First report of Platinum Group Minerals in garnet peridotites from the Central Vosges, France

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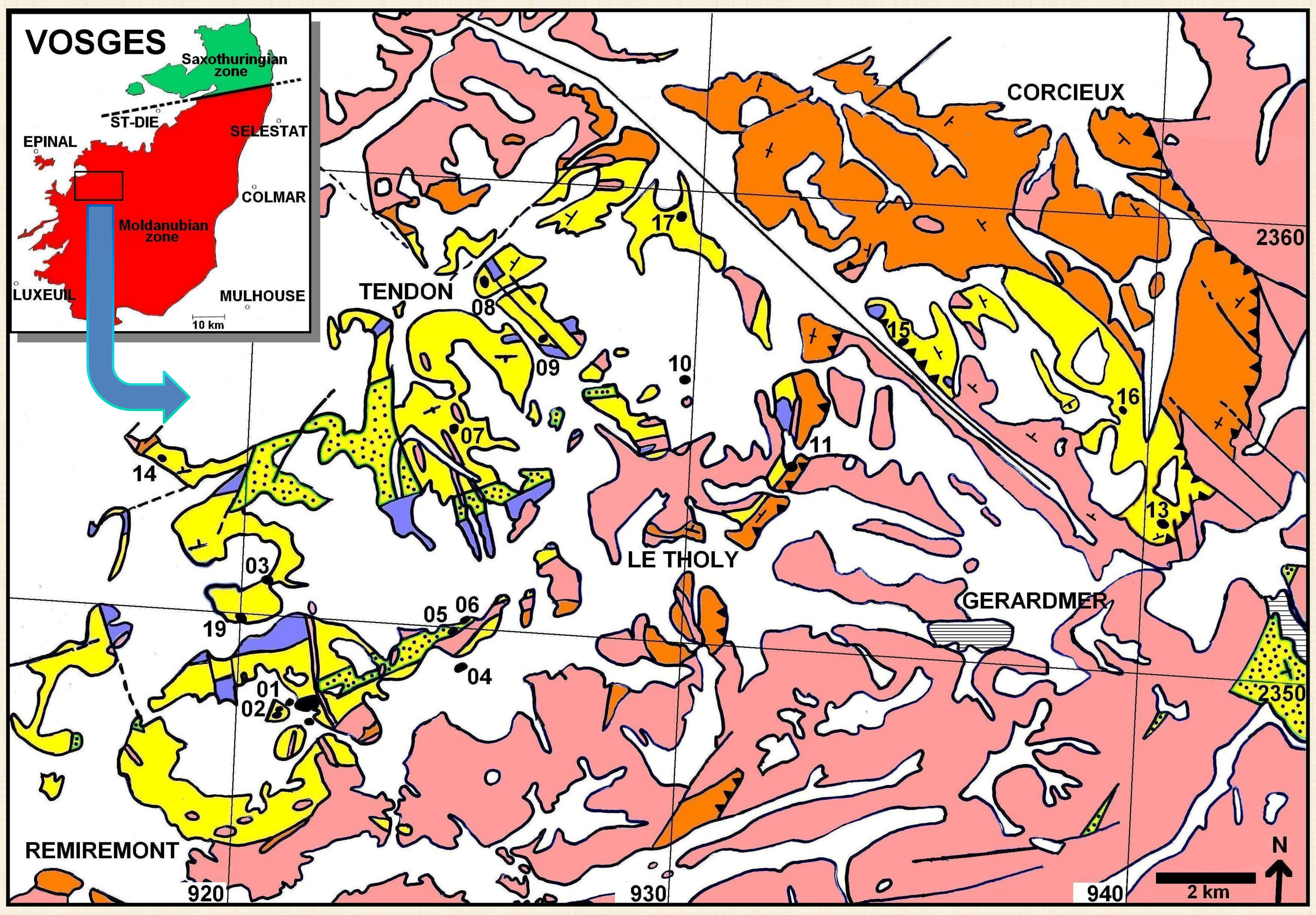
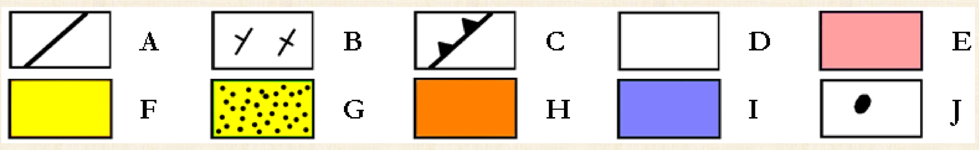
Introduction : Platinum-group elements (PGE) are ultra-trace elements in mantle rocks which are usually carried by small-size platinum-group minerals (PGM) and base-metal sulphides (BMS). The PGM and BMS association usually reflects critical magmatic and/or metamorphic events in oceanic mantle and in continental peridotite slices included within highly metamorphosed fragments of orogenic terranes. We report here the presence of PGM, associated with sulphides, in garnet peridotites of the Vosges mountains, which belong to the European Variscan belt. Deposition of BMS is related to the presence of a sulphide melt immiscible from a percolating silicate magma within variously depleted garnet peridodites. The magmatic scenario retained here puts some constraints on the origin of the garnet peridotites during collisional events, whether they could derive from a low-temperature peridotite body engaged in a subduction zone, or from a deeply rooted subcontinental mantle. In the latter case, textural evidence and petrogenetic evolution of the Vosges peridotites would favor a mantle-wedge origin above a continental subduction zone. The preliminary study on PGM distribution documents a new case of platinum-group element resetting in Variscan garnet peridotites.

Geological setting of garnet peridotites :

PGM-bearing garnet peridotites occur in the Moldanubian zone of the Central Vosges as lenses of variable size (up to 1 km) in the uppermost leptynitic granulite unit [1]. This setting is similar to that of the Gföhl terrane from the Bohemian massif [2, 3]. According to Altherr & Kalt [4], garnet peridotites in the Vosges mountains evolved from high pressure > 4,9 GPa and T° > 1100°C, towards lower pressure conditions 1,6-2 GPa and 700-800°C, during their rapid ascent towards the upper crust. These two major stages of re-crystallization were followed by final emplacement against crustal granulites at a pressure of 0,2-0,3 GPa and temperature about 800°C and 650-700°C [5].

Seventeen peridotite slices have been recorded in the uppermost leptynitic unit, including three new occurrences, Blanchefontaine, Malpoirier and Le Thin bodies, discovered during a general survey of the area.

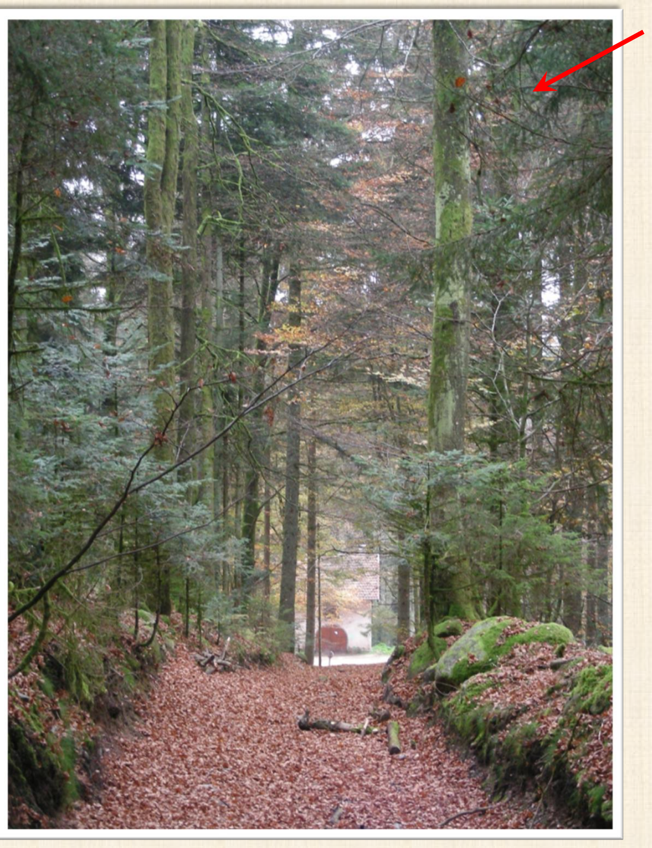




Location of the garnet peridotite occurrences in the upper leptynic unit, Central Vosges.

A - Faults. **B** - Foliations. **C** - Thrust faults. **D** - Mesozoic and Cenozoic terranes. **E** - Variscan granites. **F** - Leptynites and granulites. **G** - Garnet nebulites. **H** - Gerbépal migmatites. **I** - Kaysersberg migmatites . **J** - Garnet peridotites :

01 – La Charme,
03 – Crébimont,
04 – Flaconnière,
05 – Blanchefontaine,
06 – Malpoirier,
07 – Les Cherrières,
08 – Le Houx,
09 – Bellevue,
10 – Champ de Laxet,
11 – Col du Pertuis,
12 – Beauregard (not figure),
13 – La Béheuille,
14 – Trou Vauthier,
15 – Petempré,
16 – Nayemont,
17 – Jussarupt,
19 – Le Thin.
Modify after [1].

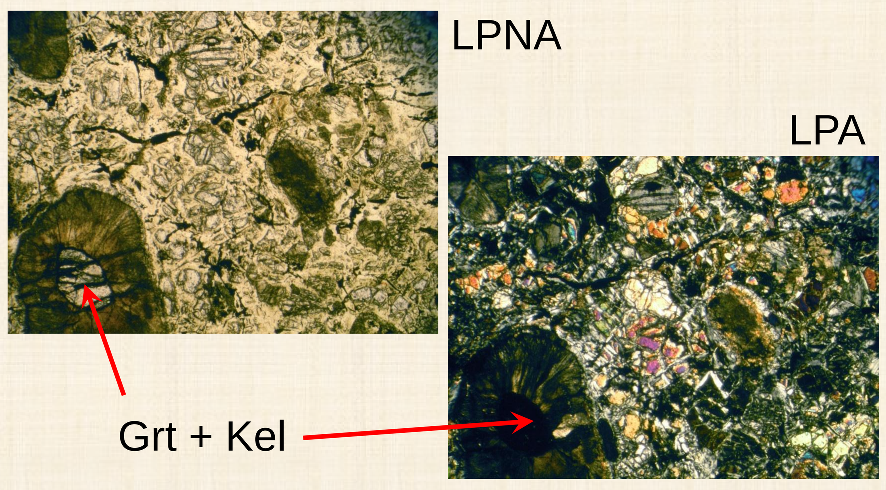


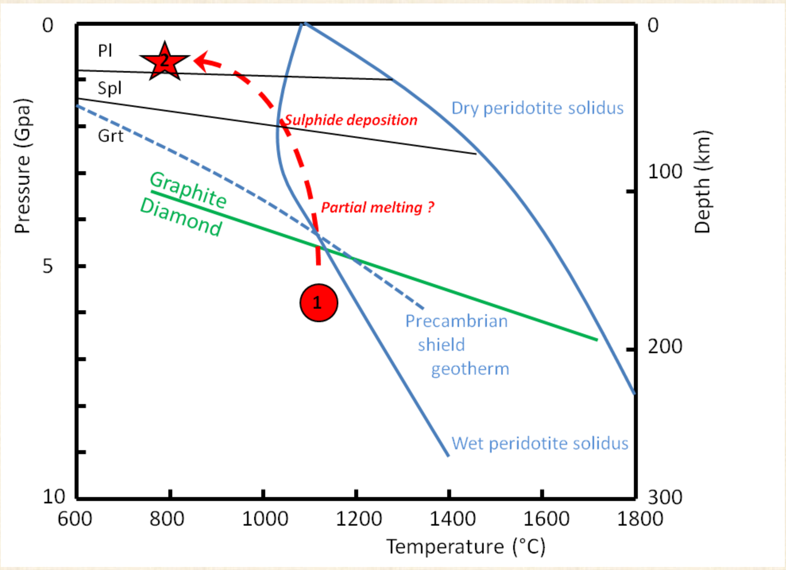
Malpoirier massif : Garnet peridotite block outcroping within the leptynitic unit.

La Charme massif : Garnet peridotite with garnets of variable size scattered in a matrix locally rich in pyroxenes.

Mineralogy : Garnet peridotites are composed of olivine (Fo_{88}), two pyroxenes in variable proportion, pyrope-rich garnet, most usually transformed into kelyphite. Spinel is locally present, being Cr-rich in scarce coarse crystals and Al-rich in kelyphite. Pyroxenes and spinel from the keliphitic rim are Al-rich.
Accessory phases in garnet peridotites comprise plagioclase of variable composition according to its setting, amphiboles, and Ti-oxydes. Serpentines and carbonates are late-stage phases.

Garnets, up to 1,5 cm, are generally kelyphitized. In few cases, a garnet core is preserved within the kelyphitic rim.

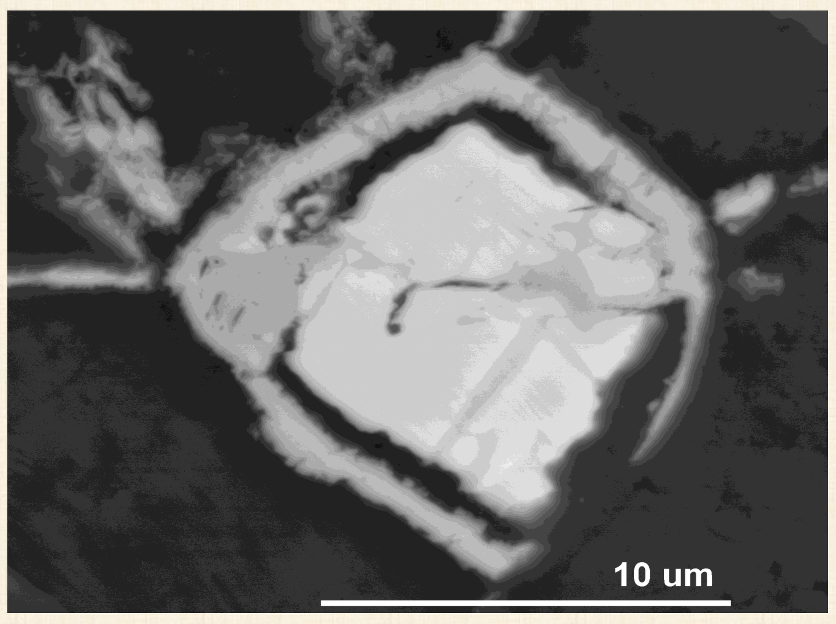




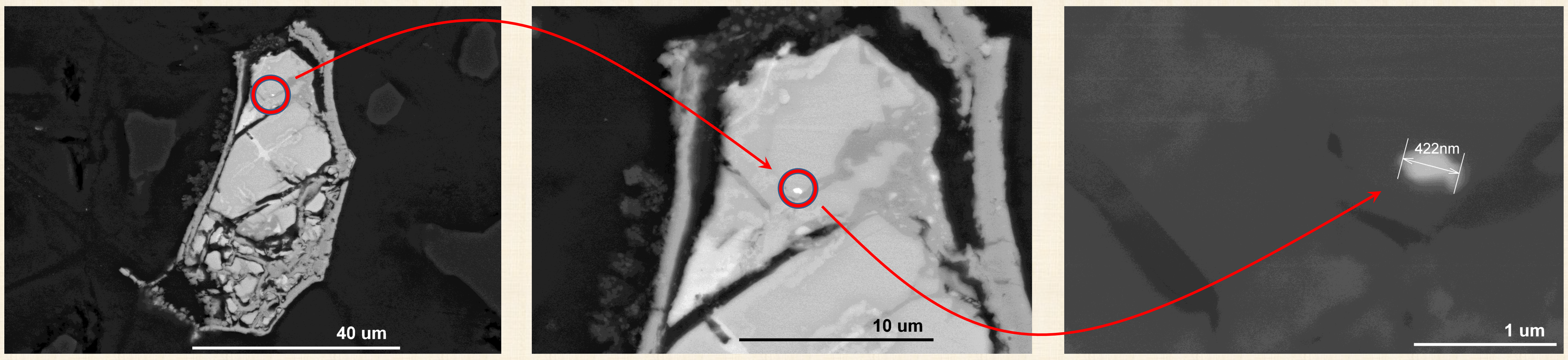
P-T path followed by garnet peridotites from the Vosges mountains, deduced from the two major stages defined by Altherr R. & Kalt A. [4]. Intersection of the peridotite path with a wet peridotite solidus under a high temperature geotherm would have made likely an early partial melting event. Deposition of sulphides and associated PGM would be related to this magmatic scenario.

PGM search :
PGM have been found in five peridotite occurrences (underlined on the map legend) from nine occurrences studied for PGM search among the seventeen recorded occurrences. The studied massifs were initially selected due to their size and freshness of the constituting rocks. For most of the massifs, one thin section or polished section was observed. Two thin sections were studied in three massifs. PGM were detected by SEM because of their very small size, less than a µm. In the most favorable case, they are analyzed by an EDS coupled with a Hitachi SEM.

Distribution of PGM :
PGM occurred in various types of peridotites from lithologically depleted garnet dunites as in the Blanchefontaine massif, up to more enriched lherzolitic peridotites, going through garnet pyroxene-poor lherzolite as in the Malpoirier massif. MicroPGM are localised in the serpentine matrix or in the kelyphitic texture generally associated with sulphides, especially Co-bearing pentlandite and less commonly pyrrotite and millerite. Other BMS are covellite, galena and chalcopyrite.



Co-pentlandite are rimmed by iron oxides (SEM).



Sperrylite included in Co-pentlandite partly transformed into hematite (SEM).

Normalized PGM EDS analyses and structural formulae :

PGM :
Sperrylite ($PtAs_2$), genkinite $(Pt,Pd)_4Sb_3$, kotulskite $Pd(Te,Bi)_2$, zvyagintsevite Pd_3Pb, and pasavaite $Pd_3Pb_2Te_2$ have been found as well as a Pt-bearing aurostibite $AuSb_2$.

Thalcusite		Genkinite		Sperrylite		Kotulskite		Zvyagintsevite		Pasavaite	
S	13,55	Sb	32,10	As	40,79	Te	9,46	Pb	41,88	Te	24,12
Cu	21,22	Pt	14,09	Pt	57,10	Bi	43,86	Pd	43,70	Pd	28,69
Tl	54,54	Pd	43,85	Sb	2,11	Pd	29,02	Cu	14,42	Pb	47,19
Fe	8,92	Ag	1,92			Ni	2,10				
Ni	1,77	Cu	6,91			Cu	15,56				
		As	1,13								
Total	100,00	Total	100,00	Total	100,00	Total	100,00	Total	100,00	Total	100,00
$Cu_{3,16}Tl_{2,53}Fe_{1,51}Ni_{0,29}S_4$		$Pt_{0,82}Pd_{4,69}Ag_{0,20}Cu_{1,24}As_{0,17}Sb_3$		$Pt_{1,08}Sb_{0,06}As_2$		$Pd_{1,92}Ni_{0,25}Cu_{1,72}(Te_{0,52}Bi_{1,48})$		$Pd_{2,03}Cu_{1,12}Pb$		$Pd_{2,85}Pb_{2,41}Te_2$	

Discussion : Only light-bearing PGE were found in PGM in association with intermetallic compounds. The presence of tellurides, antimonides and intermetallic alloys reflects hydrothermal low temperature conditions of formation [6] possibly related to late-stage serpentinization. This agrees with the recovery of some PGM in serpentinite veins far from coarse sulphides. On the other hand, BMS might have hosted the bulk of the PGE as high temperature sulphide solid solutions, before exsolution of the present-day observed PGM.
Textural evidence as the setting of the BMS in garnet gulfs, and their association with local multiple silicate phases, suggested that the high temperature sulphide solid solutions, and possibly sperrylite, were deposited from a S-saturated silicate melt. This is expected to have occurred during melt percolation in an ascending garnet peridotite sub-continental mantle fragment.
Preservation of coarse grained textures in garnet peridotites is more compatible with a diapiric uprise of a mantle piece above a subduction zone, than with deep-level ductile imbrication of mantle rocks with continental fragments at the base of the continental crust [7]. In the former case, successive partial melting events and cristallisation processes might have occurred in the ascending high temperature residual peridotites, as it was proposed for the origin of high temperature and high pressure cumulates in peridotites of Lower Austria [8]. This process is also well known in oceanic and ophiolitic mantle diapirs at a lower pressure regime [9].
The magmatic scenario retained is compatible with sulphide remobilization and deposition along previous silicate grains of the residual/fertilized garnet peridotites [10] in collisional zones. However the precise age of the magmatic event is unknown. It could be Variscan. On the other hand, an earlier age cannot be excluded as the magmatic processes occurred at a quite early stage of the petrogenetic evolution of the mantle garnet peridotite. In this case, the variscan age would be restricted to keliphitisation processs and crustal shear deformation.

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