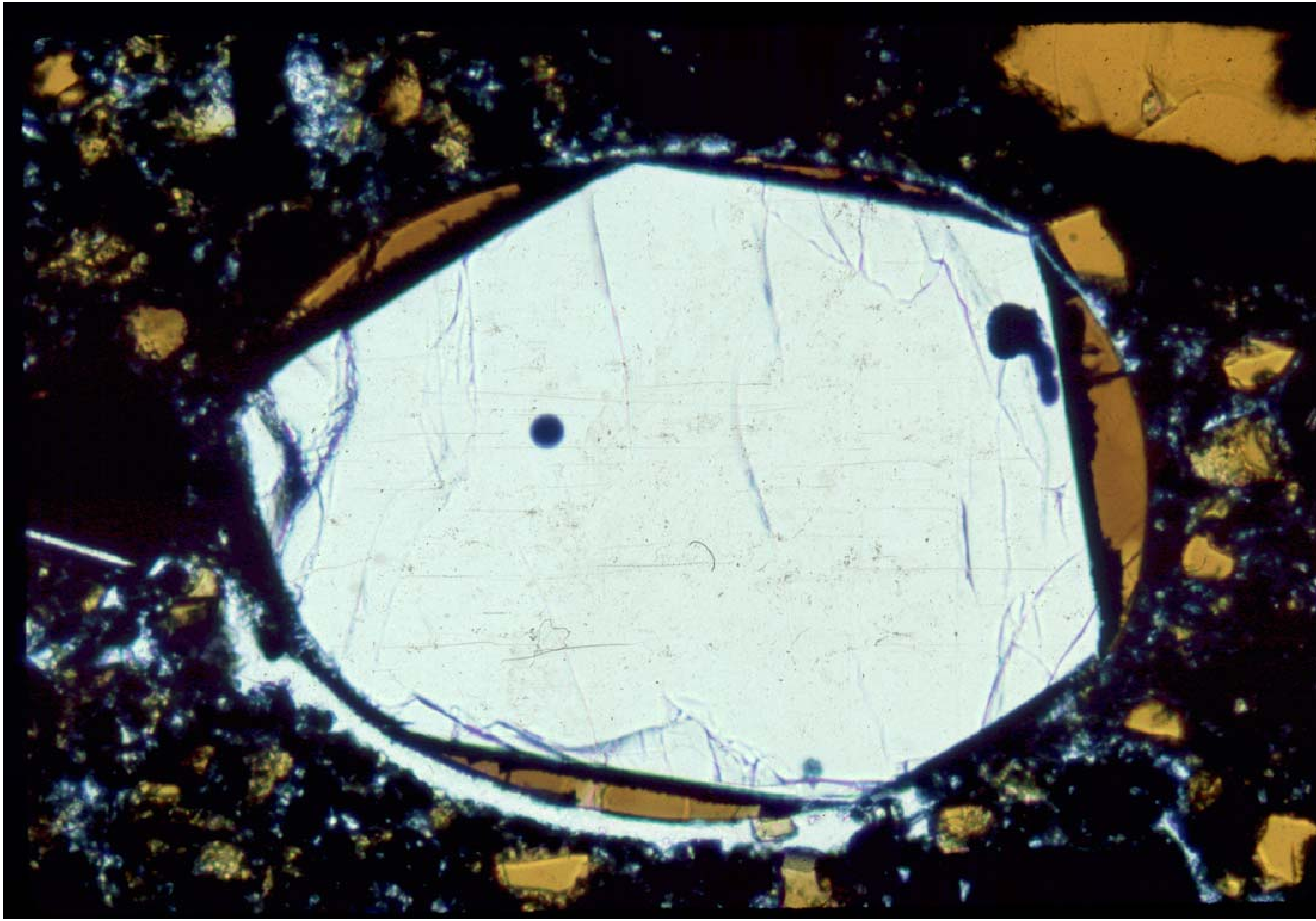
Hydrogen (micro-moles/gm)

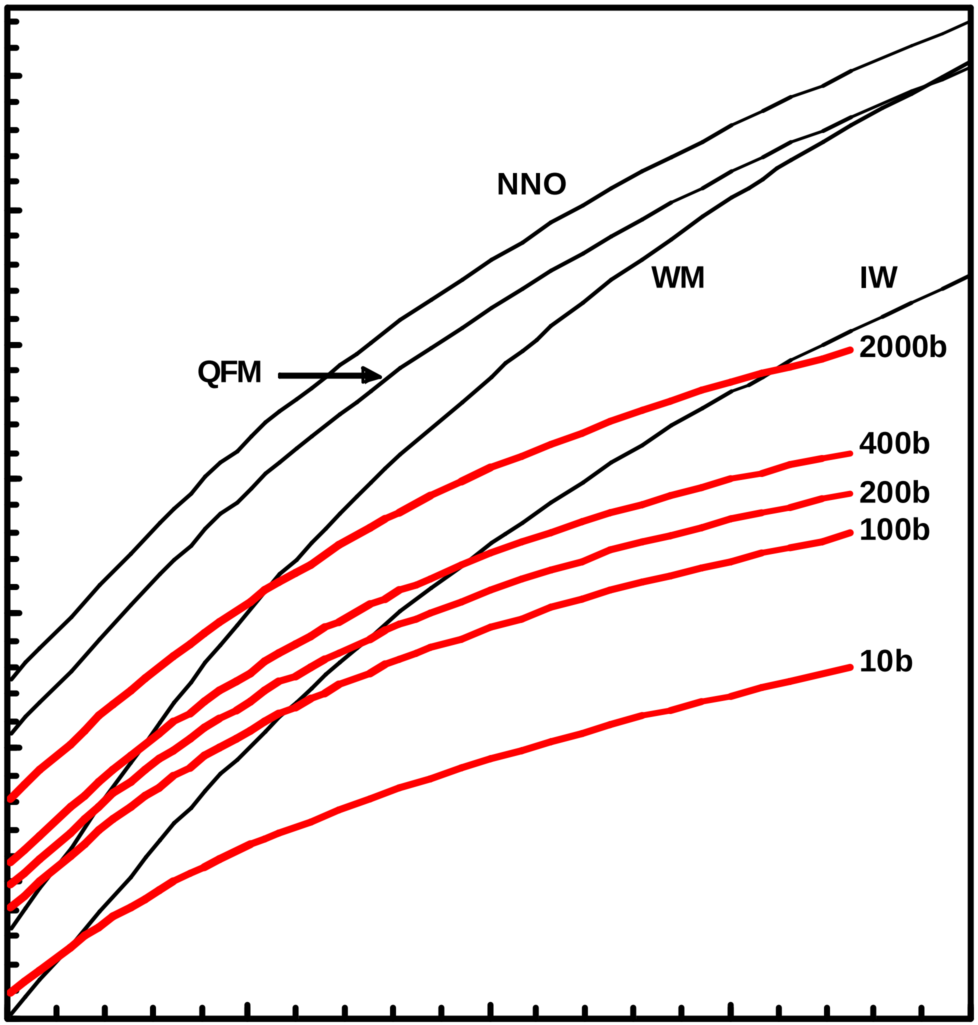
From Epstein and Taylor,1973

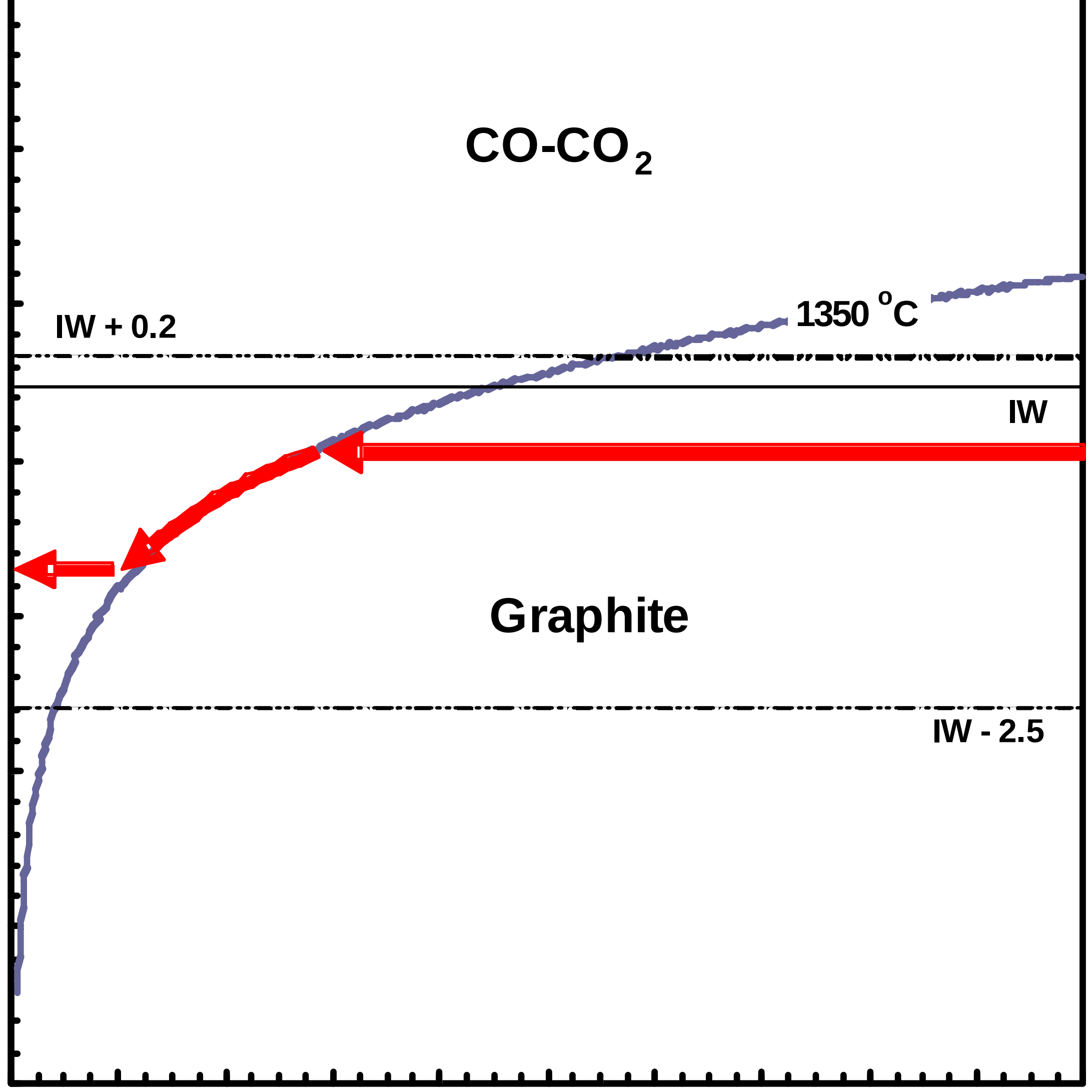
Log fO_2
(atms)



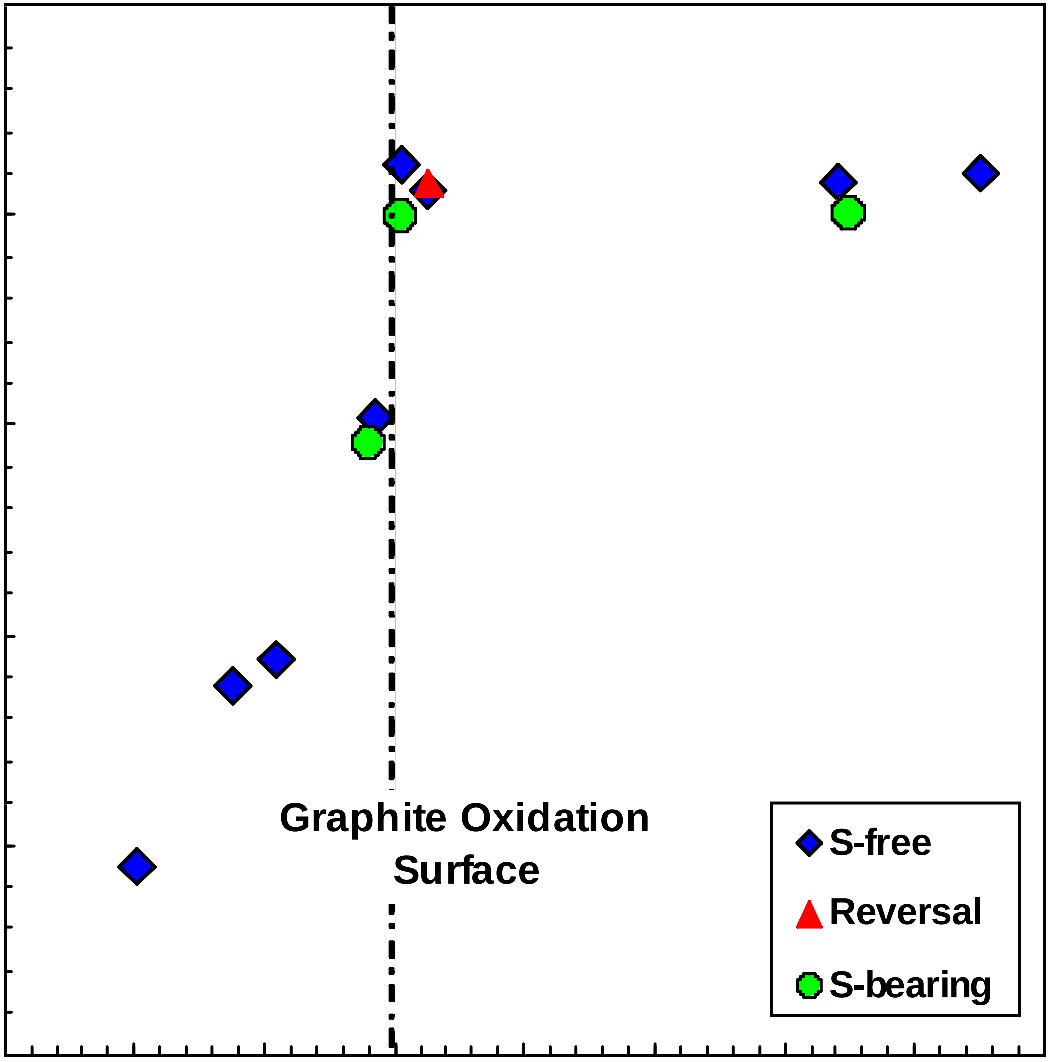
From Sato, 1976




NNO
WM
IW
QFM
2000b
400b
200b
100b
10b

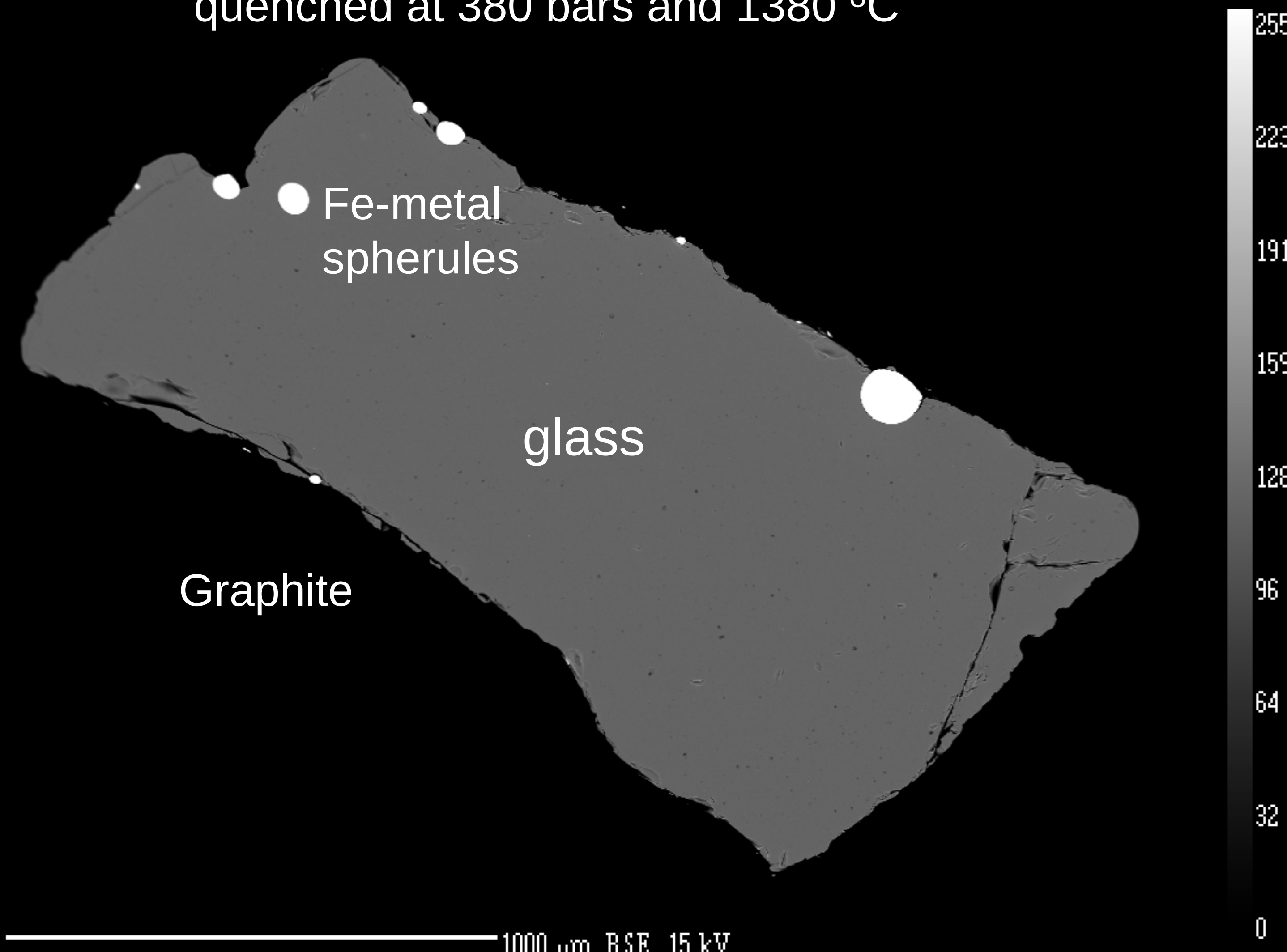


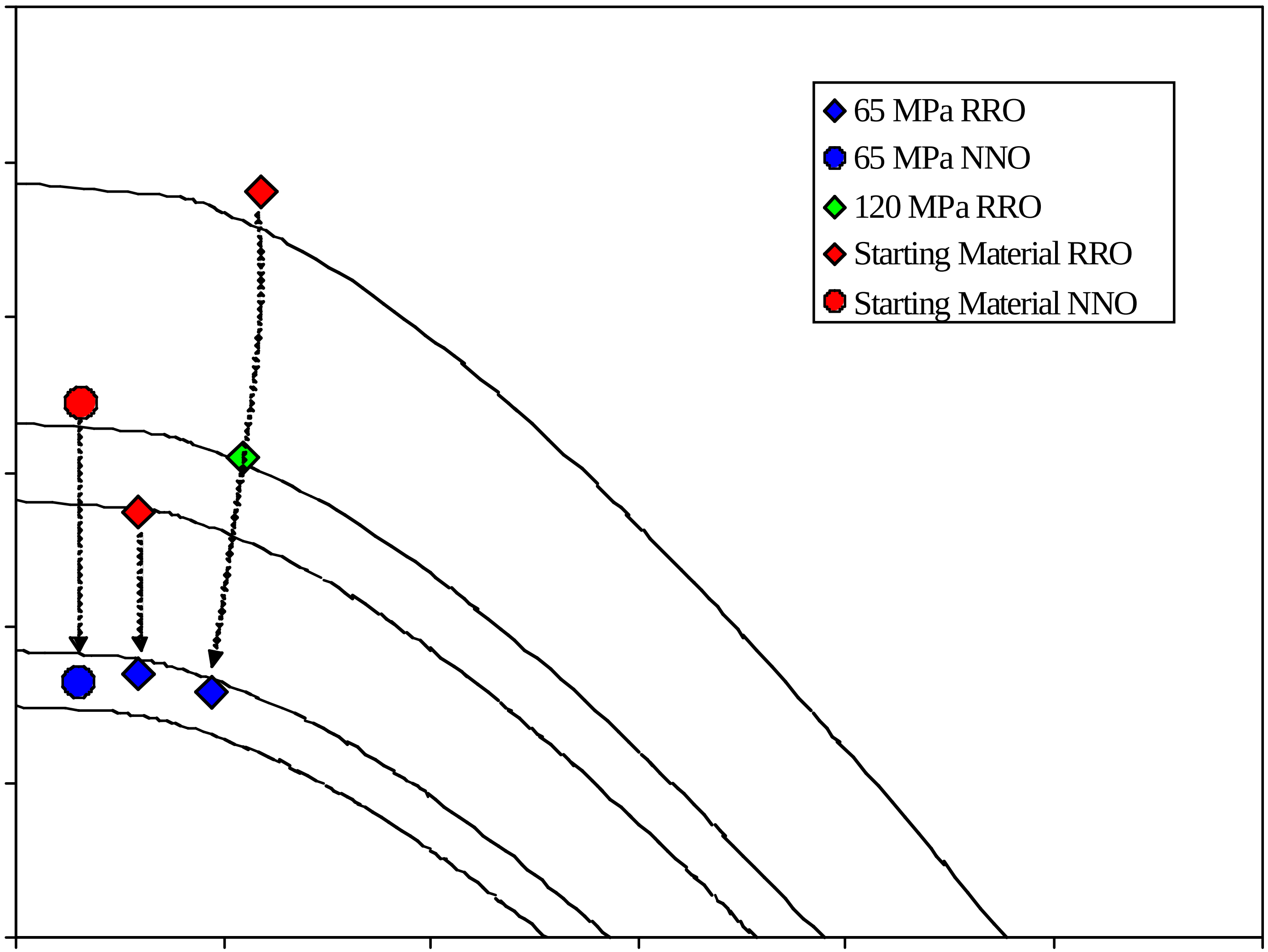
CO-CO$_2$
1350 °C
IW + 0.2
IW
Graphite
IW - 2.5



Graphite Oxidation
Surface
S-free
Reversal
S-bearing

BSE Image of A-17 orange experimental glass quenched at 380 bars and 1380 ºC



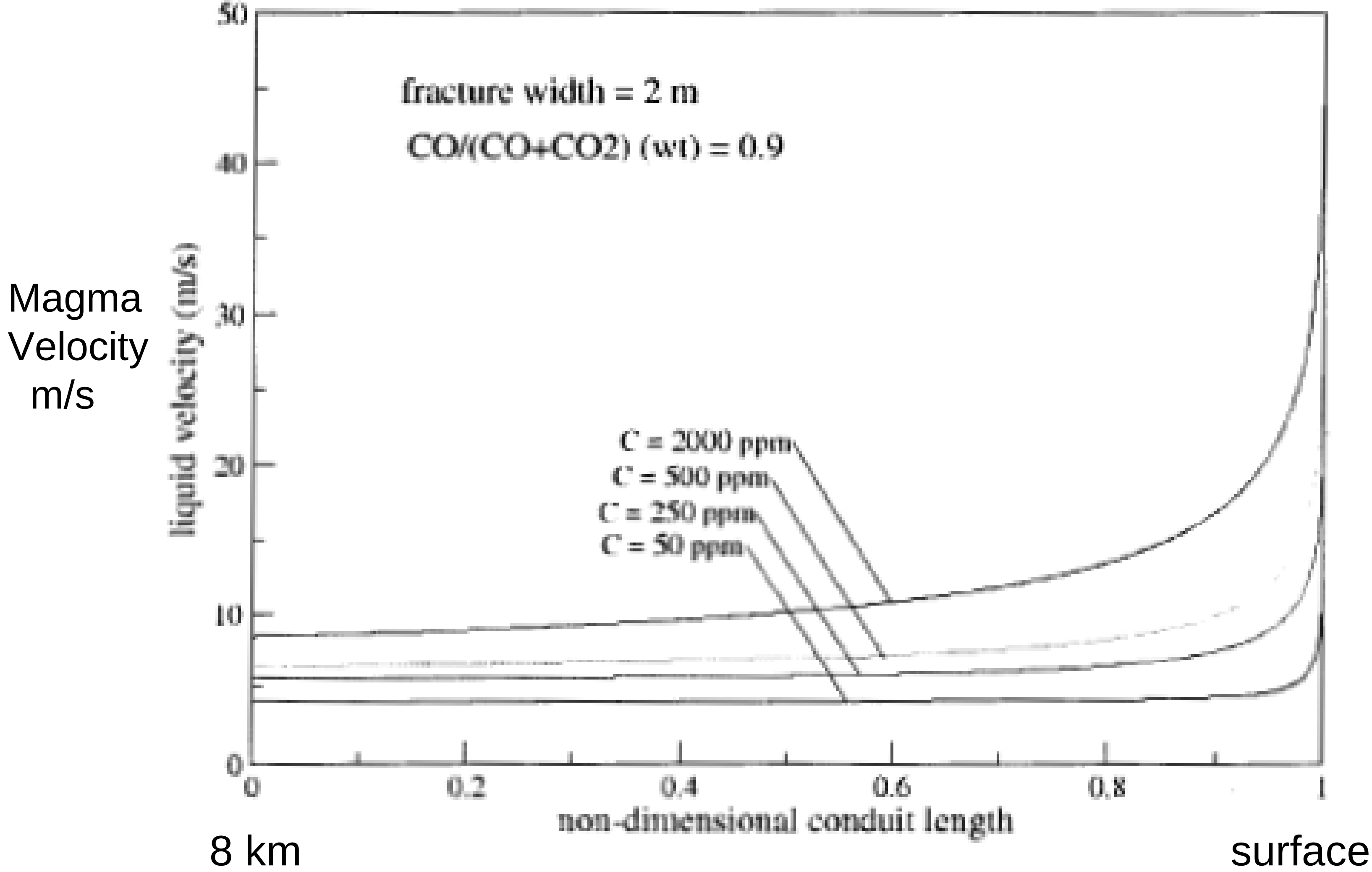

65 MPa RRO
65 MPa NNO
120 MPa RRO
Starting Material RRO
Starting Material NNO

Summary of recent Picritic Glass Analyses (from Saal et al., 2007)

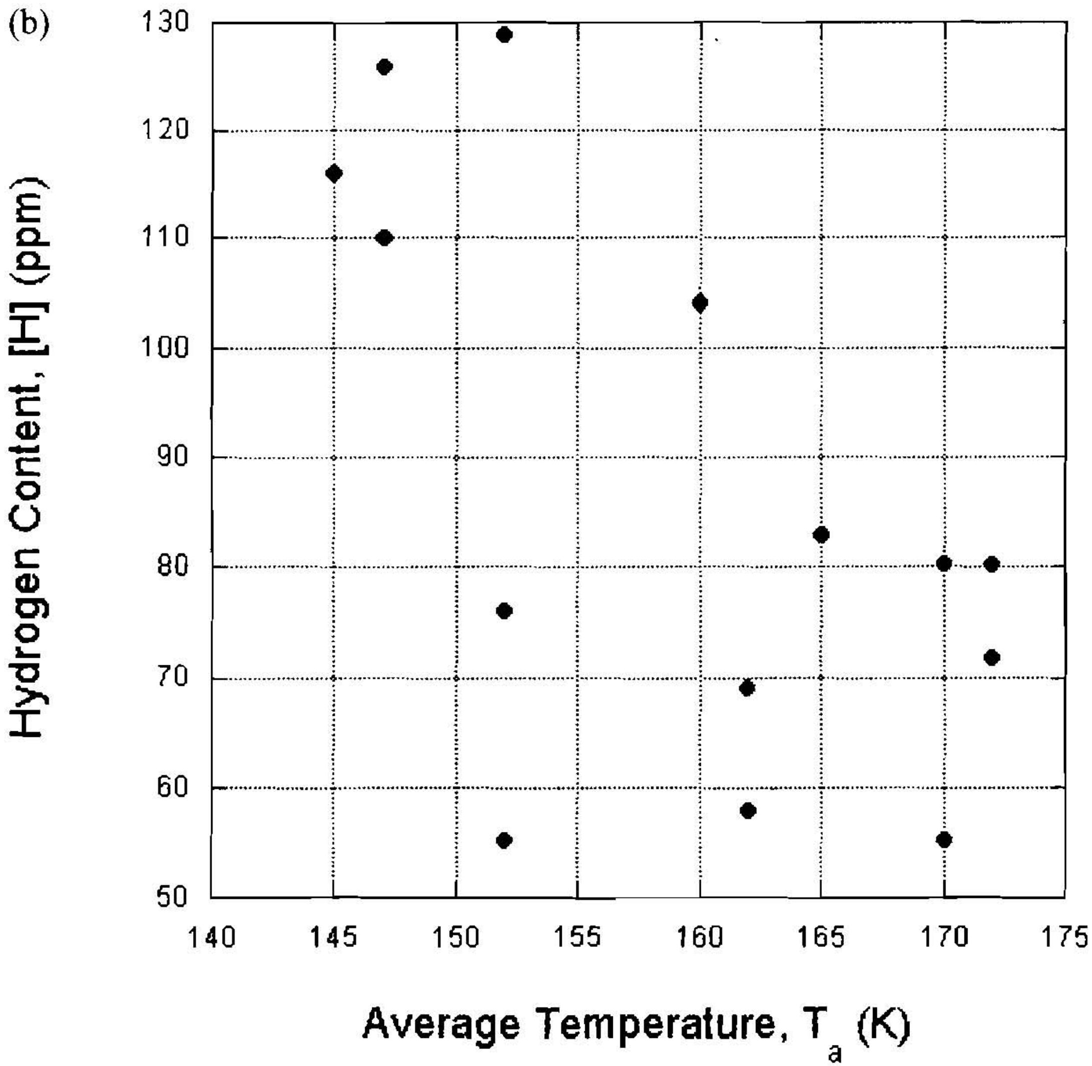
- Quantitative analyses of H, C, S, Cl, and F as well as trace and major element concentrations in A15 green & yellow and A-17 orange & red glasses.
- H_2O concentrations (10-50 ppm) in glass interiors are correlated positively with incompatible trace elements e.g. REE, and also with abundances of other volatiles (S, F, Cl, and C) although the latter correlation does show effects of near surface degassing.
- C abundance in A17 orange glass is 12 ±3 ppm; other glasses have C ranging from 12 ppm down to the detectibility limit (3 ppm).
- Cl concentration in glass bead interiors range from 20 to 50 ppm with errors on individual analyses of ±0.2 ppm.
- Although F concentrations range up to ~1000-2000 ppm in the outer 0.1 micron of the picritic glass beads (Goldberger et al.,) there is only 5-20 ppm in the core of the beads.
- All of the above are consistent with a model of a CO rich gas loss during eruption and partitioning of some S,Cl,F and volatile metals into this gas phase.

Summary

- The generation of a lunar volcanic gas occurs by C oxidation induced by decompression in lunar basalts; the gas is CO-rich and S partitions poorly into this gas (K_D = 1) as does Cl and F according to experiments. Loss of H_2O (and Cl + F) tends to occur at very low near surface pressures kinetics permitting.
- The 50 ppm H_2O from SIMS of 74220 orange picritic glass is close to the bulk analysis (64 ppm) of E &T (1973).
- This process should have occurred in the convecting lunar magma ocean although gas-loss would likely have been less effective depending on the development of the early crust.
- S partitions into a CO_2-rich gas at > NNO fO_2's with a K_D =150, but it is only 1 for a CO-rich reduced gas-melt system. No Cl partitions into the C-O rich gas phase.



A17 melt velocity modeled using “Conduit 4” code (Papale, 1999) and viscosity data from Giordano and Dingwell (2003) for 4 different initial C contents reacting to generate a CO-rich gas at 8 km depth (40 MPa) .

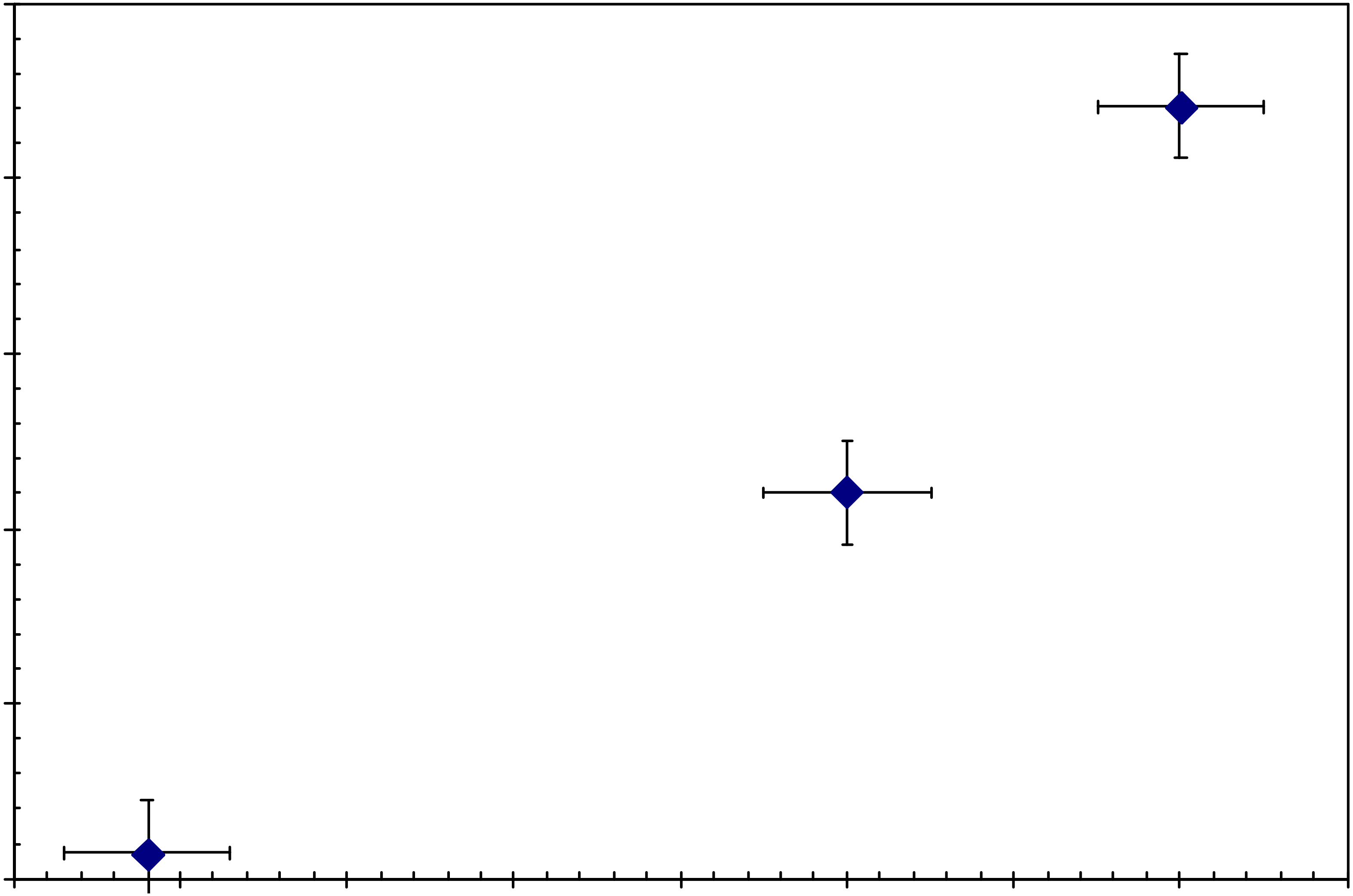


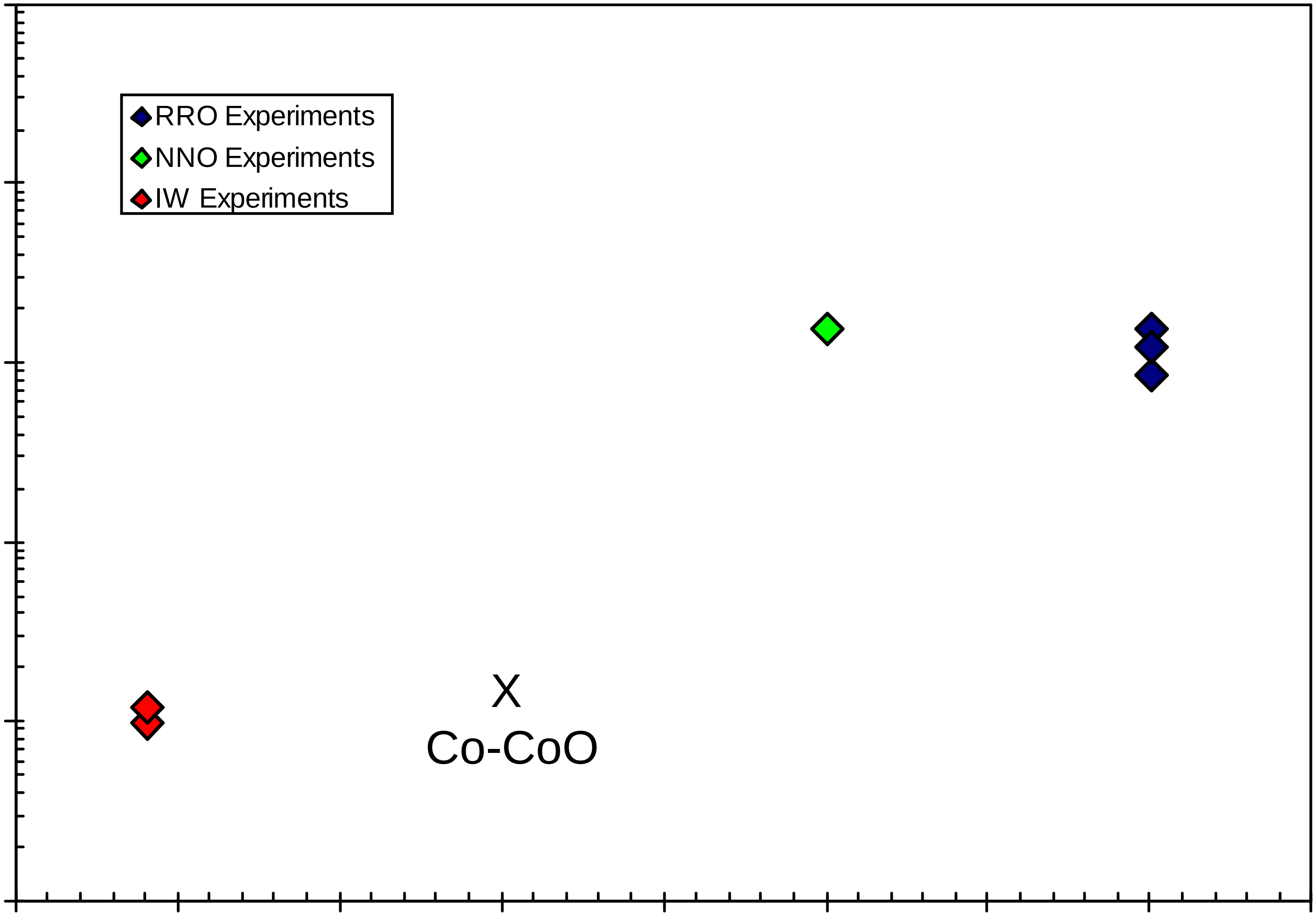
Scatter plot showing H_2 abundance from epithermal neutrons at the centers of 14 large craters poleward of 70° latitude and the average temperature of these craters from the Vasavada et al., simulations (From Feldman et al., 2001 JGR).

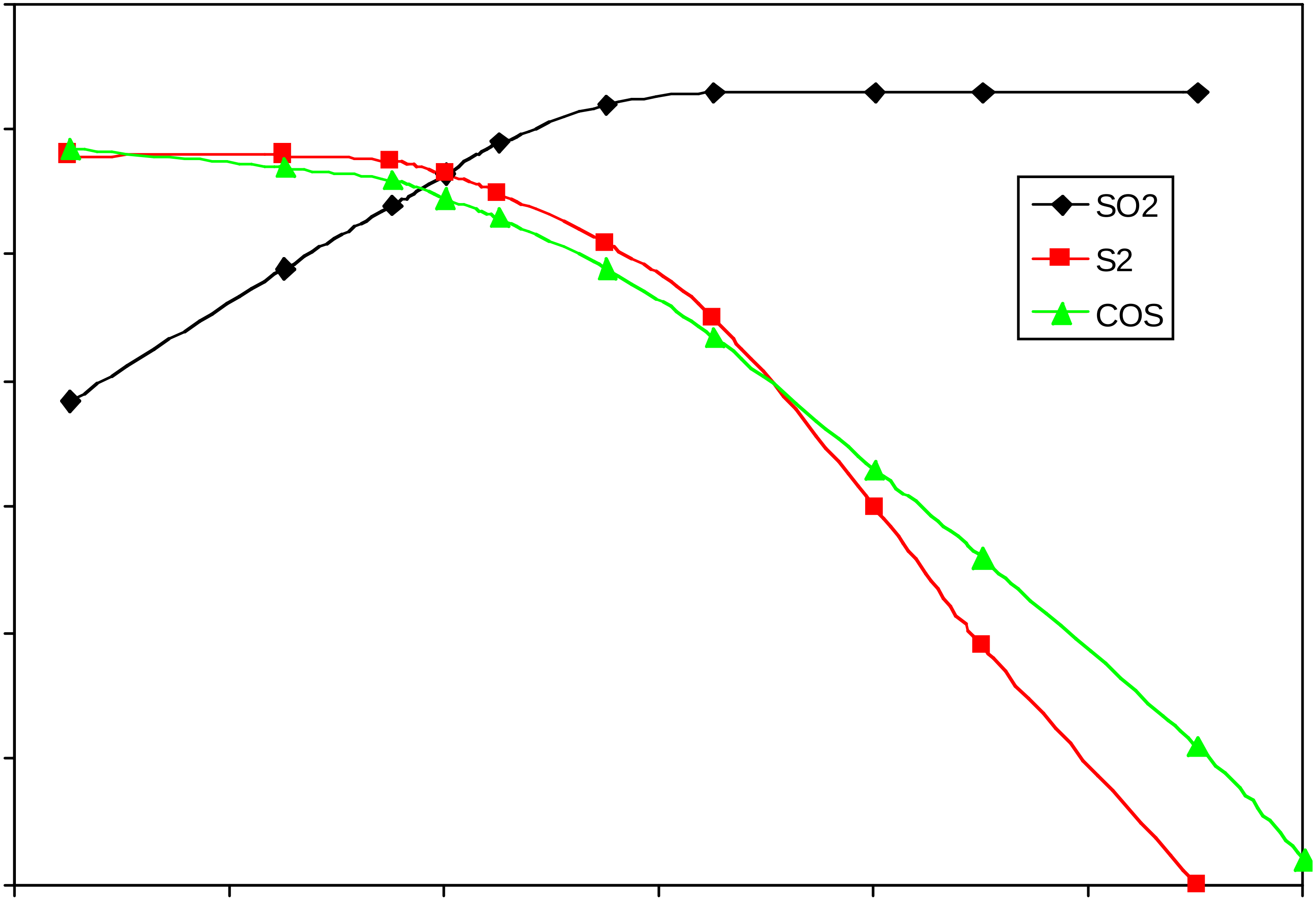
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

I mm

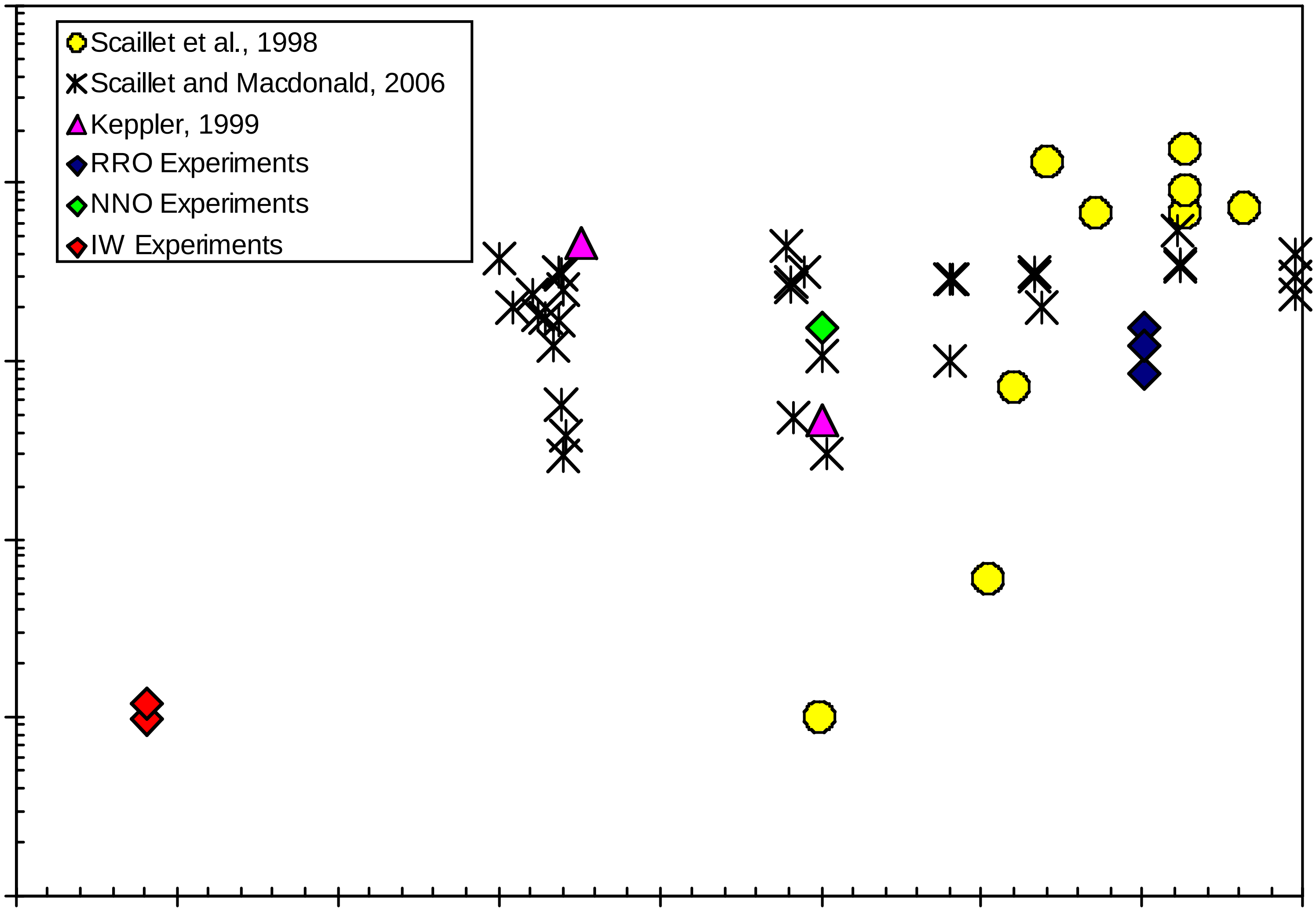
Cluster of 1 mm olivine phenocrysts in 77002 orange glass



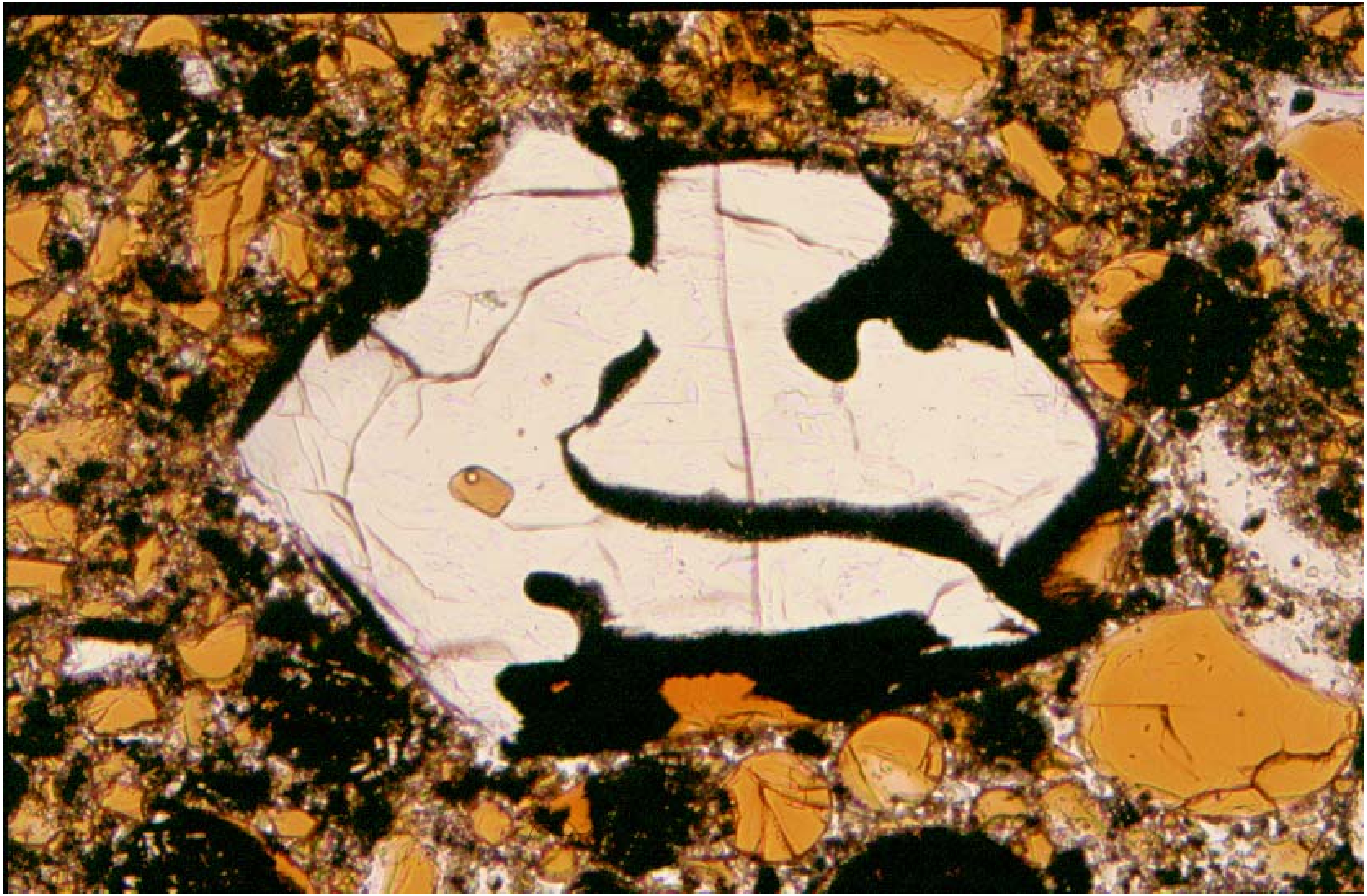

RRO Experiments
NNO Experiments
IW Experiments
X
Co-CoO



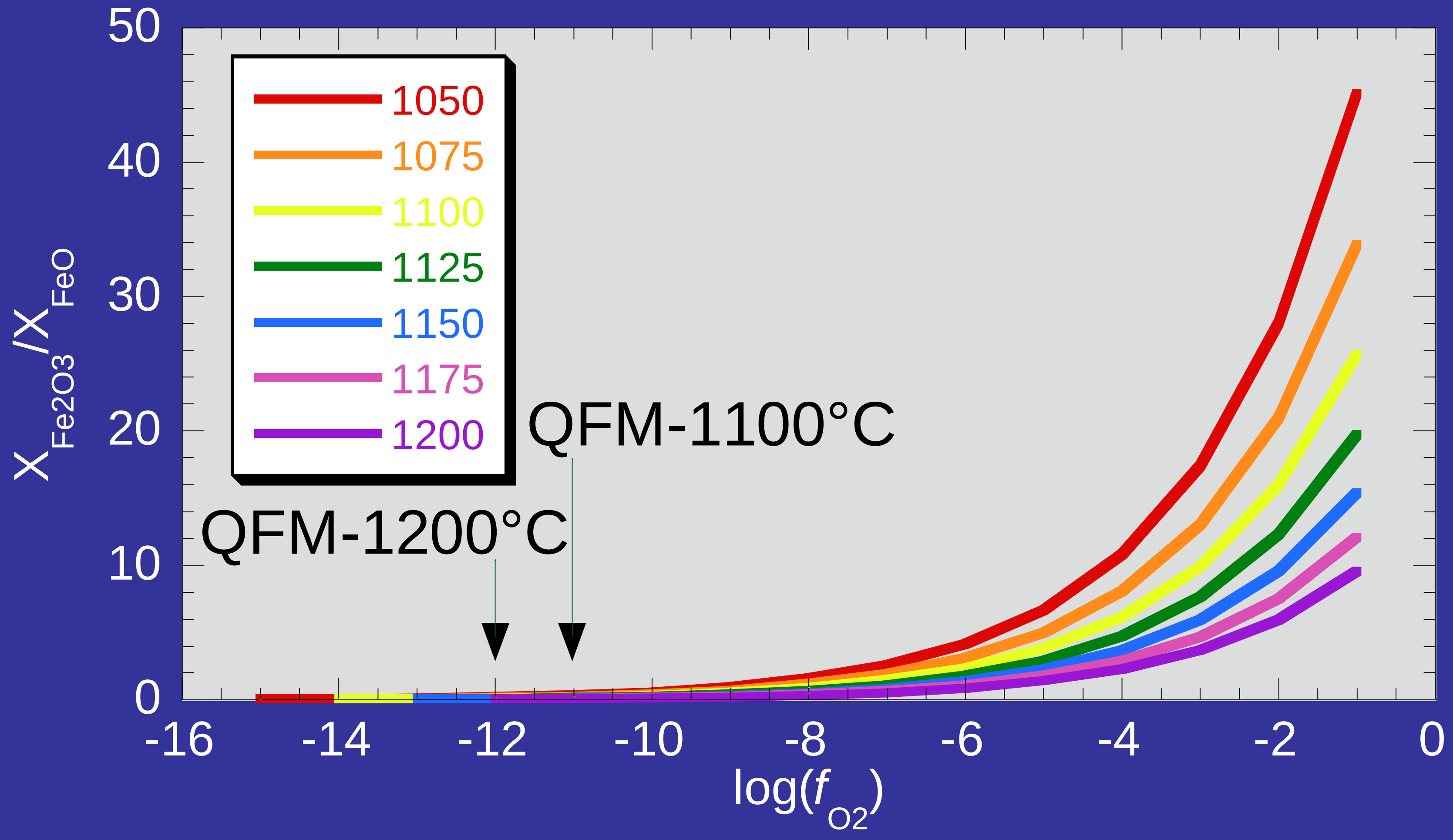
SO2
S2
COS

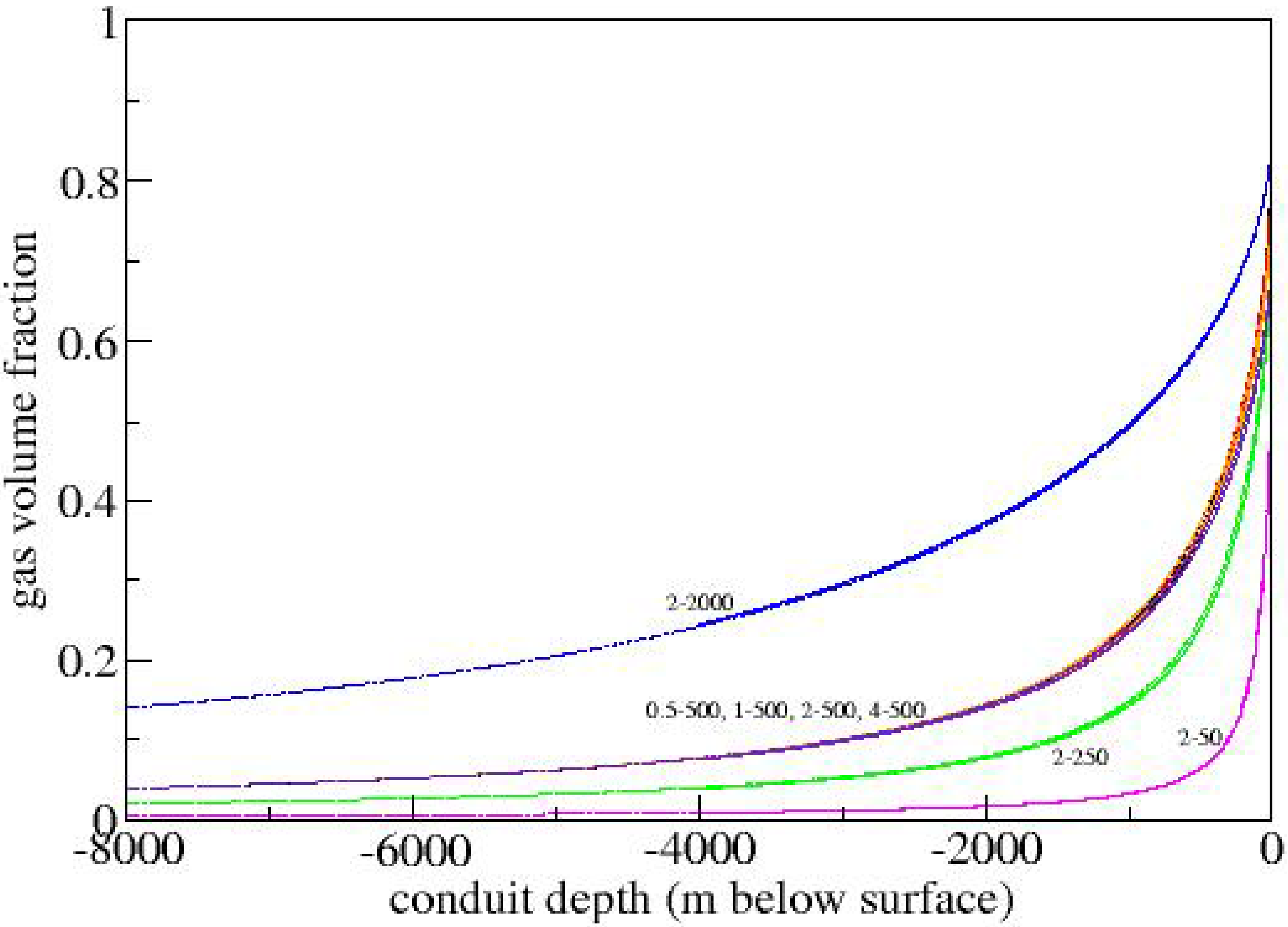


Scaillet et al., 1998
Scaillet and Macdonald, 2006
Keppler, 1999
RRO Experiments
NNO Experiments
IW Experiments

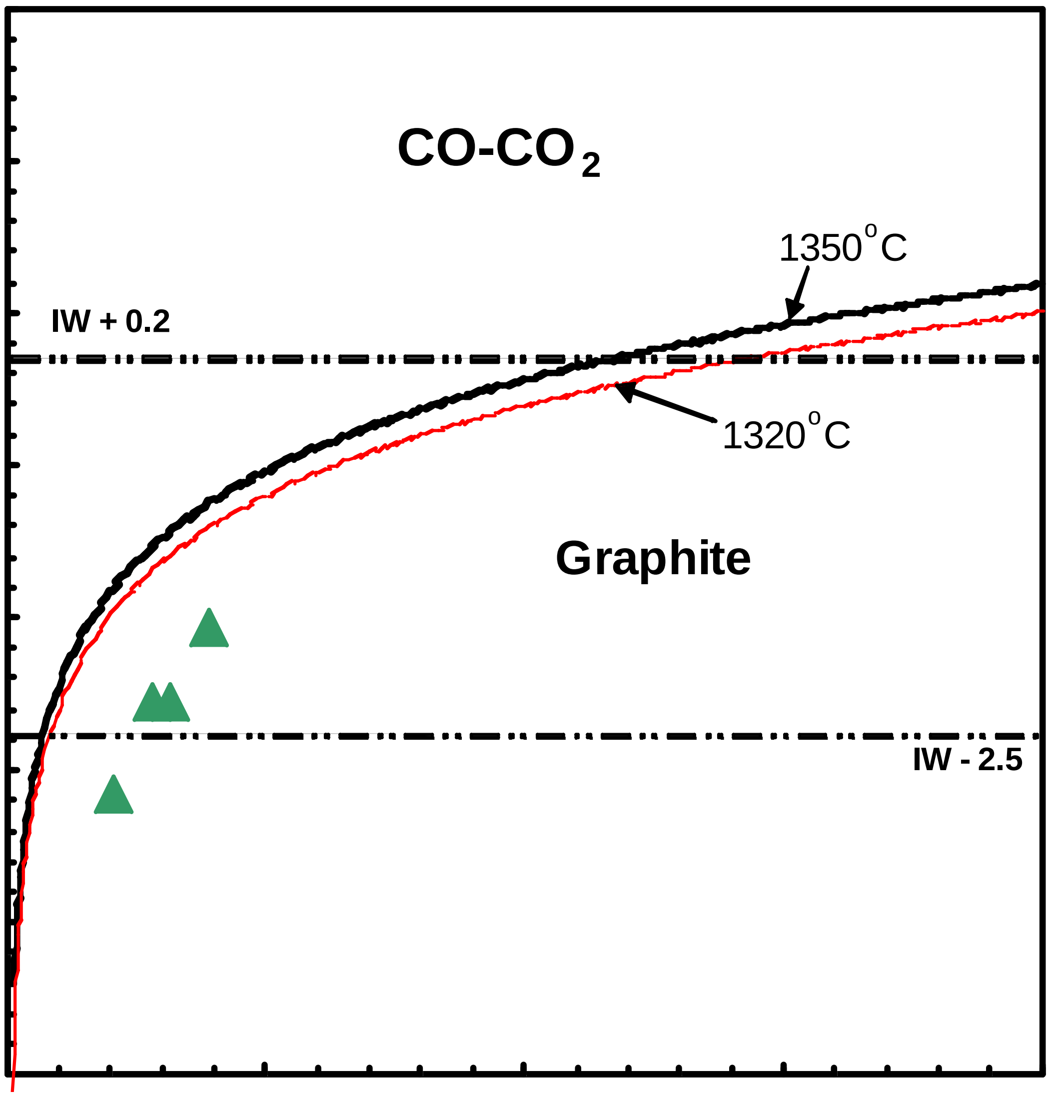


Melt Fe Content

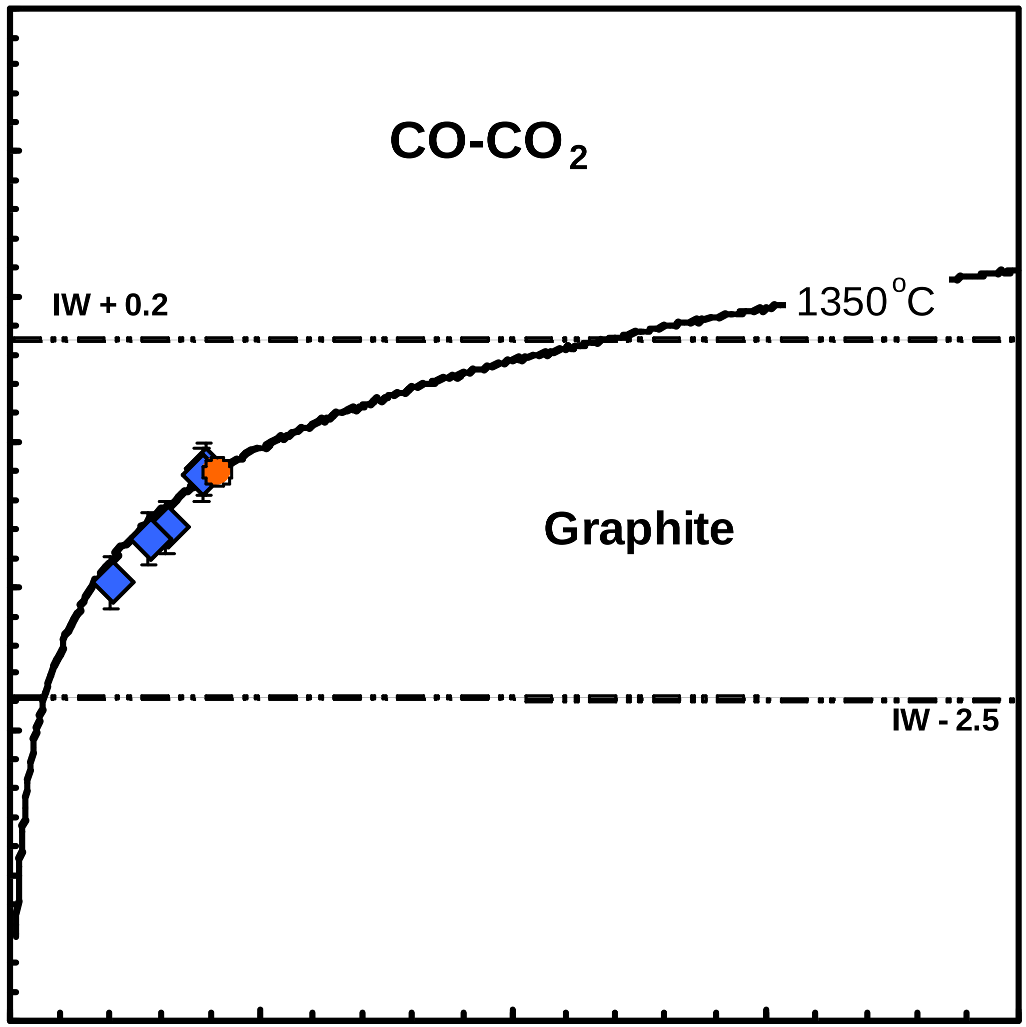


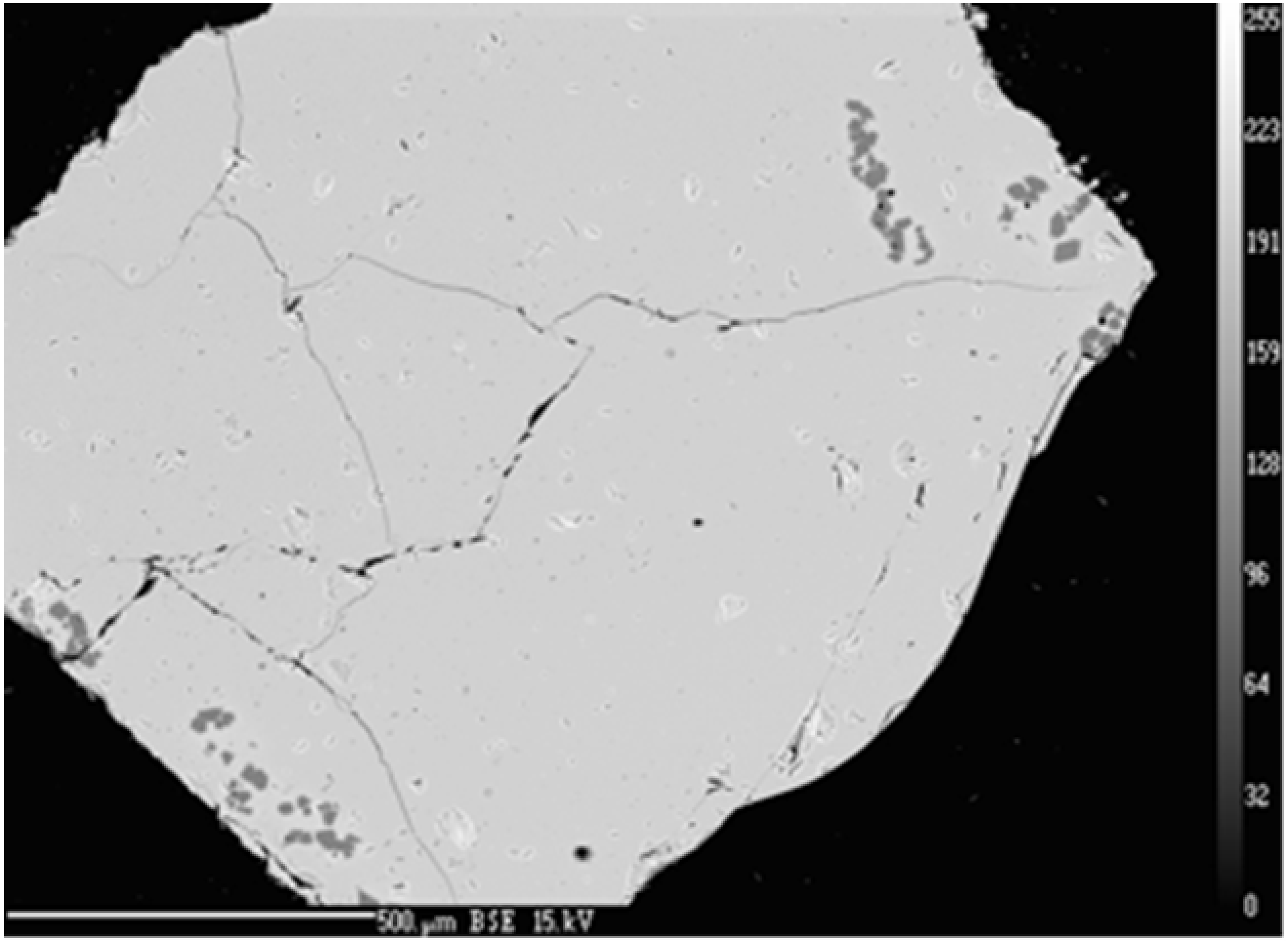


gas volume fraction
conduit depth (m below surface)
1
0.8
0.6
0.4
0.2
0
-8000
-6000
-4000
-2000
0
2-2000
0.5-500, 1-500, 2-500, 4-500
2-250
2-50



CO-CO2
1350°C
IW + 0.2
1320°C
Graphite
IW - 2.5


CO-CO$_2$
IW + 0.2
1350 °C
Graphite
IW - 2.5



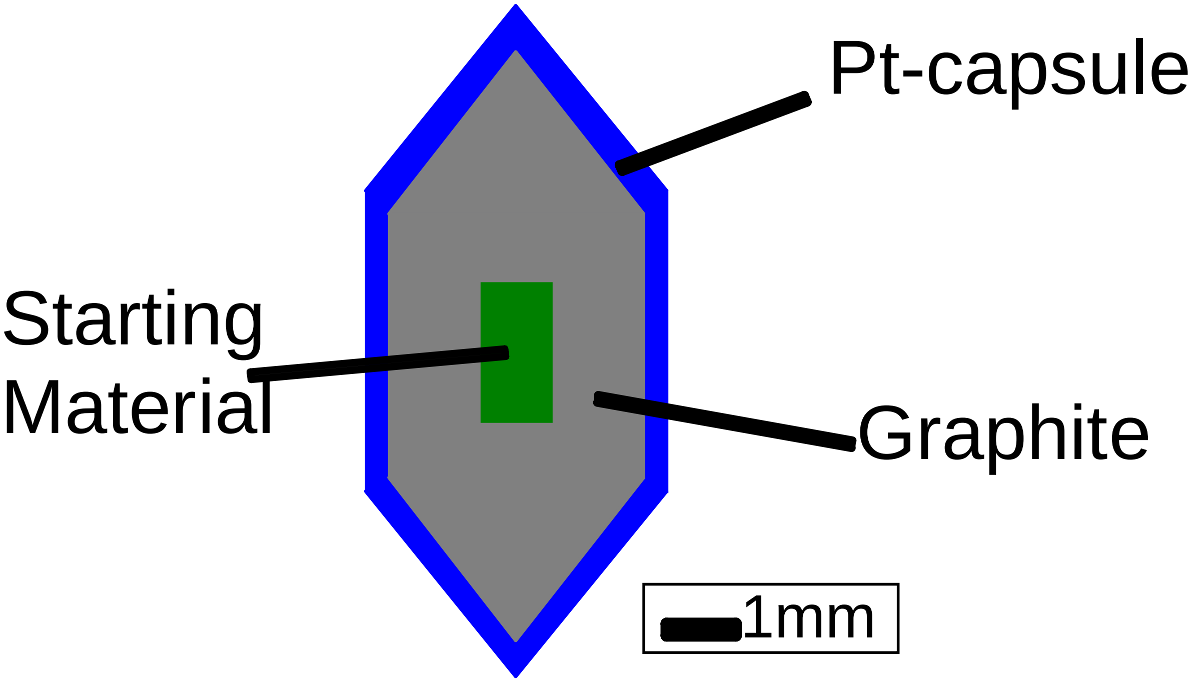
500 µm BSE 15.kV
255
223
191
159
128
96
64
32
0

Table 3-1. Starting material compositions

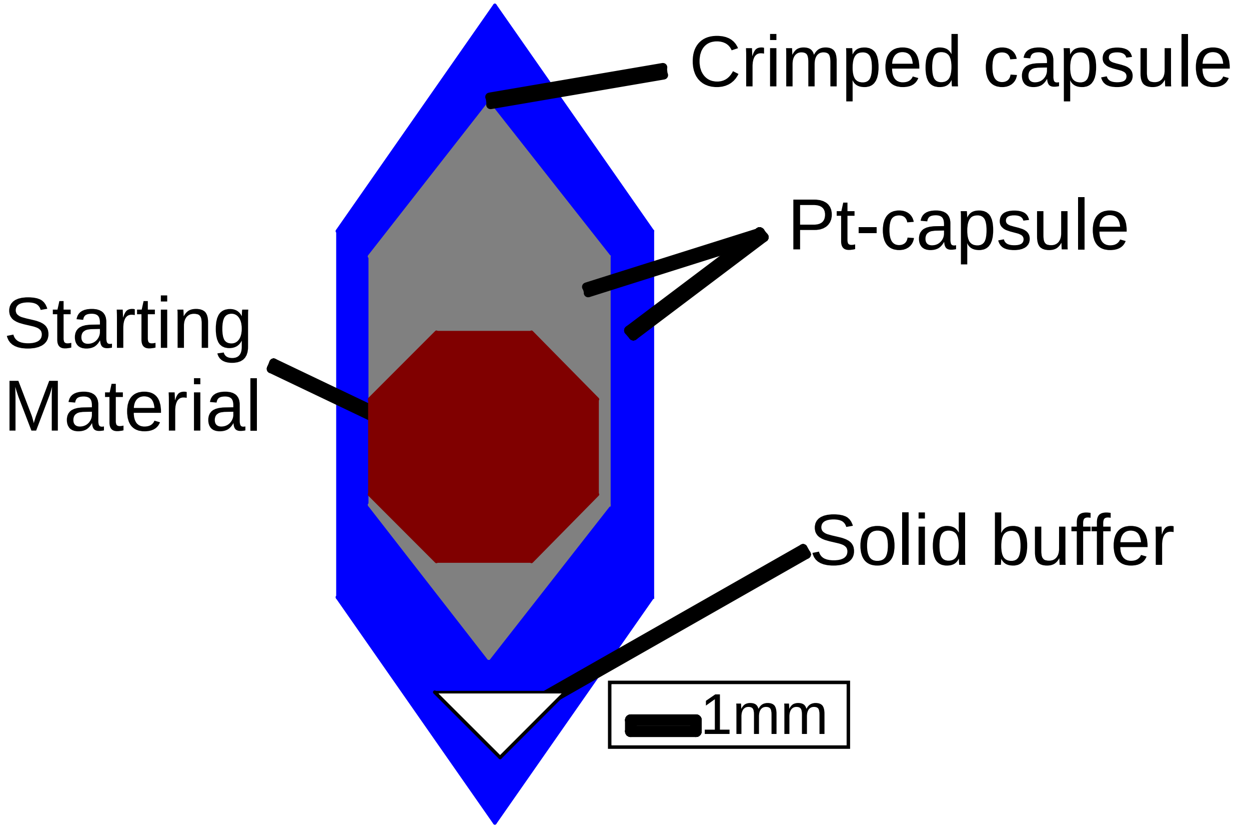
	Lathrop Wells Hawaiite	Synthetic OGS
SiO_2	49.14	39.50
TiO_2	1.85	9.37
Al_2O_3	17.39	6.27
FeO*	10.41	22.53
MgO	5.83	14.06
CaO	8.68	7.44
Na_2O	3.32	0.55
K_2O	1.68	0.08
MnO	0.16	0.34
Total	99.80	100.12

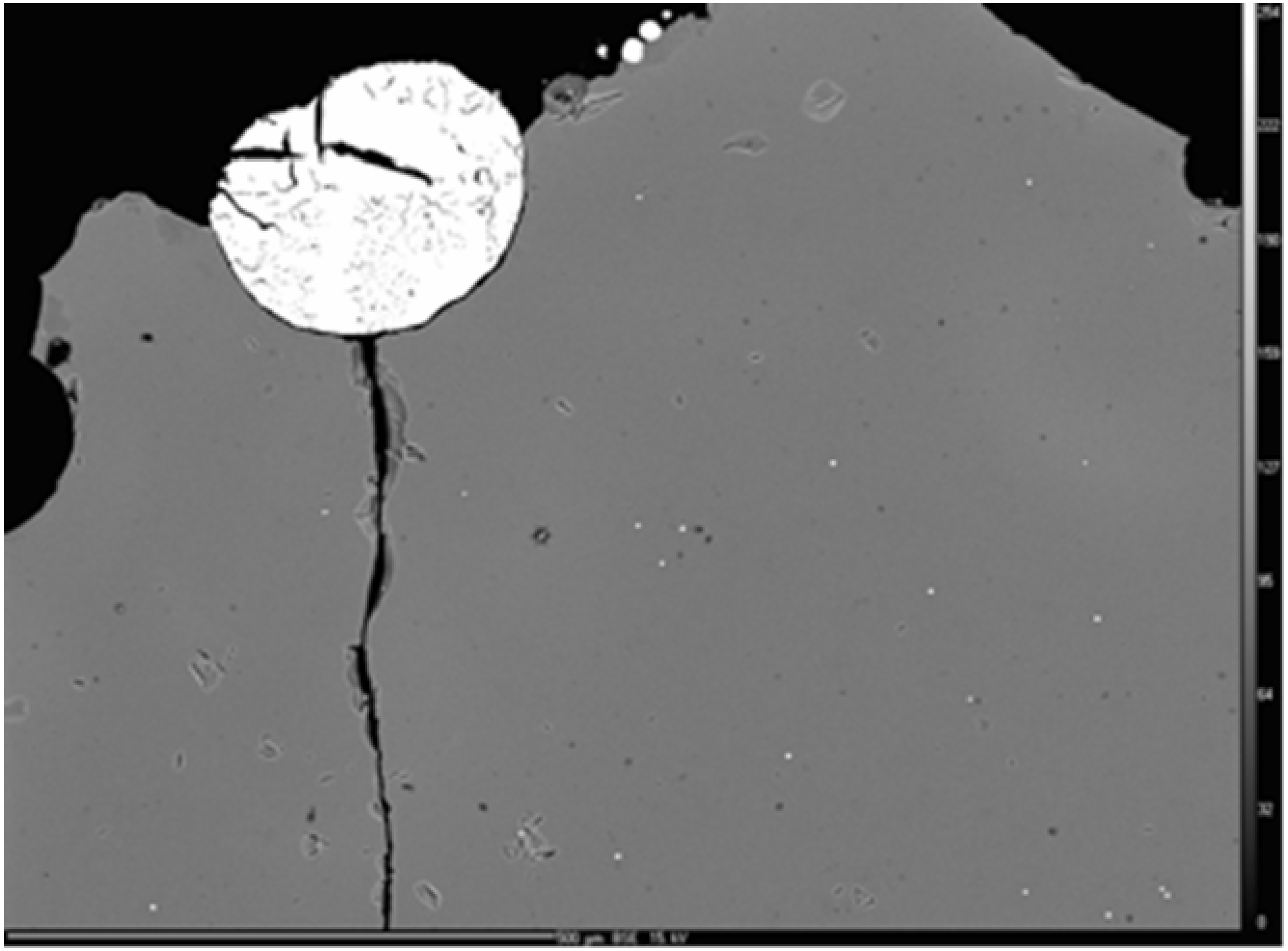
* All iron reported as FeO.

Sample

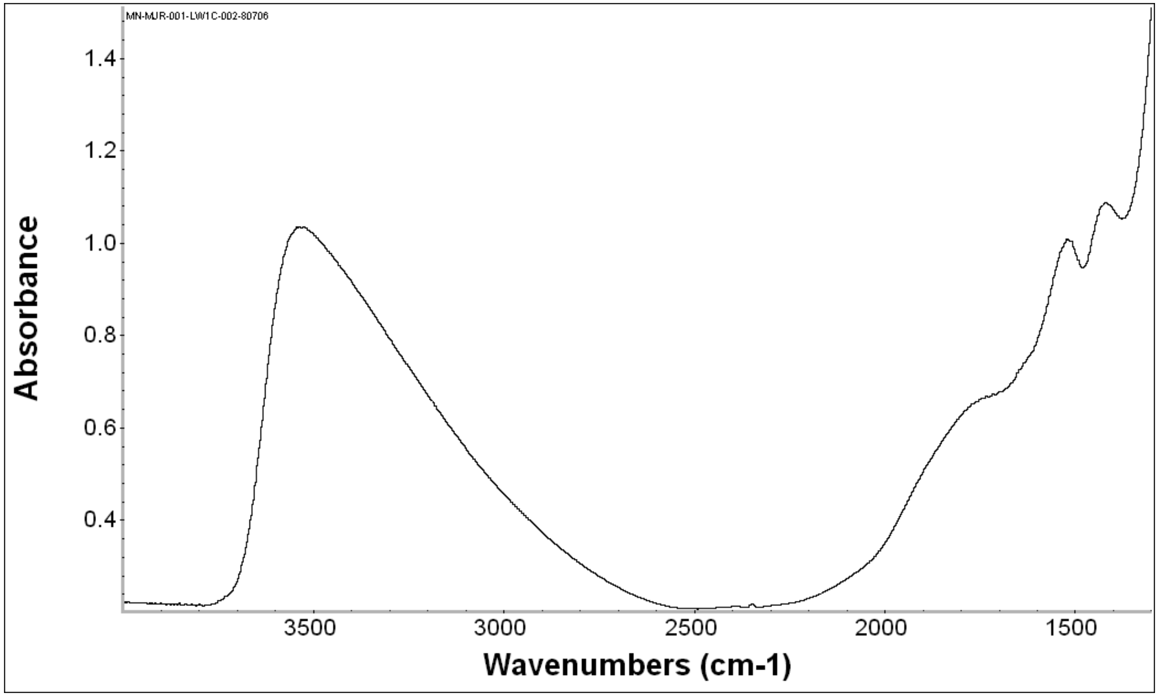


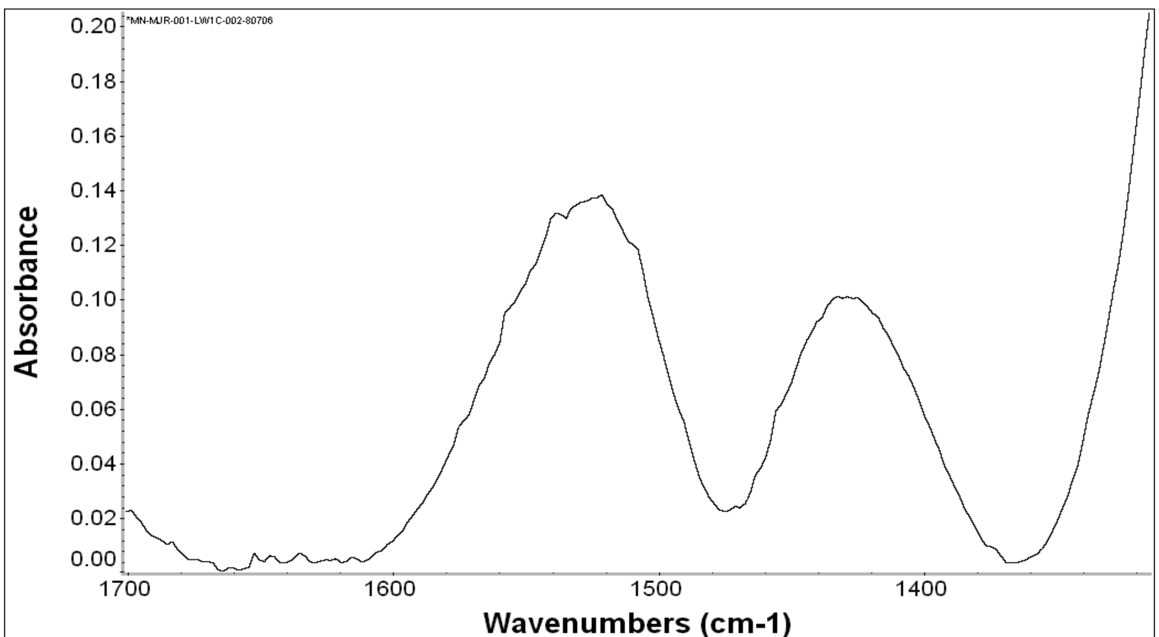
Sample


Crimped capsule
Pt-capsule
Starting Material
Solid buffer
1mm



100 micron Fe-metal spherule and many 1 um spherules in a Hi-Ti basaltic glass with 1 wt % reduction in FeO; BSE image.


MN-MJR-001-LW1C-002-80706
1.4
1.2
1.0
0.8
0.6
0.4
Absorbance
3500
3000
2500
2000
1500
Wavenumbers (cm-1)


*MN-MJR-001-LW1C-002-80706
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Absorbance
1700
1600
1500
1400
Wavenumbers (cm-1)