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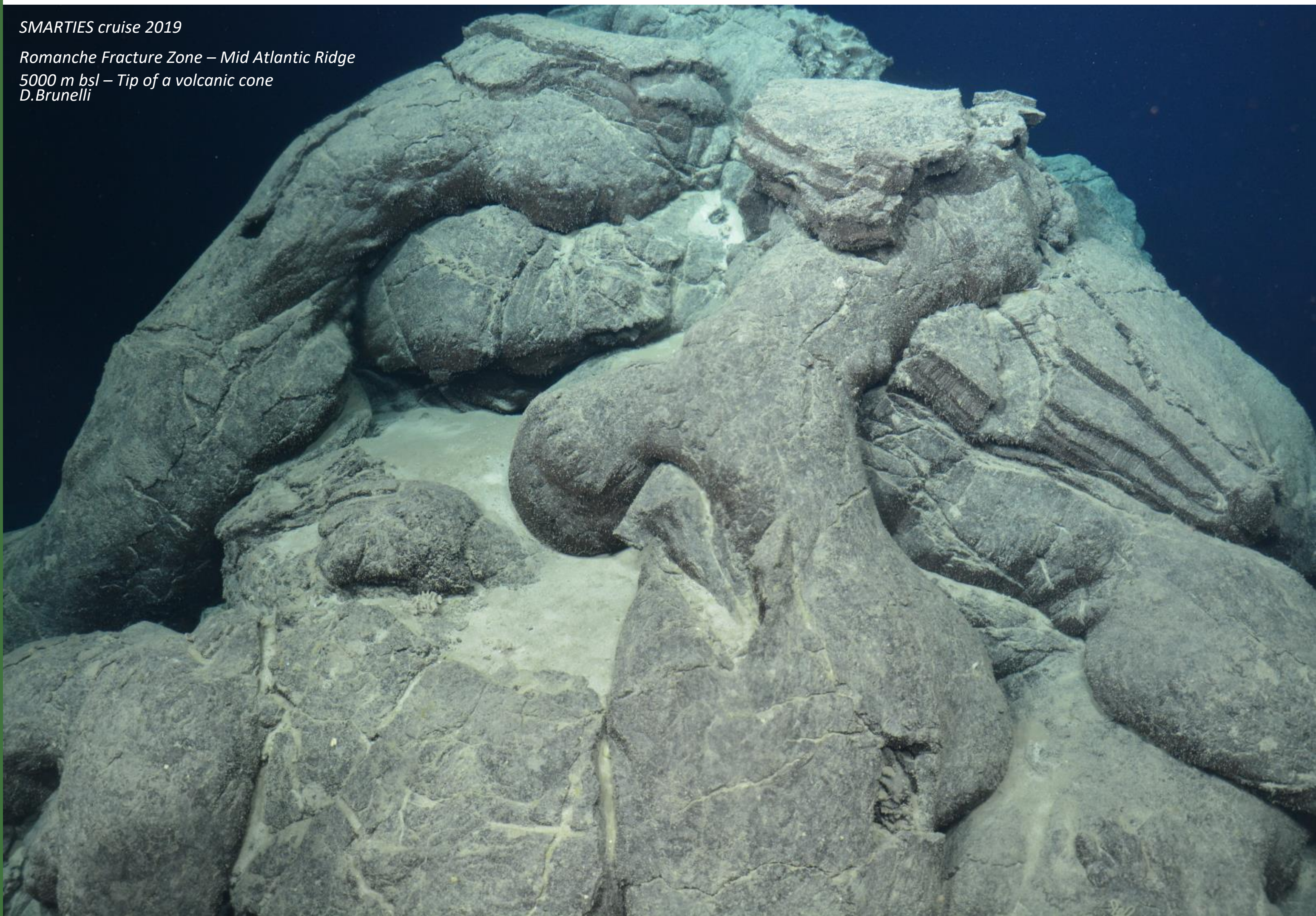

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ABSTRACTS VOLUME

BIRTH OF A LARGE QUATERNARY VOLCANIC EDIFICE SOUTHWEST OF THE BROTHERS ISLETS, NORTHERN RED SEA, EGYPTIAN MARGIN

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Keywords: *Magmatism, Cenozoic volcanism, Seamount, Quseir offshore, Northern Red Sea*

The Red Sea formed at the beginning of the Late Oligocene by rifting of the Eastern Africa continental lithosphere (Bosworth et al., 2005). The Northern Red Sea (NRS) has been usually interpreted as the result of a magma-poor rift, but several recent magmatic additions have been reported (Cochran, 2005). However, their description in terms of architectural features and relative age is still vague.

We interpreted gravity and magnetic data to discuss the possible occurrence of magmatic buildups offshore of Quseir, central Egypt. Six significant positive anomalies with values greater than 20 mGal and 150 nT were identified. One of these highs, located 10 km southwest of the Brothers Islands, was studied in detail using 3D seismic data. Combined observations indicate that the basement of the morphological high displays a different nature from the underlying basement, especially its magnetic properties. This basement was probably formed by rapid ascent and cooling of basaltic melt along a rifting related fault during post rift times.

The structural high forms an elliptical edifice that terminates upward with two conical summits, developed at 26° 15' 25" N and 34° 46' 53" E. The volcanic edifice cuts the sedimentary sequence and affects the seafloor morphology, thus testifying a recent extrusive activity. The sector of the edifice that rises from the surrounding seafloor measures about 6 x 1.6 km, while the buried apparatus about 7 x 17 km. The depth of the volcanic apparatus ranges between 215 and 2400 m bsl, while the elevation ranges from 300 to 520 m above seafloor. Different architectural elements have been recognized in the seismic volume (dikes, sills, disrupted blocks, uplift domings, cone shaped features and epiclastic plumes). The relationships with the local stratigraphy suggest a post-Pleistocene age for the magmatic event.

On a regional scale, several Tertiary and Quaternary volcanic edifices (*harrats*) have been extensively studied in the Arabian plate (Coleman, 1993). The youngest volcanic products found in the Harrat Ithnayn field date back to 500-120 ka. This volcanic field is located at a latitude comparable to the seamount studied (26° N). It is therefore possible to hypothesize that the magmatic event that forms the observed seamount may have a similar age since it originated in the same geotectonic context. These observations testify that post-rift magmatism is not limited to the Arabian plate, but extends further, towards the Nubian plate.

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TECTONO-METAMORPHIC EVOLUTION OF META-OPHIOLITES FROM PIEMONTE ZONE IN THE LANZO VALLEYS

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Keywords: *Combin Zone, Multiscale structural analysis, Ophiolitic rocks, Piemontese Zone, Western Alps, Zermatt – Saas Zone.*

A multiscale structural and petrological analysis has been performed to study the evolution of Piemonte Zone rocks from Val d'Ala and Valle del Tesso (Western Italian Alps). These meta-ophiolites are in contact and folded within the continental rocks of the Gran Paradiso Massif for the former and with the Sesia–Lanzo Zone for the latter. In literature meta-ophiolites of Val d'Ala are ascribed to the Lower Piemonte Zone of Western Alps, (Zermatt-Saas Zone; Dal Piaz, 2010), instead meta-ophiolites of Valle del Tesso to the Upper Piemonte Zone (Combin Zone; Dal Piaz, 2010). The two zones are described as recording different metamorphic evolutions during the Alpine evolution (Handy and Oberhänsli, 2004 and refs therein). In both areas meta-ophiolites comprise serpentinites, metabasites, metagabbros and eclogites. Rocks from Val d'Ala record five ductile superposed groups of structures developed under different metamorphic conditions, as suggested by different mineral assemblages. In Valle del Tesso four groups of ductile superposed structures associated with different parageneses have been described (Spalla et al., 1983; Assanelli et al., 2020).

In particular, the microstructures of eclogites and metabasites in Val d'Ala show three different stages of fabric evolution: coronitic textures are marked by Cpx+Grt+Rt±Gln; Gln+Ep+Ttn+Wm+Op mark the S2 foliation that corresponds to the regional scale tectonitic fabric; Amp+Chl+Ep+Op are generally associated with coronitic fabric and locally with the S3 foliation.

The microstructures observed in the eclogites and metabasites from Valle del Tesso show three different stages of fabric evolution: coronitic textures marked by Cpx+Grt+Rt±Gln; an S1 foliation marked by Gln+Ep+Ttn+Op; Amp+Chl+Ep+Op mark the regional S2 foliation that generally occurs as tectonitic fabric and locally as mylonitic.

Preliminary PT estimates indicate similar metamorphic evolutions for the rocks of both domains with a first re-equilibration stage under eclogite facies conditions, a second under epidote-amphibolite facies conditions, and a last re-equilibration stage under greenschist facies conditions.

The metamorphic evolutions of the meta-ophiolites suggest that Val d'Ala (Lower Piemontese) and Valle del Tesso (Upper Piemontese) rocks both re – equilibrated under a depressed thermal regime compatible with an oceanic subduction. They also show a cold exhumation PT path like other meta-ophiolites from the Western Alps (e.g., Agard and Handy, 2021).

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STRATIGRAPHIC AND PETROLOGICAL DATA ON THE LATE CRETACEOUS DURKAN COMPLEX (NORTH MAKRAN DOMAIN, SE IRAN): AN EXAMPLE OF PLUME-TYPE OPHIOLITE

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Keywords: *Makran Accretionary Prism, Late Cretaceous, plume-type ophiolite.*

Ophiolitic basaltic and metabasaltic rocks are widespread within accretionary and collisional belts and their tectono-stratigraphic setting and petrological features are sensitive to different geodynamic settings of formation. Among these different basaltic rocks, those with oceanic island basalt (OIB) chemical affinity are of special interest as they may represent remnants of deformed oceanic seamounts or, in other words, plume-type ophiolites (sensu Dilek and Furnes, 2011). It follows that multidisciplinary studies including stratigraphic and petrological data are fundamental to constraint the tectono-magmatic setting of formation and the geodynamic significance of the basaltic rocks within accretionary and collisional belts.

In the Makran Accretionary Prism (SE Iran), the North Makran domain consists of distinct tectonic units representing remnants of the Cretaceous-Paleocene accretionary-subduction complex formed in response to the northward subduction of the Neo-Tethys oceanic lithosphere. Among these units, the Durkan Complex shows abundant basaltic and meta-basaltic rocks as well as volcaniclastic rocks. We present here a summary of the results of geological and stratigraphic studies, as well as petrological investigations of the volcanic rocks forming the Durkan Complex. The latter is composed by distinct tectonic slices showing either non-metamorphic or slightly metamorphosed successions, which record volcanic activity and sedimentation during the Late Cretaceous in a seamount cap, seamount slope, and nascent seamount. Basaltic and metabasaltic rocks display transitional chemical affinity with compositions resembling those of plume-type mid-oceanic ridge basalts and within-plate OIB compositions with a clear alkaline affinity. Trace element and REE petrogenetic models show that the Durkan basaltic rocks were generated from the partial melting of depleted sub-oceanic mantle source that was metasomatized by OIB-type chemical components in a within-plate oceanic setting.

Collectively, these multidisciplinary data indicate that the Durkan Complex include fragments of oceanic seamount and can be regarded as a plume-type ophiolite, possibly formed in association to a Late Cretaceous mantle plume activity in the Neo-Tethys Ocean.

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OCEANIC DOLERITES AS A PROXY OF FROZEN AND UNCOMPACTED CRYSTAL MUSHES

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Keywords: *Magmatic processes; Crystal mush baseline; Mid-ocean ridges; Closed-system fractional crystallization.*

The accretion of the Earth's crust takes place in crustal magma chambers. Although the latter have long been considered as melt-dominated reservoirs, growing geophysical and petrological evidence called for a revision of the conceptual model of magma chambers, and suggested a new paradigm of magma reservoirs: crystal mushes filled with variable proportions of crystals and interstitial melt. The new concept has profound implications on melt migration, phase saturation and chemical differentiation of erupted melts. Nonetheless, the main processes driving the evolution of a magma reservoir are often documented in complex systems where magma replenishment, mixing, crystallization and assimilation occur concurrently and are generally overprinted by compaction and deformation. This calls for the documentation of the structural and chemical characteristics defining an undisturbed crystal mush that involves solely crystallization processes in a static closed system: a 'crystal mush baseline', that ought to be used while investigating more complex crystal mush processes.

We here present a detailed petro-structural and chemical study of metre-scale intrusions into the lower oceanic crust. Their bulk-rock major and trace element compositions compare with that of primitive MORB-type melts. They are characterized by subophitic textures of euhedral olivine and lath-shaped plagioclase embedded in poikilitic clinopyroxene and interstitial Fe-Ti oxides, thus including all the phases predicted along the crystal line of descent of a MORB melt, from liquidus to solidus. The crystal matrix is undeformed and shows no crystallographic preferred orientation, attesting of a static crystallization process. At the millimeter-scale, mineral phases are organized in primitive pockets enclosed in large evolved poikilitic crystals. Within a single thin section, mineral compositions span the whole range of composition defined by the gabbros from the Atlantis Massif. Plagioclase and clinopyroxene show normal major and trace elements zoning evidencing progressive crystal growth during fractional crystallization of the intrusion.

This study documents a proxy for frozen and uncompacted crystal mushes. It shows the complete evolution of a crystal mush, from the nucleation of primitive patches to the closure of the magmatic system. We provide here a textural and chemical baseline for crystal mushes, to be implemented with replenishment, mixing and assimilation processes in more complex settings.

FLUID-ASSISTED DEFORMATION PROCESSES AT THE ROOTS OF OCEANIC TRANSFORM FAULTS

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Keywords: *ultramafic mylonites - ductile rock deformation – dissolution-precipitation creep – oceanic transform fault – Atoba ridge.*

Oceanic Transform Faults represent more than 40% of the total length of Mid Ocean Ridges. Plate drifting results in a strike slip motion along these boundary sections, which globally release 10 times more seismic energy than spreading ridge portions. Nonetheless, very little is known on the internal mechanics and deformation pattern due to the extreme rarity of deep section' exposures.

Here we study the mineral fabrics of pervasively deformed peridotites collected from the Atobá ridge, an active transpressive ridge growing over the northern transform fault of the St. Paul transform system in the Equatorial Atlantic. These ultramafic mylonites are slices of the root of the fracture zone, tectonically exhumed along the inner thrust faults of a positive flower structure.

All samples evidence ductile deformation at 900-750°C, characterized by pervasive grain size reduction. We show that, at lower lithospheric conditions, grain size reduction occurs mainly by fluid-assisted dissolution-precipitation creep forming selvages of minor phases' neoblasts (pyroxenes, spinel, and amphibole). Orthopyroxene neoblasts formed by this mechanism display a similar CPO as the olivine neoblasts. This mechanism, previously reported in ophiolites and orogenic contexts (Hidas et al., 2016; Prigent et al., 2018), has never been recognized before in the oceanic transform environment. Fluid-assisted dissolution-precipitation creep allows deformation of stiff minerals at significant lower stresses and temperatures than dislocation creep, possibly driving an intense strain localization. The resulting weakening makes this mechanism a potential candidate to represent the main deformation law in the lower oceanic lithosphere, with important implications on the structures of oceanic transform faults and of long-lived detachments.

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CARBON AND SULPHUR ISOTOPIC COMPOSITION OF VARDAR OPHIOLITES OF NORTH MACEDONIA: IMPLICATIONS FOR VOLATILES CYCLING IN SUBDUCTION ZONES

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Keywords: *Supra-subduction zone ophiolites, volatiles, carbon and sulphur isotopes, Jurassic, North Macedonia.*

The North Macedonia is part of the Dinaric-Hellenic belt, an Alpine collisional belt extending from Slovenia to Greece. It resulted from the Mesozoic-Cenozoic convergence between Eurasia and Adria, ophiolite obduction, and continental collision after the closure of the Tethys Ocean. In this work we investigated the subvolcanic and volcanic rocks of the Vardar ophiolites of the North Macedonia, which represent the remnants of the Mesozoic Tethyan oceanic lithosphere formed in supra-subduction zone tectonic setting. Samples were collected at Lipkovo and Demir Kapija localities, in the northern and southern part of North Macedonia, respectively. Based on whole-rock major and trace element composition, two main groups of rocks can be distinguished: i) Group 1 rocks, which are subalkaline basalts showing backarc affinity and ii) Group 2 rocks, which are calc-alkaline basalts showing arc affinity. Petrogenetic modelling, based on trace and REE, indicates that Group 1 mantle sources were affected by limited metasomatic processes by slab-released components, in particular aqueous fluids and sediment melts, whereas the Group 2 mantle sources were strongly metasomatized by sediment melts and/or adakitic melts. In addition to this, the isotopic ratios of volatiles such as carbon (C) and sulphur (S) were also investigated to better constrain the nature and composition of the slab-components responsible for the metasomatism. In fact, volatiles are commonly transferred into the mantle from subduction of oceanic lithosphere and overlying sediments, whose C and S isotopic composition is well distinguishable from that of the mantle. The Group 1 rocks exhibit C-enriched and S-depleted signatures slightly different from those typical for the mantle, indicating a minor involvement of melts from the subducting sediments in the backarc basin settings. On the contrary, the C-depleted and S-enriched isotopic signatures of the Group 2 rocks suggest a major involvement of melts derived from the subducting sediments rich in organic matter and sulphate phases. Therefore, both geochemical and isotopic data of the North Macedonia ophiolites indicate that the sub-arc mantle sources are more affected by slab-released fluids than those of the backarc basin, which are more distal from the trench. This approach may be useful to better constrain the composition of the metasomatic agents, as well as to understand the origin and the fate of volatiles near subduction zones.

OPHIOLITES AT MONTEFERRATO (PO): NEW DATA AND POSSIBLE ORIGIN

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Keywords: *ophiolites, Monteferrato, Apennines.*

The Ophiolites cropping out north of Prato, in the area of Monteferrato, are overlaid by the typical oceanic sedimentary sequence, in turn covered, with no clear sedimentary/tectonic contact, by the Calvana Supergroup formations (Abbate & Sagri 1970, Principi & De Luca-Cardillo 1975).

A recent field survey at the scale 1:10,000 envisaged the Monteferrato Ophiolites consist of a main body of Serpentinite, with preserves portions, ranging in size from dm3 to dam3, of the Peridotite Lherzolitic protolith, less serpentinised; Gabbro dykes intrusive into the Serpentinite; Basalt dykes intrusive into both Gabbro and Serpentinite; and Pillowed basalts interlayered with the early beds of Radiolarite. The oceanic sedimentary cover follows with Calpionella Limestone, and Palombini Shale. This sequence is topped by the marly-shales of the sillano frm. Of the Calvana Supergroup.

For this work, a number of thin sections have been made to understand the structure and mineralogy variations in the less serpentinized peridotites bodies, from which the ornamental stone known as Verde Prato had been quarried since XII century to XX century; also, for that these analyses deserve a particular interest.

To representatively check the minero-petrographic assemblage, three thin sections, cut perpendicular to each other, have been obtained from each sample. TOM polarized analysis showed the rock is isotropic and the original high-T peridotitic minerals are pseudomorphically replaced by low-T phases. The primary minerals identified were Olivine, orthopyroxene, clinopyroxene, and spinel.

The only preserved mineral is the red spinel (chromite); in addition, peculiar coarse-grained opaque + ex-Opx aggregates were interpreted as derived from former high-PT garnet. As already evident on hand, an irregular network of discontinuous thin veins filled of chrysotile, lizardite or rarely antigorite systematically cuts the rock.

The described phases were confirmed by means of the □-Raman spectrometry (Compagnoni et al., 2021).

The inferred data indicate that the Verde Prato serpentinite did form at the expense of a lherzolite statically recrystallized in the spinel peridotite field that shows evidence of the transition from an older garnet lherzolite with a tectonic fabric.

According to Marroni et al. (1998) and Vannucchi et al. (2020), this setting can be referred to exhumed serpentinized subcontinental peridotites for diapirism of portion of the down going Ligurian oceanic slab.

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PRESERVED LAWSONITE IN THE META-MAFIC ROCKS OF THE ALBERGIAN UNIT (LIGURIA-PIEMONTE ZONE, WESTERN ALPS)

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Keywords: *lawsonite, lithostratigraphy, petrography, thermodynamic modeling, Albergian unit, Liguria-Piemonte zone, Western Alps.*

The Albergian unit (AU hereafter), belonging to the Liguria-Piemonte oceanic zone of the Western Alps, comprises a thick sequence of calcschists and minor meta-ophiolitic bodies, from metric to kilometric in size (Caron, 1977; Servizio Geologico d'Italia, 2002, 2020). The occurrence of fresh lawsonite in the meta-sediments of this unit is known since the end of the XIX century (Franchi, 1897).

Considering the AU section exposed in the Monte Albergian – Gran Mioul area (Upper Chisone valley), the aim of this contribution is twofold: (i) to report the occurrence of fresh lawsonite also in the meta-mafic rocks and, (ii) to constrain the tectono-metamorphic evolution of one of these meta-mafic bodies. In the examined area, the AU consists of a kilometric body of basalt and/or diabase meta-breccias (with minor meta-gabbros and meta-plagiogranite clasts and blocks), covered by discontinuous layers of quartzitic meta-sandstones, black micaschists, and eventually a thick sequence of calcschists. Through a detailed petrographic and minero-chemical study of these lithologies, we recognized preserved magmatic textures in the meta-mafic clasts, and the occurrence of fresh lawsonite, only partially replaced by retrograde phases.

Two representative samples were investigated for phase equilibrium modeling: a Mg-Al meta-gabbro and a meta-breccia with plagiogranite clasts. The isochemical phase diagrams approach (i.e. P-T pseudosections), applied for the first time in this unit, allowed constraining the metamorphic peak in the lawsonite blueschist-facies, at about 18-21 kbar and 380-430 °C, followed by a partial re-equilibration in the epidote-stability field.

These results, supported also by published literature (e.g. Agard et al., 2001), allow to better constrain the tectono-metamorphic evolution of the AU in the complex tectonic framework of this sector of the Western Alps (Corno et al., 2021).

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DENSITY STRUCTURE OF PERIDOTITIC SYSTEMS: CLUES FROM THE ELASTIC PROPERTIES OF MANTLE MINERALS COUPLED WITH THE THERMAL STATE OF THE LITHOSPHERE

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Keywords: *Equations of State, Mantle minerals, Upper mantle density structure, Fertile and depleted peridotites, Cold-hot geotherms*

Understanding the density structure of the upper mantle is critical to our comprehension of the tectonic and magmatic evolution of the lithosphere and crucial for understanding large-scale geodynamic phenomena. The density of the upper mantle ultimately depends on both its thermal structure and composition, which can be derived from petrological-geochemical studies on exhumed mantle samples and from the interpretation of geophysical data. The density of mantle rocks is a function of compositions, modes and elastic properties of constituent minerals and can be explored from the perspective of their Equations of State (EoS).

In this contribution, we present an assessment of the thermoelastic parameters of mantle orthopyroxene, clinopyroxene, spinel and garnet based on X-Ray diffraction data and direct elastic measurements available in the literature. These new EoS, combined with those published for mantle olivine and magnesiochromite, are appropriate to describe the elastic behavior of these phases under the most relevant P–T conditions and bulk compositions of the Earth's mantle and suitable to calculate the physical properties (elastic moduli, thermal expansions, densities, etc.) of mantle peridotites.

Following a simplified parametrization and taking into account the variability observed in natural peridotite xenoliths, we investigated how the variations in bulk composition and thermal regimes of the lithospheric mantle affect its density structure. Density profiles for fertile and depleted peridotitic systems were calculated under very cold (35 mWm-2), intermediate (45 mWm-2) and relatively hot (60 mWm-2) geothermal gradients at P comprised between 1 and 8 GPa. These results agree with classical thermodynamic modelling and show that (i) relatively hot thermal conditions promote a decrease of density with depth in the uppermost layer of Earth's mantle and (ii) the density structure of the lithospheric mantle is predominantly controlled by its thermal state rather than by its bulk chemical composition.

As a case study, we applied our parametrization to model the density structure of a virtual 1-D vertical profile of the lithospheric mantle below the Ivrea Verbano Zone (IVZ). This was done by modelling the density of the spinel lherzolite from the Balmuccia Massif before it was emplaced at crustal levels. The obtained results may have profound implications for the interpretation of the geodynamic evolution of this area.

RIFTING EVOLUTION OF THE LITHOSPHERIC SUBCONTINENTAL MANTLE: NEW INSIGHTS FROM THE EXTERNAL LIGURIAN OPHIOLITES (NORTHERN APENNINE, ITALY)

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Keywords: *mylonite; rifting; Jurassic Western Tethys*

The present study focuses on the mantle bodies included in Upper Cretaceous sedimentary melanges of the External Ligurian units (Northern Appennine), within the Monte Gavi and Monte Sant'Agostino areas. Here, two distinct pyroxenite-bearing mantle sections were recognized.

The Monte Gavi mantle section is nearly undeformed and records a process of melt infiltration and reaction under plagioclase-facies conditions, involving both peridotites (mostly harzburgites) and enclosed spinel pyroxenite layers. The melt-rock interaction is estimated to have occurred at 0.7–0.8 GPa. In the Monte Gavi peridotites and pyroxenites, the spinel-facies Cpx was partially replaced by plagioclase and new Opx (± secondary Cpx). The reactive melt migration led to relatively high TiO2 contents in relict Cpx and spinel, with the latter also having high Cr#. The Monte Gavi peridotite-pyroxenite sequence preserves high T (1200-1250°C) recorded by geothermometers based on slowly diffusing elements (REE, Y), presumably in response to the melt infiltration event, followed by subsolidus cooling until 900°C.

The Monte Sant'Agostino mantle section displays a widespread ductile shearing and no evidence for melt-rock interaction under plagioclase-facies conditions. The main deformation phase recorded by the peridotites (mostly lherzolites) is estimated to have occurred at 750–780 °C and 0.3–0.6 GPa, and gave rise to protomylonitic to ultramylonitic textures. The enclosed pyroxenite layers yielded higher temperature and pressure estimates (870–930 °C and 0.8–0.9 GPa). Most likely, plagioclase crystallization occurred earlier in the pyroxenites than in enclosing lherzolites, thereby enhancing strain localization and formation of mylonite shear zones in the entire mantle section.

We subdivide the External Ligurian subcontinental mantle section into three distinct domains, developed in response to the rifting evolution that ultimately formed a Middle Jurassic ocean-continent transition: (1) a spinel tectonite domain that underwent static plagioclase development but no significant deformation and melt-rock reaction under plagioclase-facies conditions, (2) a plagioclase mylonite domain experiencing melt-absent deformation, and (3) a nearly undeformed domain that underwent reactive melt infiltration under plagioclase-facies conditions. We relate mantle domains (1) and (2) to a rifting-driven uplift in the late Triassic accommodated by large-scale shear zones consisting of plagioclase mylonites.

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THE SEAFLOOR HYDROTHERMAL ORIGIN OF A Cu-(Zn) DEPOSIT WITHIN AN ECLOGITIC-FACIES OPHIOLITIC SEQUENCE (COLLE DELLA BORRA, WESTERN ALPS)

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Keywords: *Seafloor massive sulphides, Ophiolites, Western Alps*

This work provides the first detailed mineralogical-petrographical characterization of the massive sulphide deposit of Colle della Borra (Val Soana, Western Alps). The deposit is hosted within an ophiolitic sequence composed of calcschists with interlayered metabasites, micaschists, chloriteschists, quartzites and marbles, metamorphosed under eclogitic-facies conditions (Modesti, 2021). In particular, the ore deposit is interposed between Grt-Cld micaschists in the foot-wall and chloriteschists in the hanging-wall. The ore mineral association mainly comprises pyrite, chalcopyrite and pyrrhotite, along with subordinate sphalerite.

A detailed micro-textural study was carried out, which was supported by spot electron microprobe analyses and elemental maps of some trace elements (Co, Ni, As). Despite the extensive metamorphic recrystallization, relicts of interpreted primary oceanic features were observed in a few pyrite grains. These relicts are represented by fine-grained aggregates (2-10 µm) and by colloform textures (cf., Natale and Visetti, 1980; Giacometti et al., 2014), which are typical of seafloor pyrite. Further evidence is provided by chemical zoning in a pyrite crystal. In particular, Co zoning allows to clearly identify two generations of pyrite: a primary one (PyI), at the core of the crystal, with concentrations of Co (0.15-0.29 wt%) typical of pyrites from seafloor volcanogenic massive sulphide (VMS) deposits (e.g., Fantone et al., 2014); a secondary one (PyII), overgrown on the first, with much higher Co concentrations (2.13-2.49 wt%), attributable to metamorphic processes. Accordingly, a primary seafloor, hydrothermal-volcanogenic origin of the mineralization is suggested, which occurred on the Ligurian-Piedmont Ocean floor and was followed by subduction and exhumation during the Alpine orogenic cycle. The textural characters of the two generations of pyrite also reflect the metamorphic history: the anhedral morphology of PyI testifies the corrosion that occurred at some point during the prograde path, while the overgrowth of PyII on PyI, reflects the recrystallization processes that occurred during the subsequent retrograde/exhumation phase.

The presence of this VMS deposit and the abundance of terrigenous material in the host ophiolitic sequence suggest formation at the ocean-continent transition.

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PYROXENITIZATION OF DUNITES IN THE LOWER CONTINENTAL CRUST: EVIDENCE FROM THE IVREA MAFIC COMPLEX (ITALIAN ALPS)

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Keywords: *reactive melt migration, pyroxenite, olivine, spinel*

Reaction processes between a percolating melt and an olivine-rich matrix to generate pyroxenites were hypothesized to occur within mafic-ultramafic intrusive sequences from the lower continental crust, both in convergent (e.g., Jagoutz et al., 2011) and extensional (e.g., Locmelis et al., 2016) tectonic settings. These processes may drive the chemical differentiation of mantle-derived magmas emplaced at deep levels of the continental crust. Here, we document the process of dunite pyroxenitization within the Ivrea Mafic Complex (Italian Alps), which is a km-scale gabbronorite-diorite body intruding the lower continental crust during the post-Variscan transtensional tectonics. In particular, we have carried out new petrographic and petrological investigations of an ultramafic lens of inferred cumulus origin localized at the deepest levels of the Complex, near the Balmuccia mantle massif.

The studied lens consists of ~60 m thick Fe-rich dunites (Fo82 olivine) permeated by cm-scale thick pyroxenite veins and mantled by up to 10 m thick pyroxenites. The contact between the dunites and the external pyroxenites is characterized by orthopyroxene-rich microveins in the dunite, and minor embayed olivine (Fo80) in the pyroxenite. These contact rocks and the pyroxenite veins include up to 10 vol% amphibole and an accessory oxide-sulfide association mostly consisting of Cr-poor spinel (Cr# = 3-10), Cr-magnetite, pentlandite and troilite. Away from the contact with the dunites, the external pyroxenites contain accessory amounts of anorthite-rich plagioclase, ilmenite and sulfides. The external pyroxenites also display a gradual outward Mg# decrease in pyroxenes and amphibole, similarly to what observed along mm-scale transects from the dunites to the enclosed pyroxenite veins. Remarkably, the chondrite-normalized REE pattern of both external and vein pyroxenites has negative Eu anomaly and marked LREE depletion. In the dunites, the accessory spinel (Cr# = 11-19) includes irregular Cr-magnetite blebs and rims, and is associated with relatively low sulfide amounts.

We propose that the pyroxenites developed by reaction between dunites and infiltrating melts relatively rich in SiO2 and H2O, which had already undergone plagioclase fractionation. The process of pyroxenite formation most likely started through a replacement-dominated mechanism, involving olivine dissolution and spinel recrystallization, driven by pervasive melt infiltration through olivine-grain boundaries.

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TRACKING THE DYNAMICS OF A MIDDLE TRIASSIC VOLCANO THROUGH THE STUDY OF ZONED CLINOPYROXENE

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Keywords: *Mixing, Dolomites, Clinopyroxene texture.*

The study of compositional zoned crystals within magmatic rocks have reached a fundamental role in the investigation of the geometry and dynamics of the plumbing systems beneath active volcanoes. Owing to the lack of preservation of their products and crystals as well, Mesozoic volcanic complexes in Dolomites (Southern Alps) are normally not suitable to this approach. In this respect, the Middle Triassic volcano-plutonic complex of Cima Pape represents an exception, due to the excellent state of preservation of its products and the large presence of compositional zoning in clinopyroxene crystals. The complex is composed by a 50 to 300 m thick gabbroic to monzodioritic sill overlaid by basaltic to trachyandesitic volcanites with high Porphyricity Index (P.I. 45-48%). In the volcanites, clinopyroxene is often zoned, with the typical zoning pattern consisting of one or more high-Mg# and Cr2O3-rich diopsidic bands (Mg# 84-91; Cr2O3 up to 1.2 wt%) formed between augitic cores and rims with relatively lower Mg# and Cr contents (Mg# 70-77; Cr2O3 <0.1 wt%). Chondrite-normalized incompatible trace element patterns of the low-Mg# portions show Nb, Ta, Sr, Zr and Ti negative anomalies and Th-U positive peaks. The high-Mg# bands, in comparison have similar patterns but lower trace element abundances. REE patterns in both high-Mg# and low-Mg# domains have a convex-upward shape and La/YbN from 1.3 to 2.1. Thermobarometric calculations reveal that the diopsidic bands were in equilibrium with a more primitive, hotter and H2O-poorer basaltic melt (Mg#=65-70; T=1130-1150°C; H2O=2.1-2.6 wt%) than cores and rims, which likely formed in a colder, H2O-richer trachyandesitic melt (Mg#=43-45; T=1035-1075°C; H2O=2.6-3.8 wt%). These results bring us to define a model that involves a mafic recharge of one or multiple pulses of primitive, hot, and H2O-poor basaltic magmas into the “mush-type” shallower (7-14 km) portions of the plumbing system that led to the formation of the high-Mg# bands coating the already formed augitic cores. The peculiarity of clinopyroxene texture in Cima Pape rocks allowed us to treat this ancient volcano in the same way as the active ones, with the opportunity to make comparisons and test the methods currently adopted for active systems (e.g., Stromboli, Etna). This approach also represents a new frontier for investigating the dynamics of the Mid-Triassic magmatism in the Southern Alps, where these features seem to be more common than initially believed.

TRANSITION FROM OROGENIC-LIKE TO ANOROGENIC MESOZOIC MAGMATISM IN THE SOUTHERN ALPS: EVIDENCE FROM THE GEOCHEMISTRY OF ALKALI-RICH DYKES FROM IVREA-VERBANO ZONE

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Keywords: *Alkali-rich dykes, Mesozoic magmatism, mantle melts, Ivrea-Verbano Zone*

Dyke swarms intruding the mantle–continental crust transition of the Adria plate as documented by the Ivrea-Verbano Zone, Southern Alps represent a unique opportunity to investigate the evolution of mantle melts from Late Paleozoic to Mesozoic in the post-collisional Variscan realm. Thus, we present new petrological and geochemical data of dyke swarms intruding the Finero Phlogopite Peridotite mantle unit. Dykes are from few cm to >1 m thick and cut at high angle the mantle foliation.

The dyke swarms are composed of cumulus hydrous peridotite, hornblendite, diorite and anorthosite. Many dykes are composite, showing variable proportions of melanocratic and leucocratic layers. Volatiles overpressure during late magmatic stage is testified by plastic flow, development of porphyroclastic structure and the widespread segregation of a fine-grained mica matrix. The dykes show mineralogical and geochemical features varying between two end-member series.

A dyke series is characterized by Al-rich pargasite (Al_2O_3 up to 18 wt.%) and phlogopite, associated with apatite, calcite, sulphides ± sapphirine. The amphiboles show i) large LILE and LREE contents, ii) negative Nb, Ta, Zr and Hf anomaly and iii) isotopic oxygen composition heavier than the mantle interval, which support the occurrence of recycled continental crust components in the parent melts and impart an overall "orogenic" affinity.

The second series mainly consists of Al-poorer pargasite, phlogopite and albite, associated with apatite, monazite, ilmenite, zircon, Nb-rich oxides and carbonates. Amphiboles are still enriched in LILE and LREE, but show extreme enrichments in Nb, Ta, Zr and Hf; pointing to an "anorogenic" alkaline affinity. Zircons from the "anorogenic" dykes are mostly anhedral, with homogenous internal structure or sector zoning. The strongly positive εHft (av. +10) of zircons and the Sr isotopic composition of amphiboles (0.7042) point to a derivation of such "anorogenic" melts from mildly enriched mantle sources. Concordant $^{206}Pb/^{238}U$ zircon ages for "anorogenic" dykes vary from 221 ± 9 Ma to 192 ± 8 Ma. Some dykes show both "orogenic" and "anorogenic" affinities, thus recording different pulses of mantle melts and metasomatic overprinting. As a whole, the dyke swarms record a transition from "orogenic" to "anorogenic" affinity indicating re-opening of dykes' conduits for the melt ascending, pointing to a progressive change of the mantle sources of the Mesozoic magmatism of the Southern Alps.

SEAFLOOR GEOLOGY AT THE BIGHT AND CHARLIE GIBBS TRANSFORM FAULTS (57-52ºN, MID ATLANTIC RIDGE): PRELIMINARY RESULTS FROM AKADEMIK SERGEY VAVILOV EXPEDITION 53

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Keywords: *Long-lived transform faults, Northern Atlantic, ASV53 Oceanographic cruise*

Oceanographic expedition 53 aboard on the Russian research vessel "Akademik Sergey Vavilov" took place in the Northern Atlantic Ocean on September and October 2020. The main objective of this cruise was to investigate the Charlie Gibbs and Bight transform faults (TF), located along the Mid Atlantic Ridge at ~ 52°N and 57°N of latitude, respectively. The Charlie Gibbs right-lateral multi-transform system (52°-53°N) is one of the main transform systems of the North Atlantic, active since the early phases of North Atlantic rifting. It offsets the Mid Atlantic Ridge (MAR) by ~340 km, and it includes two distinct transform faults linked by a short ~40 km-long intra-transform spreading centre (ITR). The two adjacent MAR segments are influenced by both the Azores and the Iceland mantle plume. New high resolution multibeam surveys and a dense sampling program of the entire transform were carried out along the Charlie Gibbs TF system during expeditions of R/V Celtic Explorer (2015, 2016 and 2018; Georgiopoulou A. and CE18008 Scientific Party, 2018) and R/V A.N. Strakhov (2020; Skolotnev, S. et al., 2021). Bathymetric and magnetic data were acquired during the R/V Marcus Langseth 2013 and R/V Neil Armstrong 2019 cruises along the Bight TF (Martinez and Hey, 2022). During ANV53, we surveyed an area of 54552 km2 covering the entire Charlie Gibbs transform system, part of the Bight TF and their adjacent MAR spreading segments. We collected: a) bathymetric data using single beam hydrographic echo sounder EA600 (Kongsberg); b) more than 2500 km of magnetic profiles using a SeaSpy marine magnetometer manufactured by Marine Magnetics and towed 220 m respect to the stern to reduce the magnetic noise induced by the ship; c) two sediment cores in the Charlie Gibbs FZ region using a 6 m long gravity corer with inner diameter 11 cm; d) 1850 kg of rock samples including carbonates, basalts, gabbros and mantle peridotites from 27 dredges. We present here preliminary data from cruise ASV53 in order to discuss the geology and geodynamics of the Charlie Gibbs and Bight TFs.

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DRIFT-RIFT TECTONIC MODE AND MAGMATISM AT THE ORIGIN OF ROUND-SHAPED TO LINEATED OCEANIC LITHOSPHERE IN TYRRHENIAN BASIN

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Keywords: *oceanic lithosphere, drift to rift, MORB and granite magmatism, shallow- to deep-water seafloor, active spreading, ophiolite peridotite, late Tortonian to Present, Tyrrhenian Basin.*

Offshore Sardinia, low-angle east-dipping faults were associated to strong extension in LateTortonian/Early Messinian (LT/EM; Sartori et al., 2004). About contemporary MORB volcanim (DSDP 373A; ~7 Ma) and hyperextension in Vavilov Basin caused emplacement of round-shaped oceanic lithosphere above west-directed subduction (Savelli & Ligi, 1917). The absence of evaporites in newly formed oceanic crust can be a consequence of shallow-water until Early Pliocene. LT/EM volcanic activity was absent on the conjugated margins of Sardinia-Campania. Sardinia Miocene calcalkaline cycle linked to Sardo-Balearic Basin opening ended at ~12 Ma, and at 5/4 Ma started the Pliocene alkaline cycle linked to Tyrrhenian rifting. Alkaline basalt volcanism (4.3 - 1.9 Ma) at Gortani Ridge-ODP 655, Vavilov and Magnaghi Seamounts, ODP 651 linked to N-S high-angle faults caused foundering of Vavilov Basin seafloor (lineated spreading). Vavilov Volcano is not older than 2.4 Ma if negative magnetic high belongs to Matuyama Chron. Rhyolitic volcanism on the Campania margin (Ponza island) shows age of 4.4 Ma.

At the Olduvai subchron (1.9-1.7 Ma), low-angle east-dipping faulting along Vavilov Basin axis was associated to hyperextension and exposure of ophiolite peridotite (ODP 651). Contemporary MORB volcanim (ODP 650) and strong extension in Marsili Basin caused local emplacement of round-shaped oceanic lithosphere. By Olduvai age drift, volcanism was absent or scarce on all the margins. Such absence is evident by the LT/EM drift period, too. In the last Ma, late Pleistocene rift-related volcanism was widespread in seafloor as well as on the margins. The alkaline cycle resumed in NW Sardinia (1-0.8 Ma – Recent). Alkaline basalts erupted at Vavilov (Brunhes Chron - <0.8 Ma). Also the huge calcalkaline Marsili Volcano formed during Brunhes (lineated spreading). <1 Ma old calcalkaline K-rich volcanism developed on the margins of Marsili Basin. Active volcanism is found at Marsili Volcano, Aeolian Arc, and Neapolitan area.

To the north of 41° parallel W-E strike-slip lineation, late Miocene rifting was accompanied by acidic magmatism in the absence of MORB volcanism. Weak extension, in contrast to southern strong extension was associated with (e.g.) 7 Ma old granodiorite emplacement and ophiolite peridotite exposure at Elba island. Granite magmatism of similar age is found also at Vercelli seamount, NE Sardinian offshore (41° parallel lineation).

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TEMPERATURES AND COOLING RATES PRESERVED BY THE NEW CALEDONIA OPHIOLITE HELP TO UNTANGLE THE THERMAL HISTORY OF THE FOREARC LITHOSPHERE.

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Keywords: *forearcs, New Caledonia ophiolite, mantle*

To decipher how cooling and thermal re-equilibration proceeds in the forearc lithosphere, we have performed a detailed geothermometric investigation of the New Caledonia ophiolite, which represents a unique example of proto-arc sequence built during subduction infancy (Marchesi et al., 2009; Secchiari et al., 2020).

A large dataset, including more than 80 peridotite (lherzolites and harzburgites) and mafic-ultramafic samples, was considered.

Equilibrium temperatures calculated for the lherzolites indicate that spinel and plagioclase-bearing lithologies register similar thermal histories. Computed TREE-Y (Liang et al., 2013) are among the highest ever documented for ophiolitic peridotites (1256–1334 °C), akin to modern sub-oceanic mantle. By contrast, T up to 1400 °C were revealed by some plagioclase-lherzolites. Such elevated values can be ascribed to pyroxene disequilibrium due to reactive melt percolation (Dygert et al., 2015). Closure temperatures models (TBKN vs TREE) show that the lherzolites underwent cooling from asthenospheric temperatures at rates of ≈ 10-3 °C/y, in the range of the oceanic lower crustal lithosphere re-equilibrated via conduction (Coogan et al., 2002; Dygert et al., 2017). Similar rates were provided by Ca-in-olivine geospeedometer, suggesting that cooling rates did not significantly vary at lower temperature intervals.

As a whole, these features can tentatively be ascribed to post-melting evolution and exhumation along a transform fault, in a marginal basin predating Eocene subduction.

Cpx-free harzburgites record a high-T evolution, followed by quenching and obduction. The relatively high TCa-in-Ol, TOl-Sp and cooling rates computed from TCa-in-Ol (≈ 10-3 °C/y) are uncommon for this geodynamic setting and possibly reflect the development of an ephemeral subduction system, followed by fast emplacement.

Temperature profiles across the crust-mantle transect point to high closure temperatures, with limited in-depth variations. These results are indicative of injection and crystallization of non-cogenetic magma batches in the forearc lithosphere, followed by thermal re-equilibration at rates of ≈ 10-4-10-3 °C/y.

Our study shows that the thermal conditions recorded by forearc sequences are closely connected with regional tectonics and previous lithosphere evolution. Detailed sampling and exhaustive knowledge of the geological background are hence pivotal to unveil the cooling histories of these particular lithospheric sections.

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