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figg. 5

Geodynamics and magmatism of the Central Mediterranean region

Geodinamica e magmatismo della regione Centro-Mediterranea

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ABSTRACT - The Mediterranean area is one of the most intriguing places on Earth where geodynamics and volcanoes are strictly related, and evolved through time. The complexity of the tectonic setting is further enriched by the observed shift of the petrochemical affinity of magmas, in the same volcanic area, from subduction-related to intraplate. The successive opening of back-arc basins (e.g., Ligurian-Provençal basin, Tyrrhenian Sea), following the roll-back of the subducting Adria Plate, produced a migration of magmatism to form a transitional eastward pattern of volcanoes both onshore and offshore.

The Mio-Pliocene volcanic rocks occurring in the Central Mediterranean area are characterised by exceptional variability of the petro-chemical and isotopic features, which allow the distinction of several sectors, when also the areal distribution is considered.

Thus, the Mediterranean area has always been site of studies focused on magma genesis and on the geodynamic significance of the complex scenario achieved through time. In the scientific literature, a large number of papers were published on the magmatism of each single volcanic association/area, but very few dealt with the general picture of the offshore magmatic and geodynamic evolution.

The aim of this chapter is to provide an outline of the most prominent geological, petrological, geochemical and isotopic characteristics of the submarine volcanic centres found in the Central Mediterranean basin, with the aim of providing a fairly complete picture of the existing relationships between the geodynamics and the igneous petrology in this area.

KEY WORD: Central Mediterranean, Tyrrhenian Sea, geodynamic and magmatic evolution, volcanic seamount sectors, subduction.

RIASSUNTO - L'area del Mar Mediterraneo rappresenta una delle più interessanti dimostrazioni sulla Terra di quanto geodinamica e attività vulcanica siano strettamente interconnesse, sia nello spazio che nel tempo. Il complesso assetto tettonico generale di questo areale è ulteriormente arricchito dalla variazione di affinità petro-chimica dei magmi da ambiente di subduzione a intra-placca, anche all'interno della stesse aree vulcaniche. L'apertura dei bacini di retro-arco (e.g., bacino Liguro-Provenzale, Mar Tirreno) che ha seguito l'arretramento della Placca Adria in subduzione, ha indotto la migrazione del magmatismo verso Est come evidenziato dalla distribuzione areale dei vulcani continentali e sottomarini.

Le rocce vulcaniche Mio-Plioceniche dell'area Centro-Mediterranea sono distinte da caratteristiche petro-chimiche e isotopiche eccezionalmente variabili. Tali caratteristiche permettono di riconoscere e delimitare i diversi settori, quando anche la distribuzione areale viene considerata.

Pertanto, l'area Mediterranea è sempre stata oggetto di numerosi studi relativi alla genesi dei magmi e volti all'interpretazione del complesso scenario geodinamico che si è sviluppato nel tempo. Tra

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questi lavori scientifici, la maggior parte è incentrata sul magmatismo di una singola area o associazione vulcanica mentre solo una minima parte fornisce un quadro generale dell'evoluzione geodinamica e magmatica dei vulcani sottomarini.
Lo scopo di questo contributo è quindi proprio quello di fornire un inquadramento complessivo delle principali caratteristiche geologiche, petrologiche, geochimiche e isotopiche dei centri vulcanici sottomarini che si ritrovano nel bacino del Mediterraneo Centrale. L'obiettivo principale che ci proponiamo è quello di fornire un quadro completo delle relazioni esistenti tra geodinamica e petrologia delle rocce ignee in quest'area.

PAROLE CHIAVE: Mediterraneo Centrale, Mare Tirreno, evoluzione geodinamica e magmatica, settori di seamount vulcanici, subduzione.

1. - INTRODUCTION

The Italian volcanic seamounts lie within the Central Mediterranean area, located along the convergent margin between Eurasia and Africa plates. In the Central Mediterranean, the Africa and Eurasia plates underwent several hundred kilometres of convergence since the early Tertiary.

Such a convergence has been mainly achieved by north-westward dipping subduction of the Ionian-Adriatic lithosphere beneath the Eurasia plate. Trench retreat and the progressive fragmentation of the Adriatic-Ionian slab have characterized the Central Mediterranean subducting system (e.g., PATACCA *et alii*, 1992; FACCENNA *et alii*, 1997, 2001A, 2015; CIFELLI *et alii*, 2007 and references therein). Presently, evidences for active narrow slabs is given by sub-crustal earthquakes occurring down to 90 km depth below the Northern Apennines (SELVAGGI & AMATO, 1992), whereas a well-defined Benioff zone down to about 670 km, reveals a direct trace of a still active process of lithospheric subduction from the Ionian foreland below the Calabrian Arc and Tyrrhenian Sea (e.g., ANDERSON & JACKSON, 1987; SELVAGGI & CHIARABBA, 1995).

Slab roll-back and the decreasing in width of the active trench through time resulted in the formation of orogenic belts with very tight curvatures (Apennines, Calabrian Arc and Sicily)(MATTEI *et alii*, 2004; CIFELLI *et alii*, 2007, 2008), together with extensional back-arc basins (Ligurian-Provençal and Tyrrhenian basins; BOCCALETTI & GUAZZONE, 1974; ALVAREZ *et alii*, 1974), which have been characterized by the emplacement of medium to large plutonic bodies and by a long-standing volcanic activity that continues up today (e.g., BARBERI *et alii*, 1973; CIVETTA *et alii*, 1978; SERRI *et alii*, 1993, BECCALUVA *et alii*, 1994; CONTICELLI *et alii*, 2002; 2017; PECCERILLO, 2017).

In step with back arc basin development, the subduction-related island arc volcanism migrated from west to south- east, from Sardinia (32 - 13 Ma) to the currently active Aeolian island arc (Serri, 1997, and references therein). In this subduction system, trench retreat was particularly fast over the Neogene and early Quaternary (PATACCA *et alii*, 1990) as indicated by high extension rates (50 - 70 mm/yr) recorded in the new-formed Vavilov (Neogene) and Marsili (Early-Middle Pleistocene) oceanic seamounts (MARANI & TRUA, 2002; MATTEI *et alii*, 2002; NICOLOSI *et alii*, 2006). The rapid migration of the trench, indicated by the progressive shifting of foredeep basins, and the huge block rotations occurring during Miocene to Quaternary, were responsible for the development of the arcuate shape of the Calabrian Arc. Presently, despite active seismicity in the slab, there is no clear evidence of significant back-arc extension and foredeep migration in the Calabrian Arc, leaving the question on whether the trench retreat process is active or not still open.

In the following sections we describe more in detail the main characters of the Italian back-arc basins and of the Sicily Channel, located in the African lower plate, which provides fundamental constraints to the understanding of the origin and evolution of volcanic seamounts in Italy.

2. -THE LIGURIAN-PROVENÇAL BASIN

The early forming back-arc basin in Central Mediterranean is the Ligurian-Provençal basin, a triangular sea located between the Provençal-Catalan coast and the Corsica-Sardinia block, which opened during Oligo-Miocene times (fig. 1) (BURRUS, 1984; GORINI *et alii*, 1993). Extensional processes in the Ligurian-Provençal basin developed at the back of a north-west dipping subducting lithosphere, as attested by the presence of a volcanic arc erupting along the Sardinia and Provençal margins. Rifting established within a Variscan continental crust, except in the Gulf of Lions that was previously affected by Pyrenean thrusting. The Ligurian-Provençal basin is characterized by symmetric conjugate margins in term of crustal velocity structure (GAILLER *et alii*, 2009). From the Gulf of Lions and west Sardinia continental margins it is possible to recognize: 1) a thinned continental crust with a crustal thickness of 18 to 10 km; 2) a transitional zone where high lower crustal velocities, non-typical of continental or normal oceanic crust, might correspond to lower crustal material or a mixture of serpentinised upper mantle material with lower crustal material; and 3) an oceanic crust, 4 to 5 km thick, with typical vertical velocity gradients and relative velocity ranges. The anomalous thin oceanic crust has been related to the influence of a cool slab in back-arc basin, with the final breakup occurring close to the Sardinia side, as a consequence of the smaller crustal thickness on this margin (Gailler *et alii*, 2009). In this area the existence of mid-oceanic ridge has been proposed based on this geometry and the pattern of magnetic anomalies (Burrus, 1984), despite the characteristic of a spreading ridge relief has not been observed on deep seismic profiles (De Voogd *et alii*, 1991). These three regions, which have been recognized on both margin sides, are wide and smooth along the Gulf of Lions margin, and narrow and steep along its conjugate Sardinia side.

The age of rifting has been deduced by syn-rift deposits, located along the western Sardinian and Provençal margins, which range from Oligocene (30

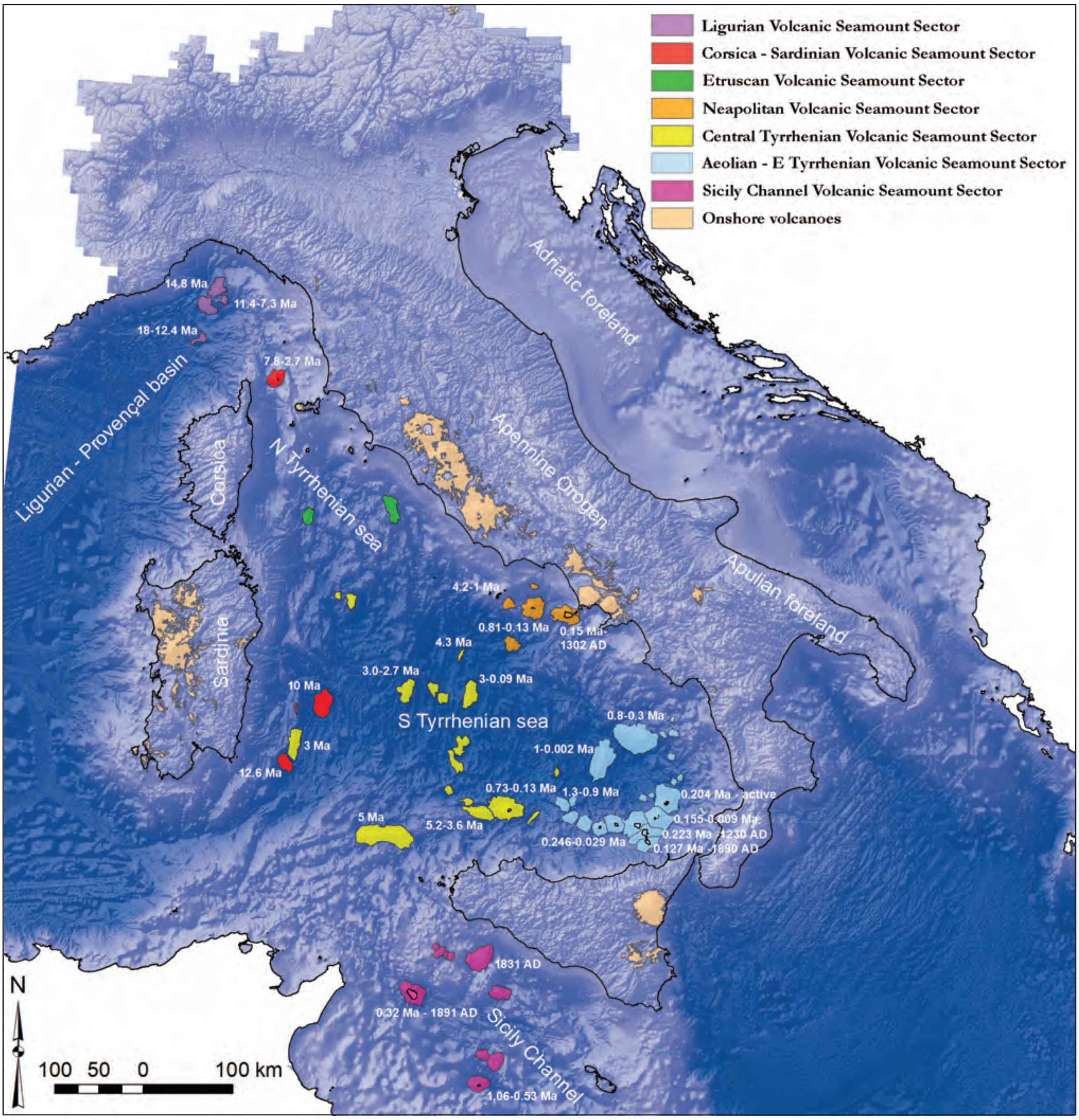

Fig. 1 - Map of volcanic islands and submerged seamounts, grouped by colour into 7 volcanic Sectors. Activity range is reported for each volcanic structure. On shore volcanoes are also reported on map.

- Mappa delle isole e delle strutture sommerse vulcaniche, raggruppate per colore in 7 Settori. Per ogni edificio vulcanico è riportato il periodo di attività. Sono riportati sulla mappa anche i vulcani di terraferma.

- 28 Ma) to Aquitanian (21.5 Ma) (CRAVATTE *et alii*, 1974; CHERCHI & MONTADERT, 1982, SÉRANNE, 1999; GORINI *et alii*, 1993). Since the late Aquitanian post-rift deposits unconformably overlie the syn-rift sequence in Sardinia and in the Gulf of Lion. The transition between syn-rift and post-rift deposits also marks the starting of oceanic crust formation in the Ligurian-Provençal basin and the counterclockwise rotation and drifting of the Corsica-Sardinia block. The oceanic crust in the Ligurian-Provençal basin has not been drilled or sampled, and no data are available to constrain the termination of the oceanic spreading, which can be, however, constrained by the end of the counterclockwise rotation of the Corsica-Sardinia block. Paleomagnetic and geochronological data indicate that the Corsica-Sardinia block rotated counterclockwise of ~45° after ~20.5 Ma, which can be regarded as the minimum rotation occurring during the Corsica-Sardinia drift, since an additional rotation may have taken place between the end of rifting (~21.5 Ma) and 20.5 Ma. On the other side, paleomagnetic results suggest that the rotation was virtually complete by 15 Ma (GATTACCECA *et alii*, 2007). Paleomagnetic results, geological correlations between Sardinia-Corsica and Provence together with oceanic crust extension defined by tectonic subsidence analysis (PASQUALE *et alii*, 1995) and compatible with the constraints on Moho depth obtained from 3D gravity inversion (OGGIANO *et alii*, 1995) suggest that, before drifting, the Corsica-Sardinia block was located at the south of the Provençal margin. In this scenario, the total opening amount of the southern part of the Ligurian-Provençal basin is ~400 km during the drift. Between 20.5 Ma and 18 Ma, with a rotation pole located in the Ligurian Sea (around 43.5°N, 9.5°E), the average rate for the basin opening reached 9 cm yr^{-1} for the southern part of the basin (GATTACCECA *et alii*, 2007).

3. - THE TYRRHENIAN SEA BASIN

During the Lower-Middle Miocene, extension migrated from the Ligurian-Provençal basin to the Tyrrhenian Basin, from Variscan to thickened Alpine crust presently outcropping in Calabria, Alpine Corsica and western Tuscany (JOLIVET *et alii*, 1997). The Northern Tyrrhenian Sea back-arc basin (fig. 1) developed during the Neogene and Quaternary on the top of an active, western dipping, subducting slab, as evidenced today by the occurrence of intermediate seismicity and imaged by seismic tomography (SELVAGGI & CHIARABBA, 1995; PIROMALLO & MORELLI, 2003). Extensional tectonics continuously followed by compressive deformation responsible for the built up of the Apennine chain.

Both extensional and compressional tectonics progressively migrated from the western Tyrrhenian region toward the Apulia foreland, as demonstrated by the age of extensional and foredeep sedimentary basins, which become younger from the Tyrrhenian Sea toward the Adriatic foreland (e.g., ROYDEN *et alii*, 1987; PATACCA *et alii*, 1992; CIPOLLARI & COSENTINO, 1995; FACCENNA *et alii*, 1997; JOLIVET *et alii*, 1998; COLLETTINI *et alii*, 2006). Extensional tectonics and crustal thinning in the Northern Tyrrhenian basin are marked by a system of spaced crustal shear zones, sedimentary basins and magmatic activity which gets younger toward the east from Corsica to the Apennine chain. In the westernmost Northern Tyrrhenian Sea (Pianosa island and Corsica) the sedimentary sequences which infill extensional sedimentary basins are Oligocene - Lower Miocene in age and are bounded by N-S trending east-dipping normal faults (BARTOLE, 1995; MAUFFRET *et alii*, 1999; MOELLER *et alii*, 2013, 2014). On the other hand, the sedimentary sequences occurring in the Apennine region where extensional tectonics is presently active and most of the normal faults strike NW-SE, are Pleistocene in age. Both extensional basins and magmatic centres shifted eastwards away from the rift axis at an average velocity of 1.5-2 cm yr^{-1}. No oceanic crust has been produced in the Northern Tyrrhenian Sea basin.

In the Southern Tyrrhenian Sea extensional processes have been more intense, and new oceanic crust formed during Messinian-Early Pleistocene (KASTENS *et alii*, 1988; SARTORI, 1990; NICOLOSI *et alii*, 2006). Seismic data, ODP Site 653 results, and structural and stratigraphic data on the on-shore western Calabria suggest that extension progressively migrated toward southeast as a consequence of the Ionian slab roll-back. In this basin rifting started along the western margin of the Southern Tyrrhenian Sea (Sardinian margin) during Serravallian, and progressively migrated southeastward in the Vavilov (late Messinian - early Pliocene) and Marsili (late Pliocene - early Pleistocene) basins. The conjugate, drifted margin of Sardinia is the Calabrian block, where the syn-rift deposits are Serravallian in age (MATTEI *et alii*, 2002). The average velocity of extension is of the order of 5-6 cm yr^{-1}.

Rifting and basin subsidence were followed by a drifting stage, with the emplacement of oceanic crust and of partially serpentinised peridotite representing exhumed mantle rocks (PRADA *et alii*, 2016). In the area comprised between the east Sardinia and the west Campania margins seismic data allow to recognize three basement domains with different velocity and velocity-derived density models corresponding to continental crust, oceanic crust, and exhumed mantle (PRADA *et alii*, 2014, 2015).

The first domain includes the thinned continental crust of Sardinia (~20 km to ~13 km thick) and the conjugate Campania margin. The second domain, corresponds to the Cornaglia Terrace and its conjugate Campania Terrace; the Cornaglia Terrace appears to be oceanic in nature, with back-arc oceanic setting affinity. The third domain, corresponding to the two triangular-shaped Magnaghi and Vavilov Basins, includes the deepest (~3600 m) region of the Central Tyrrhenian Sea. This is characterized by velocities-depth relationships and absence of Moho reflections in seismic records that suggest a basement made of mantle rocks.

This region contains two large NNE-SSW elongated volcanoes, the Magnaghi (~1500 m high above seafloor) and Vavilov (~2100 m high above seafloor) and several smaller ridges with the same trend (fig. 1). The syn-tectonic sequence interpreted in the Magnaghi and Vavilov basins by several authors is localised in few areas and contains Messinian to early-middle Pliocene sediments (FABBRI & CURZI, 1979; TRINCARDI & ZITELLINI, 1987; MASCLE & REHAULT, 1990; SARTORI *et alii*, 2004). Lava flows and basaltic breccias are found interbedded with early Pliocene sediments in the Vavilov volcano surroundings, revealing magmatic activity at the end or soon after the formation of this sub-basin (MASCLE & REHAULT, 1990). Seismic observations (PRADA *et alii*, 2014, 2015) and ODP site 651 (ROBIN *et alii*, 1987; BECCALUVA *et alii*, 1990; BONATTI *et alii*, 1990) support a basement mainly made of exposed mantle rocks, locally intruded by basaltic dikes and suggest that in this area the large seamounts (e.g., Vavilov) are underlain by 10-20 km wide, relatively low-velocity anomalies interpreted as magmatic bodies locally intruding the mantle.The Marsili sub-basin is a flat, deep (3,500 m in average), roughly elliptical abyssal plain covering ~8000 km^2, with a NW-SE- trending major axis (~110 km). It is characterised by a Moho depth, measured from sea level, in the order of 11 km, with a thinned lithosphere of <30 km (SUHALDOC & PANZA, 1989; NICOLICH, 1989; SCARASCIA *et alii*, 1994) and a heat flow values that reach over 200 mW m^{-2} (DELLA VEDOVA *et alii*, 1984; MONGELLI *et alii*, 1991). Basement depth in Marsili basin is ~4 km (KASTENS & MASCLE, 1990), giving an average basin crustal thickness of 7 km. The occurrence of magnetic anomaly stripes in the Marsili basin suggests the presence of oceanic spreading in this sector of the Southern Tyrrhenian Sea (MARANI & TRUA, 2002; NICOLOSI *et alii*, 2006).

4. - THE SICILY CHANNEL

The Sicily Channel rift, located between Sicily Island and Tunisia, lies in the lower plate of the Central Mediterranean subduction system, in the foreland of the Apennine-Maghrebian thrust-and-fold belt. Three principal NW-trending tectonic troughs (Pantelleria, Malta, and Linosa graben) characterise the tectonic structure of the area, representing morphological depressions with water depths ranging from 1,300 to more than 1,700 m, significantly deeper than the other Sicily Channel areas (400 m depths in average). The Pantelleria, Malta and Linosa tectonic depressions are controlled by NW-directed sub-vertical normal faults clearly observable in seismic lines (CIVILE *et alii*, 2010). The Sicily Channel rift system is filled by Lower Pliocene-Pleistocene turbidites characterized by thicknesses ranging between 1000 and 2000 m, whereas on the continental platform the Pliocene-Pleistocene sediments do not exceed a thickness of 500 m (MALDONADO & STANLEY, 1977).

Detailed seismo-stratigraphic analyses allow to reconstruct the entire tectonic history of the rifting (CIVILE *et alii*, 2010). In particular the pre-rift sequence is formed by undifferentiated Miocene deposits, corresponding to the Late Tortonian-Messinian Terravecchia Formation, that do not show fault-related thickness changes. The syn-rift sequence is represented by the Early Pliocene deposits (Trubi Formation), which show a growth wedge-shaped geometry and divergent fanning strata down the dip slope of the tilted fault-blocks. The post-rift succession, probably Late Pliocene-Quaternary in age, is characterized by sub-parallel reflectors that drape the morphology below (CIVILE *et alii*, 2010). A wide N-S trending belt characterized by localized uplifts and depocentres, alkaline volcanics and structural inversions, separates the Pantelleria trough to the west from the Malta and Linosa troughs to the east. This belt presents evidence of strike-slip tectonics, acting as a transfer fault zone between two segments of the rift system (ARGNANI, 1990).

The Sicily Channel rifting occurred in two main deformation phases. The first phase (Late Messinian-Early Pliocene) was characterized by crustal stretching and by the activity of NW-SE oriented normal faults that defined the main structure of the tectonic depressions. The second phase started during Late Pliocene-Pleistocene and was associated with a widespread increasing of volcanic activity.

5. - THE MAGMATISM

The Western Mediterranean is characterized by an intense volcanic activity since the Oligocene. This igneous activity accompanied the geodynamic evolution of the Africa-Eurasia convergence during the last 30 Ma (e.g., BECCALUVA *et alii*, 1985, 1990;

Savelli, 1988, 2002; Conticelli & Peccerillo, 1992; Doglioni *et alii*, 1997; Gueguen *et alii*, 1998; Jolivet & Faccenna, 2000; Faccenna *et alii*, 2001b; Conticelli *et alii*, 2002, 2007, 2009a, 2010, 2015a; Mattei *et alii*, 2004, 2010; Peccerillo, 2003; Peccerillo & Lustrino, 2005; Peccerillo & Martinotti, 2006; Francalanci *et alii*, 2007; Peccerillo *et alii*, 2008; Rosenbaum *et alii*, 2008; Avanzinelli *et alii*, 2009; Alagna *et alii*, 2010; Lustrino *et alii*, 2011; Tommasini *et alii*, 2011; Carminati *et alii*, 2012; Ammannati *et alii*, 2016; Peccerillo, 2017). However, little is known about the submarine volcanism that has occurred during the last 30 Ma in the Central Mediterranean due to the paucity of samples and data available. The following description of petrologic, geochemical, and isotopic characteristics of off-shore sub-marine and sub-aerial volcanic rocks occurring in the Central Mediterranean regions is made using the large-data set from GEOROC (For reference see records # 3226, 3483, 3932, 4345, 4353, 4369, 4370, 4371, 4468, 4670, 4672, 4862, 4923, 5163, 5164, 5444, 6128, 6814, 6817, 7254, 7480, 7583, 7585, 7586, 7605, 7714 8248, 8259, 8262, 8272, 8426, 8435, 9231, 9239, 9453, 9457, 9478, 9495, 9534, 10248, 10267, 10391, 10938, 11090, 11126, 11285, 11614, 11690, 12014, 12466, 12525, 12526, 12849, 13094, 13219, 14161, 14189, 14347, 14349, 15106, 17980, 18207, 18328, 18349, 19028, and 19143 at http://georoc.mpch-mainz.gwdg.de/georoc/).

6. - LIGURIAN VOLCANIC SEAMOUNTS SECTOR

The volcanic fields of this area are located in the north-westernmost sector of the Central Mediterranean region (fig. 1). Volcanic rocks lie well within the eastern portion of the Ligurian-Provençal basin between the Ligurian Shoreline at north-west and the western shoreline of Corsica Island at south-east (fig. 1). The volcanic fields are all submarine and comprise the Spinola/Tristanite and the Calypso ridges, the Ulysse/Genova Gulf Central Volcano, the Occhiali/Doria and the Genova volcanoes (Pensa *et alii*, this volume).

In this area the volcanic activity developed entirely during the Miocene, spanning from 20.6 to 7.3 Ma with emplacements of dikes, lava flows and few submarine ignimbrites (Fanucci *et alii*, 1993; Réhault *et alii*, 2012). Lithologies range from olivine-basalts and shoshonites to high-K basaltic andesites, trachyandesites, and high-K andesites (fig. 2). Petrological affinity ranges from calc-alkaline (Cap Corse off-shore) to high-K calc-alkaline (Tristanite ridge) to shoshonitic (Monte Doria, Genova Gulf Central Volcano) series (Réhault *et alii*, 2012).

The patterns of incompatible trace element normalised to primordial mantle (fig. 3) show a clear orogenic affinity for the samples from the eastern sector of the Ligurian-Provençal basin. Geochemical and petrological characteristics of these off-shore volcanic rocks suggest they are closely related with the calc-alkaline volcanic rocks of the on-shore Ligurian magmatic field occurring in the Nice area, between Monaco, Antibes and Cannes (Lustrino *et alii*, 2017, and references therein). However, the off-shore volcanic rocks from the eastern sector of the Ligurian-Provençal basin are younger than those of the on-shore cropping out on the north-western margin of the basin, in the Nice surroundings, which date between 33 and 26 Ma (Lustrino *et alii*, 2017).

The evolution of the magmatism in this area and its eastward migration with time are related with the counterclockwise rotation of the Corsica-Sardinia block and the opening of the Ligurian-Provençal basin (e.g., Rollet *et alii*, 2002; Gattacceca *et alii*, 2007; Oudet *et alii*, 2010; Réhault *et alii*, 2012).

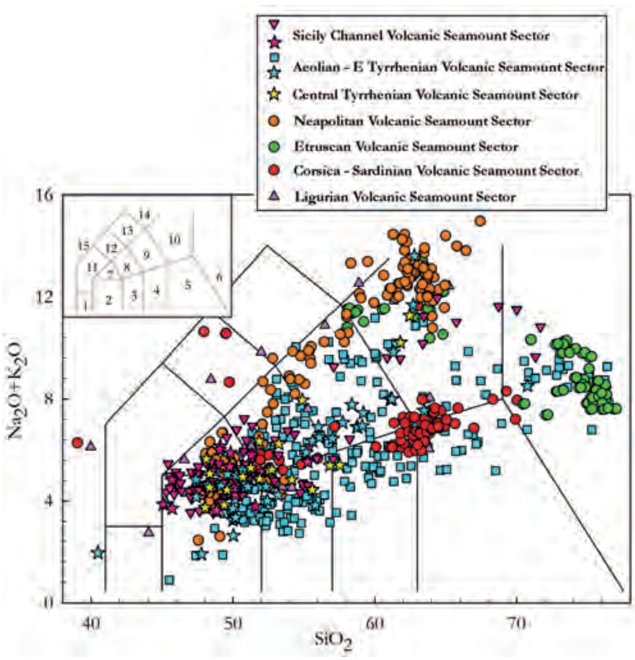

Fig. 2 - Total Alkali Silica (Le Maitre *et alii,* 2002) for the Mediterranean volcanic and seamount sectors. Source data are from GeoRoc (see text for more details). The inset shows the reference fields: 1 - Picro-basalt, 2 - Basalt, 3 - Basaltic andesite, 4 - Andesite, 5 - Dacite, 6 - Rhyolite, 7 - Trachy-basalt, 8 - Basaltic trachy-andesite, 9 - Trachy-andesite, 10 - Trachyte/trachydacite, 11 - Tephrite/Basanite, 12 - Phono-Tephrite, 13 - Tephri-Phonolite, 14 - Phonolite, 15 - Foidite.

- Diagramma Total Alkali vs. Silica (Le Maitre et alii, 2002) dei diversi settori di seamount vulcanici nell'area Mediterranea. Fonte dei dati: GeoRoc (maggiori dettagli sono contenuti nel testo). Nel riquadro sono riportati i campi di riferimento: 1- Picro-basalto, 2 - Basalto, 3 - Andesite basaltica, 4 - Andesite, 5 - Dacite, 6 - Riolite, 7 - Trachi-basalto, 8 - Trachi-andesite basaltica, 9 - Trachi-andesite, 10 - Trachite/Trachi-dacite, 11 - Tefrite/Basanite, 12 - Fono-tefrite, 13 - Tefri-fonolite, 14 - Fonolite, 15 - Foidite.

7. - CORSICA-SARDINIAN VOLCANIC SEAMOUNTS SECTOR

The volcanic fields of this area are located on the eastern off-shore of the Corsica-Sardinia block, straddling the Corsica and Sardinia channels, two deep N-S morphological features that bound the western margin of the Tyrrhenian basin (MARANI *et alii*, 1993; MASCLE *et alii*, 2001) (fig. 1). In this sector, the volcanic rocks are found both as submarine centres with the Cornacya, Quirinus and Cornaglia volcanic seamounts, at south east of Sardinia Island (SELLI, 1985; MASCLE *et alii*, 2001; CARMINATI *et alii*, 2012), and in two cases emerged above the sea level at Capraia Island with the diachronous coalescent Capraia and Zenobito volcanoes (e.g., RODOLICO, 1938; FRANZINI, 1964; ALDIGHIERI *et alii*, 2004; CERRINA-FERRONI, 2003; CHELAZZI *et alii*, 2006; POLI & PECCERILLO, 2016; PECCERILLO, 2017).

In this area the volcanic activity developed mainly during the Miocene (12.6-7.1 Ma; BARBERI *et alii*, 1986; ALDIGHIERI *et alii*, 1998; MASCLE *et alii*, 2001; GASPARON *et alii*, 2009) with only one single volcanic event, the Zenobito monogenetic volcano, occurring in the lower Pliocene at 4.6 Ma. Volcanic products are mainly made up by dikes, lava flows, cinder cones, and ignimbrites (e.g., RODOLICO, 1938; FRANZINI, 1964; CERRINA-FERRONI, 2003; ALDIGHIERI *et alii*, 2004; CHELAZZI *et alii*, 2006; GAGNEVIN *et alii*, 2007; CONTICELLI *et alii*, unpublished data). Rocks range in composition from high-K andesite to high-K rhyolites and trachytes passing through trachyandesites, high-K dacites and latites (fig. 2). Petrological affinity ranges from high-K calc-alkaline (Capraia volcano) to shoshonitic (Cornacya) series. A transitional affinity from orogenic to within-plate is observed for the Zenobito scoria and lavas (PENSA *et alii*, this volume). The patterns of incompatible trace element normalised to primordial mantle (fig. 3) show a clear orogenic affinity for all samples, showing negative spikes at Ba, Ta, Nb, P, and Ti and positive at Th, U, and Pb, with the exception of the Zenobito volcanic rocks that show a transitional character with significant decrease of both positive and negative spikes. Geochemical and petrological characteristics of Miocene rocks suggest they are closely related with the ultrapotassic volcanic rocks found on-shore at Sisco (Corsica), which are older (14 Ma, CIVETTA *et alii*, 1978) than those of Capraia and Cornacya (BARBERI *et alii*, 1986; ALDIGHIERI *et alii*, 1998; MASCLE *et alii*, 2001; GASPARON *et alii*, 2009). A decrease in the potassic character with time and eastward may be explained with the eastward roll-back of the subduction (CONTICELLI *et alii*, 2007, 2009a, 2010, 2015a; PECCERILLO, 2017).

8. - ETRUSCAN VOLCANIC SEAMOUNTS SECTOR

This volcanic seamounts sector is located between the 42nd parallel N and Ponza Island (fig. 1, PENSA *et alii*, this volume). The Etruschi and Tiberino seamounts are the northernmost volcanic seamounts, whilst at south, close to 41st parallel N, are located the Ponza and Palmarola volcanic islands, but submarine volcanic products are also found at Zannone Island and along the Tyrrhenian escarpment (e.g., DE RITA *et alii*, 2001; CONTE & DOLFI, 2002; CADOUX *et alii*, 2005; CONTE *et alii*, 2016; PECCERILLO, 2017).

No chronological and compositional data are available for the northernmost Etruschi and Tiberino seamounts, whereas several geochronological absolute ages are available for the southernmost volcanic rocks showing a wide time span of emplacement from Pliocene to Pleistocene (BARBERI *et alii*, 1967; SAVELLI, 1983; CADOUX *et alii*, 2005; CONTE *et alii*, 2016). At Ponza Island two different epochs of magmatism have been recognised: the oldest between 5.0 Ma and 3.1 Ma, which emplaced submarine rhyolitic hyaloclastites (although DE RITA *et alii*, 2001 suggested a younger age of 2.5 Ma based on stratigraphic considerations); the youngest with the emplacement of Monte La Guardia succession between 1.2 and 1.05 Ma. The Palmarola volcanic rocks have intermediate absolute ages (1.83-1.56 Ma) between the two Ponza Epochs, whilst those from Palmarola off-shore (4.01-3.86 Ma) overlap those of the oldest Ponza Epoch (PENSA *et alii*, this volume).

The oldest volcanic products at Ponza and Palmarola islands are made up by high-silica domes and dykes, which are both mantled by high-silica hyaloclastites (DE RITA *et alii*, 2001; AUBOURG *et alii*, 2002). Sub-aerial lava flows, lapilli to scoriae fall and flow deposits are found along the Monte La Guardia volcanic succession of the youngest Ponza Island epoch. The early Ponza Island rocks are high-silica and fall within the field of high-K rhyolites (fig. 2), plotting well within the igneous rocks of the Tuscan Anatectic Province (CONTICELLI *et alii*, 2010). The young Ponza Island rocks belonging to the Monte La Guardia succession range in composition from olivine-bearing trachytes to trachytes, with a transitional character from high-K to shoshonite series, which partially overlap the Torre Alfina lamproite-like olivine-latites in the K_2O vs. silica diagram (authors' unpublished data). Palmarola Island rocks, on the other hand, range in composition from latites, through trachytes to high-K rhyolites, overlapping the field of coeval Tolfa, Manziana, and Cerite rocks (PINARELLI, 1987, 1991; BERTAGNINI *et alii*, 1995; CONTICELLI *et alii*, 2002).

The petrological affinity of Ponza and Palmarola islands rocks range from anatectic for the old Ponza Island epoch, rhyolites to shoshonitic for the Palmarola Island and some young Ponza Island rocks, with La Guardia rocks being alkaline ultrapotassic (authors' unpublished data). The patterns of incompatible trace element normalised to primordial mantle (fig. 3) show strong similarities with those of the San Vincenzo and Roccastrada anatectic rhyolites (e.g., FERRARA *et alii*, 1989; PINARELLI *et alii*, 1989; FELDSTEIN *et alii*, 1994). On the other hand, the Palmarola Island rocks show patterns with a stronger negative spikes at Sr, Eu, Ti, and Ba than those on old Ponza Island, with smooth or no negative spike at Ta and Nb. The younger Monte

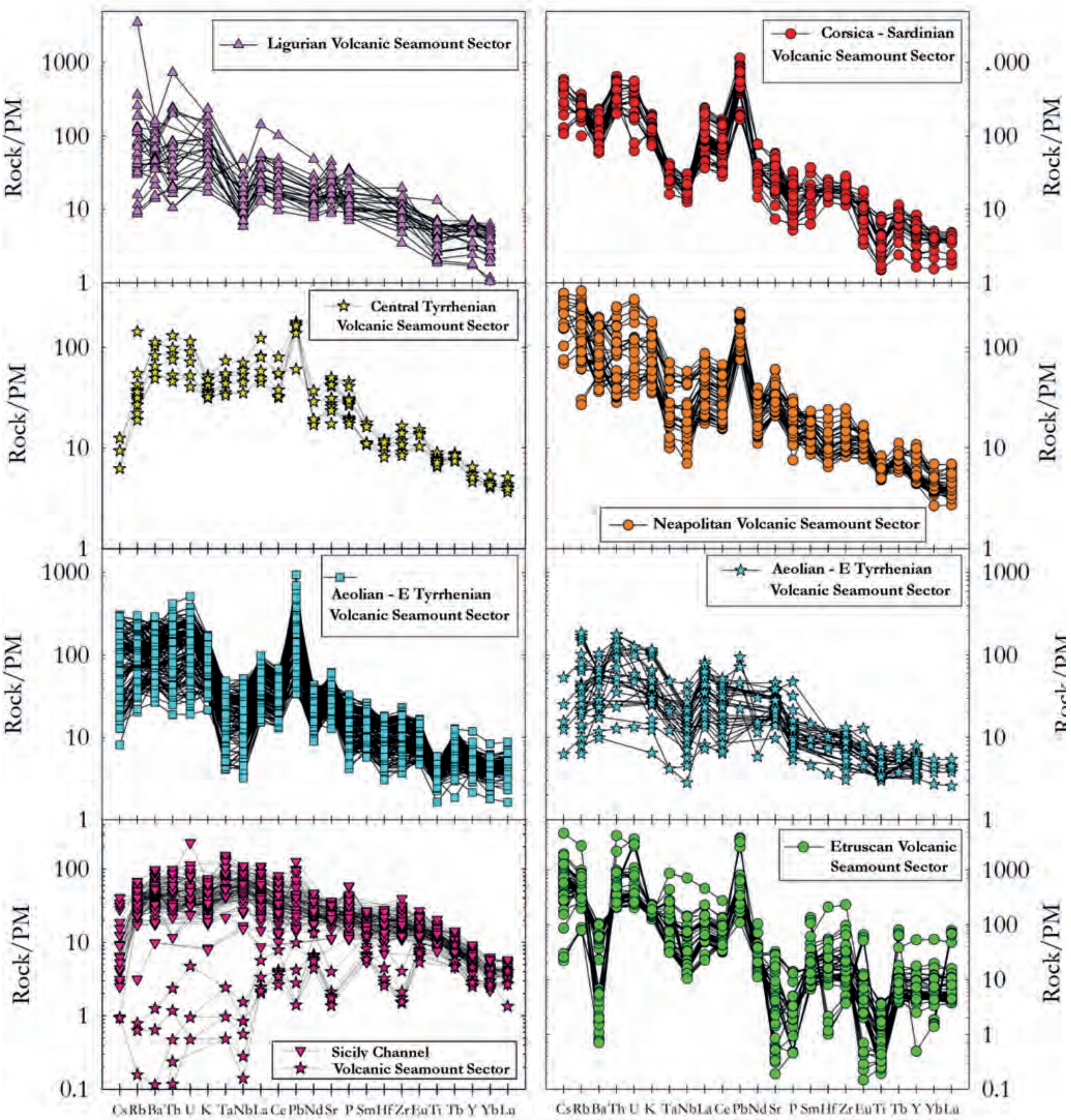

Fig. 3 - Spider diagrams (HOFMANN, 1997) for Mediterranean volcanic and seamount sectors, data are normalised to Primordial Mantle values of MCDONOUGH & SUN (1995). For all the sectors, except the Etruscan one, only data with MgO >3 % wt. were selected. Source data are from GeoRoc (see text for more details). For the Aeolian - E Tyrrhenian and Sicily Channel Sectors the offshore activity is represented by star symbols.
- *Distribuzione degli elementi incompatibili (HOFMANN, 1997) normalizzati al Mantello Primordiale (MCDONOUGH & SUN, 1995) dei diversi settori di seamount vulcanici nell'area Mediterranea. Per tutti i settori, ad eccezione di quello Etrusco, sono stati selezionati solo i dati con MgO >3% wt. Fonte dei dati: GeoRoc (maggiori dettagli sono contenuti nel testo). L'attività offshore dei Settori Eoliano - E Tirrenico e del Canale di Sicilia è rappresentata da simboli a stella.*

La Guardia Ponza rocks show patterns of incompatible trace element normalised to primordial mantle (fig. 3) that are closely overlapping those of the Tuscan lamproite-like rocks (e.g., CONTICELLI, 1998; CONTICELLI *et alii*, 2007, 2009a, 2011, 2013, 2015 a,b).

9. - NEAPOLITAN VOLCANIC SEAMOUNTS SECTOR

These volcanic seamounts are distributed in the off-shore of the active Neapolitan volcanoes (i.e., AVANZINELLI *et alii*, 2009; CONTICELLI *et alii*, 2010, 2015a), and they are made up by the Ventotene and Santo Stefano Islands, La Botte, the Ventotene volcanic Ridge, the Albatros/Cicerone seamounts, and the Ischia and Procida Islands (fig. 1, PENSA *et alii*, this volume). No data about Ventotene ridge and the Albatros/Cicerone seamount are available, although a large set of data is available for the Ventotene, Santo Stefano, Ischia, and Procida Islands (e.g., CRISCI *et alii*, 1989; POLI *et alii*, 1987, 1989; CIVETTA *et alii*, 1991; D'ANTONIO & DI GIROLAMO, 1994; PIOCHI *et alii*, 1999; D'ANTONIO *et alii*, 1999, 2013; CONTICELLI *et alii*, 2004, 2007, 2010; DE ASTIS *et alii*, 2004; FEDELE *et alii*, 2006; AVANZINELLI *et alii*, 2007; BROWN *et alii*, 2014; MAZZEO *et alii*, 2014; MELLUSO *et alii*, 2014; CASALINI *et alii*, 2017, 2018; PECCERILLO, 2017).

Ventotene along with Santo Stefano Islands are the sub-aerial remnants of a large collapsed stratovolcano with product erupted in a time span between 0.8 and 0.13 Ma (BARBERI *et alii*, 1967; FORNASERI, 1985; METRICH *et alii*, 1988). The Ischia Island is the sub-aerial remnant of a large submarine stratovolcano with the oldest outcropping volcanic rocks dated at 0.15 Ma with volcanic activity that proceeded continuously until historical times (1320 AD)(e.g., CAPALDI *et alii*, 1976; GILLOT *et alii*, 1982; POLI *et alii*, 1987, 1989; ORSI *et alii*, 1996). The volcanic activity of Procida Island spans between 70 ka and 14 ka (e.g., D'ANTONIO & DI GIROLAMO, 1994; D'ANTONIO *et alii*, 1999; DE ASTIS *et alii*, 2004; FEDELE *et alii*, 2006).

The Ventotene Island volcanic rocks range in composition from basalts to trachybasalts, shoshonites, latite trachy-phonolites and phonolites, whilst those from Santo Stefano Island are monotonously phonolites. Ischia Island volcanic rocks are known almost exclusively from sub-aerial outcrops (DE VITA *et alii*, 2010; SBRANA & TOCCACELI, 2011). They range in composition from (fig. 2) shoshonites, to latites and trachytes, with some rocks piercing the boundary with phonolites (e.g., CASALINI *et alii*, 2017, 2018, and references therein). Procida volcano is characterised by the least evolved products of the entire Neapolitan off-shore sector, and at a larger scale, of the entire Neapolitan district of the Roman Magmatic Province (e.g., CONTICELLI *et alii*, 2004, 2010, 2015a; AVANZINELLI *et alii*, 2009). These rocks range in composition from potassic trachybasalts to shoshonites, latites and few trachytes (e.g., D'ANTONIO & DI GIROLAMO, 1994; DE ASTIS *et alii*, 2004; FEDELE *et alii*, 2006).

The petrological affinity of the rocks of the Neapolitan sector is shoshonitic (CONTICELLI *et alii*, 2010), with the most mafic ones showing patterns of incompatible trace element normalised to primordial mantle (fig. 3) with orogenic signatures although with decreasing negative spikes at Ba, Ta, Nb, P, and Ti passing from Ventotene Island mafic rock to Procida and Ischia islands ones.

10. - CENTRAL TYRRHENIAN VOLCANIC SEAMOUNTS SECTOR

These volcanic seamounts belong to the central domain of the Tyrrhenian basin, which corresponds to the two triangular-shaped Magnaghi and Vavilov sub-basins. This is the deepest sector of the Central Tyrrhenian Sea, with volcanoes lying, in some cases, directly on a basement made of mantle rocks (PRADA *et alii*, 2016). Beside the large Magnaghi and Vavilov volcanic seamounts other minor volcanic seamounts occur, which are namely: Marco Polo, Columbus, Gortani, D'Ancona, Virgilio, Augusto, Quirra, and Livia seamounts, and Virgilio II lava field (fig. 1). In addition, in this sector of the Tyrrhenian Sea are also grouped the southernmost volcanic fields found at the western side of the Aeolian Islands (fig. 1), aligned almost E-W, which are namely: Creusa seamount, Ustica Island, Prometeo seamount, Aceste/Tiberio seamounts, Garibaldi/Glauco seamounts, Anchise seamount (fig. 1) (PENSA *et alii*, this volume).

Volcanic rocks from the Magnaghi and Vavilov sub-basins were erupted between 4.3 and 0.09 Ma (FERAUD, 1990; PECCERILLO, 2017), whereas volcanic rocks from the E-W southernmost alignment have ages between 5.2 and 0.13 Ma (PENSA *et alii,* this volume).

Geochemistry and petrological data of volcanic rocks from the deepest region of the Tyrrhenian seafloor are rare and in most cases samples are strongly altered. Nonetheless they range in composition from basalts and hawaiites to mugearites, and trachyte (fig. 2), but some foiditic to basanitic samples from Vavilov and Gortani seamounts are also found (e.g., DIETRICH *et alii*, 1977, 1978; BARBERI *et alii*, 1978; KASTENS *et alii,* 1988*;* KASTENS & MASCLE, 1990; BECCALUVA *et alii*, 1982, 1990; PECCERILLO, 2017). MORB-type rocks are from ODP site 655 and DSDP 373A, whilst OIB-type rocks were found in Vavilov, Magnaghi, Quirra, and Columbus seamounts, showing a roughly bell shaped pattern for incompatible trace elements when normalised to primordial mantle (fig. 3). An OIB-type petrological affinity is also found for volcanic rocks from Ustica Island, Aceste and Prometeo seamounts, among the off-shore Tyrrhenian volcanoes of the southernmost E-W alignment. The volcanic rocks of Anchise seamount, located between Ustica Island and Aceste seamount, have a clear orogenic signature with patterns showing negative spikes at Ta, Nb, and Ti.

11. - AEOLIAN - EASTERN TYRRHENIAN VOLCANIC SEAMOUNTS SECTOR

These volcanic seamounts and islands are found in the south-easternmost region of the Tyrrhenian Sea (fig. 1), and composed by the Aeolian Islands (e.g., Stromboli, Vulcano, Panarea, Lipari, Salina, Filicudi, and Alicudi) and the surrounding volcanic seamounts between them and Marsili and Palinuro seamounts (e.g., Glabro, Enotrio, Diamante, Alcione, Lametini, Strombolino I and Strombolino II and Capo Vaticano seamounts); other minor volcanic seamounts are represented by the western continuation of the volcanic arc (e.g., Eolo, Enarete, Sisisfo, and Tiro seamounts, PENSA *et alii*, this volume).

Volcanic rocks of this sector range in ages from 1.3-1.0 Ma (e.g., Marsili and Sisifo seamounts) to present time (e.g., BECCALUVA *et alii*, 1981a, 1985; SAVELLI, 1988; MARANI & TRUA, 2002; TRUA *et alii*, 2002; DE ROSA *et alii*, 2003; PECCERILLO, 2017), whilst the subaerial rocks of the Aeolian Islands range from 106 to 28 ka at Alicudi Island, from 250 to 30 ka at Filicudi Island, from 270 ka to 1220 AD at Lipari Island, from 155 to 8.7 ka at Panarea Island, from 250 to 16 ka at Salina Island, from 204 ka to present at Stromboli Island, and from 130 ka to 1890 AD at Vulcano (e.g., GILLOT & VILLARI, 1980; KELLER, 1980; GILLOT, 1987; GABBIANELLI *et alii*, 1990; PASQUARÉ *et alii*, 1993; VOLTAGGIO *et alii*, 1997; DE ROSA *et alii*, 2003; FRANCALANCI *et alii*, 2004, 2007, 2013; TOMMASINI *et alii*, 2007; LÉOCAT, 2010; WIJBRANS *et alii*, 2011; LUCCHI *et alii*, 2013; PECCERILLO, 2017).

The volcanic rocks from this sector of the Tyrrhenian Sea range in composition from basalts to basaltic andesite, andesite, dacite, and rhyolites (fig. 2), but a shoshonitic to slightly potassic series can also be found with rocks ranging from K-trachybasalts, to shoshonite, latite, and trachyte (e.g., KELLER, 1980; BECCALUVA *et alii*, 1981a, 1985; FRANCALANCI *et alii*, 1988, 1989, 1993, 2004, 2007, 2013; MARANI & TRUA, 2002; TRUA *et alii*, 2002; DE ROSA *et alii*, 2003; TOMMASINI *et alii*, 2007; LUCCHI *et alii*, 2013; PECCERILLO, 2017 and references therein). Petrological affinity of volcanic products is orogenic with patterns of incompatible trace elements normalised to primordial mantle showing strong negative spikes at Ta, Nb, P, Zr, and Ti, and positive at Pb (fig. 3).

12. - SICILY CHANNEL VOLCANIC SEAMOUNTS SECTOR

These volcanic seamounts are located in the Sicily Channel and include the Pantelleria and Linosa Islands. They are composed by Tetide, Anfitrite, Galatea, Euridice, and Empedocle seamounts (i.e., Ferdinandea/Graham, Terrible, Nerita seamounts), along with Nameless, Linosa II and Alfil/Linosa III volcanic seamounts (fig. 1, PENSA *et alii*, this volume).

Volcanic rocks of this sector range in ages from 1.06 Ma to 1891 AD (e.g., CORNETTE *et alii*, 1983; SAVELLI, 2001; PECCERILLO, 2017; LODOLO *et alii*, 2017) although a much older K-Ar age of 9.6 Ma was found for the Nameless seamount (BECCALUVA *et alii*, 1981b).

The volcanic rocks of the volcanoes of the Sicily Channel are invariably mildly Na-alkaline (e.g., VILLARI, 1974; BECCALUVA *et alii*, 1981b; CALANCHI *et alii*, 1989; MAHOOD & STIMAC, 1990; ESPERANÇA & CRISCI, 1995; CIVETTA *et alii*, 1998; BINDI *et alii*, 2002; AVANZINELLI *et alii*, 2004, 2014; CONTICELLI *et alii*, 2004; ROTOLO *et alii*, 2006; DI BELLA *et alii*, 2008; DI CARLO *et alii*, 2010; COLTELLI *et alii*, 2016; PECCERILLO, 2017), ranging in composition from basalts and hawaiites to mugearite, benmoreite, trachytes (comenditic and pantelleritic), pantellerites and in some cases comendites (fig. 3, PENSA *et alii*, this volume).

The petrological affinity of the off-shore volcanic rocks of the Sicily Channel is anorogenic, rift-related, with typical bell shaped patterns of incompatible trace elements normalised to primordial mantle showing small negative spikes at Th, K, and Pb (fig. 3).

13. - SR-ND-PB ISOTOPES

Central Mediterranean volcanic rocks range from shoshonites, high-K calc-alkaline and calc-alkaline igneous rocks, which are followed lately by anorogenic Na-alkaline within-plate rocks. As a whole, they have extremely variable radiogenic isotope compositions (figs. 4, 5), displaying a geographic variation firstly from west to east and later from northwest to southwest (see CONTICELLI *et alii*, 2007, 2010; PECCERILLO *et alii*, 2017 and references therein).

The observed isotope variation covers almost the entire spectrum of mantle and upper crust values, complicating the interpretation of the petrogenetic grid of the Central Mediterranean volcanism (e.g., HAWKESWORTH & VOLLMER, 1979; VOLLMER & HAWKESWORTH, 1981; VOLLMER, 1989; CONTICELLI *et alii*, 2002, 2004, 2007, 2009a,b, 2010, 2011, 2013, 2015a,b; GASPERINI *et alii*, 2002; BELL *et alii*, 2004; PECCERILLO, 2003, 2017; AVANZINELLI *et alii*, 2009, 2012, 2014; ALAGNA *et alii*, 2010).

$^{143}Nd/^{144}Nd_i$ vs. $^{87}Sr/^{86}Sr_i$ (fig. 4) values anticorrelate overlapping both the MORB field (e.g., Sicily Channel, Central Tyrrhenian, Aeolian - E Tyrrhenian sectors) and the fields of the Italian ultrapotassic, shoshonitic and calc-alkaline Pliocene-Pleistocene volcanic rocks (Aeolian - E Tyrrhenian, Neapolitan, Etruscan, and Corsica - Sardinian sectors). No isotopic data are available for the Ligurian sector.

The same geographic variation can be observed in the diagrams where Pb isotopes are plotted (fig. 5). The Central Mediterranean off-shore volcanic rocks, analogously to what observed for the Pliocene-Pleistocene on-shore volcanic rocks along the Tyrrhenian border of the Italian peninsula, fill the gap between upper crustal composition and FOZO (HART *et alii*, 1992) passing through the isotopic composition of EM II end-member (ZINDLER & HART, 1986), which is believed to represent a recycled sedimentary component. On the other hand, Central Tyrrhenian Sea volcanic rocks of the Magnaghi and Vavilov sub-basins have a clear MORB-type signature, with those from the Neapolitan volcanic sector (Ventotene and Ischia volcanoes) characterised by a trend departing from the general Roman array, pointing to the Central Tyrrhenian MORB (fig. 5). FOZO isotope compositions are only approached by volcanic rocks from magmatic suites south of the 41st parallel. A less-depleted asthenospheric mantle source has been

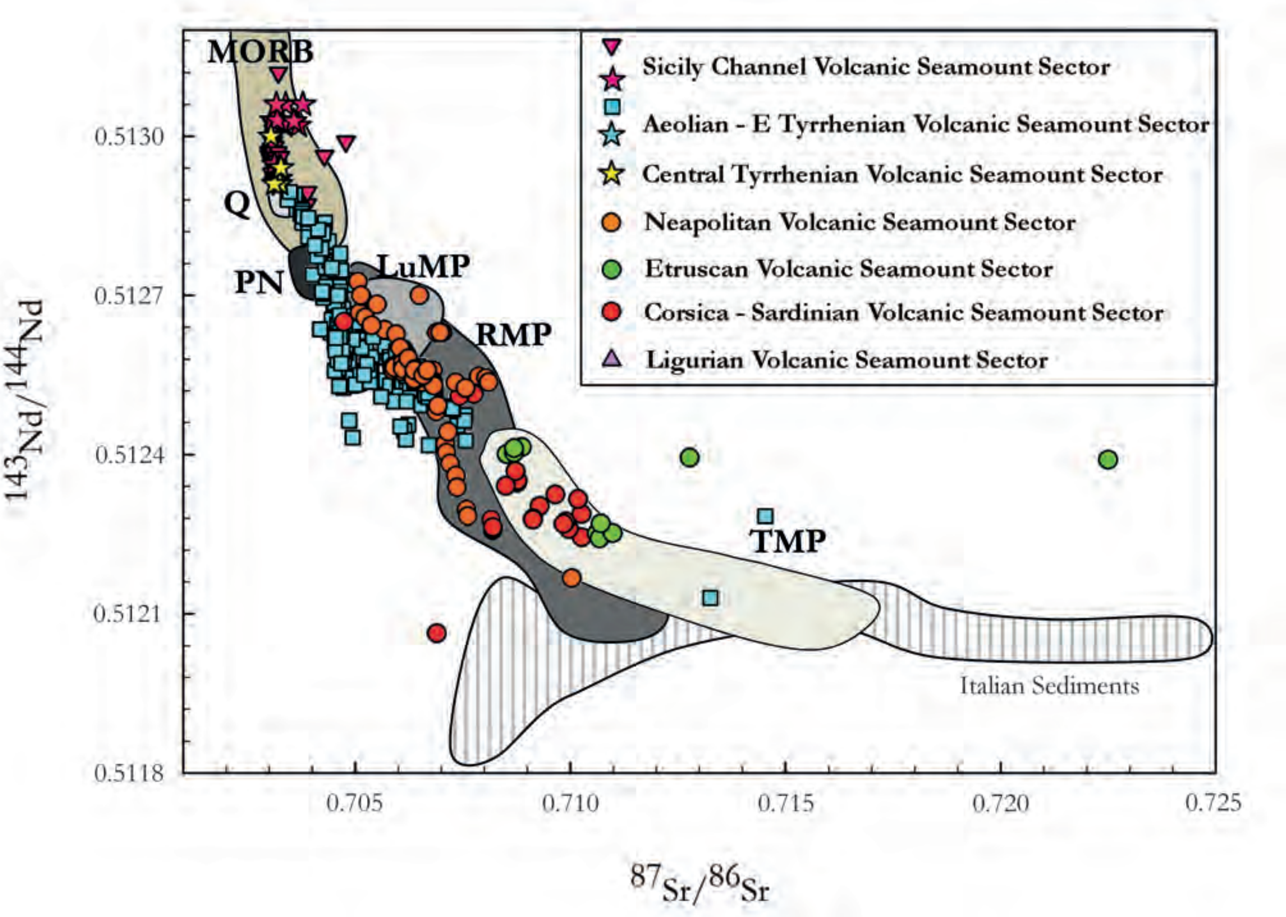

Fig. 4 - Plot of $^{143}Nd/^{144}Nd$ vs. $^{87}Sr/^{86}Sr$ for Mediterranean volcanic seamount sectors. Source data are from GeoRoc (see text for more details). Reference fields are also reported: MORBs are from STRACKE *et alii* (2003), Q: La Queglia, PN: Pietre Nere, RMP: Roman Magmatic Province, TMP: Tuscan Magmatic Province, LuMP: Lucanian Magmatic Province and Italian sediments are from CONTICELLI *et alii* (2015a). For the Aeolian - E Tyrrhenian and Sicily Channel Sectors the offshore activity is represented by star symbols. Isotopic data for the Ligurian Sector not available in literature.

- Correlazione tra $^{143}Nd/^{144}Nd$ e $^{87}Sr/^{86}Sr$ dei prodotti appartenenti ai diversi settori di seamount vulcanici nell'area Mediterranea. Fonte dei dati: GeoRoc (maggiori dettagli sono contenuti nel testo). Sono riportati alcuni campi per riferimento: MORB da STRACKE et alii (2003), Q*: La Queglia,* PN*: Pietre Nere,* RMP*: Provincia Magmatica Romana,* TMP*: Provincia Magmatica Toscana,* LuMP*: Provincia Magmatica Lucana e sedimenti italiani da CONTICELLI et alii (2015a). L'attività offshore dei Settori Eoliano - E Tirrenico e del Canale di Sicilia è rappresentata da simboli a stella. I dati di composizione isotopica per il Settore Ligure non sono reperibili in letteratura.*

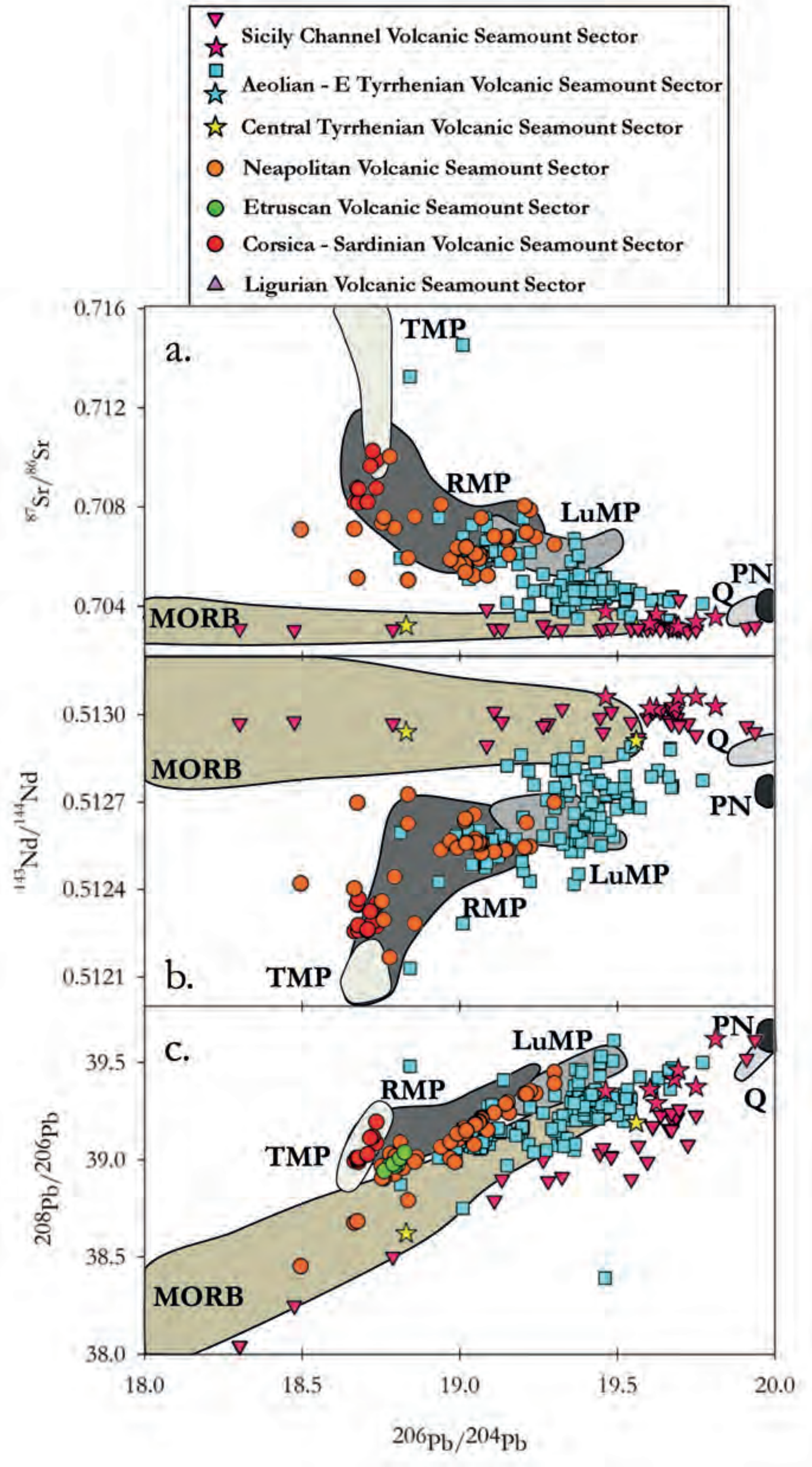

Fig. 5 - Plots of $^{87}Sr/^{86}Sr$ (a.), $^{143}Nd/^{144}Nd$ (b.) and $^{208}Pb/^{204}Pb$ (c.) vs. $^{206}Pb/^{204}Pb$ for Mediterranean volcanic seamount sectors. Source data are from GeoRoc (see text for more details). Reference fields are also reported: MORBs are from Stracke *et alii* (2003), Q: La Queglia, PN: Pietre Nere, RMP: Roman Magmatic Province, TMP: Tuscan Magmatic Province and LuMP: Lucanian Magmatic Province are from Conticelli *et alii* (2015a). For the Aeolian - E Tyrrhenian and Sicily Channel Sectors the offshore activity is represented by star symbols. Isotopic data for the Ligurian Sector not available in literature. - *Correlazione tra $^{87}Sr/^{86}Sr$ (a.), $^{143}Nd/^{144}Nd$ (b.) e $^{208}Pb/^{204}Pb$ (c.) vs. $^{206}Pb/^{204}Pb$ dei prodotti appartenenti ai diversi settori di seamount vulcanici nell'area Mediterranea. Fonte dei dati: GeoRoc (maggiori dettagli sono contenuti nel testo). Sono riportati alcuni campi per riferimento: MORB da Stracke et alii (2003),* Q*: La Queglia,* PN*: Pietre Nere,* RMP*: Provincia Magmatica Romana,* TMP*: Provincia Magmatica Toscana,* LuMP*: Provincia Magmatica Lucana da Conticelli et alii (2015a). L'attività offshore dei Settori Eoliano - E Tirrenico e del Canale di Sicilia è rappresentata da simboli a stella. I dati di composizione isotopica per il Settore Ligure non sono reperibili in letteratura.*

proposed for the southernmost sector of Italian magmatism (e.g., BECCALUVA *et alii*, 1981a; AVANZINELLI *et alii*, 2009). Similar isotopic compositions are also reported for calc-alkaline rocks from the Aeolian Arc (e.g., FRANCALANCI *et alii*, 1993, 2007; PECCERILLO, 2001, 2005; TOMMASINI *et alii*, 2007).

14. - GENESIS OF MAGMATISM AND GEODYNAMIC OUTLINES

The origin of Pliocene-Pleistocene Central Mediterranean volcanic rocks have been the subject of a scientific debate focused on two main possible mechanisms: a) within-plate origin, possibly linked to partial melting of an up-rising mantle plume (e.g., VOLLMER & HAWKESWORTH, 1980; VOLLMER, 1990; AYUSO *et alii*, 1998; CASTORINA *et alii*, 2000; GASPERINI *et alii*, 2002; BELL *et alii*, 2004); b) orogenic to post-orogenic origin, related to partial melting of the sub-continental lithospheric metasomatised mantle at a destructive plate margin, with important contributions from recycled sediments (e.g., COX *et alii*, 1976; PECCERILLO, 1985, 2005; ROGERS *et alii*, 1986; BECCALUVA *et alii*, 1981a; CONTICELLI & PECCERILLO, 1992; DOWNES *et alii*, 2002; BIANCHINI *et alii*, 2008).

Some of the authors suggesting the within-plate origin also pointed out the need for an increasing influence of an upper crustal geochemical component northward, although no convincing reasons have been provided to explain it in the frame of a within-plate, extensional geodynamic setting (e.g., HAWKESWORTH & VOLLMER, 1979; VOLLMER, 1990; GASPERINI *et alii*, 2002; BELL *et alii*, 2004). On the other hand, there is an increasing consensus that calc-alkaline to shoshonitic and ultrapotassic rocks of Central Mediterranean are subduction-related magmas, generated through partial melting of a metasomatised upper mantle (e.g., CONTICELLI & PECCERILLO, 1992; CONTICELLI, 1998; CONTICELLI *et alii*, 2002, 2004, 2007, 2010, 2015a; PECCERILLO, 2003, 2005, 2017; AVANZINELLI *et alii*, 2009; LUSTRINO *et alii*, 2011). The same holds true for the calc-alkaline to shoshonitic volcanic rocks of the Southern Tyrrhenian Sea of the Aeolian Arc and surrounding seamounts (e.g., FRANCALANCI *et alii*, 1993, 2007; PECCERILLO, 2003, 2005, 2017; TOMMASINI *et alii*, 2007; ALAGNA *et alii*, 2010), and of the Ligurian and Corsica sectors (e.g., CONTICELLI *et alii*, 2002, 2010, 2015a; CHELAZZI *et alii*, 2006; PECCERILLO, 2003, 2017; LUSTRINO *et alii*, 2011; RÉHAULT *et alii*, 2012). The orogenic magmatism migrated following the Benioff plane retreat, in eastward direction first, and later south-eastwards. Within plate magmas appeared in the back-arc basins 2-3 Ma after of end of orogenic igneous activity (e.g., SAVELLI, 2002; LUSTRINO *et alii*, 2011; PECCERILLO, 2017). In addition, the opening of the Tyrrhenian back arc basin led to the emplacement of a MORB-type oceanic crust in the deepest region of the Tyrrhenian Sea, which was followed by the occurrence of within plate magmatism (e.g., SAVELLI, 2002; LUSTRINO *et alii*, 2011; PECCERILLO, 2017).

15. - CONCLUSIONS

The brief overview on the Tertiary-Quaternary geodynamic and magmatic evolution of the Central Mediterranean region provided in this contribution highlights the complexity of processes that this region has witnessed in the last 35 Ma, where the initial collision of Africa and Eurasia was followed by rapid retreat of the subducting slabs, their fragmentation and opening of back arc basins bordered by highly arcuate orogenic chains. Within this framework, magmatism shows a complexity of magma types that is rather unique and is still open to scientific debate. The knowledge of submarine volcanism is a key part of the picture and still far from complete, so that a comprehensive understating of the geodynamics of the Central Mediterranean will benefit immensely by future campaigns aimed at unravelling the seafloor volcanism.

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