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Hydrothermal Recrystallization of Dunitic Olivine in Peridotite from Pyaung-gaung, Mogok, Myanmar: Similarities to Sapat and Zabargad Deposits

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Hydrothermal Recrystallization of Dunitic Olivine in Peridotite from Pyaung-gaung, Mogok, Myanmar: Similarities to Sapat and Zabargad Deposits

Introduction: ***Peridot*** ***(ARABIC WORD for a grass green gem)***

❖Gem variety of forsteritic olivine.

❖ Small stones (~<5 carats) mostly from dunites.

❖Large stones and well-formed crystals are from only 3 deposits: **Zabargad Island**, Egypt; **Pyaung-gaung**, Myanmar; and **Sapat**, Kohistan, Pakistan.

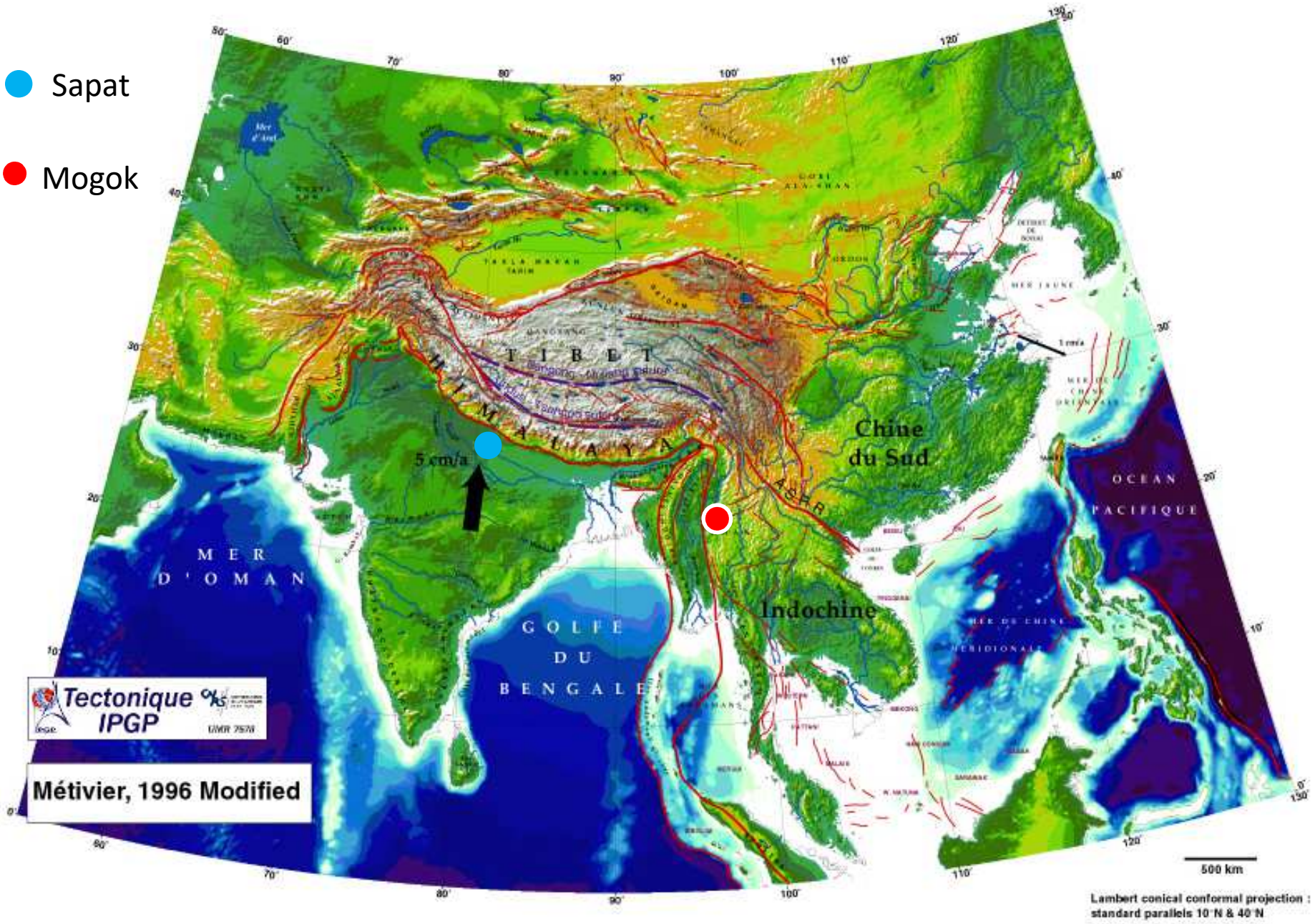
❖Sapat and Zabargad peridots form in pockets in tectonized dunite with evidence for (re)crystallization from a hydrous fluid.

❖Expedition to Mogok in 2013 with George Harlow (AMNH) and sampling from Pyaung-gaung to assess peridot origin.

Peridot: Gem form of forsterite, Mg_2SiO_4, which forms a solid solution with Fe_2SiO_4 to form the major constituents of the olivine group of minerals: $(Mg,Fe,Ni,Mn)_2SiO_4$

Crystal Symmetry: Orthorhombic
Hardness: 6
Cleavage: Imperfect in two directions: {010}, {100}
Specific Gravity: 3.22 – 3.29
Refractive Index: 1.654 – 1.690
Color: Grass green to yellow-green and brownish green; the off color is generally attributed to ferric iron (Fe^{3+}) oxidation of constituent ferrous iron (Fe^{2+})

Peridotite: A rock of basically igneous origin composed by a majority of olivine.
Three types are common:
Dunite is >90% olivine;
Harzburgite contains olivine (> 40%), orthopyroxene ($(Mg,Fe)SiO_3$) and less than 5% clinopyroxene ($Ca(Mg,Fe)Si_2O_6$), and
Lherzolite contains olivine (> 40%), orthopyroxene, and clinopyroxene generally above 5%. Chromite is a minor constituent of peridotites.
Because of the extraordinary abundance of magnesium and iron (ferrum), these rocks are also called “ultramafic.”


Sapat
Mogok
TIBET
HIMALAYA
Chine du Sud
Indochine
MER D'OMAN
GOLFE DU BENGALE
OCEAN PACIFIQUE
5 cm/a
ASRR
Tectonique IPGP
UMR 7578
Métivier, 1996 Modified
500 km
Lambert conical conformal projection : standard parallels 10°N & 40°N

4.8 cm Pyaung-Gaung Peridot (Pala Coll.)

Geology

Mogok Belt: marbles and schists.

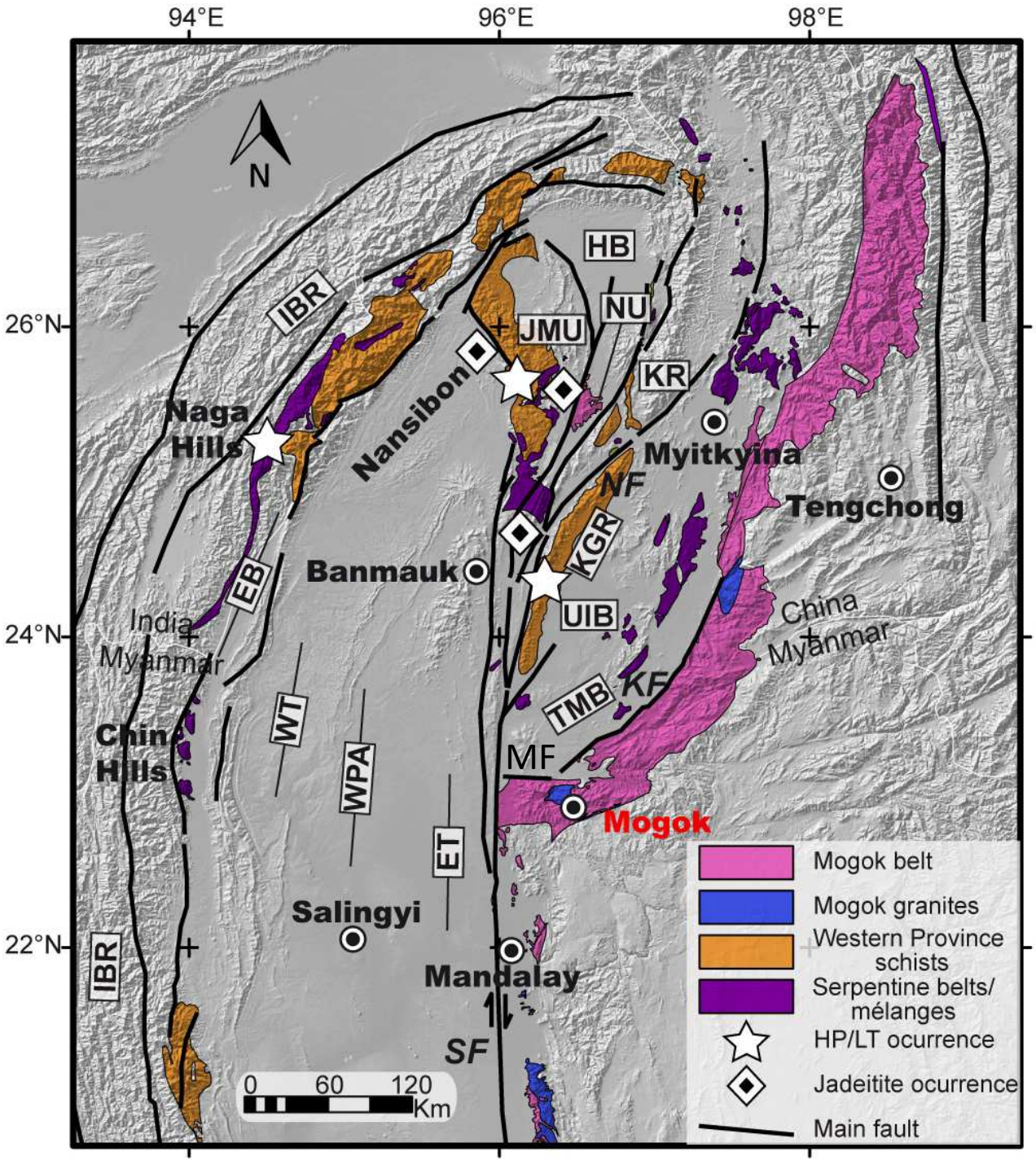
- Sediments as old as Proterozoic (>750 Ma) but mostly Paleozoic (650 – 300 Ma).

- Multiple early metamorphic events—Jurassic (185 Ma) & Cretaceous (~150 Ma), last by collision of Burma Block with Shan plateau. Boundary along which ultramafics and **peridot is associated, however no dating.**

- More extensive metamorphism and granite intrusions from Indian Block collision as recently as Miocene (26 – 15 Ma). Probable latest event affecting **peridot.**

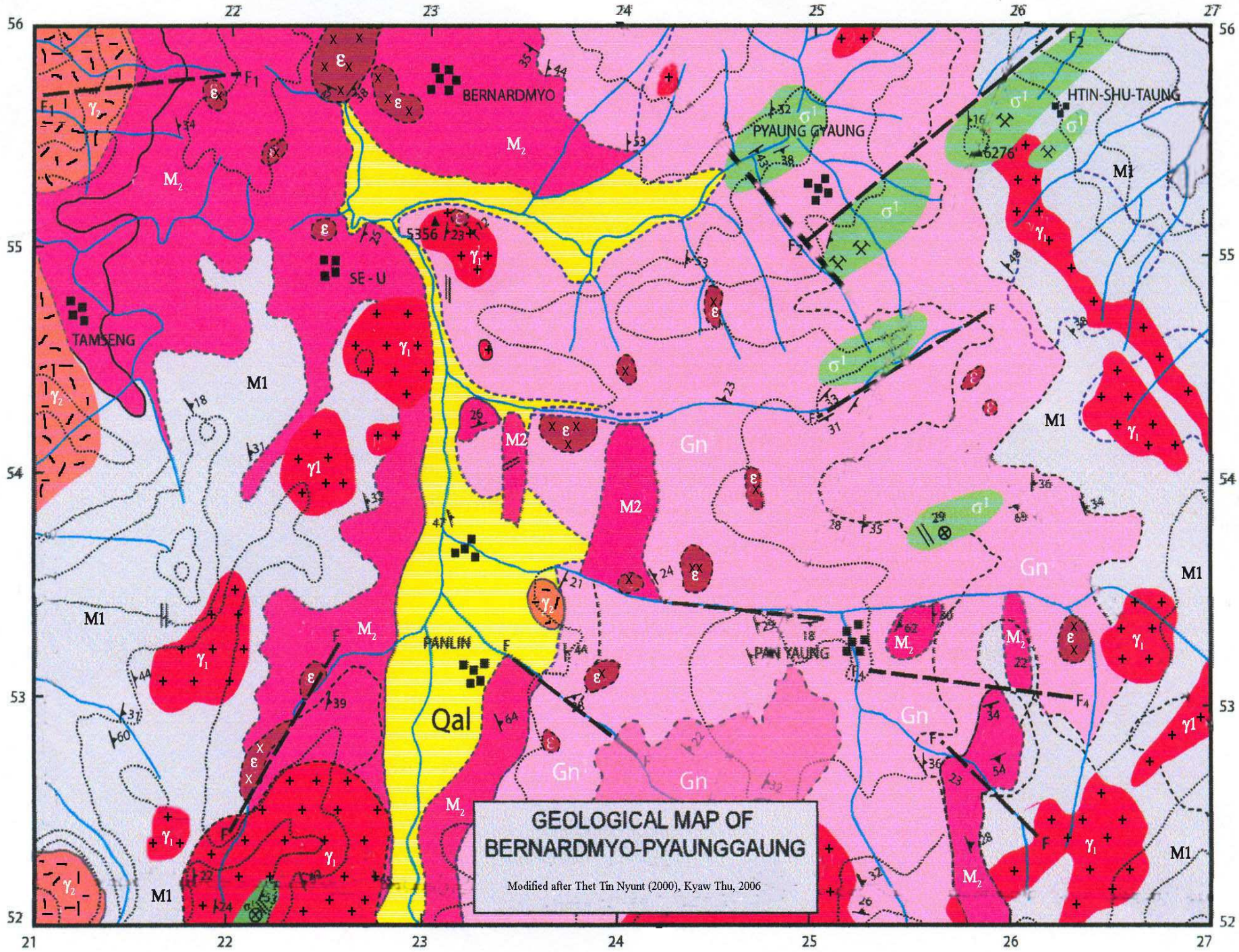
- Ruby and spinel are marble-hosted; sapphire in syenitic dikes; and tourmaline, topaz, etc. in granitic pegmatites; peridot in uplifted ultramafic.

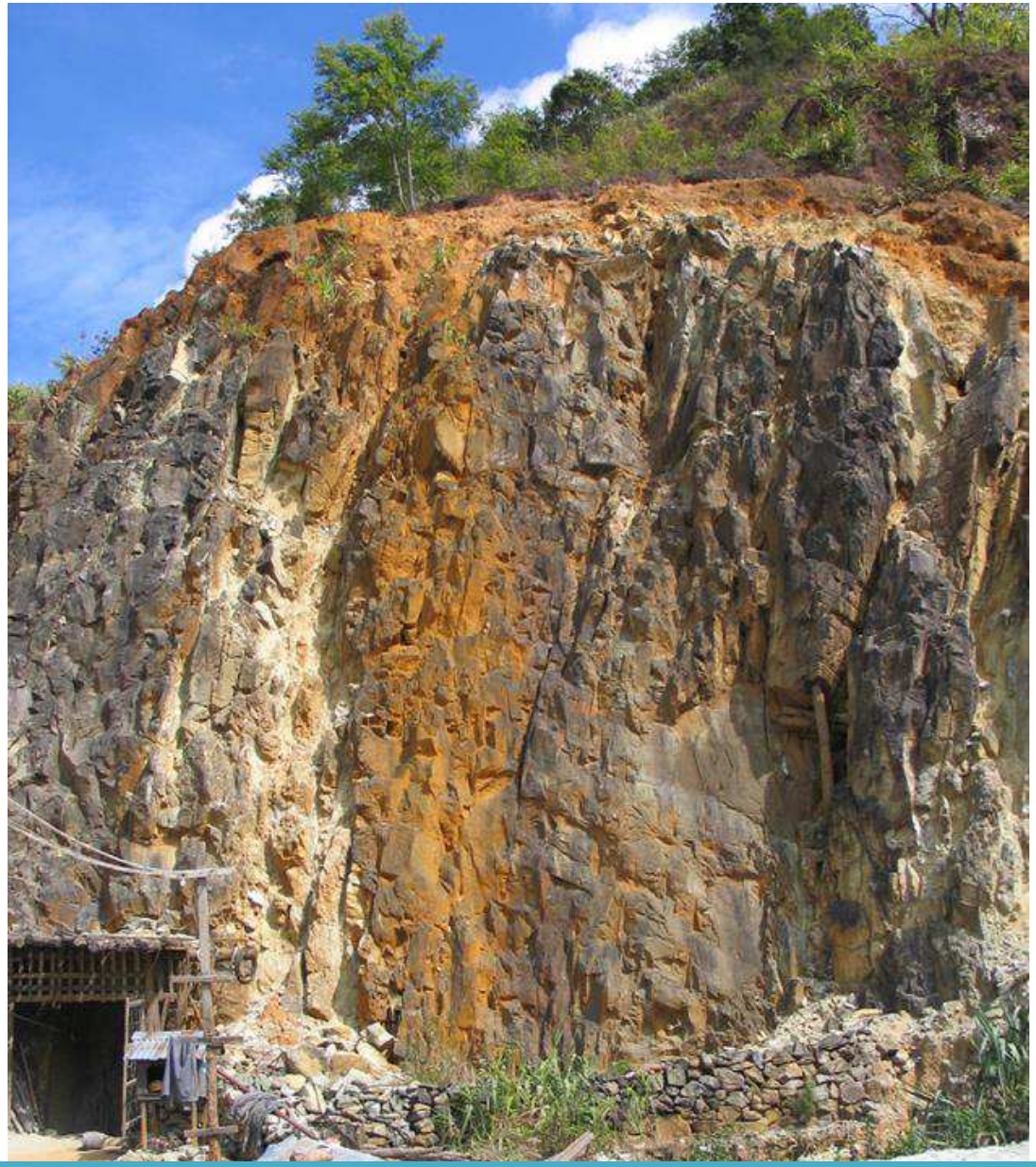
- **Lots of evidence for involvement of fluids.**



Part of geodynamic map for jadeitite inter-pretation, but showing the Mogok belt on the edge of the eastern highlands of the Sibumasu terrane: a passive margin sequence.

KF = Kyaukphyu Fault, a high angle thrust fault
MF= Momeik Fault


GEOLOGICAL MAP OF
BERNARDMYO-PYAUNGGAUNG
Modified after Thet Tin Nyunt (2000), Kyaw Thu, 2006
BERNARDMYO
PYAUNG GYAUNG
HTIN-SHU-TAUNG
TAMSENG
SE-U
PANLIN
PAN YAUNG
Qal
Gn
M1
M2
F1
F2
F4
5356
6276



Entrance to underground Mya-sein-taung mine at Pyaung-gaung with adjacent weathered outcrop of partially serpentinized peridotite. Rustiness indicates that there is still olivine in the peridotite that has not been reacted to become serpentinite.

Partially serpentinized, tectonized peridotite (yellow-green) outcrop showing the subhorizontal planar shear feature (decorated with Mgt) cut by fractures exposing surfaces partially coated with a mixture of talc and serpentine (white & brown).

Close up of outcrop exposing a large vein of brown enstatite (coated by talc and carbonate), running upper left to lower right through the chaotic exposure. The image is about a meter across.

Close up of a small area of pocket peridot, surrounded by talc + carbonate (white) and interspersed enstatite exposed in a fragmented rusty peridotite.

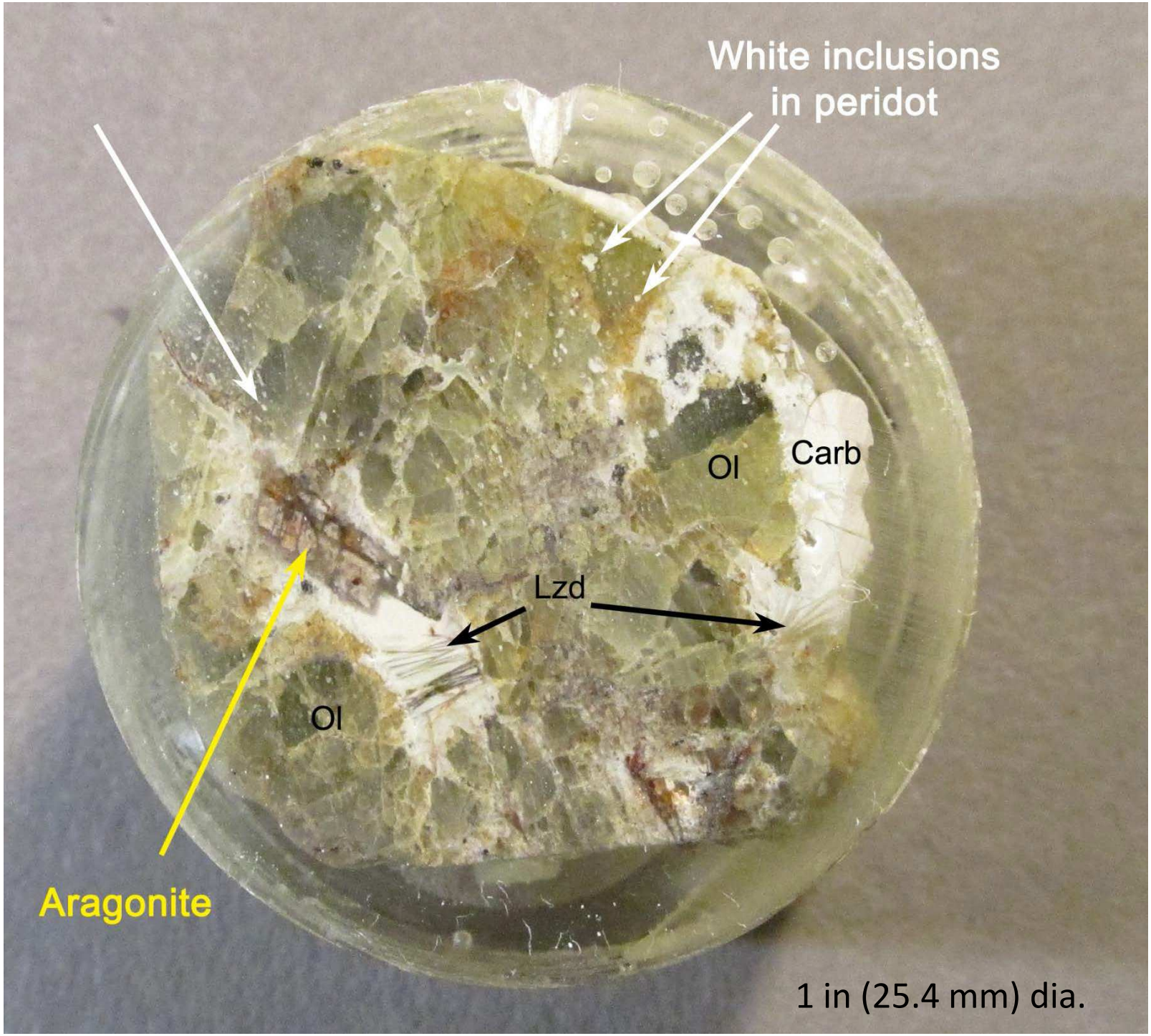
Two samples of a portion of pockets showing peridot crystals (green), white pocket filling (microcrystalline calcite, pyroaurite(?) $Mg6(Fe^{3+})2CO_3(OH)16.4H_2O$), talc, and lizardite serpentine) and grayish serpentinized pocket host rock

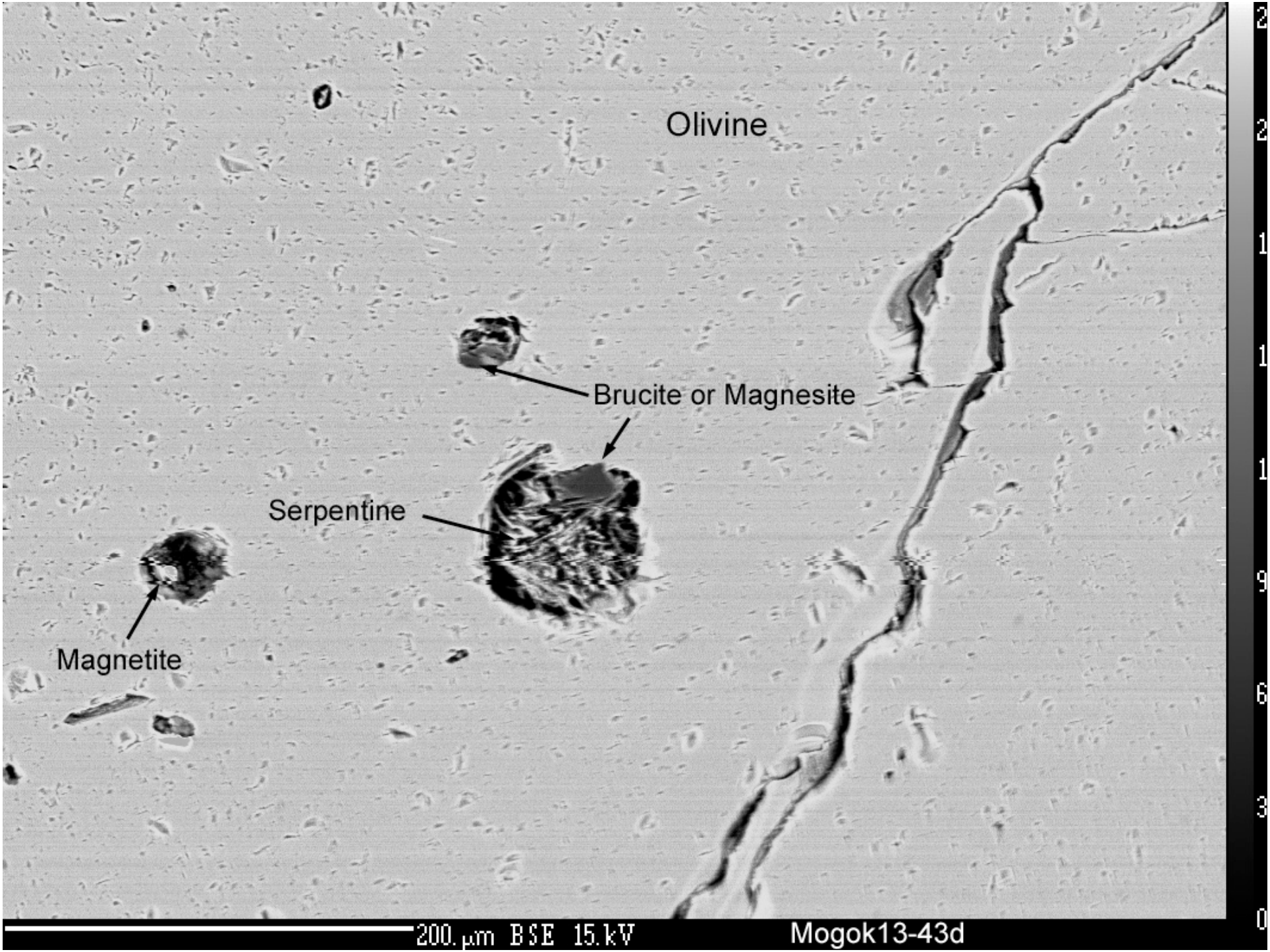
Pyaung-gaung data

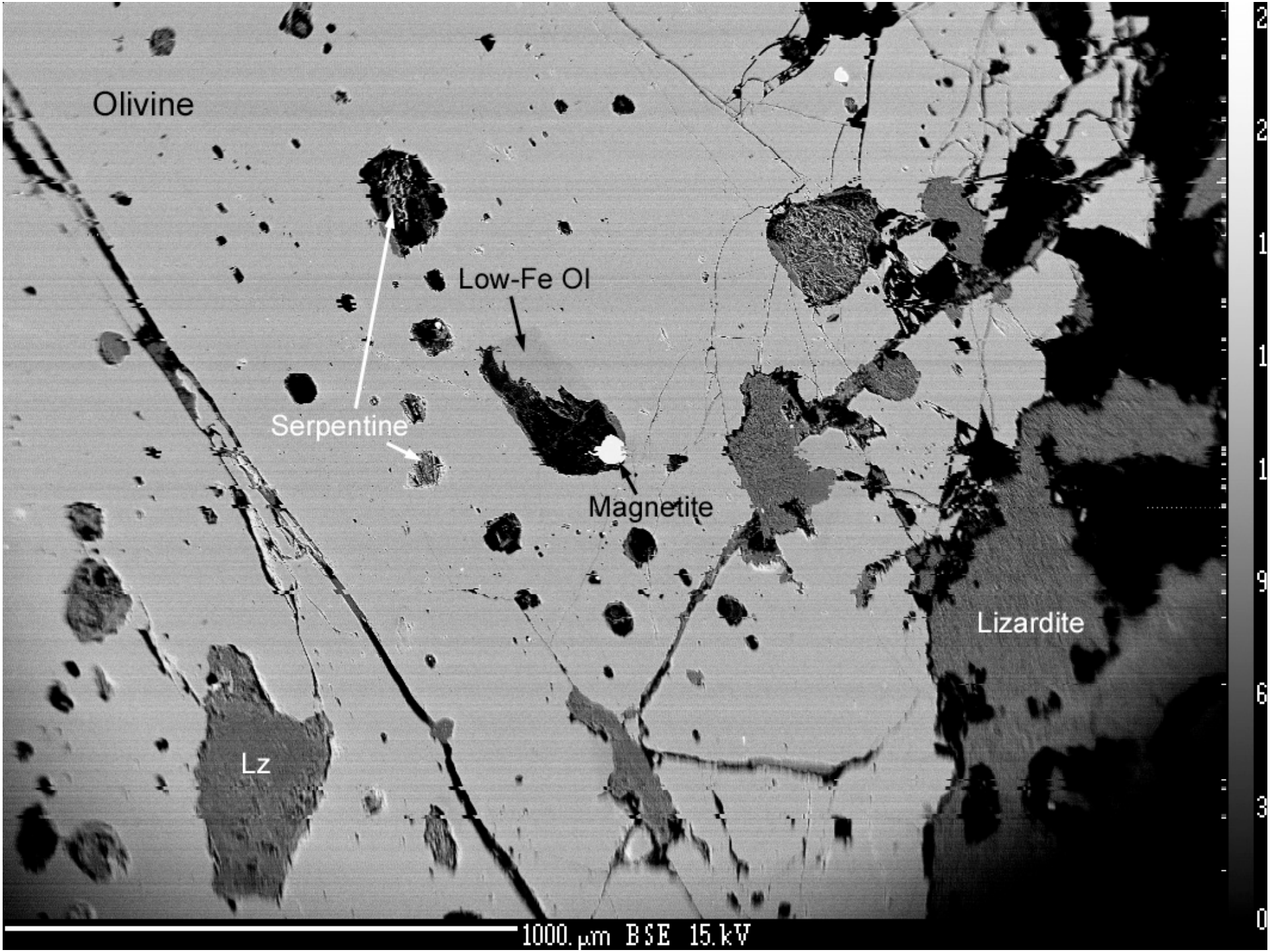
- Harzburgite (rare):
  - olivine (Fo92-93), NiO = 0.4-0.5 wt%
  - brown orthopyroxene (En92-93CaTs2)
  - chromian magnetite (Mgt61Pcm18Cm10Sp9)

- Dunite
  - olivine (Fo92-93), NiO = 0.4-0.5 wt%
  - magnetite (Mgt65-70Cm20-22Pcm8Sp4)

- Peridot composition:
  - Fo92-93, NiO = 0.4-0.5 wt%
  - Very homogeneous

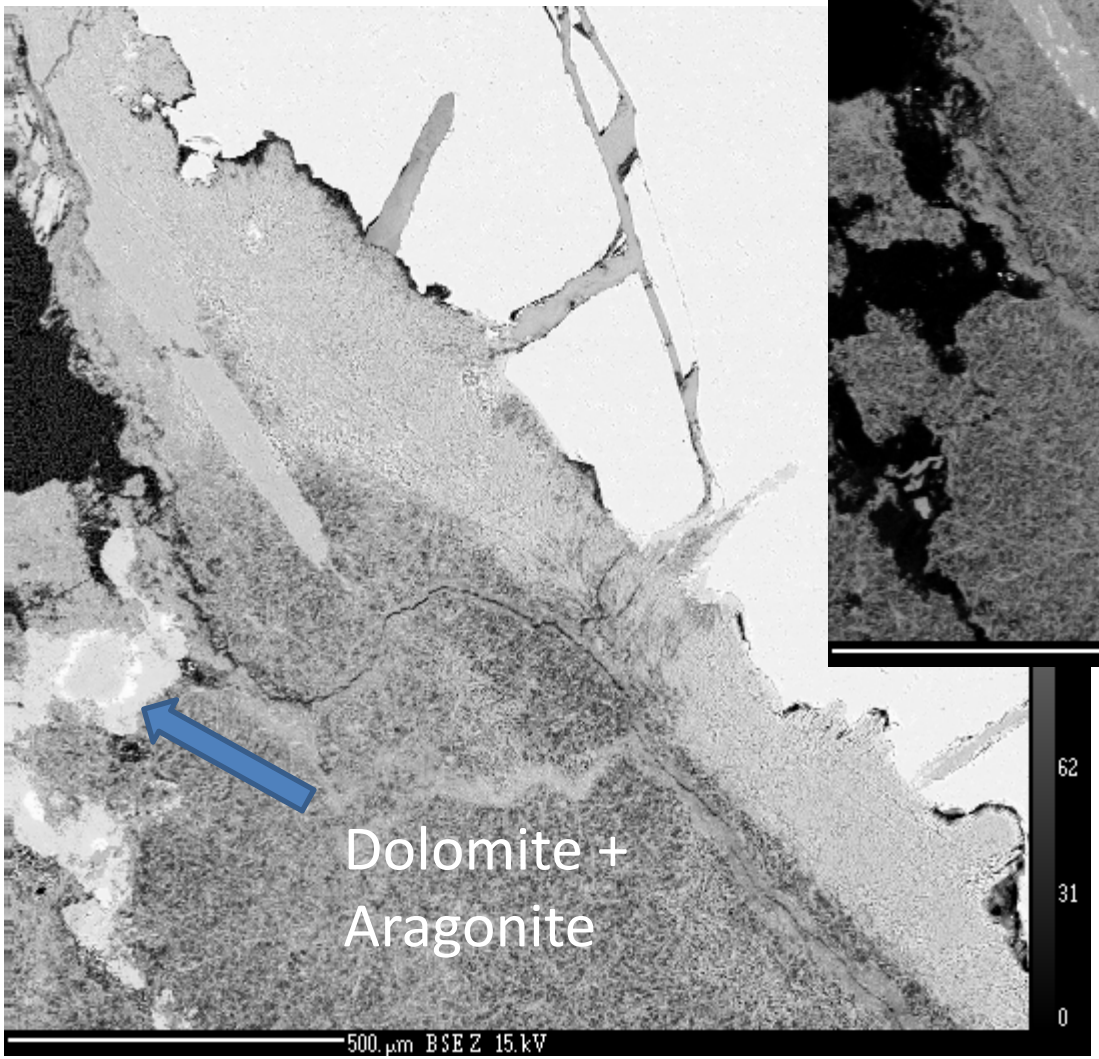

White inclusions
in peridot
Ol
Carb
Lzd
Ol
Aragonite
1 in (25.4 mm) dia.

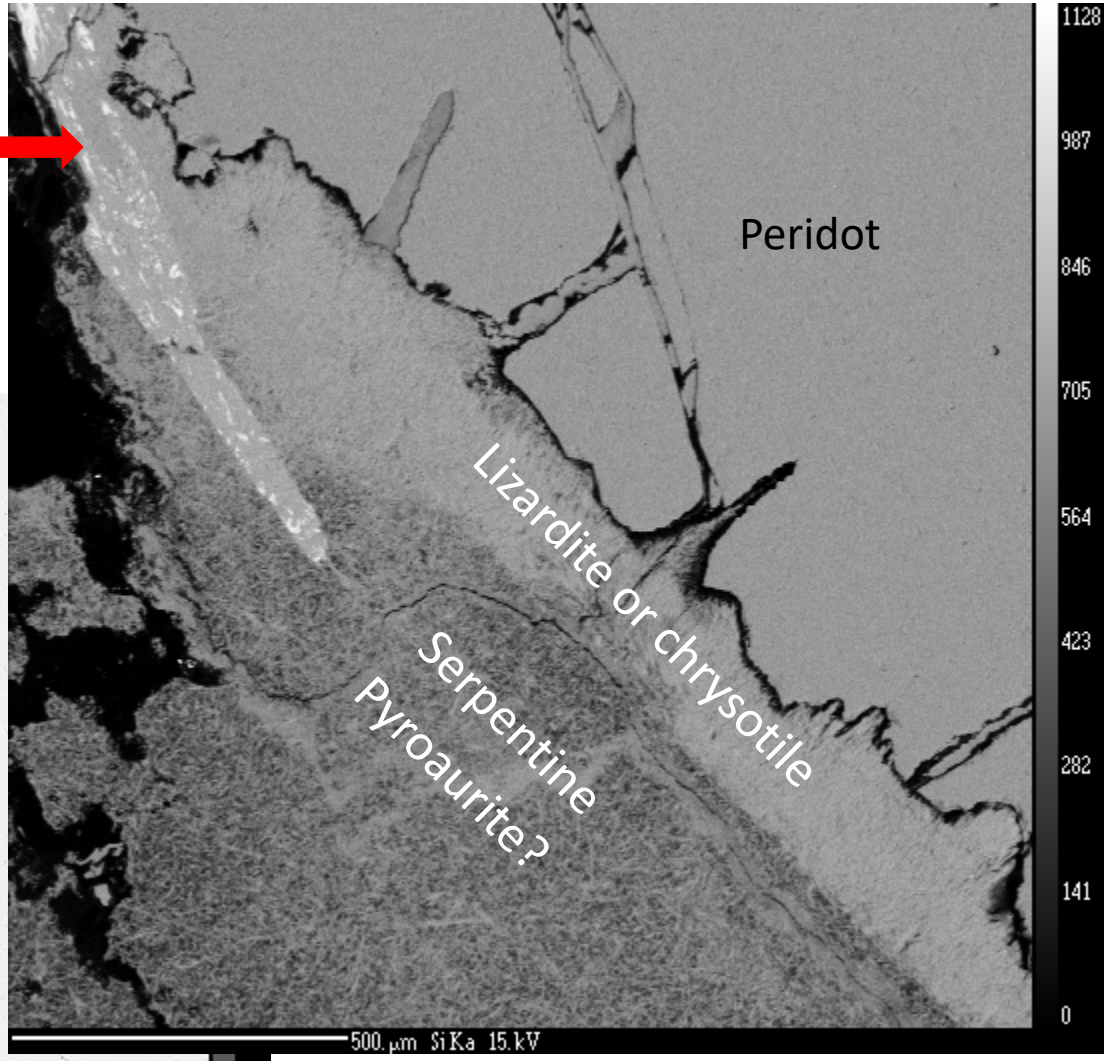

Olivine
Brucite or Magnesite
Serpentine
Magnetite
200.μm BSE 15.kV
Mogok13-43d


Olivine
Low-Fe Ol
Serpentine
Magnetite
Lizardite
Lz
1000.μm BSE 15.kV

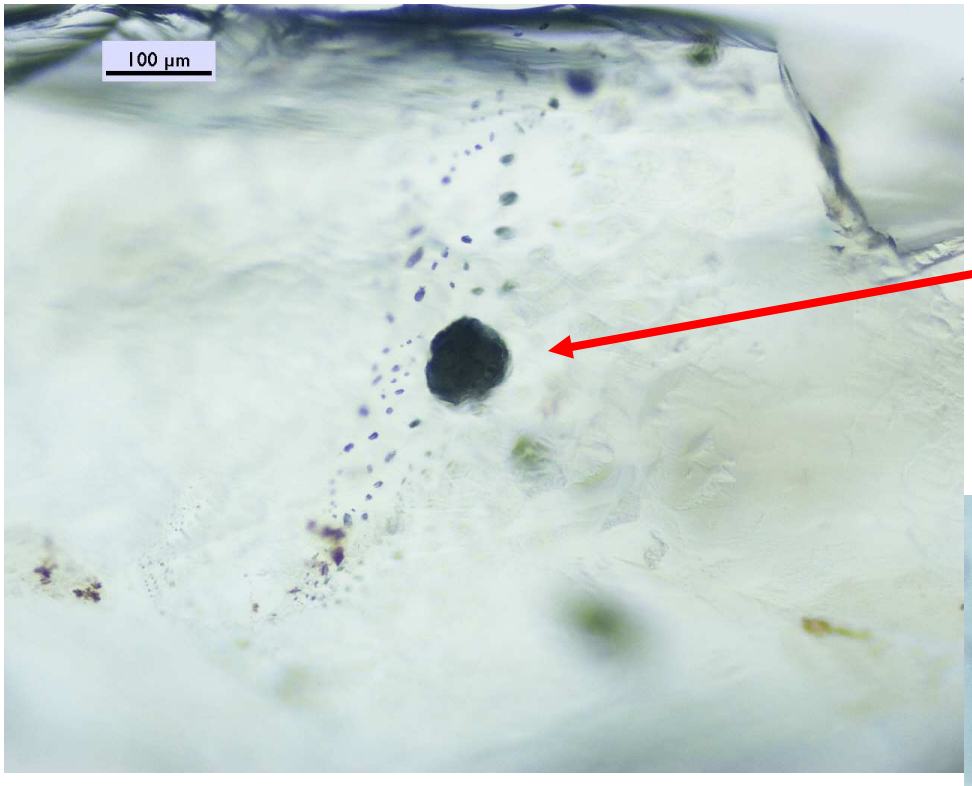
Lizardite+Talc

BSE

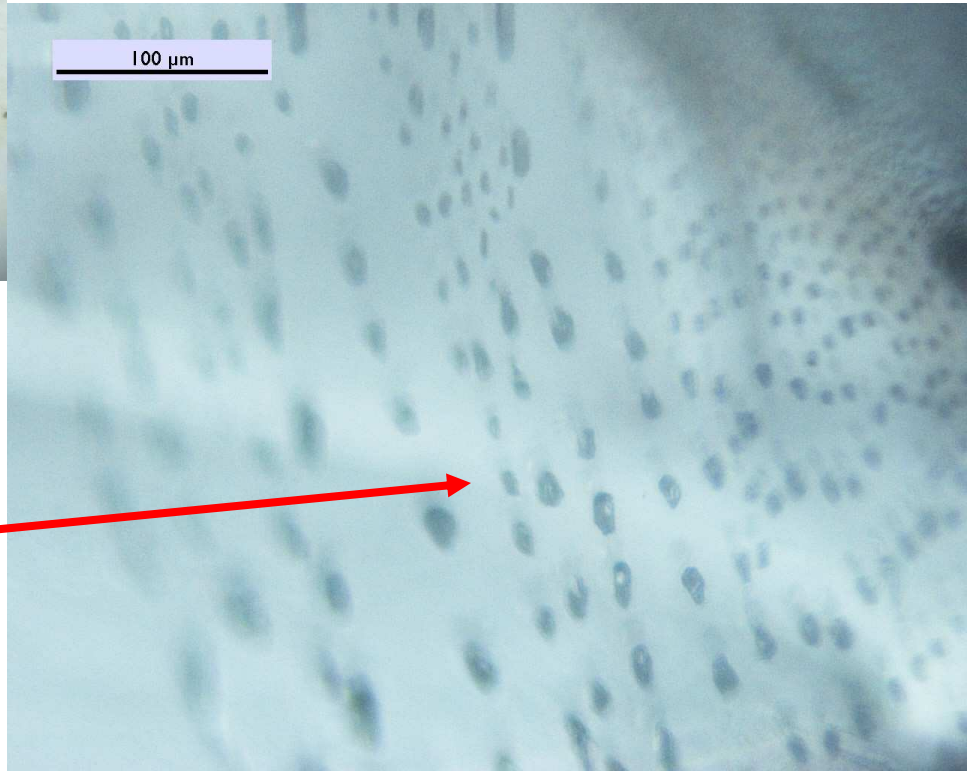




Si Map



Serpentine ball



Olivine crystals

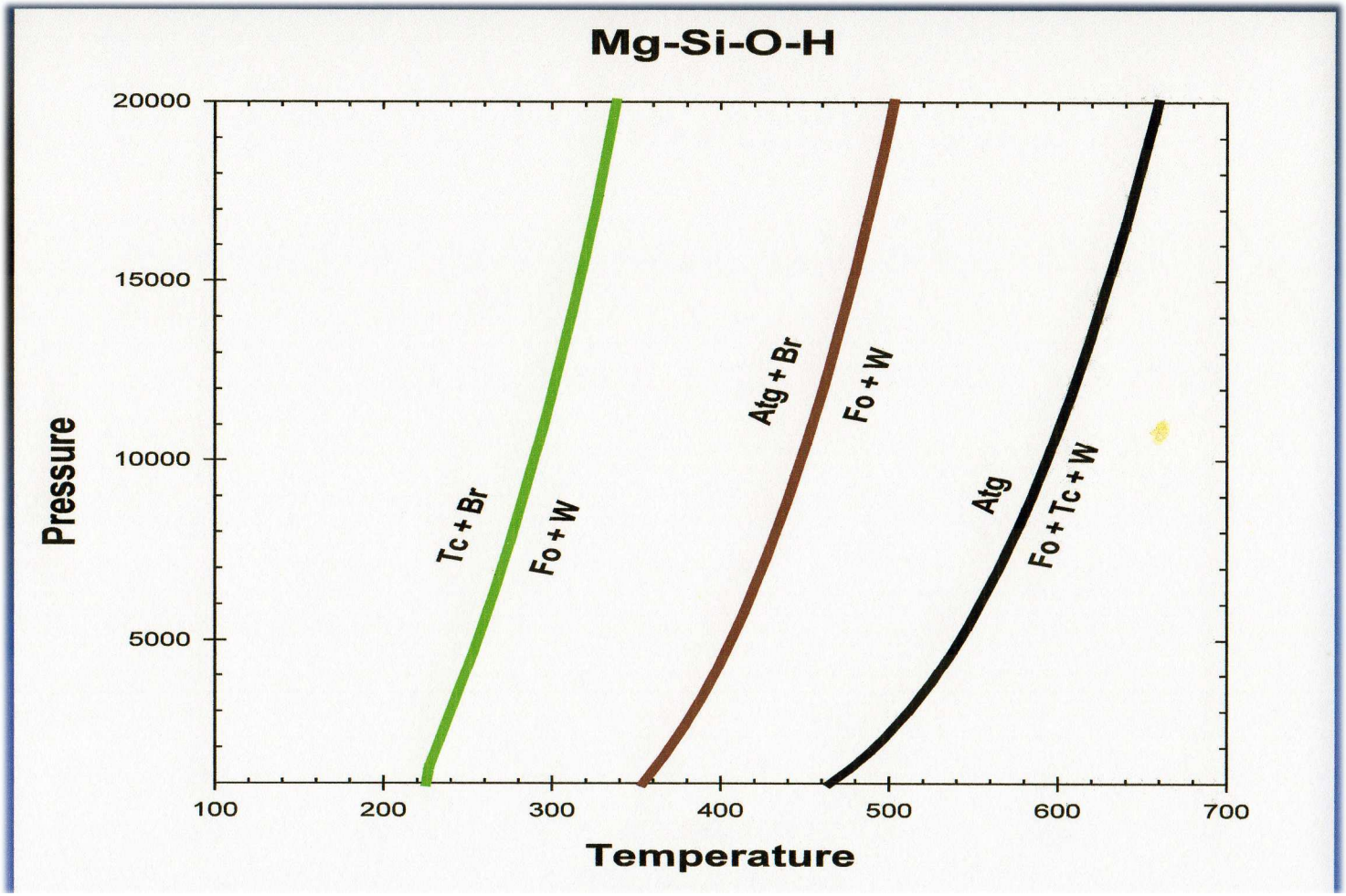
Photomicrograph of a peridot fragment in plane-polarized transmitted light , oil immersion.

The white inclusions in peridot can be interpreted as the result of the reaction:

Forsterite + H_2O = Antigorite + Brucite

or if silica activity were greater, constrained by:

Forsterite + Talc+ H_2O = Antigorite.



Thermobarometry – sort of

- Ol-Opx-Spinel thermometry:
  - 730 °C ± 100
- Original fluid inclusions
  - T > 400 ºC @ 5 kbar for Fo + H_2O
  - T > 540 ºC @ 5 kbar for Fo + Tc + H_2O
- Aragonite (hmmm??)
  - 11 kbar @ 400 ºC

❖ Spinel composition in both dunite and harzburgite < chromite (Cm:$FeCr_2O_4$) < magnetite (Mgt: $Fe^{2+}\,Fe^{3+}{}_2O_4$).

❖ High magnetite content : re-equilibration at the sub-mantle temperature, probably due to some reaction with fluid.

Other occurrences: How to compare?

❖ **Sapat:** Bouilhol et al. (2012) found **carbonate**, Fe-Mg **borate** (ludwigite-vonsenite), and fluid inclusions in gem olivine, interpreted as subduction dewatering that recrystallized olivine in tension gashes in tectonized dunite.

❖ **Zabargad:** Kurat et al. (1993) found **halite**, carbonates, and CO_2 in gem olivine from "olivinite" veins, interpreted as relics of hypersaline fluids of the latest metasomatism.

❖ **Pyaung-gaung:** Futher work is required to assess the presence of relic salinity, but we have not observed casts of halite in sections or halite crystal in inclusions. Also, we have not observed either cabonate or borate minerals in the inclusions.

❖ These differences may reflect the different tectonic histories: Rifting at Zabargad, subduction mantel wedge exhumation at Sapat, and lateral displacement and uplift along the Momeik fault.

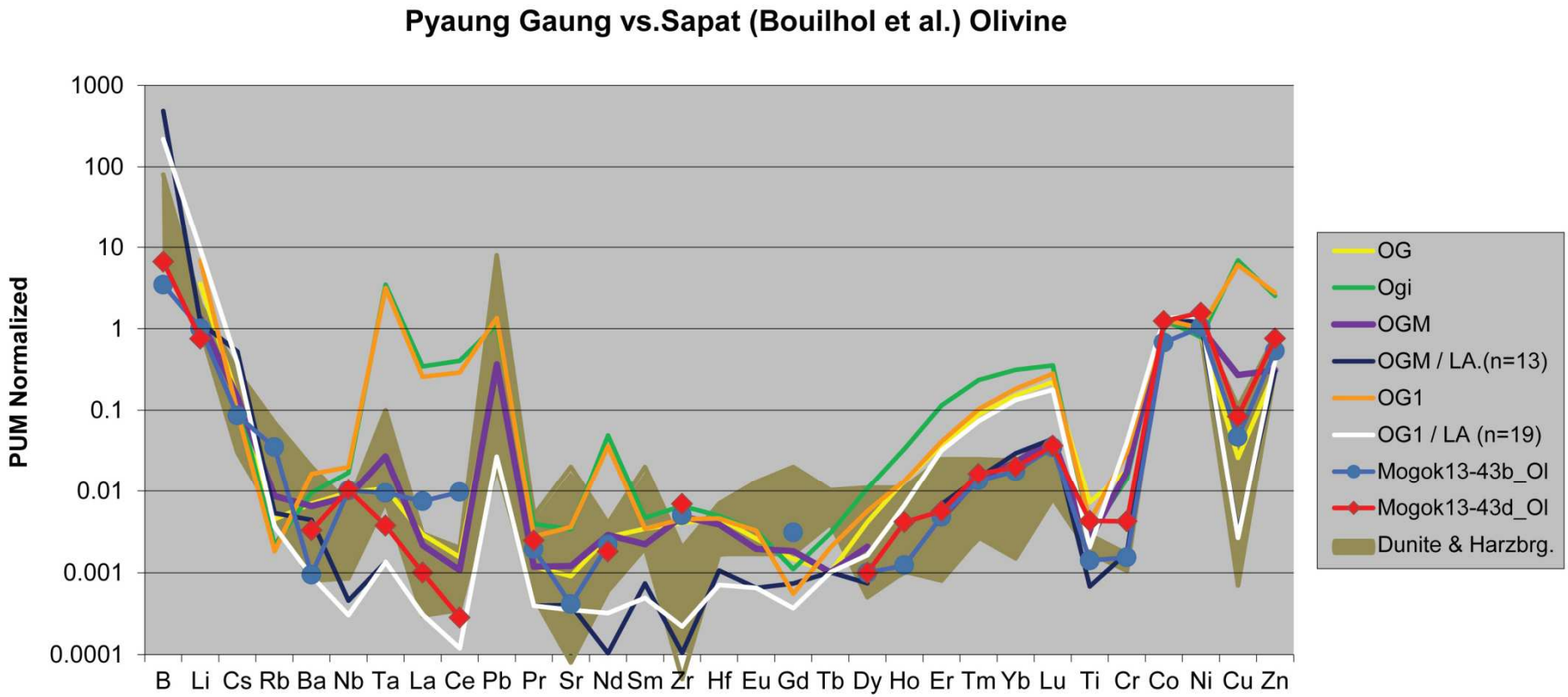
Boron in Peridot

- Bouilhol et al. (2012) reported from 54 to 121 µg/g B in gem olivine from Sapat.

- This study has measured 2 (±0.4) µg/g B by LA-ICPMS and δ11B of -14 to -9‰ (2σ < 3‰) by SIMS in peridot from Pyaung-Gaung.

- Although B data on dunite olivine is minimal, Sapat is clearly B-rich, but P-G may not be. However, P-G δ11B values are lower than primitive mantle (~ -7: Marschall personal commun.) and more like negative values associated with either **an evolved igneous source or subduction-zone-related metasomatism (Martin et al. 2014).**

Peridot/olivine trace elements



OG- OG1 = gem olivine from Sapat (Bouilhol et al. 2012, Can. Min.);
Mogok 13-43 = Pyaung-Gaung pocket olivine;
Dunite and Harzburgite from crust-mantle transition zone at Sapat (ibid)

Pyaung-Gaung Interpretation

- Tectonic emplacement with recrystallization of dunite and harzburgite (T = 700±100°C) in the presence of H_2O-CO_2 fluid; peridot crystallized from fluid in tension gashes followed by carbonate, talc and serpentine infilling.

- Too what degree are dunites, in general, modified by hydrothermal fluids?


THANKS YOU